PREFACE

Behavioural or social science has been a recognised subject area for the best part of a century. Within that time psychologists and other social scientists have written millions of words on a vast range of topics relating to human and animal behaviour – about thoughts, feeling, motivation, attitudes, perceptions, learning, anxiety and aggression. Yet of this published literature only a tiny proportion has dwelt upon the way in which people respond to danger and attempt to cope with it. Where studies have touched upon the subject they have often been carried out by researchers whose primary interest has lain elsewhere, and who have made only a brief today foray outside their chosen territory.

This has led to a fragmented literature based upon a multitude of theories whose inter-relationship is hard to unravel. Apparent contradictions abound and the gaps in our knowledge are still large and frustrating. Practitioners in health and safety therefore frequently despair of the task of trying to extract any sensible conclusions and recommendations from the literature. Despite the fact that the human factor is almost universally regarded as the major contributor to problems in the field it remains a terra incognita, frequently regarded as a hopeless mixture of trivia and incomprehensible jargon. Hopes are high but expectations low.

As psychologists and as researches, teachers and practitioners in health and safety we have tried in this book to tackle both these problems. Our aims are to show to social scientists that the subject of behaviour in the face of danger is a fascinating and rewarding one and to demonstrate to the practitioner that there is both order and value in what is known about human factors. In both cases our ultimate goal is to stimulate those concerned towards further systematic work. We also have a more negative aim – to curb the inflated hopes that some practitioners in, and commentators on the field have of the potential contribution of behavioural science to health and safety. We seek to show that psychology cannot be expected to paper over the cracks which other disciplines have failed to tackle and that for example, people cannot be manipulated into being safe in dangerous conditions. Only if the field is regarded as a whole, as a multidisciplinary system in which all the parts must fit together, is there a chance that improvements can be made.

In order to achieve our aims we present here a model of human behaviour in the face of danger. Because of the fragmented state of the knowledge upon which we have based the model we are very much aware that our book can only be an interim statement. We hope that it will serve as a structure to organise what is already known so that it can be more easily applied, and to make clear the gaps in knowledge which further work needs to fill. Such work is partly theoretical – to further our understanding of the fundamental mechanisms by which people perceive, assess and respond to danger, and partly practical – to evaluate the importance of the individual as a controlling factor in different circumstances and the effectiveness of attempts to improve that control over danger.

This book grew out of the teaching which we developed and carried out in the former Department of Occupational Health and Safety at the University of Aston in Birmingham. The challenge and inspiration from creating an entirely new multidisciplinary subject and teaching programme was enormous. We owe a great debt both to our former colleagues and to the hundreds of students from more than forty countries who served as guinea pigs for our ideas.

In compiling this book we also acknowledge our debts to the select band of pioneers in this field on whose data and insights we have built. They worked in many different countries, frequently as lone voices creating a new subject against a background of scepticism and resistance. The growing international network of conferences and seminars on the subject has provided the necessary framework to support and bind together those pioneering efforts. It has also provided us with the opportunity to meet any of those currently working in the field and to exchange ideas with them. We hope that we have faithfully interpreted those ideas and in so doing apologise for any inadequacies that my have crept in. We particularly acknowledge the contribution of colleagues from the Vakgroep Veiligheidskunde at the Technische Universiteit Delft and from the many organisations brought together by the symposia on occupational accident research in Scandinavia.

A number of people have very kindly read and commented on parts of the book in its various drafts and have contributed unselfishly to the tedious tasks associated with assembling the information, references and text. Without them and the miracles of word-processing the whole task would have become stranded. Our particular thanks go the advisory editor Dr Herbert Eisner and also to: Dr Tony Boyle, Ms Sue Glendon, Derek Grayham, Mrs Joan Hale, Ms Mary Hale, Dr Stephen McKenna and Mark Piney.

ACKNOWLEDGEMENTS

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CHAPTER 1

INDIVIDUAL BEHAVIOUR AND CONTROL OF DANGER

IMAGES OF THE INDIVIDUAL

There is a widely prevalent attitude of mind which has had deadening and damaging effects upon research and practice in health and safety. That attitude is summed up in the words that the Confederation of British Industry used in the evidence it gave to the Committee set up in the early 1970s to review the regulation of health and safety in the United Kingdom. They said:

'the root of the problem is human behaviour'.

More recently in a review of the treatment of human error in nuclear power plant design and operation, Reason & Embrey (1) referred to another element of the same attitude:

'Up to now it has been generally assumed that the nature of these alternative actions (faults in operator actions) was intrinsically unpredictable and hence could not be included in the modelling process'.

Psychologists and other social scientists who have ever worked in the field of health and safety come to recognise this attitude in the questions that they have been asked to research or to advise on:

'How can we get our workforce to take more care?'
'Why won't people use their protective equipment or follow the safety rules?'
'How can we automate people out of the system so that it works more safely?'
'Can you help us to identify the people who are going to have accidents so that we can avoid employing them on dangerous jobs?'

Considerable emphasis has been placed upon the individual as an almost wholely negative influence, the cause of all difficult problems and the source of all headaches. Thus, the finger has usually been pointed at the worker and at victims of accidents as the problem and hence as the most appropriate object of study since they are the ones most obviously involved. The role of the organisation and of society in conditioning and constraining individuals' behaviour and in designing the jobs and equipment with which they must work have been underemphasised. Accidents have been equated with human error and as coterminous with blame. The obverse side of error as an inescapable part of learning and as an essential feedback signal needed for people to monitor and to adjust their behaviour has only recently begun to be emphasised (2).

Two reactions to this negative view of the individual stand out: first to bend every sinew to remove humans from the system; or second to concentrate efforts on changing individuals' behaviour and on weaning them from their dangerous, careless and negligent ways.

The first reaction can be seen in the long and largely fruitless love affair which the safety field had with the concept of accident proneness in the period from the 1920s to the 1960s. Through the use of psychological tests, some organisations sought to exclude individuals with supposed high accident liability (see ref. 3 for a comprehensive review of the failures and successes of this approach, notably in the field of road accidents). Many engineers and designers went further and tried to eliminate all people from direct contact with hazards by linking accident prevention with automation particularly in high technology industry. A related manifestation is the almost reflex way in which personal protective equipment is seen in some quarters as the solution to health and safety problems, providing a safe cocoon in which the vulnerable human can survive unharmed. The second reaction is exemplified by the large sales of safety posters, emphasis on safety campaigns and in the search for safety motivation packages as a general panacea. Since the 1970s, insistence upon safety training too has become almost a reflex response to the existence of accidents and diseases, despite a lack of agreement upon the objectives or content of such training (4).

These two types of reaction both stem from a view of people as the cause of problems; they differ only in whether they consider people to be irredeemably flawed and so to be eliminated from processes, or as potentially redeemable. The parallels with beliefs about original sin, predestination and salvation are perhaps not too far-fetched. In either case the human is seen as independent of machines, substances, processes and hardware which inflict injury and disease. Freeman (5) serves as a typical example of this approach in stating: 'There are various estimates of the proportion of accidents in which there is some degree of human error - a reasonable figure is about eighty - five percent. Accident prevention therefore becomes largely a matter of influencing people to do the right thing at the right time... '.

The implication is that people could have chosen other behaviour which would not have led to harm and that something can be done to the human to influence this choice without altering other parts of the system. More recent analysis has tended to reduce the percentage quoted as related to human performance: thus Reason (6), in an analysis of 653 reportable accidents in nuclear power plants, finds only fifty-one percent of 'root causes' related to human performance and almost half of those precipitated by 'deficient procedures and documentation'. However, it is not the exact percentage which is at issue but rather the implicit and unwarranted conclusion which is often drawn from it, namely that it is the person and not other system elements which must be changed. Such a view is as futile as the analogous debate about the proportion of the score on intelligence tests which can be attributed to heredity as opposed to upbringing. The two elements are interactive in their effect and not simply additive.

Research into the role of the individual in accident causation which was carried out based on this person-centred view has been largely correlational in nature. It concentrated on characteristics of individuals which were associated with having accidents, and not on the process by which an accident happened (7). Research methods were strongly influenced by a medical model of accidents as a type of disease to which certain people were susceptible.

THE SYSTEMS APPROACH

This book adopts a different perspective. We suggest that such 'common sense' ways of describing health and safety problems have been unhelpful blinkers which have misdirected resources into fruitless or self-defeating counter-measures. Instead we want to present humans as one element in a mutually interdependent system which also consists of the hardware used, the situation in which it is used (both to a large extent designed and built by other humans), the rules and procedures which are laid down by others to try to govern that use, and the organisations which manage the system. From this point of view human behaviour is a response to those other system elements. However, it is not a limited one-to-one response in a strict behaviourist sense. A given piece of metal will always respond in one way to the application of heat: a person may react in a number of ways depending on an assessment of where the heat is coming from, what exposure to that heat might lead to and what options are open to enjoy, reduce or escape from the heat. Human behaviour is thus different from that of inanimate system elements in that it is potentially capable of taking account in advance of its own consequences. People can therefore potentially control and steer the system towards goals which they want (consciously or unconsciously) to attain. At the same time the choices open to individuals are constrained by other elements of the system and the power which they have over them. Have they the tools necessary to control those elements, the resources to acquire the tools, the knowledge to use them, the time to think, the right to decide?

Our emphases are first, to analyse links between system elements, second to analyse the degree to which individuals have some control over decisions in respect of actions which differ in their risk, and third to consider the factors which influence that degree of control. In addition we must realize that safety is only one of the factors which influence that choice. Only in rare situations does it come to dominate decisions, as when smoke starts to seep under the door of your hotel bedroom, or someone threatens to build a factory which you consider to be dangerous at the bottom of your garden.

While the analysis in this book is at an individual level, this is not to deny the validity of studying health and safety at the level of organisations or of society, nor to suggest that an individual analysis alone can deliver solutions to all problems. Any safety problem can be analysed at a micro-, meso-, or macro level (8), looking at individual, organisational or societal factors. All these levels are interconnected, and the choice, in practice, of the most suitable level of analysis for any given problem will depend on the level at which changes can most easily be made in the system; for example, redesign of a specific task, introduction of an industry or international safety standard, or allocation of responsibilities within an organisation.

Sociological and political analyses of accidents and of risk (see for example refs. 9,10,11,12,13) and organisational analyses (see for example refs. 2,14,15) are vital to a full understanding of the various facets of health and safety (16). Bio-medical, chemical and engineering analyses of how technical components can fail and cause harm to people or to the environment are also prerequisites for considering the interaction of people with these components.

However, an approach at the level of the individual provides a crucial link between these other levels of analysis. It is individuals who use the hardware, whose behaviour the organisations, rules, laws and procedures try to influence, and who are victims of harm. The framework for the book is therefore a model of how individuals interact with systems in the face of dangers and how they perceive and control those dangers to avoid them becoming manifest in actual harm to themselves or to other system elements.

1.1.1 Systems thinking

The word 'system' appears frequently in the previous section without explanation. There is an extensive literature on systems thinking (see for example refs. 17,18), so we will only define briefly here the essential features of a 'system' which we want to use. These are shown in Figure 1.1.

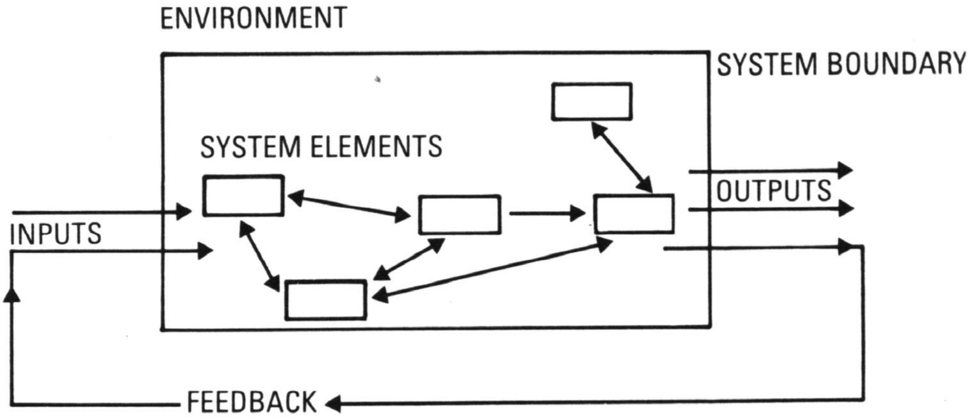

Figure 1.1. Simplified system model

A system comprises an *organisation* of a number of inter-related *elements* interacting with each other within a defined *system boundary*. In the systems which we will be discussing these elements are usually hardware (machines, buildings, materials) and people, which interact physically or through exchange of information governed by rules and procedures. The system boundary may be the factory walls, those of the department, the confines of the car someone is driving, or some other boundary appropriate to the level of the analysis undertaken. Outside the boundary is the system *environment.* The system has a number of goals or objectives towards which it attempts to progress, for example making a profit, producing a given output or getting from A to B without having an accident. Implicit in the existence of goals is the need for a *feedback mechanism* whereby the system compares its current position and state with those goals in order to monitor and to guide that progress.

An 'open system' (the type in which this book is interested) communicates across the system boundary with its environment and with other systems. Factories buy in materials and sell goods; they employ people who arrive at the start and leave at the end of their shift to go home to the family system in which they live. The car/driver system takes in petrol and information about location and gives out pollution and wear on the roads. Because of this interchange between a system and other systems in its environment it is always possible to draw system boundaries in different places and to treat any system as an element of a larger system. Thus, the individual forms part of a family system, a community system and a work system, moving between them across system boundaries. These in turn are sub-systems of larger industrial, social and political systems. The picture presented is of a series of interlocking and nested boxes (19). Individuals, each with their own self-regulating feedback mechanisms, form groups which can also be analysed as systems with norms and sanctions which guide and regulate behaviour. Departments are made up of several groups, organisations of several departments and so on up through industries and countries to the international level. Each level can be analysed using the same concepts of inputs and outputs across systems boundaries, goals and feedback loops which regulate and guide the behaviour of the elements making up its internal organisation.

Lest this appears too tidy a model, we hasten to add that interactions between elements and sub-systems are often difficult to trace or to predict in advance, and it is sometimes only clear after an accident that a number of elements formed an interacting system. Turner (11) and Perrow (12), in their analyses of major disasters both point to these unexpected interactions as a characteristic and disturbing feature of accidents in some advanced technologies such as energy production and transport. Gradual realisation over the last generation of such complex system interactions as acid rain and the effects of nuclear radiation have served to fuel on the one hand much practical interest in health, safety and environmental issues and on the other, theoretical developments within systems thinking. In this book an essentially dynamic systems model is used to analyse and to discuss human behaviour in relation to danger. This contrasts with the rather static behaviouristic models which characterised much previous accident research and thinking.

1.3 DEFINITIONS OF DANGER

In the previous sections the word 'danger' has been used several times to refer to something which the individual is faced with and tries to control. So what is it that is to be controlled?

Danger is a concept of which it is easy to give examples (radiation, whirling machinery, planes taking off with ice on their wings, toxic chemicals) but which is very hard to define precisely and satisfactorily. A first attempt at a definition might be that danger is the presence of potential harm to one or more elements of the system, either because of interactions with other elements or with the environment outside the system. 'Risk' can then be used as the measuring stick for this potential, that is the probability that harm will become manifest within a defined period. (However, see for example refs. 20,21, 22 for discussion of the definition of risk, which has been used in several other senses than the one chosen here).

1.3.1 The meaning of harm

The definition of danger as potential for harm has some serious shortcomings. It is necessary to define what we mean by 'harm'. This could be defined very broadly as damage to the integrity or functioning of any system element so that it no longer fulfils its purpose. However, that would include in the definition of danger the 'natural' processes of the wearing out of mechanical components and the ageing of living components. Since such wearing out is inevitable, danger would be present in all systems at all times, and the word would thereby lose much of its purpose. To exclude such natural processes we must import some concept of the normal lifespan of the system element, and must carefully define the integrity, functioning and purpose of those elements. This becomes particularly difficult when we are trying to study processes which are analogous with those of ageing, for example noise induced deafness compared with presbycusis (age-related deafness), joint and muscle deterioration from bad work posture and movement compared with that from ageing, or excessive compared with normal wear of mechanical parts. The dividing line in such cases must eventually be an arbitrary point on what is clearly a continuum.

Mental stress. The broad area of mental stress, impaired functioning from a range of pressures related to work organisation, social adjustment and conflict, also sits uneasily on the boundaries of the definition of danger. During debates in the British Parliament on the introduction of the Health and Safety at Work etc. Act of 1974 the responsible minister specifically included mental health, and so stress, within the definition of 'health' under the Act. However, there is little evidence that that view has been adopted in practice in Britain either by government or by employers. In some other countries, such as The Netherlands, France and the Scandinavian countries the position is very different, with factors of work satisfaction and stress being very closely associated in both law (under titles such as 'Work Environment') and in practice, for example in workplace committees which have responsibilities stretching across all of these areas. The reasons for such differences in emphasis are beyond the scope of this book, but the definitional problem remains.

Selye's (23) original definition of stress portrayed it firmly as a failure of the adaptation mechanism of the human system to external (environmental) pressures. Cox and Mackay (24) describe a model of stress in which a serious imbalance between internal and external demands and pressures on the one hand and coping strategies and support on the other results in a breakdown in individual functioning. The impairments which result from such an imbalance are very real and may be just as serious as physical injuries and organic disease which result from accidents and from exposure to toxic chemicals. Over longer periods of stress, physical impairments such as digestive and coronary disorders can follow. The arguments for including stress and its avoidance in this book are therefore strong. However, pragmatic reasons alone mean that it cannot be dealt with in this book. Much of the literature on stress is concerned with problems of establishing clear links between 'causal factors' and symptoms. As such, the literature is no more relevant to our viewpoint than is the medical literature in establishing the link between for example, exposure to asbestos fibres and mesothelioma. Stress therefore takes its place as merely another of the somewhat ill defined threats to health which individuals have to face and try to control. (For detailed specific treatment of the subject the reader is referred to refs. 25,26,27,28,29).

System impairment and human error. Problems also arise in deciding whether to include all impairments to the functioning of the system as a whole under the definition of harm. If we were to include everything which causes factories not to meet their production targets, trains not to run on time and individuals not to achieve their career ambitions this book would need to be an encyclopaedia. For pragmatic reasons the definition must therefore be limited. We do not deny that the individual behaviour which contributes to or avoids such broader system defects has the same psychological basis and overlapping causes as that which is relevant to us. Our focus, however, is on behaviour and related system elements relevant to physical harm to the people.

Our approach is also somewhat different from that of Reason and others (see for example 2,30), who approach the subject of safety primarily from the point of view of human error. Reason studied the 'slips, lapses, biases and blunders' of everyday life, such as forgetting to put tea in the pot before pouring the water in, writing a shopping list and leaving it on the kitchen table when you go to the shops. From these sorts of errors he derived a classification and theory of error mechanisms which he has since applied to the analysis of more serious incidents to draw inferences about the causes of disasters (see refs. 6,31). This makes the implicit assumption that the mechanisms underlying human behaviour in situations where only mild embarrassment, irritation or delay can result are of the same type as those which can lead to physical injury and gross material damage. This assumption, though plausible and attractive, is as yet largely untested (32). Reason's work is considered in Chapter 3 where the insights it offers into the genesis of situations in which harm is likely to occur are discussed in detail. It suffices here to say that in this book our focus is in one sense narrower than his - being upon that sub-set of errors which the individual (or someone else) does not control or recover from, and which lead to physical harm to system elements. This means that human error per se will not be the focus of our discussion.

'Human error' is a loaded term implying blame, and one which has become too closely linked with the approach sketched in the opening paragraphs of this chapter. Error implies the existence of a clearly definable correct or appropriate behaviour from which the error is a deviation. In other words the definition is normative. Where blame is being officially or legally allocated and where error is written about from a management or system design point of view the norms which are most usually used to judge any behaviour are those of the people in charge of the system, not those of the people whose behaviour is being judged. A further complication arises where means and ends become confused and, for example, the breaking of safety rules is only regarded as an error when it results in an accident, but as praiseworthy when it results in meeting a production deadline. Human error becomes problematic within this context because it is defined in terms of real world outcomes rather than being a set of a priori conditions. The objectives and the behaviour of the person breaking the rules may have been identical in the two cases.

Error also becomes an increasingly problematic concept the more we consider non-routine and problem solving tasks (33) where 'correct' behaviour is hard to define in advance, since the situations are new. Leplat (2) sums up this normative aspect of error diagrammatically (see Figure 1.2). This book will have much to say about error, but will not treat it as either a necessary or a sufficient condition for harm to occur.

1.3.2 Intention

A further problem in defining danger arises in considering whether harm was deliberately caused. In a number of instances it is the express or implied purpose of one system element to damage another; the strike by workers to damage the employer, the lockout by the employer to damage the employee, theft to deprive someone else of an object, sabotage to damage production or to stop an activity, a fight to harm another person. Many definitions of danger and accidents incorporate words such as 'unintended' and 'unforeseen' in order to exclude such events. Other definitions, however, do not. 'Loss control' and 'Risk Management', both concepts widely advocated in the safety world, specifically include theft, industrial espionage and computer security together with injury, damage and disease control (see for example refs. 34,35). We accept that there may be arguments at the organisational level of analysis for lumping all of these types of 'harm' together, for example because their prevention or financing shares some features in common. However, we exclude them from consideration here because we believe that the human behaviour which causes or avoids them is very different from that relevant to truly accidental physical harm to individuals. Clearly however, there are incidents which sit on the boundary between intended and unintended harm, for example horseplay in which people get injured (36) or the deliberate employment of migrant labour to carry out work which is known to be dangerous.

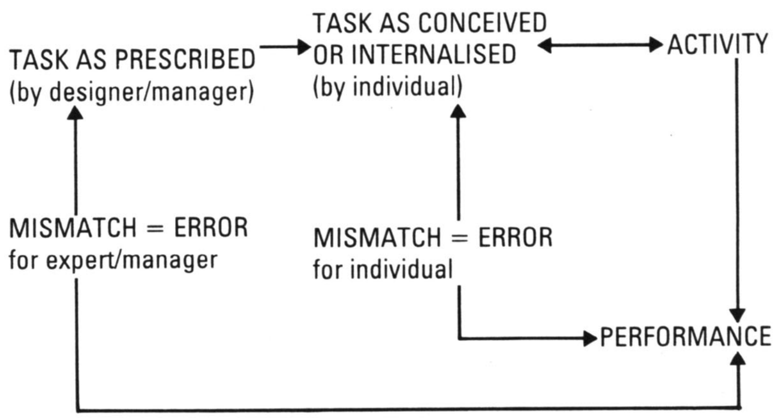

Figure 1.2. Error as a normative concept (adapted from 2, Leplat 1985)

A special problem arises in the case where a system element damages itself on purpose, for example self-injury to escape from unbearable stress or a suicidal kamikaze mission to destroy the enemy, or deliberately to put oneself in greater danger for some reason. Thus, firemen and rescue workers deliberately approach physical hazards in order to save others. Some psychiatrists’ (37) consider repeated accidents to be a pathological sign of an unconscious motivation to self-injury. While not wishing to deny this as a possible explanation in a few extreme cases we see no evidence that it helps as a general explanation of accidents. Other researchers (38) have shown that accident absence and job satisfaction are related, and have implied that people with low job satisfaction will sub-consciously have accidents in order to go absent. We tend to the view that the motivation (conscious or sub-conscious) is more likely to come into play by taking longer absence from such accidents which do occur.
Intention is also important in considering why people indulge in behaviour which increases their risk of being harmed, (even behaviour which they themselves, if asked, would label as dangerous). This topic is dealt with in Chapters 5 and 6. There is no clear-cut distinction between intentional and unintentional behaviour, and we shall have to treat them as a continuum in which we must make an arbitrary dichotomy, just as the law does when proof of intent becomes the test distinguishing murder from manslaughter.

1.3.3 What is 'potential'

There is still a further problem with the original definition proposed for danger. This rests in the use of the word 'potential'. That implies some predictable future state of the system in which harm occurs. We have already said that, if we wait long enough, all system elements will wear out, and that we must therefore make an arbitrary decision about excluding 'normal ageing' from our definition of harm in order to make it useful. But even if this is done we are still left with the question of what rules we are to use to predict the future states, and how far we project them into the future. We may not want to limit the time scale to the 'normal life span' of current elements in the system, because we may want to be concerned with teratogens or with long-term ecological toxins or radiation. Even if a time limit is imposed, there is a further problem. In all situations it is possible to envisage some future state where harm could occur; any house could be struck by lightning and no hardware is one hundred percent reliable. Thus, we can say that danger is ubiquitous and again the word loses much of its value. There must be rules for excluding some situations from consideration.

Again we have to impose a restriction which takes account of what is 'reasonable to expect', 'foreseeable' or 'credible' in order to exclude some (hopefully very low probability) future events which are theoretically possible, and so limit the range of future states of the system that we consider in assessing potential harm. The law does this in deciding about moral and financial liability for damage. Techniques such as Probabilistic Risk Assessment do it also in producing design calculations for the disaster potential of industrial plants. Individuals do it in the decisions they take about what could conceivably go wrong. We return to this point in detail in Chapter 5, and consider in particular whether it is ever reasonable to talk of objective definitions of what possible future states should be excluded.

In dealing with this area of very low probabilities we are in any case up against two fundamental limitations. First, it is in all practical senses unprovable whether judgements or calculations of probability are accurate or not. We would have to wait too long to accumulate empirical evidence to prove whether a failure probability was really one in 100,000 years or actually one in 10,000. Second, hindsight is not necessarily a good predictor of future probability of an event. We have to take account of the basic notion that systems are goal-directed and not totally deterministic. They are steerable or controllable by their human elements. Hence not all theoretically possible future states are credible, since it is likely that progress towards them will be detected and corrected for. We are not dealing with a first order system whose behaviour can be predicted from simple derivation from its current state. We have to take account of the effect of complex feedback loops. Predictions of future probability then become very dependent on the assumptions made about the working of such recovery loops (see for example, discussion on methods of probability assessment in the nuclear industry, refs. 39,40).

1.3.4 A working definition

The preceding sections have led the way into a number of morasses in which the concept 'danger' may appear to have sunk from sight. Indeed, one of the purposes of those sections was to demonstrate that the concept is neither straightforward nor self-evident. It has a number of components, many of which are themselves highly abstract and complex. Another objective was to indicate how the discussion of a definition of danger leads into consideration of individual perceptions, understanding and behaviour. Danger is fundamentally a subjective concept. In many senses the rest of this book is an extended exploration of the definition through a detailed consideration of the way in which people in practice react to situations which may contain danger. It should also come as no surprise that the range of behaviour to be discussed is also complex. In particular the sometimes glib contrast made in the literature between 'objective' and 'subjective' danger (or risk) is often portrayed as the contrast of concrete reality versus some distorted perception of that reality. On closer examination 'objective' danger will usually turn out to be the particular, and inevitably arbitrary, definition (or perception) imposed by one protagonist which is being contrasted with the different, and equally arbitrary definition of another (41).

Having stated that any definition of danger is arbitrary, it is time to be arbitrary for the sake of progressing this book. The field being covered by this series of monographs is occupational health and safety, so our discussion will focus primarily on harm which arises at or from work. However, it is neither possible nor desirable to exclude altogether research studies relating to harm in other fields. Much of the psychological research on safety and accidents has been carried out on road accidents, and many of the relevant theories come from these studies. The nature of work is also neither clear cut nor static. Lorry are exposed to similar hazards to people at home in their kitchens; health care workers and maintenance staff work in other people's homes and there have always been a large number of people who have worked at home. What is covered here will therefore have some relevance for non-work situations.

In relation to the other issues discussed here, we shall use the definitions in the paragraphs below.

Danger. A situation or system state in which there is a reasonably foreseeable potential for unintended harm to human or physical elements in the system. The definition of danger used will be partly reflexive in that some of the later chapters will look at the question of how individuals recognise or decide that they are in danger in their own definition of that term.

Hazard. A specific agent which in defined circumstances would cause damage to a system element. Every dangerous situation therefore contains one or more hazards.

Risk. The probability that damage of a *specified type* to *specified system elements* will occur in a given system over a *defined time period*. Thus, any specification of risk in numerical terms should have (specified or implied) these three elements to its units; for example deaths in the general population per year or serious injuries to employees per 1000 hours worked. Because of the way in which statistics are collected and risk is calculated it is a population measure, the average chance that the harm will occur to a typical system element. When people talk about the risk to an individual in a population they usually assume that the individual is typical and therefore that the population measure applies. Each individual may have other views, regarding him or herself as either more or less at risk. The problem is ultimately unresolvable because there is no way of assessing instantaneous individual risk objectively. In order to assess the total potential for harm in a dangerous situation over a given period the risks must be summed across two dimensions; the probabilities of different outcomes from each hazard in the situation and the probabilities of each outcome arising from the different hazards.

Harm. Damage to a system element so that it can no longer carry out its system function and requires repair, treatment or rehabilitation over a significant period. Occupational injury, disease and to a lesser extent strain are included as types of harm to people. Breakdown, damage and destruction as types of harm to physical system elements, as well as fatigue, inefficiency or production loss are excluded as primary foci of attention. Harm which is clearly intended by other people (such as theft, personal attacks or vandalism) is also excluded.

Accident. The process of occurrence of unintended harm where exposure to the hazard results immediately in harm. The comparable process of occurrence where exposure results in delayed harm has no convenient single word to describe it, since the word 'disease' is normally used to describe the type of harm (cf injury). The similarity in the two processes is discussed in the next section.

Safety. Although strictly defined as the converse of danger, safety is more loosely a situation in which the system is under control and the harm process (see Figure 1.3) has not begun. The particular question of the relation of safety to health and to long-term, delayed-in-effect (42) harm is treated in more detail in the next section.

These concepts are shown in pictorial relationship in Figure 1.3.

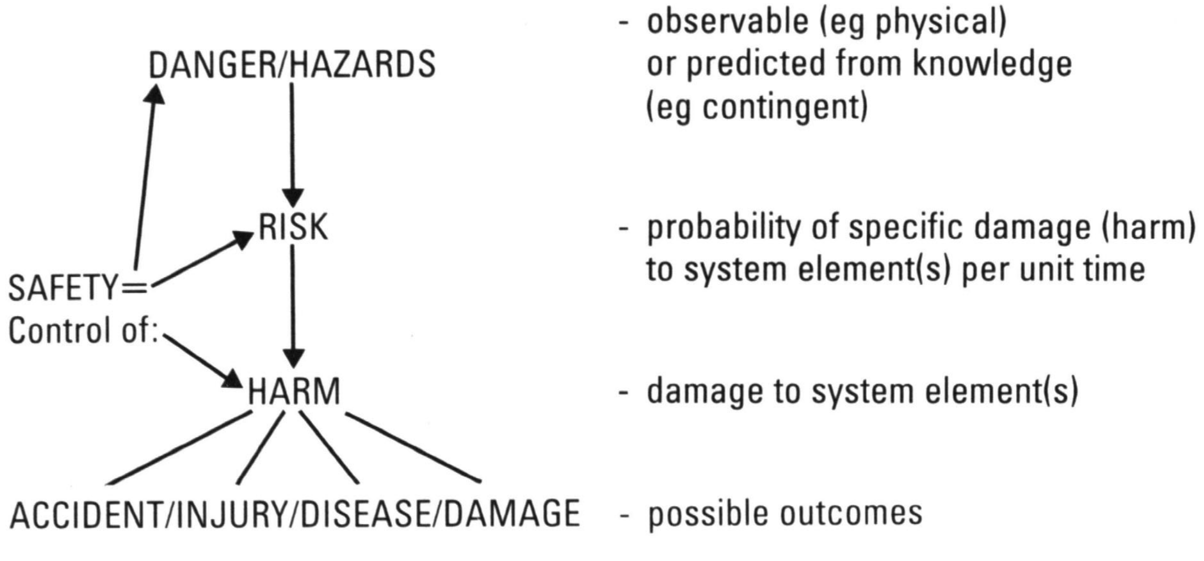

Figure 1.3. Relation between safety, danger and other concepts

These uses of the defined words are far from universal in the scientific literature (see for example refs. 7,20). For example, in common parlance 'hazard' and 'risk' are frequently, but incorrectly used synonymously, as are 'accident' and 'injury'.

1.4 MODELS OF THE HARM PROCESS

As a prelude to discussing the role of the individual in either threatening or ensuring safety we need to present a model of how harm occurs in the system, in order to indicate where the individual can intervene.

Several authors have discussed the close relationship between the ideas of change, deviation and danger (2,14,43,44,45). Others have used models of danger build-up and release to indicate the dynamic nature of the harm process (46,47,48). These models share the idea that it is possible to define a 'normal' situation which is safe, and from which danger develops through a process of progressive deviation from normal. As an idea it has proved fruitful in breaking the habit of thinking about accidents as unicausal and rather static phenomena. Kjellén & Larsson (49) found, for example, that employees and managers in industry were able to identify over twice as many relevant factors related to accident occurrence in their factories using such a model than when using conventional accident report forms. The major advantage of the model is that it focuses attention far more at the point when the deviation starts than at the point where harm occurs.

1.4.1 The normal state and system design

Figure 1.4 adapts MacDonald's comprehensive accident sequence model (43) and indicates the phases of Kjellén's similar model. Although MacDonald's model was developed to explain only accidents, it is also possible to apply it to delayed effects producing occupational disease.

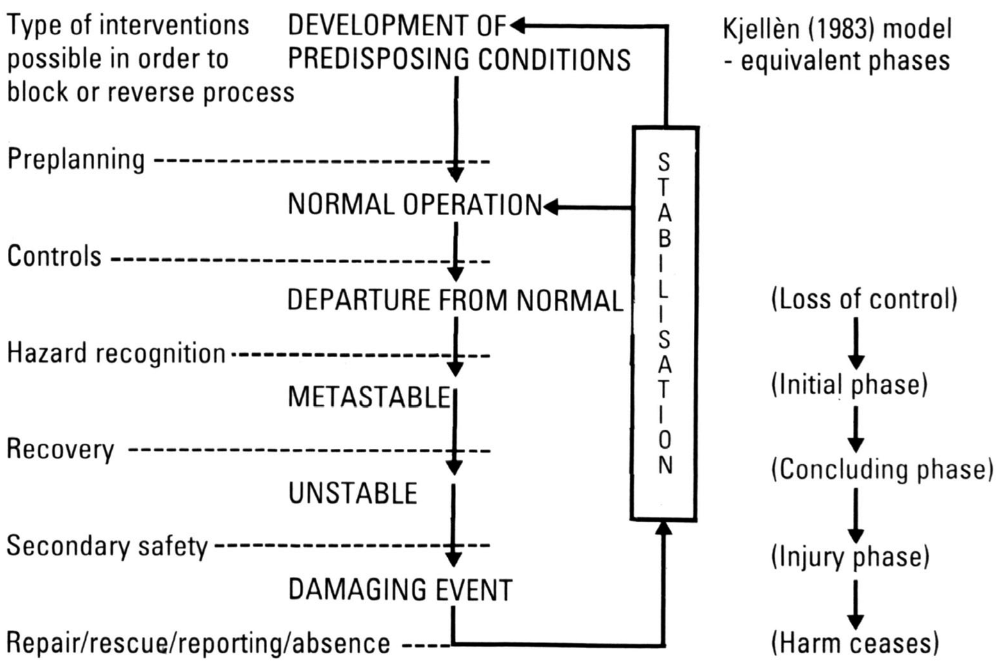

Figure 1.4. Accident sequence model (after 43, MacDonald 1972)

The key concept in MacDonald's model is that it is possible to define some state of a system which can be called its 'normal operating state'. This might be a machine being used by a competent user in the way for which it was designed in conditions for which it is suitable. This normal state does not necessarily imply that there is no danger, as is shown by the fact that there is a preceding stage. This first phase of the model represents the design and building of the system into which may be built, either knowingly or not, a number of hazards. As indicated in Figure 1.4, all pre-planning methods are ways of minimising the number and importance of those built-in hazards. The 'normal' state can thus often be equated with 'the state as designed', and deviations are then by definition unplanned events.

This only works as a definition of the normal state where it is reasonable to talk of a system having been consciously designed. That is the case with some work situations, particularly in the more complex technologies, where great efforts are made to design in a systematic and detailed way. In many other work situations it is only partially true. Certain elements and sub-systems may have been very consciously designed, for example, buildings and machines, even the combination of plant to form integrated processes, and perhaps the characteristics and competence of the human operators through selection and training. However, it is often not possible to say that the combination of all of these into a system has been fully designed. In yet other work situations, particularly in rapidly changing circumstances such as construction work, or in small organisations doing ad hoc contract work, conscious design plays little or no part. In such situations the 'normal' operating state for our purposes has to be somewhat arbitrarily defined. One way of doing this is to take the definition of 'normal' that is used by the people who work in the situation. We shall return to that concept in later chapters. In yet other situations the boundary of the system whose stability we are considering may not be at all clear. Perrow (12) points to this problem in his consideration of large scale disaster potential which may come from unexpected interactions which were not envisaged by system designers because they drew the system bounds too narrowly. Only after a disaster is it clear that the larger system interactions existed, and that the larger system had become unstable.

1.4.2 Deviation and controls

Since all systems are constantly changing, implicit in the idea of a normal state is that such changes stay within defined limits, and that these limits are adhered to because of in-built controls. These may be automatic devices such as thermostats, pressure regulators or speed governors, or they may be procedures such as the automatic replacement of specific machine parts at planned maintenance intervals. At some point these normal, in-built, planned controls are exceeded. Defining this point is not easy, and is often arbitrary. Leplat (2) uses the term destabilisation to describe this point, which implies that the system starts to move progressively away from its normal state and cannot be brought back except by some specific intervention. It is clear from this that systems may differ in the degree to which such controls are built in, and also in the narrowness of their control limits. The point at which a deviation becomes great enough to be considered by individuals to be a departure from normal will be the subject of later chapters.

1.4.3 Metastable state

Once there is a loss of control and a departure from normal there may be a quite lengthy period in which the system continues to operate with this increased or increasing level of risk before any harm becomes imminent. MacDonald (43) labelled this period the metastable phase; Kjellén (45), the initial phase. A similar concept of a finite, relatively slow danger build-up period is also present in other accident models such as that of Surry (46), considered in the next chapter. Turner (11), in an analysis of disasters such as the spoil tip collapse at Aberfan and the accident at the Hixon level crossing where a train collided at full speed with a low-loader carrying a transformer, points to the complex organisational factors responsible for the undetected continuation of such a build-up.

This phase forms the room for manoeuvre of the system; the space in which individuals can intervene by recognising the hazards and the increasing risk, and by initiating recovery actions to bring the system back into its normal state. As such, this is the part of the process which is the main focus of the rest of this book. However, this process of recovery is not without its own dangers. Faverge (14) and Winsemius (50) both point to the fact that, in their studies of heavy engineering industry, a major proportion of accidents followed an attempted recovery from a deviation, which made matters worse rather than succeeding in returning the system to a safe state (for example, someone noticing an unsteady stack of materials, reaching rapidly to steady them and either precipitating the fall, or stumbling over something in their attempt).

1.4.4 Unstable phase

The metastable phase may last weeks or it may last only seconds. This will depend upon the system dynamics, for example the rate of an exothermic reaction between two chemicals which have inadvertently become mixed; the number of occasions on which a vessel or machine part is placed under stress before cracks propagate far enough to reach a critical size; the interval before a pump that has become faulty is called upon to operate, or before someone uses a stairway which has become slippery with leaking oil. However, at some point there will usually be a change in the system dynamics, and some degree of damage becomes inevitable. The reactor vessel will burst, or the part break; an object is dropped from a height which is heavy enough to damage whatever it lands on; a foot is placed in the oil with such a force that the individual loses their balance. MacDonald (43) called this rapidly changing phase the unstable phase; Kjellén (45), the concluding phase and Surry (46) the danger release phase. It leaves room only for measures to divert the energy flow, to escape from it or to absorb it, so that damage is minimised or 'less important' system elements are damaged. The devices for achieving such a result are often called 'secondary safety' devices. Examples are bursting discs on chemical plant which break before the reactor vessel, handrails on stairways which can be grabbed if one slips, hard hats worn on building sites, seat belts in cars which absorb kinetic energy and emergency evacuation in case of fire.

The division between metastable and unstable phases is typical of accidents which involve release of energy (51). This energy may be kinetic, potential, electrical, chemical or thermal. In machines and processes this energy is normally held under some form of constraint, guard or control. If this barrier fails, then energy is released suddenly, and if present in greater quantity than the human body (or other system elements) can absorb, the damaging event occurs quickly. Road accident research in particular has used the observation of recovery behaviour around the changeover point from the metastable to the unstable phase as a technique to increase the potential number of incidents about which data can be collected and upon which prevention decisions can be based. This observation of traffic conflicts is closely parallel to the collection of data about near-misses or critical incidents at work (for example ref. 52) and of defined deviations such as failures of plant safety systems, or 'air-misses' in the nuclear and aviation industries respectively. Reviews of comparisons between situations where conflicts and emergency manoeuvres (but no harm) occur and situations where actual harm occurs (see for example refs. 53,54) show them to be similar. As might be expected, the more serious the conflict the better the correlation.

In the case of long-term, chronic hazards typically associated with occupational disease there may be no such clear division into two phases of the harm process. Here the damaging event may start from exposure to very small concentrations of a toxic substance which may be released even under 'normal' system conditions (particularly where the hazard from the substance was unknown to either system designer or operator).

1.4.5 Damaging event

This phase begins when the system element starts to suffer damage. This is usually clear-cut in the case of an accident, and here the only safety measures which can still be taken are ones to reduce the damage by spreading out the time over which the body absorbs the energy (for example fall arrest harnesses, energy absorbing front ends to cars) and rescue actions which limit the time of exposure to the energy (for example disconnecting the current in electrocution cases, washing off the caustic chemical, escape from the burning building).

With many occupational diseases the point at which damage begins may be unclear, since it depends on the ability of the body to resist, detoxify and dispose of the substance (55), and there may be significant individual differences in this ability. The time scale over which damage develops may also be very long. In some cases such as noise induced deafness or impaired lung function from some chemicals, impairment may be measurable from an early stage. In other cases, such as occupational cancers there may be a long latent phase before any pathological changes are apparent. In such cases there may be an extra set of safety measures possible, namely removal from exposure, which can sometimes limit or reverse damage. The degree to which this is possible differs between occupational diseases; some, such as withdrawal from exposure to lead in the case of lead poisoning result in complete recovery from harm, while in other cases such as mesothelioma due to asbestos, once started, the harm process is irreversible.

1.4.6 Stabilisation

This is the phase of the model in which the system and its components return to normal operation, or to a modified operating state incorporating the lessons of the incident. Speedy first aid and effective medical treatment can limit the seriousness of both diseases and injuries and speed recovery. Indeed, one of the major causes of the reduction in fatalities and prolonged absences following accidents in the early years of the twentieth century was the advance in the prevention of sepsis from small wounds. Rehabilitation also fits under this phase. Neither subject is dealt with further in this book. A subject which receives passing mention is that of absence. This is because most official accident reporting systems are based upon absence criteria (56), and lack of absence is dependent not only on the type and seriousness of the injury, but also on factors such as job satisfaction, company policy and morale (38,57). Individual differences in accident rates found in studies based upon analysis of official accident reports may be due to differences in behaviour during the accident process but they may equally well be due to differences in decisions about how long to remain absent and when to return to work. This phase also contains the 'post-accident strategies' (55) of incident investigation and reporting, redesign, and retraining. These are the feedback loops to redesign of the system to remove inherent hazards, to improve upon built-in control mechanisms or to equip the people in the system better to detect and to correct deviations.

THE HARM PROCESS AND THE ROLE OF THE INDIVIDUAL

The essential features of the model presented are that it is pitched at a system level, and that the concepts of control, feedback and recovery are central. Danger results from a deviation or failure of that control and develops through a dynamic process leading towards harm. The role of the individual in this framework is twofold: first a negative role in causing deviations (dealt with particularly in Chapters 3, 5 and 6); second a positive role in recovering from them (considered in Chapters 4, 5, 6 and 7).

The options open for the individual to control deviations differ at each stage. It is inherent in the structure of the model that the later the intervention the less time there is for it to be carried out successfully, and hence the greater the stress under which the person will have to operate. This leads to the general rule of thumb that deviations should be controlled as close to their source as possible (58). The models of human behaviour presented in the next chapter demonstrate the operation of this intervention process in more detail.

A finding which emerges from a number of studies is that accidents tend to happen more in conflicting and abnormal situations than in normal ones. Powell et al. (59) found that serious accident injuries were more likely to occur during non-routine activities. Hoyos and his colleagues in Germany (see for example, 60) consistently found high task demands and conflicting safety demands to be associated with high accident rates. This was also a finding from work in the European Coal and Steel Community (14). Glendon and Hale (36,61) found that the more severe accidents to people on youth training schemes tended to happen during non-routine work activities; Saari and Lahtela (62) found a higher accident rate on non-production (and hence less routine) work; Hagbergh (63) found a higher accident rate on unusual tasks in a steel works. Rasmussen (64), in analysing nuclear incidents, found that over fifty percent occurred during test and maintenance tasks, although these activities take up far less than fifty percent of the time worked in such plants. Shannon and Manning (65) analysed accidents in a car-making plant and found that the more severe ones had a more complex and longer build-up phase. Wagenaar and Groeneweg (66) point to the complexity of the factors they found in analysing accidents to shipping and to the difficulty for those involved in maintaining an oversight of what was happening; a comment echoed by both Turner (11) and Perrow (12) in their analyses of disasters. All this points to the fact that the tasks at which individuals fail are often highly complex or have novel features. We should be surprised not by how often people fail to control danger, but by how frequently they succeed. We should also take this as fair warning that attempts to improve on what is already a good performance are unlikely to be straightforward.

CONCLUDING REMARKS

In discussing the definition of danger and its related concepts this chapter has raised a number of issues which will recur in later chapters when we consider the way in which people identify and respond to danger. These issues indicate the complexity of danger, the difficulty of defining it, and so, by implication, of recognising and controlling it.

We have tried to stress the active, dynamic nature of the control of danger. People are not passive objects responding to external stimuli in stereotyped ways. They plan and are goal-oriented, and hence are strongly influenced by their predictions of the future. Nor do people conform to the engineering image of simply another component in the system which can be considered using the same techniques of analysis and the same assumptions as the hardware. Similarly strong criticism

has been levelled (see for example 67,68) at the unquestioning application of methods derived from technical reliability theory to model human reliability.
We also stress the rationality and purposiveness of human behaviour. The idea that human behaviour in the face of danger is unpredictable is naturally contrary to our thesis. The prevalence of the use of words such as 'panic' to describe behaviour in emergencies is part of this set of beliefs (see ref. 69). Only in rare and extreme conditions is human behaviour random or literally out of control. At other times it is in principle predictable, or at least explicable provided that the relevant cognitive and emotional factors are considered. The task of the rest of the book is to try to set those factors out in a coherent way.

STRUCTURE OF THE BOOK

The rest of the book is organised in two main parts. The first part presents a model of behaviour in the face of danger. The objective of that part is to show how people may create danger through their actions and how they are able to control that danger and prevent it from manifesting itself in the form of accidents or disease. The model tries to provide a structure into which the diverse and fragmented research literature on human behaviour and health and safety can be fitted. Part I concentrates on the processes concerned and on the identification and explanation of the factors which play a role.

In Part II we change the focus to a more dynamic perspective; how does the behaviour of people adapt and change in relation to hazards? and how can it be deliberately influenced to achieve greater health and safety? The focus there is thus on the scope for prevention. A final chapter draws together the main conclusions from the book and sets out areas in which further work is necessary.

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CHAPTER 2

MODELS OF BEHAVIOUR IN THE FACE OF DANGER

In introducing the systems model in the previous chapter we mentioned earlier models of the involvement of individuals in accidents and the deleterious effect they had had on research in health and safety. Before presenting the systems model of behaviour which we shall use in this book we want to take a step back and look at the overall purpose of constructing models of behaviour. We shall then trace briefly the history of models in the area, and why we propose the one used here.

2.1 MODELS IN BEHAVIOURAL SCIENCE

The behavioural sciences have throughout their history used metaphors, analogies or models in their attempts to understand and explain the complexities of human behaviour. These models have usually been drawn from the prevailing dominant technology; mechanical and steam in the nineteenth century, the telephone exchange in the early twentieth century, and the computer in the post second world war period. Model building is an essential part of constructing theories in behavioural science. It is used to try to reduce the enormous complexity of behaviour to concrete and graspable form. The models crystallise what is known and themselves suggest new ideas of how so far mysterious human attributes may function. In these days of computers and expert systems it is becoming harder to tell where the metaphor ends and where reality begins. The field of artificial intelligence is faced with the question of whether to design computer systems which make decisions in the same way as experts (with all their faults) or to design 'better' systems which arrive at decisions in other ways. Whichever answer is chosen the problems encountered in writing software which will carry out the functions previously carried out by humans throws light on the way that those humans function. Indeed, the flowering of artificial intelligence has led to a parallel growth of interest among psychologists in cognitive functioning and information processing and to the development of new fields of cognitive science. This book benefits from some of the fruits of that growth.

The models used in the history of behavioural science have been designed to explain human behaviour in its entirety, but most have had something to say about slips, errors and accidents. For some of them the occurrence of such incidents played a central role. In formulating his psychoanalytic theory Freud (1), was centrally concerned with 'the psychopathology of everyday life' (better known as the Freudian slip). In his theory of the working of the conscious and unconscious mind many errors and some accidents were seen as the result of the conflict between the 'animal' id (unconscious) and the controlling forces of the conscious mind (the ego and superego). The analogy he used is very much of the steam age, with the energies (particularly sexual) of the id being bottled up within the pressure vessel of the conscious mind, or redirected by it into safer channels. Occasionally when the pressure became too great the energy would escape in ways which frustrated the conscious control or were even self-destructive. Thus some accidents were interpreted as unconscious attempts by the victims to punish themselves for thoughts and actions which they could not consciously admit. This psychoanalytic theory will return briefly in our discussion of motivation in Chapter 10.

In this chapter we shall discuss three types of model, that associated with accident proneness, the engineering model and the interactive information-processing system.

2.1.1 Accident proneness model

One of the great debates of the nineteenth and twentieth centuries has been the controversy over heredity and environment, the nature versus nurture debate. In it two factors are contrasted, in-built individual capabilities and the influence on behaviour and abilities of the environment in which the person lives and works. Part of that debate traces back to the social and religious uproar over Darwin's evolutionary theory. Its influence can be seen in the discussion of eugenics and attempts by such scientists as Dalton to detect and classify 'criminal types' on the basis of their physiognomy. Those who believed in the predominance of heredity held individual differences to be of central importance and took a pessimistic view of faults in human behaviour as essentially uncorrectable, while their opponents recognised the potential influence of change.

In the years from 1911 to 1920 several committees were set up to investigate the alarming increase in the number of accidents occurring in British factories, particularly in the aftermath of the introduction of war production (2,3,4). The question which was put to the pioneer accident researchers Greenwood and Woods (5) was phrased in terms of the individual versus environment debate. They were asked to seek an empirical explanation for the unacceptably high accident rate in manufacturing industry by testing two contrasting hypotheses:

> Were accidents a result of demands from the environment which were beyond the response capability of the general human being? or
>
> Was the problem that only some individuals, because of their personal characteristics, could not cope with these demands?

These questions must be seen against the background of their time. Some people were blaming the alarming increase in accident rates which had occurred in the period from the 1890s on the speeding up of machines and the increased pressure of work (an environmental hypothesis) while others pointed to the massive drafting of (by implication less competent) women and young and old workers into heavy industry to release able-bodied men for the first world war (an individual hypothesis).

The early research designed to distinguish between these two hypotheses appeared to show that a significant contribution to the accident rate could be found in individual differences (5,6). However, at no point did the research prove that the contribution of environmental factors was unimportant, nor indeed did the researchers ever set out to do so. It was assumed that removal of hazards would promote safety. Indeed much of the specific health and safety legislation in the UK passed in the first half of the century was based upon the control of those environmental factors. However, what the early results did suggest was that there was, in addition, a viable path to accident reduction through the identification of the characteristics of those individuals who did suffer more accidents. What was important for modelling of accidents was that these two paths were seen as almost totally independent of each other (7). The individual factors were seen, by definition, to be ones which made people possessing them more liable to have accidents, regardless of the nature of the hazard. Hence the psychologists and physicians could retire into their own research area to identify those individual factors which led to 'accident proneness' (8,9), leaving the engineers to worry about the environmental factors.

The research which followed ran the gamut of individual differences from sensory (for example, visual acuity), through psychophysical (for example, speed of reaction), to personality (for example, aggression); (see refs. 10 and 11 for reviews). However, results from the research were generally disappointing except in some areas of transport accidents. The field was also characterised by some very poor research methodology, and subsequent reassessment of the original research of Greenwood showed that his results were explicable by theories other than accident proneness (12,13). The resulting disillusionment with the theory caused it to be rejected, perhaps prematurely (11,14). Despite this, the underlying model of accidents implied in the whole approach had taken on a life of its own and refused to die.

Shortcomings of the accident proneness model. We do not propose to discuss in detail here the methodological shortcomings of the research on accident proneness which can be found in the lengthy reviews refered to above. Further discussion can be found in Chapter 11. We do, however, want to emphasise the effect that the model had on the way people thought about behaviour in relation to danger and how accidents might be reduced.

1. It encouraged a retrospective view of human involvement in accidents. The existence of accident proneness could only be investigated or 'proved' once people had had accidents. Thus, it fostered the collection of accident statistics which emphasised the characteristics of the individual rather than those of the accident.

2. It focussed upon only one factor, the characteristics of the victim, and paid little attention to how the accident happened. In most of the research all accidents were lumped together as though they were a homogeneous group of events, despite the fact that there was no plausible way that the human factors being tested could have influenced all of them. When deciding on groups with high and low accident rates, only some studies excluded accidents in which victims were injured in circumstances over which they had no control.

3. With the focus on individual differences, accidents and causal factors which were common to many individuals were largely ignored.

4. The preventive actions which could logically be derived from the model were all related to influencing the individual differences studied. This could be done either by preventing those with the undesirable traits from entering the dangerous work (for example, forbidding young persons to work on dangerous machines or including tests of accident proneness in selection procedures) or by trying to modify through training, counselling or motivation any traits which were not regarded as immutable (for example, anxiety or aggression).

The theory suffered from a central paradox which it never overcame. On the one hand accident statistics too easily seemed to show that some people, however defined, had more accidents than others. Thus proneness in a statistical sense was almost a self-evident fact. On the other hand all attempts to find reasons in the personal characteristics for such statistical differences were disappointing; either those characteristics explained only a maximum of 20% of the variance in accident rate, or a factor found to be relevant in one circumstance was found to be irrelevant in others. In other words proneness appeared not to be a global psychological entity. Yet this low validity of tests is hardly surprising in view of the number of different personal factors which can influence the occurrence of accidents, and the fact that no psychologically meaningful classification of types of accident was used in most of the research. Higher correlations should not have been expected in these circumstances. The better researchers did not themselves expect high correlations, but the potential users of the tests often did.

The first part of the paradox made proneness a concept which was attractive to managers and employers in industry. They looked at accidents through the statistics which emphasised those individual differences, and so its existence seemed to be staring them in the face. This attractiveness was also bolstered by the opportunity offered by the theory of assigning responsibility for accidents to the victims themselves, and causes which lay in their own make-up. This meant that both the moral and financial responsibility of prevention was, to an extent, lifted from the employer, who did not have to make any changes to the workplace, but merely to identify and exclude those who were unable to cope with its hazards.

The continuing strength of the accident proneness concept can be seen in the periodic surfacing of 'new' explanations of the statistical 'facts'. The theory of biorhythms is one of these more recent re-emergences. This mixture of astrological and biological theorising postulates three interlocking cycles of functioning which make accidents more likely in specified phases. It enjoyed some vogue in the 1970s despite the lack of substantial evidence to back up its claims (15,16).

The failure of psychologists to identify characteristics which could form a basis for excluding individuals from dangerous work can be seen as an important factor in the low opinion held by many in industry of the contribution, both actual and potential, of psychology to accident prevention. Researchers had awakened expectations which were too great and employers became sceptical of psychologists' ability to deliver theories which provided a basis for action. Among designers similar disillusionment led to a sort of 'play safe' attitude; 'if it is not possible to tell which people are accident prone, let us assume that they all are and design for idiots or children'.

More importantly, people continued to see technical and human factors in accidents as independent. This is reflected in the persistence of the division of accident causes so commonly quoted in accident prevention manuals (17), and known as the 80:20 rule (80% of accidents being due to human and 20% to technical causes). People also held fast to the view that human causes were only removable by modifying the humans and technical factors by modifying the machines and environment.

2.1.2 Engineering models

The engineering out of hazards has had a long history. It was identified by early factory inspectors in the UK as their major contribution to the reduction of accidents and occupational disease. Indeed for much of the Nineteenth Century they considered only accidents at machinery which could be cured by guarding to be of relevance to their job. Other accidents were considered as either unpreventable or as the concern of the victim (18). This view was also influenced by the contact of health and safety with insurance. A crucial part of any insurance investigation was the establishment of responsibility for the injury. If there was no technical fault it was much easier to place blame on the victim. It is not surprising that the most influential accident prevention book written before the Second World War (17, 'Industrial accident prevention') was produced by an insurance company employee (H.W. Heinrich), and was responsible for the popularisation of the 80:20 rule and the dichotomy of accident causes into 'unsafe acts' and 'unsafe conditions'.

The designers and engineers took as their task the reduction of the 20% of technical causes, and exerted enormous ingenuity in making headway against it. Wagenaar (19) suggests that the sign of a mature and stable technology is that the contribution of human factors to accidents in it has reached a maximum, since most of the soluble technical problems have been tackled. In the process of reducing technical failure the importance of the study of reliability increased, and theoretical advances produced the highly sophisticated reliability engineering techniques now used in the process industries (20).

We have suggested that one of the automatic responses of the designer faced with a fallible (and to the designer with no human factors training, a largely unpredictable) human in the system was to design the human out, that is to mechanise and later to automate (7,21). Where this was not possible, due to limits in technology - and hence the human had to be left in the system - the inclination was to try to apply to the human the same theories as to the hardware elements of the system. For example, designers calculating the time needed to evacuate people from a building in the case of fire modelled them as particles flowing in a duct (22). The initial model was inadequate, since it did not take account of the psychological space that people, even in an emergency, maintain around themselves. However, in this case the addition of this extra factor in the equation enabled it to produce quite accurate predictions.

Although the application of engineering models to humans has a long tradition within behavioural science, practised by researchers from both disciplines, it has its limitations. The application of component reliability theory to human reliability is a topical example which we will sketch briefly here (see refs. 23,24 for detailed discussion).

Human reliability. A central technique of reliability analysis is Fault Tree Analysis which is a logical exploration of the failures which can lead to a defined 'top event' failure, such as a catastrophic leak of chemical, or a meltdown of a reactor core. The fault tree is constructed by considering how hardware elements (such as pumps and vessels in the system) could fail and cause larger sub-systems to fail. Once the tree is constructed, failure probabilities for the individual events are inserted from reliability data banks, and the overall probability of the top event is calculated. It seemed attractive to apply the same logic to human elements, and indeed this has been widely done, based on a data-bank of human reliability figures (25).

The problem with this approach is that it is a purely normative one. Systems are analysed in terms of what they should do, and how they should work. Failures are conceived of as elements not fulfilling the function they were designed for. Applied to human elements this translates into people not performing the task assigned to them at the time they should. Such a classification into errors of omission (failure to act at all) and commission (the correct function at the wrong time) work well for hardware elements which have only a limited number of functional capabilities and ways of failing. When it comes to humans the classification runs into problems. Humans have many functions, and so can produce far more varied errors of commission. They also have their own understanding of the task objectives as well as having objectives of their own outside the task as defined. Omission and commission are defined in terms of the task, not of the person carrying it out. The same reason can lie behind both types of error (for example, incorrect diagnosis of a problem), and many different reasons behind any one omission or commission (for example, attention failure, misdiagnosis, memory failure, deliberate act, clumsiness, confusion of instruments). In other words the classification has no psychological validity (26,27), and hence cannot serve as a basis for estimating probabilities of error.

Singleton (28) and Rasmussen (29) identify a further misconception in the application of component reliability ideas to human factors. This is in the very nature of the role of error in behaviour. Technical reliability is based on the notion that failure is bad, and that the target of prevention is to stop it happening. If technical failure is equated with human error the analogy immediately breaks down. Humans are essentially error-making and error-correcting entities. Since they pursue goals they have sophisticated feedback and monitoring mechanisms which measure deviations from the path to the goal. Error (deviation) is therefore the input to the whole human decision-making process, and cannot be designed out of the system. Rasmussen (29) therefore redefines the role of the designer as one of enhancing the possibilities for error recovery, and producing an error-tolerant system.

Uncritical application of engineering analogies therefore has dangers and limitations. Discussion of engineering models has, however, led us again to the ideas of humans as active controllers of systems and of the errors in them. The next section presents the models that behavioural scientists have produced to put flesh onto that idea.

2.1.3 Interactive models

From the late 1960s a new sort of model began to be proposed to explain human involvement in accidents. These models came from the systems approach, strongly influenced by the concepts of information theory and cybernetics (30,31). The person was seen as a processor of information, taking it in and filtering it from the environment, ordering and making sense of it, using it to make decisions, taking actions and so modifying that environment, and then monitoring the results of those actions in order to guide subsequent behaviour and to achieve short- or long-term goals.

Hale and Hale (32) produced such a model, derived from studies of accidents in the manufacturing, power, and transport industries (Figure 2.1). The essential features described in the previous paragraph are present, with the important addition of a second input to perception, namely the expectations which people have of their environment. These are either built up from direct experience or adopted vicariously from parents and others or from the role models provided in newspapers, books, television or films. The decision process is divided into two conceptually separate parts, the generation of possible courses of action and the choice between competing actions, which is seen as a cost/ benefit decision. The model as such does not use the words 'error' or 'accident'. It was presented as a general model of human behaviour which could be used to analyse accidents. These were seen as instances where the processes described in the model failed to cope with the control of the danger present in the environment.

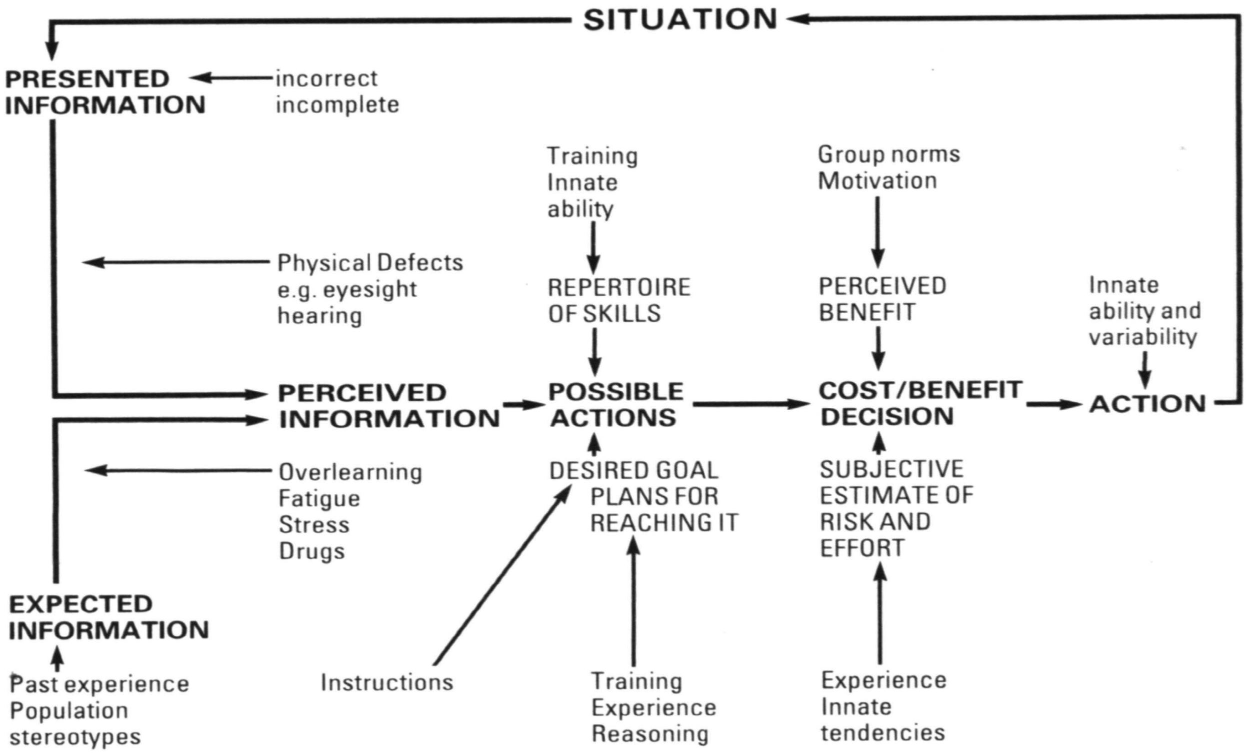


Figure 2.1. Model of accident causation (source 32, Hale and Hale 1970)

The advantages of Hale and Hale's model were that it stressed interaction between human and environment, that it conceptualised accidents as a loss of the control normal to that interaction, and that it introduced a dynamic element into the processes involved.

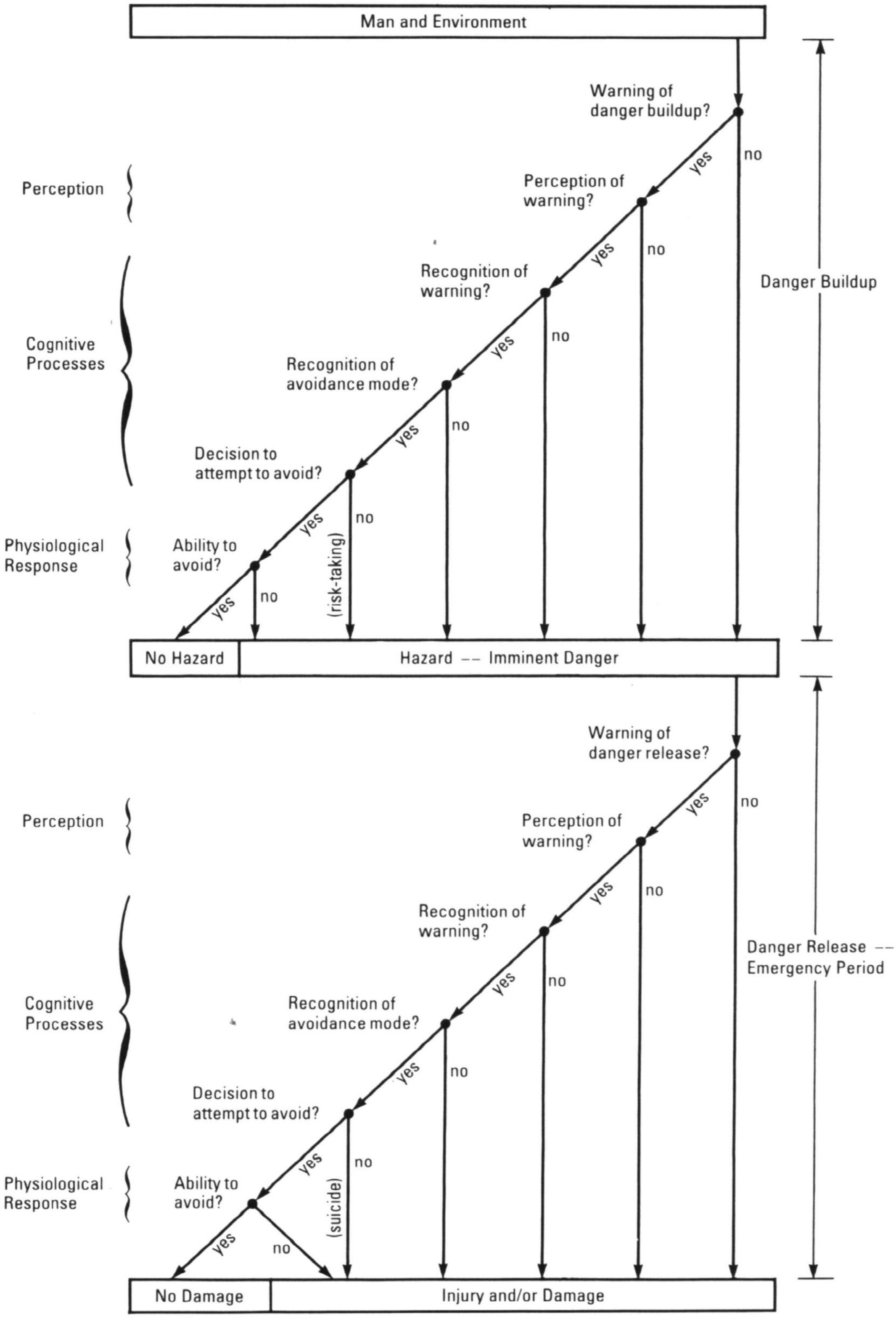
Surry (33) had contemporaneously developed the model shown in Figure 2.2. Surry's model has many features in common with Hale and Hale's model; in particular the perceptual, decision making and action phases are present. What is different is that the model is specifically linked to danger, with two phases of danger build-up and release being postulated, largely equivalent to the metastable and unstable phases of the model of MacDonald (34) set Figure 2.2. Decision model of the accident process (source 33, Surry 1969) out in Chapter 1. There is an emphasis on warnings as the crucial factor in the perception phase, and on avoidance as the crucial factor in the decision phase. The model also emphasises the dynamic nature of the accident process, though the fact that the process described occurs only twice, once for each danger phase, may give the false impression that a person has only two chances to control any hazard. In fact there may be many, depending on how long the hazard is present. As an aside the word 'hazard' is used by Surry as a synonym for imminent danger, and so includes the notions both of energy and of probability of its release; this is in contrast with the definition used in this book (see Chapter 1).

Both models have been used and modified subsequently by other researchers (35, 36, 37, 38, 39, 40, 41). In particular, additions have been made to include consideration of the process by which hazards are introduced into the system (37), and to emphasise the issue of responsibility for taking action (38).

In one important respect neither of the two models matches the complexity of human functioning shown by research both into accidents and into normal behaviour. Kay (42) discussed two distinct levels of human functioning which he called 'stimulus-response' or closed-loop and 'pre-programmed' or open-loop. In the former mode individuals monitor their behaviour consciously and interactively, while in the latter whole sequences of behaviour are run off as if the person were on automatic pilot. The sort of problems and errors at the two levels of functioning are very different.

Rasmussen, in the late 1970s, carried out a number of studies of errors in the nuclear industry (27,43,44) and arrived at a similar concept of different levels of functioning - this time three - see Figure 2.3.

The three modes of Rasmussen's model indicate three different levels of abstraction in the behaviour. At the 'skill-based' level an incoming piece of information is connected directly to an automatic response which can be carried out without conscious thought or control (for example, a copy-typist reading 'a' striking the end key in the middle row of a typewriter; a driver hearing the car engine labour and changing down a gear). If there is no automatic response available, or, if the individual has several possible responses from which to choose, the behaviour must move to the next, 'rule-based' level where the appropriate procedure is chosen, taken out of store and executed (for example, turning left at the traffic lights on a standard route to work, carrying out a standard check routine on receiving a low-pressure alarm on a process plant). If there is no appropriate rule, or the individual does not want to apply the available rules, the behaviour must pass to the 'knowledge-based' level, where constructive thought must take place to interpret what the problem is and what would solve it (for example, working out how to drive to a new destination, diagnosing a fault with unusual symptoms).



Man and Environment
Warning of danger buildup?
yes
no
Perception
Perception of warning?
Recognition of warning?
Danger Buildup
Cognitive Processes
Recognition of avoidance mode?
Decision to attempt to avoid?
Physiological Response
Ability to avoid?
(risk-taking)
No Hazard
Hazard -- Imminent Danger
Warning of danger release?
Danger Release -- Emergency Period
(suicide)
No Damage
Injury and/or Damage

Figure 2.2. Decision model of the accident process (source 33, Surry 1969)

LEVEL OF FUNCTIONING	COGNITIVE FUNCTION		BEHAVIOUR RESPONSE
Knowledge	Interpretation	→	valuation/ task definition
	↓		
Rules	Identification	→	procedure
	↓		
Skills	Observation/activation	→	execution

Figure 2.3. Rasmussen’s model of levels of functioning (after 26, Leplat 1985)

This model has been used by Leplat (26) and by Reason (45,46) to discuss errors and accidents. The studies and theories of Reason in particular will be discussed in detail in Chapter 3. The model fits with the concepts of Singleton (21) of a slow analytical central processor which monitors fast peripheral processors which take their own decisions most of the time; the central processor picks up errors and intervenes to put them right. The three levels also coincide well with ideas which come from learning theory. Gagne, for example, discusses different levels of learning (47). The simplest levels are the basic types of conditioning of behaviour familiar from the work of Pavlov and of the behaviourist school in which automatic stimulus-response links are built up into programs. Then follows the learning of concepts in which objects and ideas are associated in categories (the 'concept' lathe as a sub-category of the 'concept' machine tool, or of carcinogenic as a sub-category of toxic); subsequently people learn to associate these concepts into rules (if the lathe is operated in a certain way then it runs 'safely', but not if it is operated in a different way). Finally people learn to combine rules and concepts in novel ways to solve problems.

The three levels should not be thought of as differing in 'goodness'. Knowledge-based behaviour requires more intellectual processes to carry it out, and could in that sense be considered as higher than the other levels, but it is inappropriate to use it when jumping out of the path of an on-coming car or in signing one's name. Each of the three levels are appropriate to different behaviour in different situations, and a large element of safe behaviour is in the choice of the correct level for given circumstances. Thus it is far preferable to choose to entrust one's life as a plane passenger to a pilot who will fly most of the time using behaviour at a skill- and rule-based level, rather than to the designer of the aircraft, who may have unparalleled ability at the knowledge-based level.

A further potential confusion must also be pointed out. The word 'skilled' is used in common parlance to mean two psychologically very different things. It is applied to someone who does a task (often a simple one) very fast or competently; here it means that the action sequences have been very well learned and can run smoothly. Rasmussen uses 'skill' in this sense. 'Skilled' is also used to refer to a worker who has gone through a long training and has a breadth of ways of coping with problems (a skilled carpenter or fitter). In this second meaning the worker is able to operate very efficiently at rule- and knowledge-based levels when faced with different and novel tasks within the defined area of competence. For the sake of clarity we shall avoid using skill in this second sense. There is an overlap in the two meanings, since an expert will always spend less time than the novice operating at the knowledge-based level. The expert has met all aspects of the task before and has learned the skills and rules for coping with them. The novice has to work them out by operating at the knowledge-based level. However, experts are also more capable than novices of operating at the knowledge-based level since their grasp of the fundamentals of the task is greater. Therefore, compared with the expert, the novice tends to make not only more, but also different kinds of mistakes.

Rasmussen's three stage model has not been without criticism, for example over the exact boundary between the three levels. The crucial factor is the degree of 'automation' of the behaviour, and it is perhaps better to think of knowledge-based and skill-based behaviour as two ends of a spectrum, with rule-based behaviour as a somewhat ill-defined region half-way in between. The details of the model will be described further in Chapter 3. Despite this slight vagueness the model provides a valuable contribution to a systematic understanding of errors and incidents. In particular it introduces the notion of the correct level of functioning appropriate for any given task or situation, and the problems which occur when working at the wrong level.

2.2 A SYNTHESIS

The model which is now presented (Figure 2.4) is an attempt to synthesise the main points from the last three types of model discussed. Before describing it in detail it is important to indicate its status. It is not a fully tested model which completely describes the way in which all people necessarily behave when faced with danger. Its prime purpose is to organise a vast bulk of literature and ideas into a structure which is comprehensible, and to put forward hypotheses for further study. It has been developed from three major sources:

1. An attempt to make sense of the large literature on human behaviour, accidents and occupational diseases, and to categorise the factors emerging from it in a way which orders the factors identified and shows how they might relate to each other, and how apparently contradictory results of different studies might be reconciled.

2. A similar review of the literature on people's response to hazards and the measures put in place to control them (for example; safety rules, personal protective equipment, machine guards, norms and standards).

3. Logical inference derived from more general theories in the social sciences; for example, of perception, memory, decision making, motivation, learning and attitudes.

However, in many of the areas discussed further refinement of the steps of the model will be necessary before good predictions and testable hypotheses can be made. It is one of the purposes of this book to stimulate such tests, which may lead to significant revisions of the content or order of the steps set out here.

2.2.1 The model: description

Structure. Our model adopts the general structure of Rasmussen's, but fills it out with the somewhat expanded and retitled stages adapted from Surry's model. The feedback loop from the Hale and Hale model is retained to emphasise that the process is an iterative one. For clarity of presentation the branches from the last mentioned model which lead into the main 'perception-decision- action' sequence have been left out of Figure 2.4. The factors covered by those branches will be dealt with in the course of the book under the appropriate chapter headings.

The model portrays what has to occur if an individual is successfully to avoid being harmed by hazards in the environment. As such it is a prescriptive model, and the book will explore the factors which determine whether actual behaviour is likely to follow this prescriptive route.

The model takes as its basic premise that there is some danger in an environment or system. It starts from an assumption that the danger is not already producing harm, that is, that the individual is not already exposed to some chemical or environmental factor at above the threshold for long-term damage. The model does not deal specifically with the way in which hazards appear. As was described in Chapter 1 danger is always present to some degree. Even where the danger level is very slight, the individual may go through the stages represented in the model to verify that. Without the intervention of the person whose behaviour is being considered, the danger may be increasing, decreasing or static. The danger is made up of one or more different hazards each with an associated risk of producing harm. The probabilities associated with each of these will also be increasing, decreasing, or static, the sum producing the overall picture of danger.

Conscious versus unconscious control. Hazards are only a part of the whole environment in which people are operating. For most people most of the time danger is a very minor concern. For example, in drilling a hole in a wall, they will often be more concerned with getting the hole in the right place than with whether the drill is bending or their hair is in danger of getting entangled with the drill. This concern with doing a good job may sometimes therefore distract from safety. However, it may also enhance it, as in the case of using a clamp to hold a piece of metal while drilling, which makes it not only easier but safer. Much of the time there will be no conscious consideration of hazards as such. If the programs and procedures which individuals have learned for carrying out their tasks well also contain the appropriate steps to keep out of the reach of the hazards there may be no conscious awareness of whether danger is present or not. We would stress that this state, which might be labelled 'lack of safety consciousness' is both a normal and a healthy state of affairs, despite what has been said in countless books, articles and speeches. Being constantly conscious of danger is a reasonable definition of paranoia. What is vital is that in the learning of the programs and procedures, the appropriate responses to the danger signals are built in as necessary, and that people switch over at the appropriate junctures to the more conscious rule- and knowledge-based levels of thinking about and planning against danger when the learned skills can no longer cope automatically.

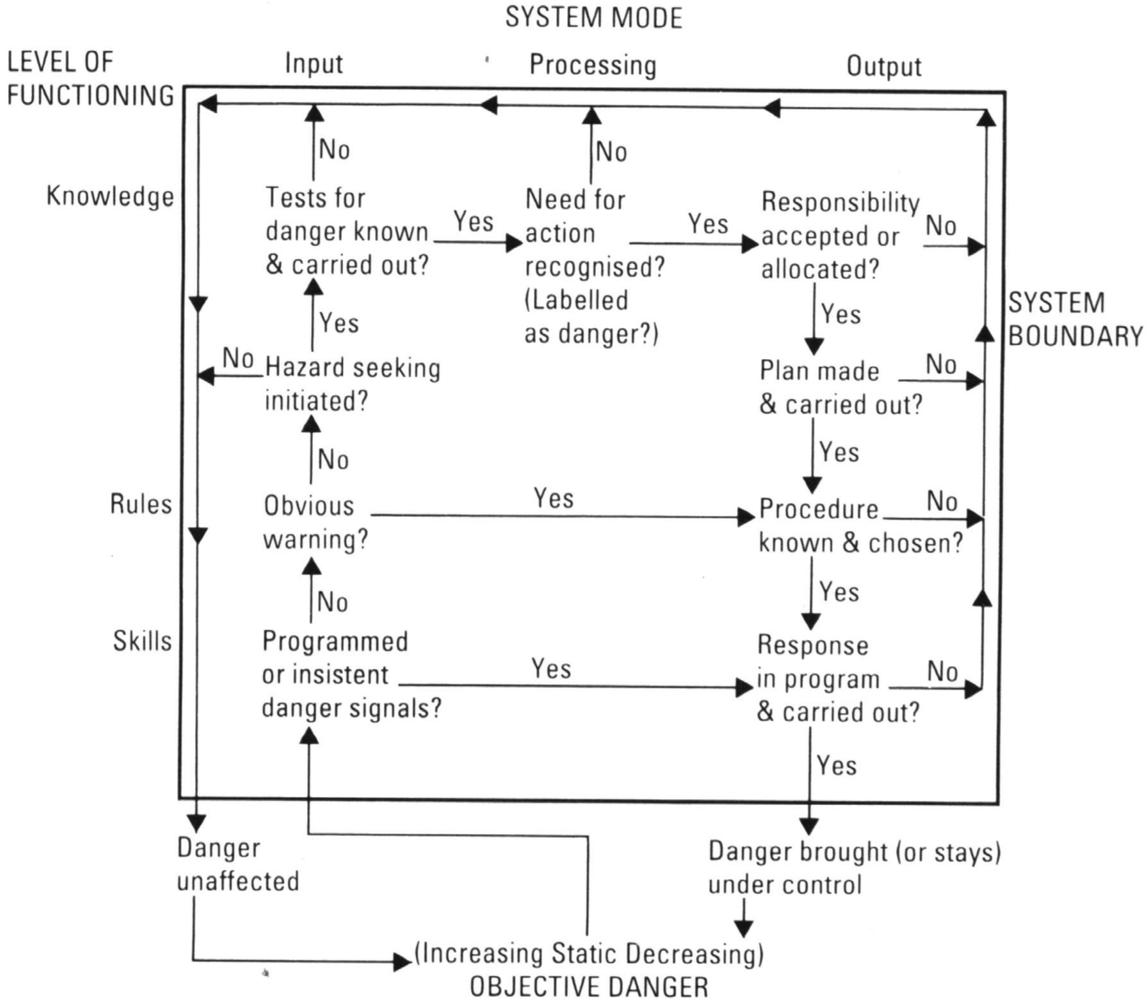


Figure 2.4. Behaviour in the face of danger model

Chapter 3 will consider the skill- and rule-based levels of behaviour in detail and discuss how the programs and procedures operate and how errors in them can cause people to act in a way which leads them into danger. That chapter therefore considers behaviour which starts by being essentially 'under control', and the ways in which that control can be lost without the individual necessarily realising it.

If circumstances arise where the danger now starts to increase there may come a point when attention is more directly and consciously given to it. This also happens when people are specifically asked to think about hazards and their beliefs and attitudes about them. At that point a whole series of other factors play a role. These factors are also important in the process of learning about danger which will usually occur at a conscious level. These factors are discussed in Chapters 4 to 7 under the headings of hazard detection, assessment of danger, attribution of responsibility and plans and procedures against danger.

The 'task' of the individual in avoiding harm is to steer a path through the model so that the questions at the appropriate level receive a 'yes' answer, and hence any danger increase is arrested before harm starts to occur. Any 'no' answer short-circuits the process and allows the danger to go on increasing. But the cycle can repeat on as many occasions as there is time before the harm process starts (and, if the harm process is a slow one, as in an occupational disease, thereafter until the individual is removed from the danger). These feedback loops are a vital part of the process and will be considered specifically in Chapter 9.

For simplicity's sake the model is presented as a single line process. If a 'no' answer is given at any point it is implied in the model in Figure 2.4 that the whole process must start again. This is not logically necessary, and it would be perfectly possible to add further loops whereby, for example, an answer between a 'yes' and a 'no' at any point might loop back to the previous stage to examine that question in more detail. In particular a check at any point in the more basic levels of functioning may result in the problem being referred to the next level for more conscious analysis.

In the course of presenting what is known about each phase of the model we shall discuss a number of studies which have looked specifically at the way in which behaviour in the face of danger can be changed. Since the task of many people reading this book is to produce just such an influence we gather together the conclusions of those studies in the second part of the book. We also discuss the gaps in knowledge which still exist, and therefore the sort of research which is needed to fill them.

Although the above description of the model has been given in terms of danger which threatens the individual personally, it is also possible to use the model as a basis for actions to protect other people from danger. Thus the activities of the designer in anticipating hazards at the design stage of a project can be covered, as can the actions of a manager or supervisor looking after subordinates, or of workers who might endanger (or protect) their fellows.

2.2.2 Use of the model

The discussion so far in this chapter has been almost entirely theoretical and rather abstract. In order to provide an empirical context for the discussion we conclude with some figures from studies which have used this model (or similar ones) to classify accidents. The examples are deliberately chosen from very different types of activity in order to show the breadth of applicability of the classifications.

Hale (48) used a preliminary version of the model to analyse incidents in the electricity supply industry which resulted in loss of supply and involved human error. In the 106 incidents analysed there were 146 errors made, all but six of which involved activities at the skill- or rule-based levels of operation. In nine cases the procedure for carrying out a task had been incorrectly learned, and in six more a correct procedure was badly or clumsily carried out. In all the remaining cases the incident involved either the selection of the wrong procedure or omission of a step in it. The analysis showed that most of these problems were related to difficulties with perception or with incorrect expectations - frequently associated with poor equipment design, labelling and layout.

Lawrence (49) used Surry's model (Figure 2.2) to analyse 405 accidents in the South African gold mines, involving a total of 794 errors by 575 people. In all but three incidents there was some indication of the approaching danger. Nearly fifty percent of the people involved failed to perceive the warnings such as they were, and so made no attempt to avoid the danger (often a rock fall). Of the 290 who perceived the warning, 257 (89%) recognised it as such, but only 57 (22%) of them correctly estimated the risk. 140 of the 257 (54%) made no response to the warning, 40 (16%)

responded appropriately (by warning others), and the remaining 77 (30%) made an ineffective response. The perception and estimation stages emerge here as predominant.

As a final example Snyder and Knoblauch (50) analysed 2517 pedestrian accidents in US cities. They categorised the errors under the following headings:

	Pedestrian		Driver
Poor course (procedure) selection	30,6 %		4,6 %
No search for danger	29,4 %		12,9 %
No detection of danger	6,0 %		7,4 %
Poor evaluation of danger	4,0 %		2,1 %
Poor decision	0,4 %		0 %
Poor control/action	0,5 %		1,9 %
Interaction pedestrian & driver		0.2%	
Total	70,9 %		28.9%

Again it is the perception stage which emerges as very important, together with the correct selection of procedures from the repertoire. These examples underline the importance of cognitive factors in the danger control process and emphasise that many problems occur in the input stage to the human system and in the subsequent selection of the appropriate program or procedure to respond to what is perceived.

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CHAPTER 3

DANGER IN ROUTINE TASKS

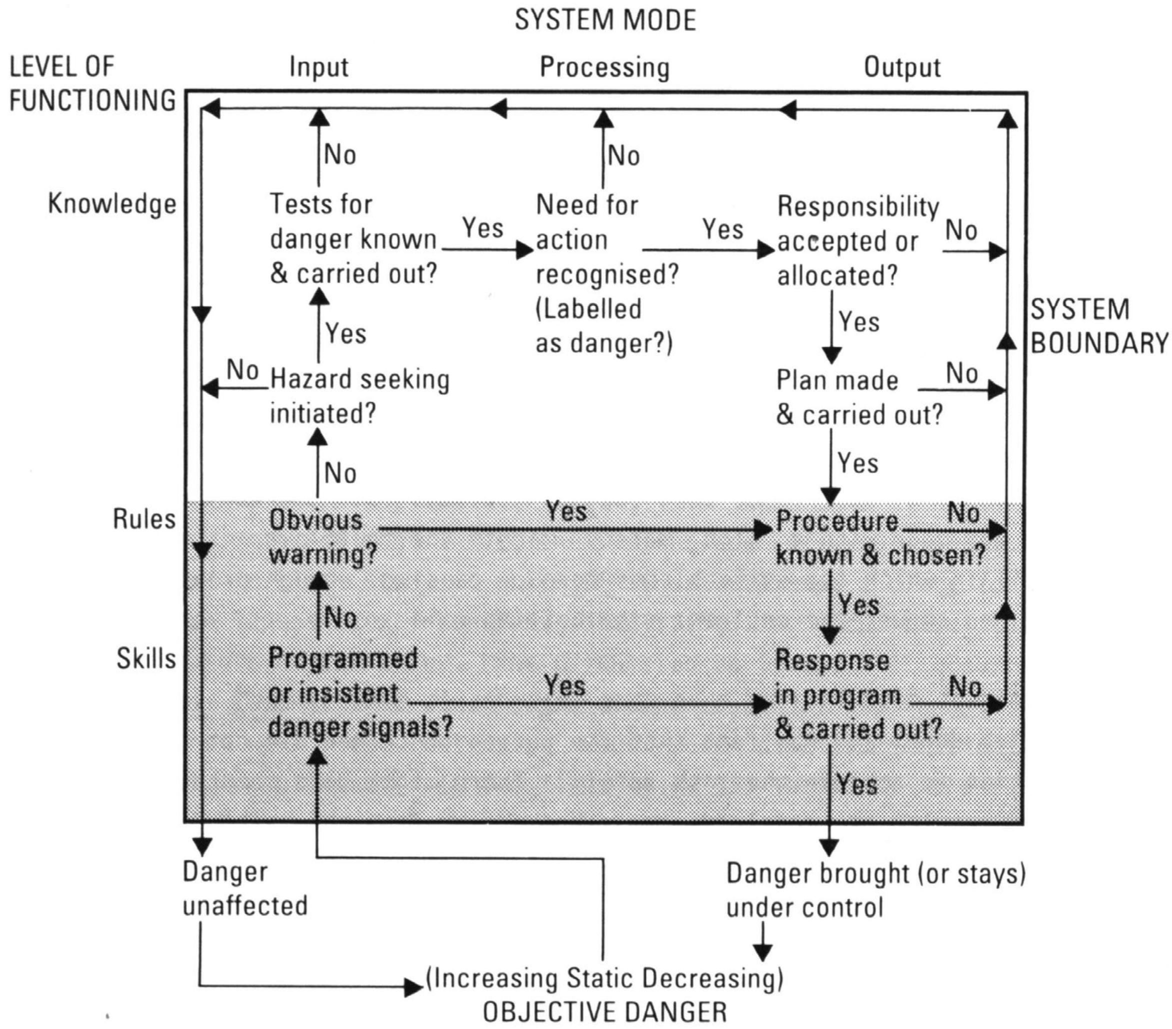

Figure 3.1. Behaviour in the face of danger model - routine tasks

3.1 INTRODUCTION

1. It is early one Friday afternoon and two fitters are working on the installation of a new lathe, which is required to be in production for the start of the next week. In order to level it they need to pack some material under one corner. There is no overhead crane in the shop, and they have not got a shear-legs with them. The machine only needs to be lifted a fraction to get the shims under, so, after some discussion, they decide that one will lever with a long crowbar while the other slips them in place. The fitter finds a leverage point and heaves upwards on the bar. Just after his mate has put the first bit of packing in place the bar slips. The fitter tries to save it by twisting to adjust his grip and collapses to the floor clutching his back. He is off work for six months with a severe lower back injury.

2. It is 17.00hr on a Tuesday and an electrical engineer is restoring power to a piece of the electrical network after his work gang have finished jointing a feeder cable into a new housing estate. He is working to a checklist operating on switchgear with which he is very familiar. The restoration of power involves a series of switching actions on gear in several substations to which he has to drive through the rush hour traffic. Most of the switches are identical, with two handles one above the other controlling the service (on/off) and earthing functions of the switch. One switch, made by the same manufacturer, has the same two handles controlling the same two functions, but the earthing handle is above instead of below the service handle. When he comes to operate this piece of gear the engineer moves the earthing handle to 'on' instead of the service handle to 'on'. In doing so he earths the incoming live line carrying 11,000 volts, causing a massive fault current which activates protective trips, interrupting supply to a small housing estate, but also causing damage to the switch which has to be taken out of service. In earlier times before switchgear was made with a high safety margin the fault current was enough to boil the oil in which the switchblades moved, causing enough pressure to burst the casing and shower the engineer with boiling oil.

The two accident descriptions have some features in common, such as the pressure to get a job done, and the fact that the person concerned did not carry out the correct action to achieve the task safely. There might be a temptation to label both as the result of carelessness. Looked at from the point of view of the psychological factors concerned, and the appropriate preventive actions to take there is a crucial difference. The fitter was carrying out a non-routine task which he had consciously planned (and discussed with his mate); the problem arose because his planning was bad, he underestimated the weight of the lathe, did not pick an adequate leverage point, and chose a bad procedure. Levering upwards using the floor under the machine as a pivot is much less effective than putting a pivot between him and the machine and pushing downwards. The engineer was carrying out a routine task with which he was highly familiar, and which was set out in detail for him on a schedule; this involved repeating the same actions several times over on a number of examples of one design of switch. His problem arose when he was faced with an apparently similar switch and carried out the same actions on it without noticing that it was in fact crucially different.

In terms of our model the fitter was working at a knowledge-based level, the engineer at the border between the skill- and rule-based levels. In terms of prevention it is reasonable to think, in the case of the fitter, of giving him some guidance on job planning, or doing something to affect the resources at his disposal when he has to make those decisions. In the case of the engineer exhortations to take more care and to check every switch before operating it may have an effect for a few days or even weeks, but nothing short of standardisation of the switchgear design, or introduction of suitably designed interlocks will have a long-term effect on the problem. Operation on routine tasks is controlled and influenced in different ways from operation on one-off tasks. The sort of errors and accidents which occur during the one are therefore significantly different from those that occur during the other. In this chapter we tackle danger in routine tasks. In doing so we shall draw very heavily on the work of Reason (1,2,3,4,5).

3.2 'ABSENT MINDS'

In 1976 Reason published the first results of a study in which he had collected descriptions from volunteer subjects of 'absent-minded' errors - situations in which people had suddenly realised that they were carrying out an action that they had not intended. He cites numerous cases, for example going upstairs to fetch a wallet from a bedroom, stopping on the way to wind the bedroom clock and coming out again without the wallet; getting into the bath with your socks on; looking for your glasses and finding them on the end of your nose. The data came from an initial study in which 35 volunteers kept a diary for two weeks recording these lapses from intention, specifying in each case the intended action, the nature of the error, the circumstances in which it occurred and the time of day. Further data came from a second study of 63 people keeping a diary for one week, and answering much more detailed questions about the circumstances of the lapses. In the first study 433 incidents were recorded and analysed - an average of just over twelve per person. In the second study 192 errors were reported, an average of about three per person (4).

The most striking finding of the studies was that these slips almost always occurred during routine, common tasks which were reported as being carried out in a largely automatic way. The diarists frequently reported 'waking up' to find themselves doing something inappropriate, often without being aware of how precisely they had got into that situation. Analysis showed that the behaviour substituted for that intended was usually conservative - it involved actions which were more frequent, practiced or recently used than the intended behaviour. Reason called these 'strong habit intrusions'.

In later studies Reason analysed the literature on a number of serious accidents in order to see if the same sort of phenomenon could be found in situations where the consequence was not the mild embarrassment and annoyance of the subjects in his first experiment, but loss of life and/or major damage. He presents a number of case studies of such disasters drawn mainly from aircraft and rail accidents, and nuclear plant incidents (5,6,7,8).

Examples include:

1. The 1975 Moorgate underground train crash in which 42 people died when the driver drove the train at speed into the buffers in a blind tunnel. Reason suggests that he lost his place on the journey, thought he was one station earlier on the line and carried out actions appropriate to that point.

2. The 1977 runway collision between two jumbo jets at Tenerife in which 577 people died when one aircraft took off in thick fog while the other was still taxiing up the runway before turning off onto a taxiway. Reason points to the fact that the captain of the first aircraft was a training captain, highly experienced on simulator flights, but lacking much recent actual flight experience. In the simulator, clearance for take-off was always given immediately after route information in the same message. In the incident the route information was given without that clearance, and a somewhat ambiguous conversation between captain, co-pilot and air-traffic controller failed to pick up the fact that the captain had 'understood' clearance also to have been given.

3. In 1979 an operator in the Oyster Creek nuclear plant in the USA was coping with a reactor trip. Procedures required him to close two of the four recirculation pump discharge valves as part of the system recovery. Instead he closed all four, resulting in loss of natural circulation of water to the core, and a series of further problems in controlling the transient. The error was discovered only 35 minutes later by a supervisor. Reason & Embrey (5) suggest that the operator had inadvertently selected from his mind - triggered by standing in a preoccupied state of mind in front of the control panel - a procedure in which all four valves did have to be closed.

4. Rasmussen (9) in an analysis of 200 operational incidents also found that the majority were on routine tasks and involved simple faults or mistakes (for example, steps left out of procedures accounted for 34% of the errors).

As a result of these studies Reason developed an extensive theory explaining how such errors can happen, and what can be done to reduce their occurrence (2,3,4,10).

3.3 THE CONTROL OF ROUTINE ACTIONS

The study of habits or routines has a long history within psychology. Reason traces the influences of Freud (11) who was interested in the way in which habits in everyday life could be disturbed by slips (usually of the tongue), the work of William James (12) and his study of awareness, and the work of Bartlett (13) who coined the term 'schemata' to describe behavioural and memory routines which direct and control behaviour. The behaviourist psychologists (for example, Skinner, 14) were also interested in how routines of behaviour were built up from the linking of stimulus to response through the reinforcement of reward. Learning theorists such as Gagne (15) extended these ideas to suggest the development of hierarchies of skills or routines.

What is common to many of these approaches is the idea of sequences of actions which are associated together into chunks which can then be run off rapidly and smoothly in response to an initial stimulus. This idea forms the basis of Reason's theory.

An appropriate analogy for these actions and chunks of behaviour is the computer program. A program consists of specific steps which are linked together in a particular way to accomplish a particular task. Some of the steps will be single items, such as multiplying two numbers, others can be sub-routines, for example increasing the value of a variable by one in order to count how many times an operation has been carried out, and stopping the iteration after a set number of times. Depending upon the level at which a program is considered, different levels of organisation into routines are apparent. At the lowest level all actions are represented in binary form as a sequence of ones and zeros; at a higher level these are grouped to perform defined mathematical operations; higher still come the sub-routines just mentioned; and above that come the standard packages which perform, for example, statistical tests on data when told to 'run', and expert systems which conduct an interactive dialogue with the user.

Similarly human 'programming' can be seen at the lowest level of nerve impulses generated in the brain, at the level of specific muscle contractions, at the level of routine skills, and at the level of goal oriented purposive behaviour. A vital element which is built into human behaviour is the process of monitoring and control of actions at various levels. (This is also a vital part of computer programming, to avoid producing nonsensical results; for example, attempting to perform operations on non-existent data, or data in the wrong form). Miller et al. (16) were among the first to point to the centrality of this mechanism in the control of behaviour. They coined the term TOTE routine to describe it. The acronym stands for Test-Operate-Test-Exit (see Figure 3.2).

Figure 3.2 shows just one TOTE routine for the process of hammering a nail into a surface. The OPERATE block will also be a series of TOTE routines which will control holding the nail in such a way that it can be hit by the hammer (without hitting the fingers), raising the hammer head a suitable distance, and striking the nail with appropriate force. The TOTE shown is in turn a part of the sequence of hanging a picture on the wall. However, it can also be applied in other sequences, such as building a new kitchen cupboard, attaching a petition to a church door, or sealing a coffin. In each case there may be slight modifications in the exact behaviour shown (depending on such factors as whether the item is to be hammered horizontally or vertically, the hardness of the material and the size of the nail), but the structure of the action will be the same.

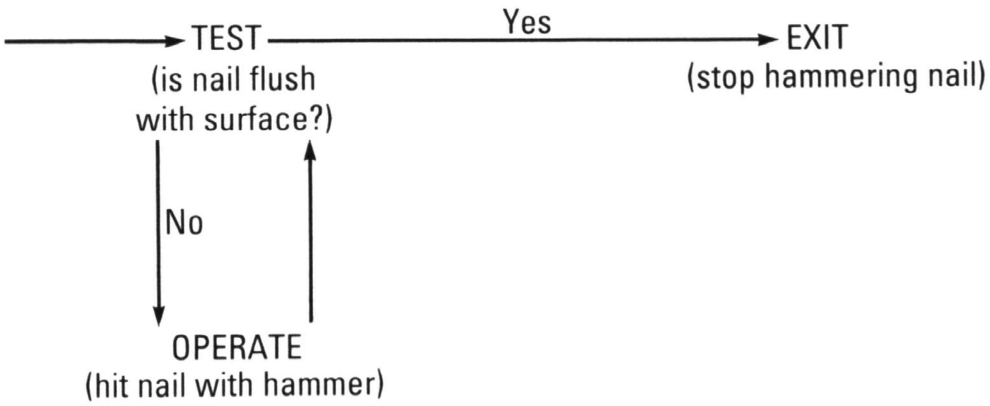

Figure 3.2. TOTE Routine (after 16, Miller et al., 1960)

There will be many thousands of such routines stored in the repertoire of skills (17) which individuals have at their disposal. In theory the routines can be ordered into almost countless sequences, providing the basis for the flexibility which is characteristic of human behaviour. This flexibility is limited by the degree of monitoring which is needed to control the behaviour. The TEST phase of the routine requires an input of information to determine which action comes next. If the test is clear-cut and the difference between the two possible outcomes is large, the test may be automated and carried out below the conscious level. If it cannot be so automated it will take up time in the relatively slow central processing unit of the brain, and may come under clear conscious and deliberate control. Even when largely automated, the test phase will still occupy processing space, and thus limit the speed with which the sequence can be carried out. This limit can be removed or reduced by leaving out some of the TEST phases. In our example the test for the nail still protruding from the surface might be carried out only after say every three blows of the hammer. The cost of such a reduction of monitoring is that actions may go on longer than appropriate (denting the wall or trapping the fingers), or despite a problem which has arisen and which would require a switch to another program (the nail bending). The degree of monitoring which takes place is thus crucial not only to the success of the sequence but to the occurrence of errors or accidents. This means that there is a trade-off between speed and safety inherent in the control of most activities.

Reason's theory gives a central place to this process of monitoring, which he calls the control of attention. He conceives of attention as a resource which is in limited supply, and which can be concentrated on very detailed control of one activity, or spread out rather thinly over many. Since people are faced with ever changing situations they must continually adjust the distribution of their attention to meet the demands, not just of coping with what is happening at this instant, but in planning for what is going to happen in a few minutes, or a few hours time. Activities thus compete for the limited supply of attention. Building up sequences of behaviour which can be run off with little monitoring is thus an extremely efficient method of conserving a scarce resource. Reason seeks to explain errors in routine tasks as failures in this process of distributing attention. Figure 3.3 shows the mechanisms which he invokes.

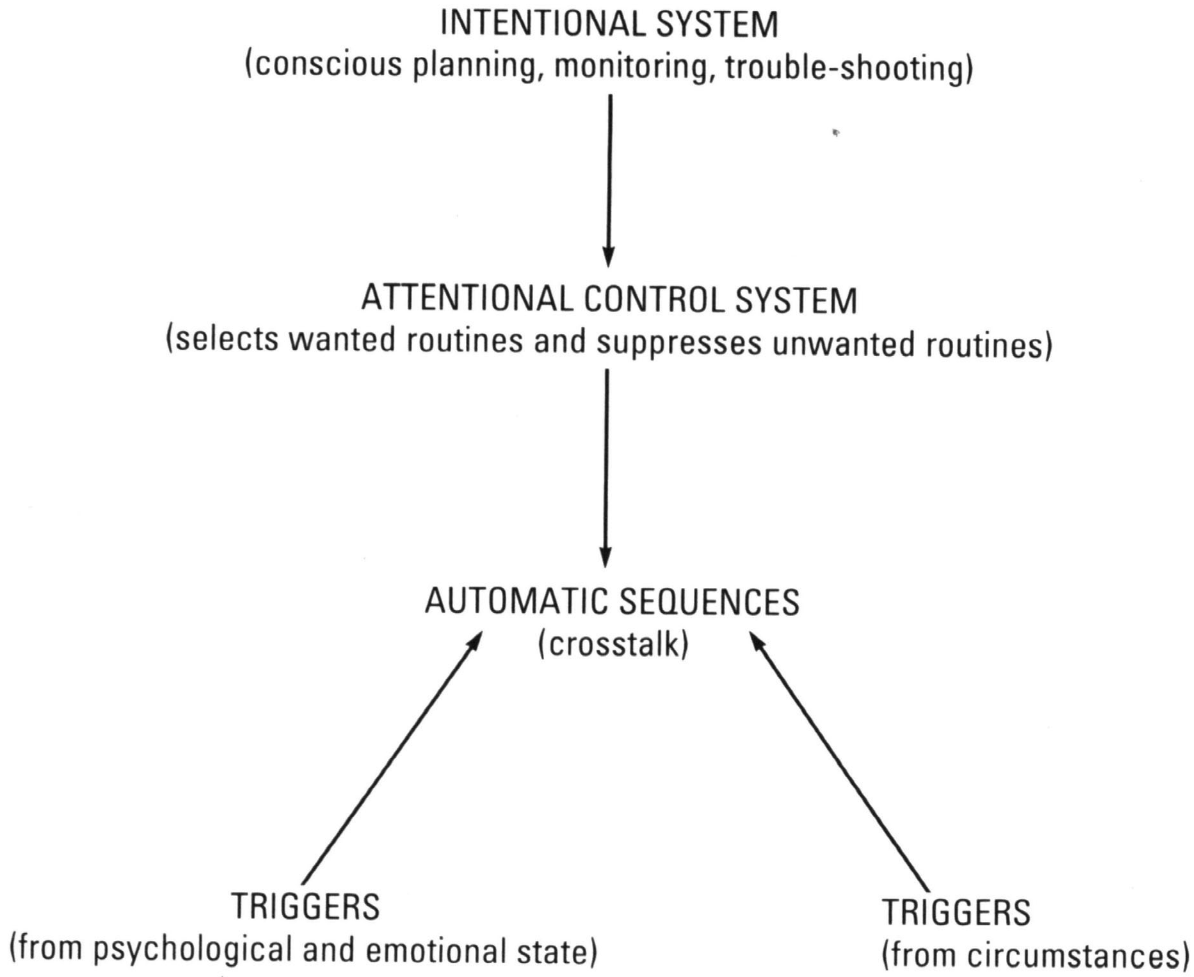

Figure 3.3. Attention distribution (after 2,3, Reason 1984,1986)

3.3.1 Types of error

An important aspect of the model in Figure 3.3 is that the attentional control system must not only activate and select the sequences that are necessary to achieve the individual's intentions, but also suppress sequences that might otherwise become active and capture the control of behaviour. At the level of automatic behaviour there are three influences at work which can result in such capture.

1. Crosstalk between sequences. Different sequences of behaviour may use some of the same TOTE elements or sub-routines. Confusion between them will occur when sequences varying only in a few steps are needed to achieve the same goal in different circumstances; for example direction indicators on the left of the steering wheel as opposed to the right in different cars. Confusion will also occur when sequences with common elements are used to achieve different goals with the same equipment, for example making a load adjustment on a power station as opposed to shutting it down. Where sequences are similar and one is used very much more frequently than another it is possible that behaviour will slip from one to the other; the strong habit intrudes and captures the system. This can occur also in the form of blends of two sequences, or failure to switch from a familiar sequence to another. Examples are:

1. the driver who is used to the gear layout shown on the left of Figure 3.4, and when faced with that on the right of the figure finds reverse gear instead of first when setting off from rest;

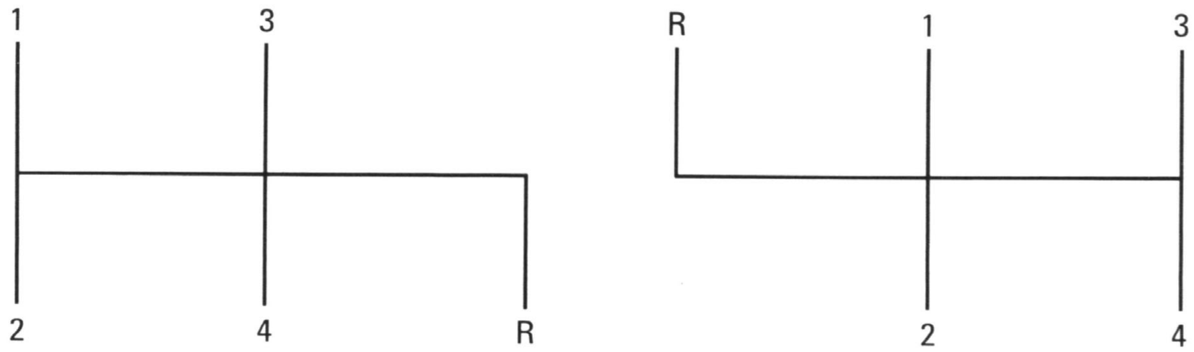

Figure 3.4. Crosstalk: gear layouts

2. the manager who has been receiving a stream of visitors knocking at his door all day, and who answers the telephone when it rings with an abrupt 'Come in';

3. the electrician carrying out a test on some equipment and carrying on to reenergise it instead of stopping at the end of the test because there is more repair work to be done.

This sort of error is particularly likely to occur when carrying out two activities at the same time, for example screwing up the top copy of a letter and throwing it in the waste bin and filing the rough notes.

Winsemius (18) noted a related phenomenon in his study of accidents in machine shops. He found that people involved in tasks with distinct phases which required the use of different tools would often keep very close by them tools for the main phase while they carried out the subsidiary phases. They would sometimes even use the main tool for the subsidiary phase, even when it was not appropriate (driving in a screw with a hammer); and would be very likely to use that tool to try and put right any deviations which occurred in the task (for example hitting a piece of the machine which was coming loose with the hammer in order to put it back in place, rather than using a spanner). This 'bridging' of task phases produced a number of accidents when the actions caused or aggravated 'deviations' from normal work sequences.

2. Capture by external circumstances. Certain actions are associated very strongly with particular situations and circumstances, and entry into those circumstances in a state of distraction can result in that behaviour being triggered. This often results in the same type of error as mentioned in 1, for example the person in Reason's study who went up to the bedroom in the evening to change and go out to dinner, and ended up getting into bed; the person who was fanatical about switching off lights and power points which were not being used and switched off the computer on leaving the room to go to the toilet, so losing the last hour's work.

3. Capture by internal preoccupations. If the central processor of the brain is preoccupied either with planning ahead, or with trying to solve an emotional or intellectual problem it can allow behaviour to run on with no guidance. For example, people quite frequently report arriving at a place and not having the slightest idea of how they got there, because they have been so preoccupied. Alternatively, such preoccupation can trigger pieces of behaviour associated with that worry which override the routine activity going on. Such capture can result in plans intruding on actions. Students are prone to such errors when they try to encapsulate in note form what the lecturer has just said while trying to listen to what follows: words from the latter may appear in the former. Verbal slips may fit into this category, such as the (perhaps apocryphal) story of the lady who was warned by her husband that their dinner guest was very sensitive about the size of his nose, and that she was not to mention it or stare at it; he insisted so much that she became obsessed with the problem and greeted the guest gaily with the words 'good evening Mr Nose'.

Reason also describes failures of the attentional control system itself:

1. Interference in the middle of highly practised routines which disrupts the smooth running of the routine. He calls this monitoring, the 'nosey supervisor syndrome'. It occurs if you ask a highly skilled craftsman or sportsman to be aware of and then tell you precisely how he carries out a skilled movement.

2. Setting of actions in train and then forgetting of the intention; for example the reports in Reason's study of people who had gone into offices or opened cupboards and forgotten what for, or who had opened their mouths to speak and then could not remember what they wanted to say.

3. Losing the place in a sequence or reentering it at the wrong point after an interruption; either too early, for example, pressing a toggle key on a control board a second time, thus switching a two-state function back to its original state, or too late, for example, missing out a stage in the isolation of a piece of equipment thus allowing it to restart while someone is working on it. This sort of distraction can also result in the sequence not being reentered at all, because the attentional system failed to register that it was not finished. A study of chip-pan fires (19) reported a large number which resulted from this problem; people putting a pan on to heat and going to do another task, and either forgetting it totally, or badly underestimating the time necessary for it to heat up to ignition temperature.

4. Devoting only a small amount of attention to the initial perception of situations, and hence accepting rough approximations to the expected stimulus as being the real thing; the runner on the starting blocks and keyed up to go interpreting any loud noise as the starting pistol. Haga (20) found this behaviour in a simulation study of train drivers setting off from stations. They should have waited for two distinct signs, one from the stationmaster, and another that the line was clear. They got so used to the fact that the former practically never gave his signal until the line was clear that they frequently failed to notice on the few occasions when the other sign did not confirm his signal.

Rasmussen (9) found that the proportion of nuclear incidents which occurred during routine activities to restore the system to normal after testing or calibration work, was higher than would be expected given the time spent on such tasks. The reason could be a relaxation of the accuracy of attentional control towards the end of a job.

3.3.2 Predisposing conditions

It is clear from the descriptions of error types given above that there are a number of circumstances which repeat themselves, and which can be grouped together as general predisposing conditions for errors in routine tasks.

1. **Changed goals in familiar circumstances.** Actions which are out of the ordinary in familiar surroundings or with well-known equipment are likely to be infiltrated by habitual action sequences; for example, drivers who set off on a familiar road on Saturday morning and end up at their work instead of at the shopping centre.

2. **Familiar goals in changed circumstances.** This is the opposite side of the coin to 1, and results in attempts to follow old action sequences which are no longer appropriate for the new circumstances. This is known to training specialists as negative transfer of training, in which experienced people perform worse than novices at a task on a new model of a piece of equipment. For example, word processor operators who are experienced on one program may have great difficulty getting used to the different conventions employed - for example, to shift paragraphs - on a new package.

3. **Preoccupation or distraction** (called a reduced state of intentionality by Reason). This is merely another way of saying that the attentional control system is busy elsewhere, and is not free to do the monitoring and switching necessary. Reason (2) found no evidence that this preoccupation was likely to be particularly related to emotional state, sickness or to being in a hurry. There was some evidence from his study that fatigue might play a part, and attempting to carry on several tasks in parallel was certainly a common cause. Other work (21) suggests that a number of general factors such as workload, stress and consumption of alcohol or tranquilisers can have the effect that control is left too much to the automatic sequences, and not monitored sufficiently.

4. **Individual differences.** From questionnaire studies (10,22) there seems to be clear evidence for large and relatively stable individual differences in the reported frequency with which people make the everyday sort of slips and lapses which formed the basis for Reason's original research. The studies also found a good correlation between self-report and the rating given by the subject's spouse, which gives confidence that the tendency is not just one to report more errors, but a real tendency to make more. The personality trait was correlated with both obsessionality (associated with low errors) and with vulnerability of performance to stress (associated with high errors). Before this is leapt on as a chance to resuscitate accident proneness under the guise of error proneness, it is worth making some caveats. There is no evidence that the liability to such lapses is strongly correlated with having accidents. It could be that those who make more errors are also more aware of their occurrence and so are more alert to recover from them before they lead to serious consequences.

3.3.3 Frequency of different error types

During the course of his research, Reason used a number of somewhat different ways of classifying the errors he collected. The initial classification of the 433 incidents collected in 1976 was according to a broad classification related to the stage at which the program failed. While it is possible to recognise many of the categories derived from Figure 3.4, the two classifications do not match perfectly. The percentage of the incidents falling into each category is set out in Figure 3.5.

In the same figure are the results of an observational study by Langan-Fox & Empson (23) which used the same categories to classify the errors made by air-traffic controllers (ATCs) in carrying out their tasks. The categories are explained below.

TYPE OF ERROR	STUDY	
	Reason (1976) (N = 433, trivial lapses) %	Langan-Fox and Empson (1985) (N = 131, including 23 serious) %
Perceptual/discriminatory	10.9	24.4
Memory/storage	41.4	12.2
Test	6.0	12.2
Program/assembly	24.7	30.5
Subroutine	12.5	14.5
Other/multiple/unclassifiable	4.5	6.2

Figure 3.5. Percentages of different types of error in two studies (1,23)

Perceptual/discriminatory errors involved a complete mis-identification of the situation and the choice of a completely wrong plan or sequence.

Storage errors involved forgetting the plan intention, items in it, or the place in it.

Test errors involved terminating a sequence too early or not early enough.

Program assembly errors involved false starts, branching into the wrong plan, or misordering items.

Subroutine errors involved insertion or omission of items from a plan

The large differences in percentages may be due partly to the fact that Reason's figures are from self-reports while the other study was based on observations. Memory failures such as forgetting plan intentions would not be so open to observation. A subsequent questionnaire study about the frequency with which people had experienced different types of slips and lapses (4) confirmed the preponderance of memory lapses in everyday errors. The other differences could be due to the nature of the task itself, and the job aids built into the ATC task. The classification system itself is open to criticism. Some items are hard to distinguish and rely on inference about the intended plans or the reliability of self-report about intentions. Reason abandons the classification in his later papers, and reverts to a more descriptive classification of errors into:

1. repetitions - where some actions in the intended sequence are repeated unnecessarily,

2. Wrong object(s) - where the intended actions were made but in relation to the wrong object,

3. Intrusions - where unintended actions (not related to 1 and 2) became incorporated into the sequence,

4. Omissions - where intended actions (not related to 1, 2 or 3) were left out of a sequence.

It is clear from this discussion that there is a problem in arriving at an adequate classification of types of error at this routine level of operation. As Leplat (24) points out, there are several levels at which classification can be attempted; the significance for the system or task (omission v commission errors), observed actions (the immediately preceding classification) or the underlying part of the processing system which failed (the classification used in Figure 3.5, or derivable from Figure 3.4). In terms of prevention, the deeper the classification the more insight it gives into what must be done to alter the behaviour, but equally the more difficult and dependent upon inference (and thus unreliable) is the classification itself. An adequate classification remains to be developed and without one, quantitative studies of error type are impossible.

Problems occur even in trying to estimate the overall rate of errors on a task. Self-report as a study technique is subject to bias from time pressure and varying sensitivity to error. What is sufficient to be called a deviation from plan for one person or at one time, may not qualify for another person or at another juncture. Reason's subjects reported between zero and 36 lapses in two weeks. Any amateur typist among the readers of this book knows that they can clock up that many errors inside thirty minutes, but probably would not have thought them of sufficient interest to include in such a survey had they been a subject. It is therefore probably fruitless to speculate on the absolute error rate at any task, or to expect to be able to collect data which give more than an order of frequency of types of error. The value of the studies described is in the insight they give into the mechanisms which underlie errors in routine tasks, and hence into the potential for redesign of those tasks.

3.4 DESIGN FOR ROUTINE TASKS

We have so far looked at routine tasks only from the point of view of the underlying mechanisms of behaviour. Along the way we have given a number of examples of errors on such tasks and of their circumstances, which gives a flavour of the practical situations in which they can occur. In this section we want to look at the problem from the point of view of the tasks, in order to summarise the charateristics of equipment, procedures and working conditions which trap people into making errors on routine tasks. In doing so we are moving into one of the central areas of the subject of ergonomics, the study of the interface between operators and their tasks. In this book we cannot devote a great deal of space to this topic, and the interested reader is referred to standard textbooks of ergonomics (for example, 25,26) for further information.

We have portrayed human behaviour on routine tasks as being governed by (semi-)automatic programs of actions triggered by recognition that the situation calls for that program. Monitoring of the carrying out of the program is to an extent built into its structure in the form of the TOTE routines which check between some of the steps that the program is still on target. It is clearly important therefore that the programs contain all the steps to cope with any hazards which are a 'normal' part of the task.

Thus, for example, if the task is the boning out of carcasses in a slaughterhouse where a very sharp knife is used, there is a constant risk of cuts if the knife comes into contact with an unprotected part of the worker's body. Short of complete redesign of the task to eliminate the use of hand held knives, there are only two types of protection against the cuts - skill in wielding the knife and use of protective equipment. If either or both are to succeed they must be totally incorporated into the action sequences which form the worker's repertoire, so that they form automatic steps in the action chains in just the same way as the other actions. Donning the protective equipment must be taught and become as automatic a part of beginning the task as picking up the knife: habits such as cutting away from the hand which is holding the meat must be ingrained into the skills from the start.

If they are not it will be enormously difficult to insert them later. The programs in humans cannot be as easily altered as the text in a word-processor. There you can delete an error and insert a new word with a few strokes of the keys. With humans such reprogramming involves breaking down existing skills and building anew with the extra steps incorporated. We shall deal with the process of such learning in Chapter 9, since the learning itself involves people in operation at the knowledge-based level of our model.

Once the skill has been succesfully learned with the relevant steps to keep constantly present hazards under control, the problem of safety rests on four factors:

- unambiguous information to select and control the sequence
- absence of overload on monitoring of the sequence
- absence of disruptive external changes during the sequence
- clear signals of the need to switch out of automatic pilot and into a conscious level of functioning.

3.4.1 'Default values', stereotypes, illusions and other distortions of perception

Skilled routine behaviour demands that information coming in from the outside world is processed very rapidly in order to keep up with the speed at which the person is working. This means that only very selective features of the situation are attended to. It is as though people are only checking that things are as they expect them to be (17). 'The next step of the action sequence demands that the situation should be in state X: let us check whether it is state X or not: if not then we must break out of the sequence: otherwise carry out the next step'. The check is done on the basis of seeking confirmatory evidence (that is, the opposite of the scientific method which demands that hypotheses are formulated and attempts made to disprove them). The rest of the mental picture of the outside world is then filled in with what computer jargon calls 'default values' (5,27,28). In other words, if I am driving down a street and see a car approaching on a side-street, I may only take in factors such as speed, general size and shape; my stored expectations associated with 'car' will supply the 'facts' that it has four wheels, at least two doors and a driver, and I will confidently report them as having been present should anyone ask me afterwards. I may also just as confidently report which side of the car the driver was sitting on, only perhaps to be told later that it was in fact a car coming from a country in which they drive on the opposite side of the road. I will have 'seen' what was not in fact there, because my expectations have supplied what I did not have time to take in. This is an example of a stereotype at work.

There are stereotypes related to many aspects of the way in which equipment and systems work. People expect certain movements of knobs, switches and levers to produce certain changes in direction, flow or loudness (29); colours have particular connotations, particular symbols have become associated with particular meanings, such as 'No entry' and 'No smoking' (30); rules and conventions governing driving, as well as social and business activities create expectations of behaviour which can amount to stereotypes. A few stereotypes may be innate, but most are learned, and so will only be shared by people with similar learning experience (for example, light switches operate in different directions in different countries, as do rules for which side of the road to drive on and for priority at junctions).

Where strong stereotypes exist, and an individual piece of equipment does not conform to that stereotype, skilled behaviour will be very vulnerable and inappropriate responses are likely to result. This will also be the case when someone shifts from one machine or system to another where different stereotypes apply. In these circumstances the world has not lived up to the victim's expectations.

Illusions are also distortions of perception, but of a different nature. They result from basic design features of the perceptual apparatus which are impossible to overcome. For example, images coming into the eyes are projected onto a two-dimensional screen, the retina; from that two-dimensional information the brain must reconstruct the third dimension of the real world. It uses a number of clues to do so. The main one is the slight difference between the images recorded in the two eyes; but there are other important clues such as relative size and movement of objects, texture gradients and direction of illumination. Where two or more clues contradict or appear to do so, the brain must make a choice or a compromise. The illusion in Figure 3.6 is an example of contradiction between expectations about three- dimensionality and about the symmetry of figures. The figure is seen as a skeleton cube; it can only be that if it is in 3-D, and there are two ways it could be a 3-D figure, so we see it changing between the two, sometimes spontaneously, sometimes when we 'decide' to see the alternative. Again we 'see' what is not there.

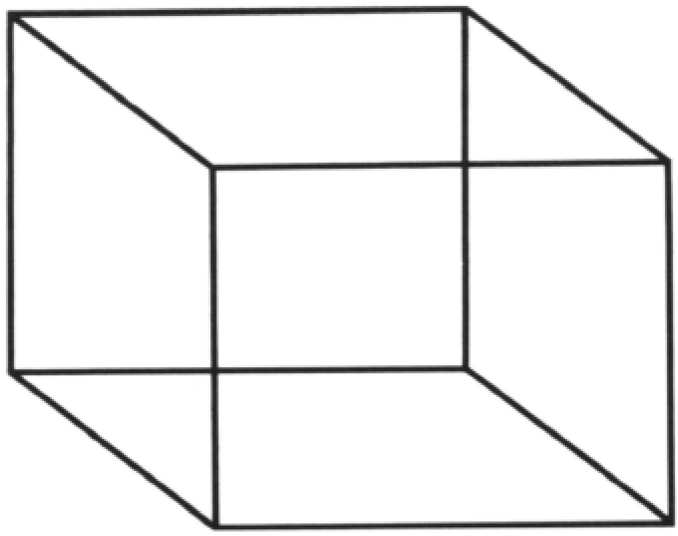

Figure 3.6. 'Necker' cube

Practical examples of illusions which have safety implications are size/distance illusions experienced by pilots, and by drivers in fog. A given image projected onto the retina can be either a small oject close by or a much larger one far away. Where clues are few or misleading, as in fog, a car just in front can be seen as a van further away; pilots suffer from similar distortions in aircraft landings in certain conditions (31).

Other distortions include those caused by habituation. Drivers travelling at constant speed on a motorway cease to notice how fast they are going, as they habituate (get used) to the speed with which objects move by them in their peripheral vision.
Only when they turn off and need to slow down do they realise how fast they were going, and often have to brake much harder than expected (32).

3.4.2 Overload on attention and memory

The action sequence itself will make certain demands on attention and memory. It may require the individual to monitor more than one source of information for the signals to control the sequence. Driving is a typical task of this sort in which attention must be split between the car instruments, the road ahead, behind and to the side. Process control tasks make similar demands to monitor many instruments. In this case the individual must distribute attention appropriately between the sources (33,34). Tasks which make heavy demands on this skill may be more subject to errors at the skill-based level (35). It is interesting that some of the more promising studies relating individual differences in psychological factors to accident rate in drivers (36) found some success with tests of divided attention which measured this ability. To carry out such tasks people must learn appropriate strategies of monitoring the various sources. These will be based on their mental models of the processes being monitored. If you are trying to keep a check on a reaction vessel filling with chemicals while getting on with filling in the control log, the rate of checking will depend on how fast you think the inflow is, and the distance it had still to go when you last checked. There is evidence that the error rate on such tasks is related to the type of strategy used, and varies from individual to individual (37).

Demands on memory will also vary from one action sequence to another; for example some sequences may require a particular action to be carried out more than once, and the short-term memory will then have to hold the information of how many times it has been done already. In other tasks the results of one action (for example, a reading from an instrument) may have to be stored for use at a step later in the sequence (for example, comparison with an expected reading from a procedures guide). Yet other tasks will involve long lists of check items with no obvious connection between many of them (for example, preflight checks on aircraft); these present problems of remembering where you have got to on the list. These and the forgetting of intentions and of the point to restart sequences mentioned above form a very common cause of error (3,10). They emphasise the susceptibility of the short-term or working memory to overload. Its size is small, and information seems to be stored in a particularly vulnerable form.

3.4.3 Unexpected external signals

Skilled action sequences can run with limited monitoring, and so are vulnerable to unexpected disruption. Hence anything which can cut down the external disturbances which occur while they are in operation will contribute to increased safety. Again the demand is to make the world live up to the individual's expectations. The action sequence is built up on the basis that it is to operate in given, quite narrowly defined circumstances. Therefore, to avoid accidents, we must ensure that those circumstances remain in effect.

Behaviour at the skill-based level requires a protected environment. Frequently that protection must be given by something or someone other than the person exhibiting the skill. For example, operators at machines such as power presses and punches require access to the danger zone of the machine to insert components. They are normally protected by an interlocked guard which prevents the tools descending when the guard is open. Such guards have in the past been subject to failure due to worn or poorly designed microswitches and they occasionally fail (38). It would be totally unreasonable to expect the operators to spare any part of their attention to look out for signs of the press recycling. This could only be done at the cost of operating at the rule-based level, and hence very much more slowly. The operator must work on the assumption that the guard is 100% reliable, and the setters, inspectors and maintenance people must take on the burden of ensuring that it is (39).

The example we used above of the people working in the slaughterhouse is similar. Skilled wielding of the knife relies on not slipping and falling. It is too much of a burden on the skill if workers must constantly give a large part of their attention to retaining their balance. The floor must be kept reasonably safe for them by others, who thus take on the responsibility for keeping the environment predictable enough for the skill to operate succesfully.

Distraction falls also under this heading. Its effect is greatest when someone must hold information in short-term memory. The result is the place-losing error mentioned in the earlier part of this chapter. Distraction will be particularly disruptive if it comes in the middle of an automatic action sequence between points where TOTE routines or monitoring normally take place. At these points the system may have no accurate record at all of where it has got to. At 'natural' break points in a sequence the distraction may be far less disruptive. This equates with the experience that most people have of trying desperately to get to a particular point in, for example, a mental arithmetic calculation before stopping to answer the telephone. The external distraction disrupts in the same way as the internal monitoring labelled the 'nosey supervisor' syndrome by Reason. It shifts behaviour from the skill-based to a more conscious level at the wrong point.

3.4.4 Signals to change levels of operation: relationship to the Rasmussen 3 level model

Reason (5,7) has related his theory of errors to the model proposed by Rasmussen (see Chapter 2) with its three levels of skill-, rule- and knowledge-based behaviour. Figure 3.7 shows in tabular form the characteristics which he associates with each level.

It is evident that rule-based operation shares some characteristics with each of the other two levels, and is thus a sort of halfway house. Reason (10) discusses the distinction between rule- and knowledge-based behaviour as the difference between:

- a global, non-specific or diffuse awareness of activities, characterised by the matching of situations to applicable sequences of behaviour (rule-based), and
- a specific focal awareness associated with planning and novel combinations of sequences (knowledge-based).

FACTOR	LEVEL OF FUNCTIONING		
	Skills	Rules	Knowledge
Activity type	routine	problem solving	
	familiar situations		unfamiliar situations
Control mode	automatic processors operating in parallel		serial operation, resource limited
Information input	used as continuous signal	used as sign to modify /activate plan	used as symbol to feed mental model
Attention focussed on:	things other than task	problem related issues	
Type of behaviour	smooth and effortless		slow and halting
Form of error	predictable, strong habit intrusions		variable type, beginner's errors
Sensitivity to stress	low	medium	high
Error detection	usually rapid	difficult, often only with the help/ intervention of others	

Figure 3.7. Reason's classification of Rasmussen's three levels (7)

Skill-based is distinguished from rule-based behaviour by being far more resistant to outside interference (including stress) and far more subject to built-in control of errors, which releases attention completely for other tasks.

As people gain experience in tasks and build up their repertoire of skills they are able to spend more of their time operating at the less demanding skill-based level of functioning and less at the interactive and often mentally exhausting knowledge-based level. What starts for the novice as a string of conscious actions with a decision point between each eventually becomes for the experienced person a smooth sequence which, once triggered, runs through to its conclusion (compare the speed and rhythm of a novice 'hunt-and-peck' typist operating at the level of letter by letter coordination, with that of an experienced touch typist who programs finger movements at the level of words or even phrases). This means that experts are (contrary to what might be expected) working most of their time at the skill- and rule-based levels, while novices in the same circumstances have to work at the less efficient knowledge-based level. This explains why the errors of the latter level are labelled 'beginners' errors'.

The 'design principles' behind the three levels of mental operation are:

1. that control should be delegated to the most automatic level compatible with the predictability of the situation and with the repertoire of action sequences available to the individual facing it.
2. that, as soon as problems are noted, control should be shifted up a level of consciousness in an attempt to solve the problem. Problems include all cases where the TOTE operation built into sequences comes up with anomalous answers, and where monitoring shows that things are not going to plan (5). An increase in danger should function as a signal in this way. Implicit in the idea of a hierarchy between the three levels is that the initial response to a problem at the skill level is to try and look for another known rule to match and cope with the problem. Only if this fails is there a shift to any fundamental analysis of the problem at an interactive problem solving level. As later chapters will discuss, the initial response to increasing danger is therefore often stereotyped and rule bound rather than innovative and adaptive.

These shifts between levels correspond to the shifts in attention described in Reason's model. The succeeding chapters of the book deal with the extent to which these design principles operate in practice. At this point we merely wish to emphasise that shifts from one level of functioning to another can be just as disruptive if they occur too early as too late. We have given the examples of distraction and the 'nosey supervisor' syndrome. As another example, general criticism can be levelled at an uncritical advocacy of 'safety awareness' as a solution to errors on industrial tasks. Many commentators on safety (40) portray the errors which occur in industrial tasks as due to lack of vigilance, care or conscientiousness. The implication is that more attention should be paid to the task - that it should be shifted from the skill- to the rule- or knowledge-based level of control. The cost of such a move is that the actions will take much longer (thus directly influencing productivity), and the very smoothness of operation which makes many of the sequences succesful will be lost. If such exhortations of greater care come from the same managers and directors who at another time demand greater production, the individual is placed in an impossible conflict.

3.5 INSISTENT WARNINGS AND ESCAPE FROM IMMINENT DANGER

Before leaving the level of automatic action sequences we need to look at another side of the coin. We have dealt so far with sequences which are carried out in familiar situations, and which may keep constantly present hazards of a comparatively minor nature under control. In some cases people respond in just as automatic a way to the sudden presence of imminent danger.

3.5.1 Innate and learned response to emergencies

There is ample evidence that animals are innately afraid of some stimuli which represent a threat to them (41). Even when brought up in isolation they will still show that fear in response to quite specific stimuli. For example, baby monkeys responding to photographs of the threat display of adults (42). The evidence is far less clear that humans are innately afraid of specific stimuli, although they may react to more general attributes of stimuli. Gibson (43) describes the sudden occurrence of loud noise, loss of support, and objects looming up (rapid increase in size) as fear stimuli prompting automatic responses such as jumping, dodging, blinking, clutching. Other reflex reactions are snatching away a hand which is placed on a very hot surface. Rachman (44) concludes that: 'The prepotent fear stimuli are those which have the attributes of novelty, suddenness and intensity'. They produce both an immediate behavioural response and increased alertness and concentration of the attention on the object, accompanied by hormonal and other physiological responses. In other words the control of subsequent behaviour is shifted up to a more conscious level.

However, research on fears and phobias (44) shows that these innate responses are only a small part of the picture. Fear in humans and the response to it are things which are largely learned, either from conditioning, association of specific stimuli with others which are already frightening, or with the experience of pain, or through learning from other people. For example, the automatic response by drivers of stamping with the right foot and turning the steering wheel are learned responses to an imminent collision. Such emergency responses tend to be very simple and coarsely controlled (variations on the flight or fight response). They are typical examples of external circumstances capturing control of behaviour. It is very difficult for the attentional control system to capture control back again rapidly even when the response makes the situation worse rather than better. Avoiding the braking and swerving reflex on black ice or a greasy floor in a warehouse requires conscious suppression of the demand from the situation. Johnson (45) provides another example in the emergency avoidance manoeuvres of motorcyclists. The 'natural' response of motorcyclists to avoid an oncoming car, especially if they are also experienced car drivers, is to steer in the direction they wish to turn to avoid the collision. However, because of the dynamics of a bike travelling at high speed, applying a torque to the handlebars in fact results in the bike turning in the opposite direction to the torque, and hence towards the collision. The correct response is to lean in the direction they wish to turn, without turning the handlebars.

Complex responses to emergencies, especially those which must be carried out very rapidly and smoothly in response to rarely occurring situations impose a considerable demand on the human system. In order to keep them functioning effectively at the skill-based level they must be thoroughly and meticulously learned and frequently practiced. This is a particular problem for first aiders in trying to retain skills in cardiopulmonary resuscitation, which are complex and decay rapidly without use (46).

If these learned emergency responses are triggered in humans largely by learned cues, the reverse side of the coin is that all types of fears and responses to them can also be unlearned. One of the standard techniques for eliminating unwanted phobias, such as fear of spiders, is habituation (44). In this technique the fear object (the spider) is presented in an attenuated form (a very small one securely contained in a box), or in the far distance, and in circumstances where no harm occurs, and where reassurance is given. Gradually the distance between the person and the fear object is lessened, still giving constant reassurance, until the person is able to cope with, or handle the fear. This is an analogous process to the experience of someone new to a working situation where there are sudden loud noises, whirling machinery or strong chemical smells. While they may initially arouse fear, and the associated reaction to it, if the person continues to work with them for some time without taking any precautions against them and without harm occurring habituation will occur.

The implication of all these findings is that skill-based response to emergencies can only play a small part in keeping danger under control, and then only if considerable effort is invested in retaining the skill. A more fruitful design response to the presence of emergencies in a system is to build in enough time between the warnings that things are out of control and the occurrence of the harm so that an individual can respond at the knowledge-based level.

3.5.2 Panic

One of the pieces of received wisdom concerning people's behaviour in emergencies is that they frequently panic. This idea was examined by Canter and his colleagues (47) in relation to behaviour in fires. They found very little evidence of anything which could usefully be called panic even in major disasters where there were large numbers of casualties, such as the fires at the Summerland entertainment complex on the Isle of Man in 1974, a Beverley Hills supper club in 1977 and a Munich bierkeller in 1973.

Panic implies either uncoordinated behaviour (usually flight) which takes no notice of circumstances or other people, or 'freezing' and inactivity. On the contrary the studies found that behaviour was remarkably orderly and known rules and roles were adhered to (for example, waitresses showed customers from their own tables out of the building). In other words behaviour was controlled at the rule-based level. There was some evidence that rules were sometimes adhered to for too long before switching to knowledge-based behaviour - for example, persistence in trying to leave by exits that were blocked - but behaviour was almost always perfectly rational for those who were indulging in it. The researchers concluded that the label 'panic' was attached to behaviour by those who came on the scene later (media, fire authorities) and saw with the benefit of hindsight that it had not succeeded in getting the people out of the building.

3.6 CONCLUSION

We have portrayed routine behaviour as a process of bringing into effect routines of action which have been previously very well learned. Accidents occur when the learning is inappropriate to the problem, when the wrong routine is deployed for the prevailing circumstances, or when two sequences become confused. Once the routines have become learned they are very difficult to alter, or to break into without losing the great benefits of working at the skill-based level. The focus of prevention for such routine tasks must therefore be on the learning process itself (Chapter 9), or on the design of the tasks and equipment to avoid triggering the wrong routines (Chapter 12).

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CHAPTER 4

HAZARD DETECTION

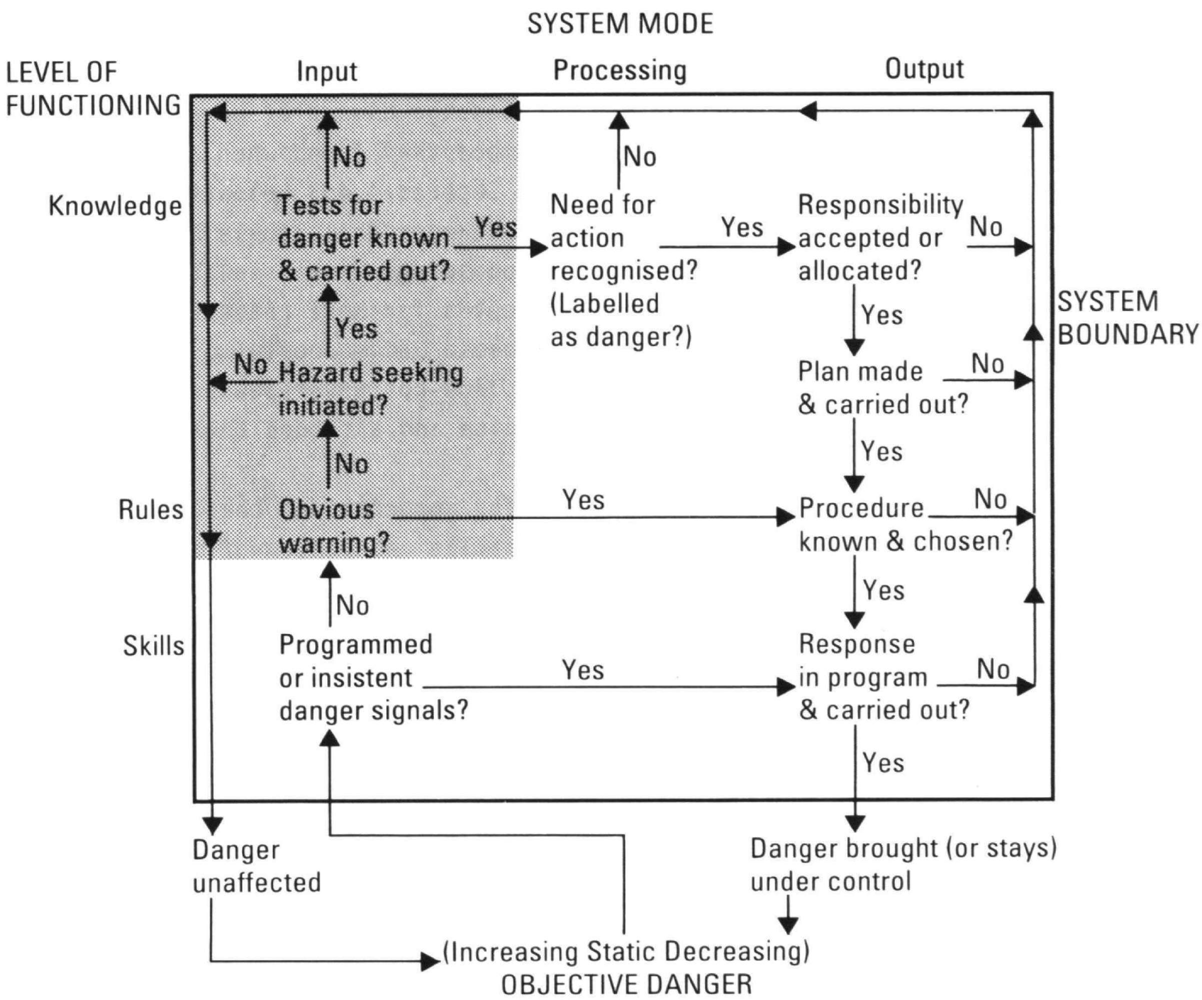

Figure 4.1. Behaviour in the face of danger model - hazard detection

4.1 INTRODUCTION

In a study of gold-mining accidents Lawrence (1) found that fifty percent of the accident victims failed to detect the hazard to which they succumbed. Brown (2) reports that problems with perception of hazard played a part in 49% of accidents in daylight to drivers unimpaired by alcohol or other drugs. In another study seventy supervisors on construction sites were asked to carry out a safety inspection of their sites; 44% of the hazards seen on the sites by a construction safety expert were not reported by them (3). Such findings are typical of research across a range of tasks (4,5). In view of such figures it is surprising how little research has studied the way in which people detect hazards.

During the course of a study in a heavy engineering works Pérusse (6) asked a sample of people to report all the hazards they saw during a period of five weeks. He gave them small file cards to carry around with them and asked them to record brief standard details of the hazard (time seen and nature of hazard). 'Hazard' was left undefined, because part of the purpose of the study was to see how it was interpreted by participants. He found considerable variation in the number of hazards recorded by different participants, despite the fact that all were working in the same area of the factory. The number reported ranged from none to 84. He found a correlation between the number of hazards reported by individuals in this exercise, and the number they found when asked to list the hazards in a standard hazard picture (see Section 4.4.3 below for a further description of that part of his study). The longer that people had worked in the factory the more hazards they reported, and safety representatives, safety committee members and first aiders tended to report far more than other workers. The latter finding may have been partly because such people moved about the factory more than others, but evidence from follow-up interviews suggests that it was also a question of approach to the exercise and attitude towards hazards.

During the follow-up interviews Pérusse asked for comments on the exercise and why so many (or so few) hazards had been noted. The response of one machine operator was typical: 'I'm too busy carrying out my job. I haven't got time to look out for 'hazards'. This was neither a confession of laziness nor of a devil-may-care attitude. It was a perfectly rational, if perhaps tart, statement of a conscientious worker, and points up an important basic feature of hazard detection. It usually has to be an active process which occupies both time and effort.

Danger is only rarely insistently threatening in most people's working lives. In most cases it arises from quite complex and rare interactions of events which are not immediately obvious. This is particularly the case with serious hazards (7,8). If danger is looked at only through the prism of accidents which have happened this fact is easy to forget. With hindsight the danger tends to look obvious. Indeed, in every accident there must have come a point when the danger was imminent and insistent (and unavoidable) (9). But accidents represent only a small proportion of the occasions when danger was present; in most cases it is detected and avoided before it becomes imminent, or it simply goes away without being specifically noticed or labelled as a hazard.

This chapter examines the processes involved in hazard detection, and the factors which seem to determine whether or not danger is detected. The questions of detection and response to emergencies, and of the control at the skill level of dangers which are constantly present were dealt with in the last chapter. The latter are good examples of hazards being kept under control without being consciously labelled as such. In this chapter the discussion will deal with situations where people would almost certainly label their own behaviour as involving consciously dealing with hazards. We are therefore talking about perceptions and behaviour at the rule- and knowledge-based levels of functioning.

The process of danger detection is complex, and we have divided it in our model into four phases (from warnings to recognition of the need for action), shown in Figure 4.1 at the beginning of the chapter. The four phases are shown for simplicity as a linear progression. In practice the answers to the questions posed may not be the clear-cut dichotomy of 'yes' and 'no' and there may be iteration between the steps; a particular warning may be interpreted as worrying and result in the person looking actively for further information, which may either reassure them or convince them that danger really is present. Canter (10) reports finding this behaviour particularly in the early stages of fires, with people taking considerable time and some effort to confirm information before accepting that there really is danger and that something needs to be done about it.

There is a considerable literature about what factors people use in the final assessment of whether a situation is labelled as hazardous and if so, how hazardous. There has also been a large body of research about the way in which these factors are combined to make that assessment and about the biases (that is, departures from formal logic and mathematical/economic reasoning) in that process. In order to simplify our presentation we discuss that literature in the following chapter (Chapter 5). In this chapter we deal with the process by which the evidence for danger assessment is collected. But it should be remembered in reading both chapters that the two processes are intimately and iteratively linked.

In this chapter three rather different situations will be discussed:

1. detection of deviations in routine tasks which are leading the individual into danger; here the behaviour is initially mainly at the skill-based level and the detection results in switching it to a more conscious level of control,

2. detection of hazards during formal or informal šinspection in the ordinary work environment; here the individual is already alerted to look for hazards,

3. prediction of danger at the design and planning stage of a system (process, plant or machine); here there may be no opportunity to carry out a physical inspection, because there are no comparable systems in existence, and the activity must rely much more on the purely mental processes of induction and deduction.

In this chapter hazards are therefore not confined to ones which could threaten the individual who is trying to detect them. Indeed from 1 to 3 above there is an increasing concern with hazards to others. There is no clear evidence from the small amount of research carried out so far that the process of searching for hazards to self and to others differs, but this aspect is an important one in assessing and evaluating hazards (see Chapter 5).

4.2 ALERTING TO DANGER

4.2.1 Detection of deviations

We described the process of monitoring and control of behaviour at the skill- and rule-based levels in Chapter 3. The important elements in the process are the TOTE (Test-Operate-Test-Exit) routines built into the sequences of action, and the allocation of the resources of the attentional control system to general monitoring. The TOTE routines are programmed to cope with simple tests; whether the situation corresponds to state A or state B. Reason & Embrey (11) suggest that the individual may often accept very broad approximations to states A or B as sufficient evidence to go ahead with the sequence, and therefore that deviations may have to reach quite a major level before this monitoring mechanism breaks into the sequence and indicates to the central processor that something is amiss. This mechanism is in any case only checking up on the progress of a given plan. It is not equipped to detect whether the plan is leading in the right direction and achieving the larger goals that the individual has. This second sort of monitoring must rely on the attentional control system. Where there is a sudden and dramatic signal that danger is present this monitoring will pick it up. This is the startle response which is found in both animals and humans (12), and which was dealt with in the last chapter. Normally however, the signs of danger will not be so dramatic, and all that may be expected is a vague feeling of uncertainty and unease (10,13) which leads to further searching. This is a sort of mental early warning which concentrates the attentional control system onto the specific topic, and sets it actively seeking the problem. These two error detection systems correspond to the two levels of behaviour; the TOTE system is detecting errors at the skill-based level, the attentional control system at the rule-based level.

If these two separate methods of monitoring exist, it would suggest that small errors in execution of plans (skill-based) are likely to be more easily and rapidly detected than deviations from larger goals (rule-based). Reason supports this prediction with an analysis of nuclear incidents (14) and quotes the study of Woods (15) in which a simulator was used to look at the error detection ability of 23 experienced control room crews. Figure 4.2 shows the results of the latter study.

PROBLEM TYPE	Not corrected	Corected by crew alone	Corrected only by external agent
Execution failure	10	10	0
State identification	14	0	5

Figure 4.2. Error detection by operators in nuclear plants (source 15, Woods 1984)

Execution failures were deviations in action sequences, while state identification failures were problems of wrong diagnosis of situations. The latter lead to plans being carried out which do not lead towards the desired goal, namely correcting the problem. Rouse & Morris (16) make this same distinction and suggest that operators will be much more willing to admit that they have made a slip in execution, but will require much more evidence that they have made a large mistake at the rule-based level. Reason (14) suggests that execution failures will be picked up quite rapidly in normal working conditions, but much less so in emergency conditions, where stress, work load and the rapidly changing environment may mask them.

A study of errors made by typists supports the first contention (17). In this study experienced typists, even without sight of the keyboard they were using or the copy as it came out of the typewriter, could detect 55% of the keying errors they made. With sight of copy the figure was 71% and with sight of the keyboard 81%. In about 20% of the errors the typists struck the wrong key with a much lighter force than usual, indicating that they had already begun the correction process (recalling the finger) before their finger had finished executing the movement. It is interesting that omissions were detected with a far lower frequency (4%) than other errors.

A rather different type of task is an aircraft pilot's selection of a lever or control where the critical factor is the speed and quality of feedback. If an action has been taken which is incorrect but which is made at the appropriate point in a sequence remains initially undetected and there is no obvious feedback, then the belief that the correct action has been taken often persists (18). There are incidents in which a pilot or co-pilot has operated one lever or switch in place of another (for example, confusing landing gear with another function, confusing flaps with leading edge droops as in the Trident crash at Staines in 1972).

Looked at logically one of the factors which must affect the speed and likelihood of detection is the evidence which is presented to the individual which contradicts prior expectations. What warnings are there from the environment that things are going astray? All of the lapses reported in Reason's study of everyday errors (19) had, by definition been detected (otherwise they would not have been reported). The stimulus for detection would appear in many cases to have been arrival at a point in the sequence to be carried out which could not be completed, or which produced a ridiculous result, such as arriving at the shops and reaching for the shopping list which had been left on the table at home. Blends of two sequences are thus less easy to detect, since they often involve switching out of, and then back into the intended action sequence. They may only be detected much later when coming across the effect of the interpolated action, often by chance.

It will also be less easy to detect omissions in action sequences which are peripheral to an activity. This is what Davis found in his study of errors made by pilots in simulators (20). It was the occasional checks on such items as fuel gauges which were left out and whose omission was not detected, especially as the pilots got more fatigued. Baddeley (21) suggested that this was a general property of tasks which were not central to the activity being undertaken; they received less than their fair share of attention and so errors in them were more likely to go undetected.

The availability of disconfirmatory evidence is a necessary condition for recovery, and one which can be deliberately incorporated by designers into equipment. However, it is not sufficient on its own to ensure that the error is detected. As may be seen in a number of aircraft accidents pilots can ignore quite strong evidence that something is wrong. Norman (22) also reports a number of cases which show that there is a difference between detecting that something is wrong and discovering exactly what that is. He reports cases of operators making the same error several times over (for example, in repeating a calculation) and of being convinced that the error lay in some other facet of the system. This phenomenon of blinkering is well-known in the problem-solving and reasoning literature (23,24) and has been the subject of study in the literature on errors in the comprehension and production of language (25).

The evidence thus far seems to suggest a paradox. There are very good error detecting mechanisms which can pick up discrepancies between planned and actual states of affairs, but they can fail to cope on some occasions even where there is evidence of very large discrepancies.

Norman (26) points out one factor which helps to explain this, namely that an erroneous action or diagnosis may initially produce feedback which appears to be confirmatory (for example, a steam tube leak and a small Loss of Coolant Accident in a pressurised water reactor produce initially similar signs, and respond initially very similarly to corrective action). This serves to confirm the initial choice of diagnosis or rule, which becomes progressively harder to break out from. The course of the Three Mile Island nuclear incident, where operators persisted for about two hours in action based on incorrect diagnosis in the face of disconfirming evidence, is a good example of this problem (11). The clue to the apparent paradox may therefore lie not just in the size of the discrepancy between expected and actual situations, but in how far into the execution of the action sequence or rule the discrepancy begins to appear; the later this is, the greater it must be before the emotional commitment to the rule can be overcome, and it can be acknowledged as a mistake.

4.2.2 Detecting deviations in dynamic situations

In some activities or environments in which the situation is changing rapidly, which present particular problems for the detection of hazard. The difficulty here is knowing when a deviation is great enough to mean trouble, since the deviation must be seen against the background of many other changes. One such activity which has been studied in detail is crossing the road in traffic. The task is to identify a gap large enough to cross safely. A number of studies (27,28) have shown the complexity of this judgement, which is based on judgements of speed and hence the time that will be taken for cars to arrive at the crossing point. The behaviour takes a long time to learn, and young children carry out the task inefficiently. They are less able to anticipate the complex interactions involved, and, while they compensate by being conservative in choosing the gaps to cross in (they wait for gaps larger than adults), they take so long to make the final decision to cross that they end up taking more risk. Similar judgements of speed of other traffic have to be made by drivers overtaking, and studies show that they usually estimate wrongly the point at which they would meet the oncoming traffic (29,30); they underestimate the time they have in which to overtake (err on the safe side) if the other car is going slower than they are, and overestimate (err on the dangerous side) if it is going faster. The estimates seem to be based, therefore, on the assumption that the oncoming car is travelling at the same speed as the overtaker.

This type of research emphasises the need to study the mental models which people use to predict the future state of the system, and to estimate hazards. For example, Brown (31) shows that one of the causes of lack of detection of hazards by pedestrians is that they usually base their assessments on the expectation that cars are adhering to the speed limit in built-up areas. This theme of mental models will return in the next chapter.

Another rapidly changing situation which has been studied in this context is fire. Canter (10) emphasises the fact that the early stages of a fire are often very ambiguous. There are some warnings and deviations from normal, but they may not be sufficient to enable one to make an unambiguous decision that there is a fire. For example, Tong (32) reports that less than twenty percent of people believe that a fire alarm bell going off is a sign that there really is a fire. The rest interpret the bell in the absence of other evidence as either a test, a faulty alarm or a joke (see Section 4.3.1 below). The recognition of the presence of fire is therefore often delayed, and the first reaction to warnings of a fire is often to approach the area where it is, in order to find out more, rather than to run away (33). This is particularly so in buildings with multiple occupancy where people know less about the situation, and where they may think that an apparent deviation from normal may just be their neighbour's eccentricity.

4.2.3 Enhancing feedback on deviations

It should be apparent from the discussion in the preceeding two sections that remarkably little is known about what initially alerts people who are going about their normal tasks to the fact that something is wrong. It would appear that deviations in skill-based behaviour š(execution errors) are more likely to be picked up by those doing the task than errors at the rule-based level. This is consistent with findings from general analyses of accidents (34,35,36) which show that more serious accidents have a greater than expected tendency to occur during abnormal work, which cannot by definition be carried out at the skill-based level.

A detailed analysis of near-accidents or incidents, (accident sequences which were arrested and restored to normal before harm could occur) might reveal which factors enabled those involved to detect the problem in time. A comparison of near accidents with actual accidents in the same activities would reveal whether there were specific differences in the dynamics of the accident process in the two cases (37). The only other research method which offers any potential is lengthy unobtrusive observation of behaviour on tasks.

Even in the absence of this research it still makes sense to conclude that designers should attempt to improve upon the availability of information about deviations. They should, wherever possible, consciously build into their designs feedback about the actions which the individual has just taken, and their consequences (38,39). This is a strategy which enhances the process of monitoring and recovery from error which is already a feature of normal behaviour at the skill-based level. Examples of such enhancements of feedback are displays on telephones which show the number you have just keyed in, a click or bleep when a key is pressed hard enough to enter an instruction on a keyboard, commands echoed on a visual display as they are entered on a keyboard, incorporation of control switches into mimic diagrams so that operation of the switch automatically changes the diagram, and the use of tick boxes on a checklist to indicate the stage in the check reached.

Reason (14) advocates a similar approach in exploiting the potential of information technology and expert systems to support natural error detection. He suggests that such enhancement of feedback can help to detect errors at the rule-based as well as at the skill-based level, by showing operators in advance what the consequences of their chosen behaviour would be (see also Chapter 9).

4.3 THE OBVIOUSNESS OF DANGER AND THE USE OF WARNINGS

The previous section tackled the problem of becoming alert to danger from the viewpoint of the mechanisms involved. Even though little is known of these mechanisms, people have always designed warnings to attract attention to the presence of danger. This activity has been based largely on common sense, and what is known of the workings of the human senses and attention mechanisms.

There are clearly some hazards whose presence is not directly perceptible to the human senses. Examples are colourless, odourless gases such as methane and carbon monoxide, X-rays and other forms of radioactivity, oxygen deficient atmospheres, and many fine airborne particulates which are only detectable visually when a beam of light shines through them. These hazards therefore present a special problem. Their very presence must be signalled by devices which translate the presence of the hazard into something which is perceptible. The time-honoured šprecaution of taking cage birds down coal-mines is an example of this. They fell off their perches in concen¬trations of carbon monoxide below the level dangerous to people. Their function was later taken over by the modern carbon monoxide detector. In that case the warning means 'evacuate now'.

Warnings are also used in cases where it is not immediately clear to someone walking into the area whether the safe level has been exceeded or not. For example, it may not be obvious to people entering a noisy area whether the equivalent continuous sound level is above or below the current standard. Similarly, in areas where hazards are only intermittently present signs will also frequently be used - for example, where welding or grinding sometimes goes on. These may be designated as eye protection areas and people may be told always to wear their protective equipment when they enter. In strict logic this is not necessary, and the warning actually means; 'be prepared to put on protective equipment when other information tells you that the hazard really is present'.

Another type of hazard which may be missed is one which requires a complex test to detect it - for example an unsafe condition of temperature and pressure at a particular stage of a chemical reaction. That too can be detected by apparatus and translated into an alarm. In all these cases the alarm needs to be presented in a way which will attract attention. The most widely used forms of alarm are loud noises (sirens, bells and buzzers) or flashing lights, which capitalise on the fact that the human attention is geared to pick up changing elements of the environment and to ignore constant elements. However, it is possible to use other sensory channels, to avoid overloading the eyes and ears. For example, drivers and pilots are used to being alerted to problems by unusual vibrations coming through the steering or control column. This has been used in the design of the system to warn of incipient stalling in some aircraft (see for example, the description of the Trident aircrash, 40)

Cunitz (41) talks of the following common sense criteria for the design of warnings:

- to be present when and where needed
- to be clearly understandable and to stand out from the background in order to attract attention
- to be durable
- to contain clear and realistic instructions about action
- preferably to indicate what would happen if the warning is not heeded.

The last two criteria relate to later stages of our model, and will be discussed in later chapters; the point about durability requires no further comment. However, the first two criteria need further discussion.

4.3.1 Hazard symptoms and false alarms

Where warnings of danger are introduced artificially into the situation, as in the examples given above, it is obvious that they should be present when the hazard is present. What is less obvious is that they should be absent when the hazard is absent, otherwise the problem of false alarms will arise. Where a warning can be present without the hazard, people can rapidly learn that it is not necessarily dangerous in that area. They then look for further confirmatory evidence that something really is a problem before reacting to it. If there is frequently no such evidence they will learn to distrust the warning and to ignore it. Yet there is a widespread belief among managers and safety personnel, in the case of hazards which are only sometimes present; 'if in doubt put up a warning sign'.

In all such cases a degree of trust enters the situation. Individuals must take it on trust that the warnings and alarms are true indications of danger. As an intangible entity trust is something which is constantly open to modification based upon experience. If the alarm goes off and turns out to have been a false one there is likely to be a small, but perhaps significant shift in confidence. If the false alarms exceed the true ones (not an unusual circumstance in some systems) the first hypothesis the individual is likely to have when a new alarm goes off is that it is a false one. Similarly if someone enters an area with danger warnings and finds no danger, especially if they do so without using the required protection and are neither harmed nor reprimanded, there is likely to be a fall in the confidence felt in the warnings, and in the likelihood that precautions will be taken.

The research of Tong (32) on the lack of trust in fire alarms was cited earlier. Pauls & Jones (42) found in a Canadian study only ten percent of people who invariably treated a fire alarm as a sign of an emergency and immediately took action to escape. Gardner & Rockwell (43) questioned drivers about their behaviour when they saw flashing warning signs on freeways. Only 50% said they slowed down immediately; a further 20% did so if they could see road works at that point, while the rest drove on at undiminished speed. This is likely to be the result of false alarms experienced in the past.

There is a well tested theory in the area of vigilance and decision making which explains what is going on in situations where detection of signals is not clear cut, and false alarms are possible. This theory, known as 'statistical decision theory' (44,45) showed that such detection problems can be represented by the paradigm of discrimination of a signal occurring against a background of noise (Figure 4.3).

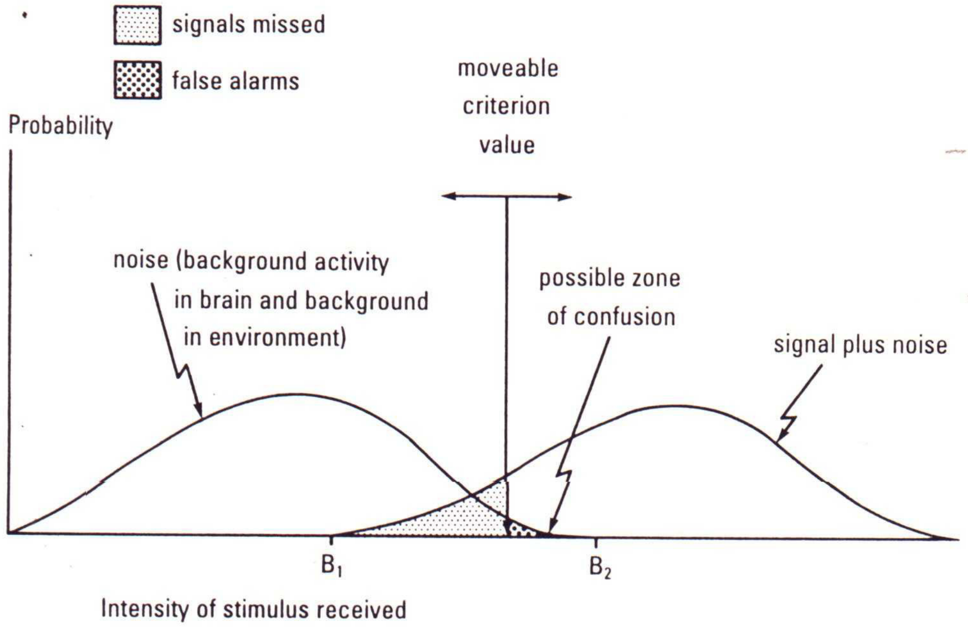

Figure 4.3. Statistical decision theory for signal detection (44)

This theory can best be explained using the example of detection of a faint sound against the varying background noise of a room. The 'noise' against which the signal has to be detected is made up of the neural noise (spontaneous firing of the nerves in the sensory pathways of the brain) and any irrelevant background signals in the room. This background noise varies in intensity around a mean value, and can be represented by the left hand curve. When the signal to be detected is present the intensity of the stimulus is increased by a constant amount, the size of the signal. The curve on the right therefore represents presence of the signal plus the background noise. Where the signal is faint the two curves overlap and there is a zone of potential confusion; a given intensity of stimulus could either occur with a high level of background noise alone, or a lower level of noise plus the signal. People cope with this problem by imposing an arbitrary 'criterion value', reporting a signal when the stimulus intensity exceeds that value and no signal when it does not. The same sort of decision process seems to apply to any signal detection problem. It can also be applied to hazard detection.

Where the two distribution curves overlap error is unavoidable. The individual can only make a choice to place the criterion used to make a decision either low (nearer to B1) or high (nearer to B2) and to accept either a high number of false alarms associated with few or no signals missed, or few or no false alarms with more signals missed. The positioning of the criterion value is an indication of how much confidence the individual must have before announcing that a signal (in our case the hazard) really is there. The decision is influenced by both conscious and unconscious factors. It is partly a function of the trade-off between the relative values of missed signals and false alarms. If I have been severely reprimanded for reacting to a false alarm, or it has cost me time and embarassment in the past, I will be likely to shift my criterion value up the scale and so will miss more true signals. The placing of the criterion value is thus strongly influenced by experience. Feedback that something was a false alarm therefore literally shifts the confidence criterion used to judge subsequent events.

The implications of this are that:

- false alarms should be kept to a minimum

- warnings should not be given needlessly (crying wolf) nor designated danger areas be drawn greater than is really required 'to be on the safe side'

- other efforts must be made to keep the criterion value at the appropriate level, by enforcing compliance with the danger areas and providing other rewards for compliance

4.3.2. Clarity, conspicuity and comprehensibility

Statistical decision theory can also be used to argue for clear warnings. If the two curves in Figure 4.3 are shifted apart by increasing the signal to noise ratio no problem of discrimination remains. The criterion can be unambiguously placed at the bottom of the upper curve. The idea is clear in theory, but less straightforward in practice. It requires research in particular instances to find out what features of a warning render it unambiguous. Pauls & Jones (42) found in the case of fires that announcements over the public address system had a major effect on people's assessment of the reality of danger, and so on their behaviour. Carter (46) on the other hand found that announcements of impending hurricanes over the radio and TV were not seen as authoritative by American inhabitants of the hurricane belt. Only a third would automatically follow them, while the rest (particularly those who had previous experience of hurricanes, 47) waited to make their own personal assessment before evacuating. Tong (32) draws on such research to argue for much more informative public fire warning systems in buildings, which gave not only information that there is a fire somewhere in the building, but where, and which people should react immediately.

Conspicuity is also not always an obvious concept. Shinar (48) found that the use of reflective tags on clothing by pedestrians only increased the distance at which observers reported the presence of the pedestrian if the observers knew what they were looking for. If 'small reflective tag' was not associated in their minds with 'pedestrian' the precaution had no practical effect even though the observer noticed it. Thompson (49) reports similar differences between noticing and understanding in relation to the problem of motorcycle conspicuity. There is an active process of associating a stimulus with a meaningful hazard before any action will be contemplated. Having pointed out the problem, it must be said that common sense increases in conspicuity, such as use of headlights by motorcyclists in daylight, can significantly reduce the number of occasions when motorists pull out in front of them (50).

A number of studies have tested signs and warnings for legibility, and comprehensibility (51,52,53,54). The results stress the need for great simplicity in the signs, and for consistency in the 'language' used (for example, a red triangle round a sign indicating a warning, a red circle meaning a prohibition). They also underline the necessity for people to be taught this language. Where words are used in warnings the reading age of the intended audience is crucial (55), and the proportion in the population of illiterates or foreign nationals with a poor understanding of the language will affect whether words can sensibly be used at all.

4.3.3 Warnings and personal protective equipment

Apart from the design of the warnings themselves one other factor frequently interferes with the perception of warnings in industry. Many people are required to wear personal protective equipment to guard them from exposure to noise, sharp, flying or falling objects, aerosols, gases and vapours. Aside from their protective value many devices restrict and interfere with the input of information to the worker. They are imposed sensory defects. Ear defenders partially deafen; goggles restrict the field of view; gloves remove the sense of touch as effectively as extreme cold.

The ability to localise the direction of warning sounds is also impaired by ear defenders (56); for example a 180-degree error in direction was reported in 30-40% of cases in localising an ambulance siren (57). Dunn (58) also reported significant problems among chainsaw operators using ear defenders who could no longer detect the changes in the sound made by the saw engine as it neared a knot, or as the saw blade emerged from the hidden side of a branch. As a result the number of 'kickback accidents', where the saw jammed in the cut and kicked back out of it at the sawyer, and cuts to legs and feet increased after the ear defenders were introduced. Talamo (59) found problems of a similar nature in detecting and interpreting abnormal sounds after the introduction of noise-reducing cabs on tractors. The general approach to solving such problems lies in careful selection of warning signals and protective equipment which complement each other.

4.4 INSPECTION AND HAZARD SEEKING

We turn now to situations where the people concerned are already alerted to the possibility that there are hazards present, and are actively seeking them. The most common situation in which this occurs is during workplace inspections, whether these are being carried out formally by a safety committee or labour inspector, or informally by a worker or supervisor before work on a task begins.

There has been considerable research on the tasks of quality control inspection and detection of signals on radar (or other vigilance task) (see for example, 60,61,62). Far fewer people have studied safety inspection. We begin this section with a summary of three studies which have looked specifically at the actual process of safety inspection and hazard description, in order to give a flavour of the factors which are relevant.

4.4.1 A field study of 'naive' inspectors

The first study was undertaken as part of a course for future safety committee members in an engineering factory. While it cannot claim to be a controlled study, the results were so clearcut that they can be treated at least as indicative. At the start of the course and before any discussion of hazards or inspection techniques an exercise was organised on safety inspections. The 17 course members were asked to inspect independently an area of the company apprentice training school, where some dozen apprentices were working under supervision and to note down all the hazards they saw. Beforehand the apprentice school manager, the company safety officer and the course organiser carried out their own detailed inspection aided by checklists to produce a master list on which there were some fifty hazards. This list was updated as the course members carried out their exercise in order to detect any new hazards.

The lists produced by the course members were compared individually with the master list, and then grouped together for a second comparison. Not surprisingly no one course member noted down more than forty percent of the hazards on the master list. When all the lists of the 17 course members were combined, just over seventy percent of the hazards on the master list were present (plus a small number of hazards not on that list). This merely confirms that naive inspectors working singly are not as good as a group of experts. It is in the analysis of the type of hazards which did not appear on the course members' lists that useful information about the hazard detection process emerges. The missing hazards were characterised by one or more of the following features:

1. they were not detectable by the unaided eye, simply by walking round the area concerned; it required the person šinspecting to look in, behind or under things, to rattle guards to see if they were loose, to ask questions about the bag of white powder in the corner, and so on.

2. they were transient; they were not there all the time, and although they might be seen if someone watched the whole of an activity, or happened to be looking in the right direction at the right moment, they could only reliably be discovered by asking questions and using the imagination about what other things might go on in the apprentice school which were not happening at the time of the inspection.

3. they were latent; that is, the danger was contingent upon one or more events, such as a tool on a machine having to be changed, a fire breaking out, or work having to be done by artificial light. The same comments about detection of these hazards apply as for those under 2.

Only about ten percent of the hazards with any of these three characteristics which appeared on the master list were noted by any of the course members.

The conclusion from this study is that, at least for untrained people asked to recognise hazards in an area in which they do not work, obvious hazards mean those which are visible to the naked eye and present at the time of inspection.

4.4.2 Hazards according to the experienced operator

The second study was of approximately 200 jobs carried out by some 80 operators in a light engineering factory (63). The operators were asked to describe how it was possible to get hurt doing their job. Their replies were compared with a list of hazards drawn up during job safety analyses of their jobs by trained observers.

The majority of the hazards which were described were ones where the respondents themselves had personally suffered an accident or near miss, or had seen or had heard about one from a close colleague. Hazards which were rarely if ever mentioned were:

- ones which would only produce trivial injuries, such as cuts, scratches or small bruises
- serious but rarely occurring accidents involving some incident outside the normal pattern of work; for example, uncovenanted strokes on presses or rivetters, catching hair or clothing in moving machinery parts.

In this study, experience was clearly playing the dominant role and operators were responding as though the question had been not; 'how could you get hurt?', but; 'how have you or people you know got hurt?' This personal experience fills some of the gaps in the study of the 'naive' group of inspectors, but the out-of-the-ordinary incidents requiring the postulation of intermediate events still do not appear.

4.4.3 Hazard spotting by 'safety' personnel

During his study of hazard perception Pérusse (64) carried out a direct observational study of the way in which people seek hazards. He used as stimulus material drawings prepared by the Royal Society for the Prevention of Accidents (RoSPA) for use in hazard spotting competitions (see Figure 4.4 for an example). Each picture was supplied with a list, drawn up by RoSPA, of the hazards that competitors were supposed to find. Subjects for the study were drawn mainly from the staff and students of the Department of Occupational Health and Safety at Aston University. Because of their background and interests they are certainly not typical of the general population; compared with the samples in the previous two studies they might be called experts in safety (or at least enthusiastic amateurs intending to become experts). They were asked to identify hazards in the pictures, circling them with a pen and describing out loud what they were doing as they con¬ducted the exercise. No definition was given of hazard nor was there any instruction on how to go about the exercise. When the subjects said they had come to the end of the hazards they could find they were encouraged in general terms to look further, but no clues were given as to other possible hazards. The exercise terminated when they could find nothing more in response to such urging.

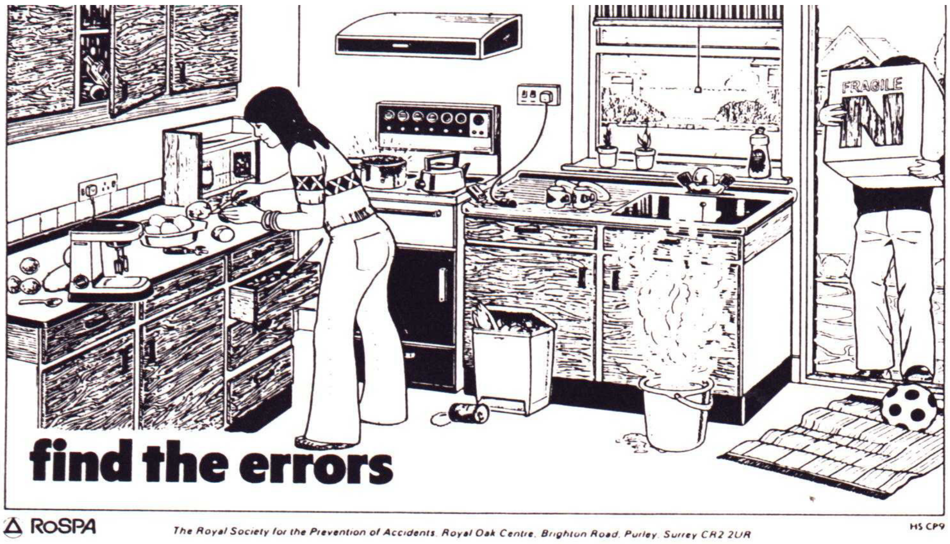

Figure 4.4. RoSPA hazard spotting picture

The first noteworthy finding was that some subjects found more hazards than were on the official list. There were 19 for the picture illustrated in Figure 4.4; several subjects found more than 20, and when the lists of all the subjects were added up 32 hazards were identified for that picture. This confirms what has emerged from many of the studies reviewed in this chapter, namely that what is a hazard for one person is not noticed by others, and if pressed people can usually find a few more things to label as a hazard in any given situation.

Other findings of interest came from the verbalisations of the subjects during the exercise. There were clearly several different strategies of hazard-seeking used by different people, or by the same person at different times. These could be characterised as follows:

1 Focus in on a small part of the picture and point out specific hazards related to it. Thus, the food mixer has a frayed electric flex and is overhanging the counter, two separate hazards according to this approach. Individuals using this strategy would usually work their way methodically round the picture item by item. This is a concrete, item-related strategy.

2 Scan the picture more globally and draw large circles around items of equipment with a general statement: 'that looks dangerous to me'. So the food mixer would present one hazard to people using this strategy. Only when prompted to explain why the circled item was a hazard would they elaborate and (sometimes) identify more than one way in which the item could be involved in producing injury. This is a global strategy.

3 Less commonly, subjects would postulate an activity which was taking place, or might take place in the kitchen as shown, and would follow the activity through, identifying hazards associated with it. These hypotheses clearly influenced the hazards mentioned. For example, only a few subjects specifically made the deduction (from the presence of a ball in the picture) that there were likely to be young children in the kitchen. Following on this deduction one then pointed to the bottle standing on the windowsill and said that, if that contained bleach and the kids got to it they could drink it or get it on their hands. This is a process-oriented strategy.

With the third strategy in particular, but also when asked to justify why they had indicated something to be a hazard using one of the other two strategies, the verbalisations were frequently in the form of hypotheses: 'If that happened, this could go wrong'. As the search went on the hypotheses tended to become more elaborate, that is to include more than one step in the chain of reasoning from the situation in the picture to the harm. Particularly towards the end of the session words of doubt began to creep into the descriptions: 'I suppose you could imagine that, if X were to do that, this might happen'. In some cases people verbalised such a chain of reasoning and then decided that it was too far fetched, and did not in fact include the item as a hazard. In a few cases where subjects were asked at the end of the session why they had not mentioned a particular hazard they gave the reply: 'Yes, I thought of that, but then I really did not think it was likely'.

What seemed to be going on was an active and creative search process, involving neither simply the memory of past accidents nor just the recognition of previously learned physical signs of hazards, but also the development of hypotheses about how the system depicted in the picture might develop, and what might reasonably be expected to happen in it. They were using factors such as expectations, beliefs and mental models to arrive at a personal risk assessment.

None of the three studies described could be called a controlled scientific experiment, but a picture of the process does emerge, which can be compared with the available literature on related topics.

4.4.4 Inspection as an active process

It is clear that hazard detection is to an extent an open-ended process. We mean by this that there is not a fixed number of hazards in a given situation which are there to be detected, and about which everyone will objectively agree. Each person applies a cut-off in their search, which is partly dependent upon a decision about what they consider to be plausible. It will also obviously be influenced by the time available to them, by their motivation, their knowledge of the situation and their expectations about it. Research on quality control inspectors confirms the last point. Inspectors tend to stop the process of inspection once they have found one fault, since they generally expect there not to be more than one in any one article (65). This is also a problem with people looking for the causes of machinery breakdowns; they (quite correctly on probability grounds) expect single rather than multiple failures, and are therefore less likely to detect the latter when they occur. It may well be that safety inspectors have other expectations; that is, if they find one safety hazard they may be more likely to look for others. The point we are making is that the expectations or mental models of the inspectors will govern how they carry out the inspection.

The importance of experience and memory is confirmed by Laitinen's study of workers in a heavy steel plant in which he compared the actual accident statistics with the list of near accidents obtained from interviews with workers in the plant (66). He found that the average potential seriousness of the near accidents described was higher than the average seriousness of the actual accidents. He interpreted this as an indication that the hazards which people saw, or remembered were only the more serious ones.

The process of hazard detection, being an active one, requires the allocation of mental resources, and while the finding of one hazard may motivate the search for more in the short run, the process cannot be sustained indefinitely. Pérusse (6,67) found this in his study of hazard reporting. The number reported on the cards he asked people to carry with them declined through each week, recovered slightly each Monday when people were reminded of the exercise at the start of work, but to a lesser point each week. Kjellén (68) found a similar problem in the regular reporting of near accidents after a period of several weeks. Only with professional people reporting potentially serious events does there seem to be little fall off in reporting with time.

A conclusion which can be drawn from this evidence is that hazard detection needs to be organised as a distinct activity carried out by specified people at prescribed intervals and subject to monitoring and reinforcement. If it is left to individuals simply as one extra task to be fitted in with the rest of their duties it will be inefficiently done by many of them. For most it needs the stimulus of having the required mind-set switched on at intervals and of being answerable for the completeness of the resulting inspection. Only a minority will do it conscientiously on their own without reinforcement, and then probably only in situations where danger is relatively frequent or serious in nature.

4.4.5 Inspection strategies

Rule- v knowledge-based. A major feature of the three studies described was the way in which the participants went about their task. For the 'naive' group in the strange environment it was probably almost exclusively a process of matching what they saw with some pre-existing categories of 'hazardous situations'. This was probably also the strategy with the machine operators in the second study, but here they had their own experience and that of their friends and colleagues to draw on as the basis for the matching. A different strategy, which was present to an extent in the first two studies, but which did not emerge clearly until the third one, using 'experts', was an active analytical strategy, based on the formation and testing of hypotheses.

It is unwise, on the basis of such uncontrolled studies, to draw firm conclusions about whether the three different groups were all capable of both strategies, but simply chose different ones because of the differing circumstances and questions asked, or whether a combination of level of expertise and intelligence and of the effect of experience constrains the strategies available to individuals. However, it is possible to relate these two strategies to operation at the rule- and knowledge-based levels respectively of Rasmussen's hierarchy and to suggest that the ability to operate at the latter is likely to be associated with intelligence, and that the possession of appropriate experience both allows and encourages an individual to operate at the former.

This distinction between 'structural' matching of stimuli with categories and 'functional' reasoning about future events is also noted in the literature on childrens' accidents (69). Sheehy (70) noted that young children have difficulty with cause/ consequence reasoning in relation to road hazards, and Faber & Scott (71) found in their study of product safety that only from the age of seven did analytical reasoning about accident causes begin to appear. Soliday (72) found a difference between younger and older car drivers in the type of hazards they reported. The younger drivers cited mainly static hazards, while the older gave most prominence to moving ones. This may reflect a persistence of structural reasoning into early adulthood. Sheehy & Chapman (69) point out that an exclusively structural response to hazards really only allows of a black or white decision of what to do about them; to avoid them altogether if they are called hazardous, or to accept them without reservation if they are not. In order to be able to use an object which has hazards associated with to it if used in some ways but not in others, a functional approach is necessary.

Field dependent v field independent. There is a considerable general psychological literature on the strategies which people use to process information and make decisions upon it (73). Many of the studies contrast two styles under a variety of different names (field dependent v field independent, holistic v serial, divergent v convergent, impulsive v reflective). While the theories underlying these different names have specific features which distinguish them, it is possible to draw some common ideas out of them. In his discussion, Robertson (73) speculates on the relationship between the two strategies and activities which go on in the two halves of the brain, analysis in the left hemisphere and synthesis in the right. He suggests that choice of one or other strategy reflects the difference in dominance between the two hemispheres in different individuals and at different times. Such speculation is beyond the scope of this book. What concerns us here is the implication of the two different strategies for hazard detection.

The main differences in the two strategies can be described as follows:

The field dependent strategy takes a global view of the situation, and has more difficulty in extracting details embedded in it. People using this strategy take longer to search for specific details and find it harder to ignore irrelevant clues (74). In a review of six studies, Goodenough (75) found such people slower to react to traffic emergencies and worse at detecting road signs against a confusing background; they also concentrated much more intently, while driving, on the car immediately in front of them, and less on the situation further ahead.
In contrast the field independent strategy concentrates on details one after another, systematically, but more slowly analysing them, and therefore seeing details of the situation more independently. What little evidence there is suggests that field dependent are more likely than field independent drivers to have accidents.

However, this result must be treated with some caution since neither the definition of the strategies nor the ways of measuring individual differences in tendency to use them are well validated. It is possible to speculate that each strategy will work well in different circumstances, and that people can learn to use both. Certainly quality control inspectors can and do learn to use the holistic field dependent strategy (59). Studies show that they learn a 'gestalt' of an acceptable product which they compare mentally with each product passing on the line in front of them, in order to detect any significant differences. 'Gestalt' derives from the German school of psychology of the early twentieth century and refers to a complete mental picture of something, which is seen as a 'whole', which is more than a simple sum of the characteristics which make it up. Inspectors were found not to look successively at each possible way in which something could be wrong with the product, but perceived rejects only as being 'in some way different from' a good article. They frequently needed a second look at the reject before they could identify what the specific defect was. The analogy is clear with the second strategy used in Pérusse's study (6) described above. Here the inspectors are using a global strategy to identify hazards, but are capable of switching to the analytical strategy to obtain further information.

The danger of the holistic strategy is that the person using it leaps too quickly to a conclusion about the nature of the problem or hazard and acts precipitately. This may have been the problem with the drivers mentioned in Goodenough's review (75). Such a view would also be supported by the findings of a driving simulation study (76) and an analysis of mining accidents (77) in both of which those who had more accidents were slower than the average on perceptual tests, but average or faster on reaction time tests (see also 78).

It may be that such a holistic strategy would be better able to pick up global indications that something is going wrong, which require the combination of several bits of disparate information; whereas a more systematic field-independent strategy would be better for identifying small pieces of evidence embedded in the situation which gave clues to problems.

A problem in drawing firm conclusions in this area is that the dichotomies we have presented of rule- v knowledge-based functioning, and of field dependence v independence may not coincide completely. Insufficient research has been done linking the two concepts and other related ones together. Only further study can unravel the distinctions and establish whether there are more factors than one at work. Specific studies of hazard detection are also necessary to establish which strategy would be most appropriate in which circumstances for the detection of which sort of hazard.

4.5 PREDICTING DANGER

The two previous sections have dealt with the detection of danger in existing systems as it arises in the course of activities. A subject which has claimed increasing attention in the last two decades has been the prediction of danger at the design stage of projects. This development has accompanied the growth in high technology systems in which there is so much energy stored that its escape has catastrophic results (for example, the partial core melt down of the Russian nuclear reactor at Chernobyl in 1986). In such systems the old policy of redesigning plant and equipment on the basis of failures and accidents with early production models is totally unacceptable as a safety strategy, and every attempt must be made to make the system as reliable as possible from the start. Added pressures have come from the realisation, derived from the research in the field of ergonomics, that many inadequacies of plant and machinery stem from decisions of the designer, which cannot be corrected at a later stage in system use. One development which has followed on this realisation is an increase in the legal responsibility and liability incurred by designers for the accidents which occur with their products (79). Another has been the development of systematic techniques for the prediction of failure causes and consequences (80).

The literature on the techniques of probabilistic risk assessment has, particularly since the partial core melt down of the nuclear reactor at Three Mile Island nuclear power station, given a central place to problems of predicting and quantifying human error (11,81,82,83). The techniques developed for the prediction of hardware failure in such systems are based upon logical analysis of the functions which each hardware component is designed to fulfil in the system. It is then a relatively simple matter to postulate and to trace the consequences of failure of each component to fulfil that function (event tree analysis). Since any given component can usually fail in only a limited number of ways, the task of constructing fault trees of causes of defined system harware failures is conceptually not too difficult. Such trees can then be used as the basis for calculation of the probability of given system failures such as toxic and flammable releases or core meltdown. In extending their analyses to cope with the role of the people in the system, risk analysts have imported the same techniques and tried to apply them. The problems which they have come up against are reviewed by Reason & Embrey (11). Only some of the problems are relevant to this chapter, namely the difficulty of predicting the ways in which human actions could lead to system failure, and the problem of incorporating the important ability of humans to recover from error.

Analysis of hardware failure sets out from a defined correct mode of operation. Hardware (despite occasional apparent evidence to the contrary) has no mind of its own. It cannot decide to work in a different way from one day to another. Nor is it so versatile as humans, and hence it cannot switch from one objective to another. Therefore, what is a relatively simple problem in hardware reliability analysis, the prediction of modes of and reasons for failure, becomes highly problematic when dealing with the human elements in the system. Fischhoff (84) points to copious examples in which pre-use analysis failed badly to predict a dominant problem which was met with once the system or technology was in use (for example, the DC 10 aircraft, North Slope oil development, WASH 1400 analysis of nuclear energy). He points to failures in the creative, divergent thinking involved. Imagination and creativity are relevant attributes for this predictive phase in addition to both plant knowledge and expertise in the behavioural sciences. The problem facing designers and risk analysts thus resembles the task which faced the subjects of Pérusse's study (6) described earlier in this chapter - namely generating appropriate and credible hypotheses.

Research evidence about the process of creativity comes from the studies of Guildford (85) and Hudson (86,87). In their studies they used so-called open-ended tests such as 'The Use of Objects Test'. In this test subjects are asked to think of and to list as many uses as possible for a common object such as a house brick. Responses are counted and analysed for content. Results from such tests have been used to measure creativity and to distinguish between what Hudson has called 'convergent' and 'divergent' thinkers whose cognitive style differs independently of their conventionally measured intelligence. Convergent thinkers tend to give few and generally conventional responses to the test, while divergent thinkers give many and sometimes bizarre or surreal responses. Hudson provides evidence that the former tend to gravitate towards the science, maths and engineering disciplines, and the latter towards the arts, with the social sciences often falling in between. We have already suggested that the process of hazard seeking resembles a creative active process of formulating hypotheses about possible future events. This should be easier for the divergent thinker than for the convergent, who will tend to be bound by experience and convention, and therefore not anticipate the more unusual combinations of events which could lead to harm. An interesting hypothesis arises, if the analogy is accepted, namely that, with due allowance for experience and knowledge of the system being analysed, engineers (being more convergent) will find less hazards in a given situation, and will be less good at predicting the more unusual ways in which accidents could occur than either social scientists or arts graduates. Such a hypothesis, if proved true would have profound implications for the practice of risk assessment.

While it cannot throw direct light upon the above possibility, an interesting small-scale study was undertaken by one of the authors (Glendon) who showed a film of a machine shop accident to a class of 43 students. Thirty-three were taking engineering degrees, four science and six management/social science. Despite the small numbers, the pattern of responses to a request to write down as many causes of the accident as they could, was along expected lines. Thus, engineering and science students were more likely than management/social science students to identify physical aspects of the environment or mechanical factors as causes of the accident, whereas management and social science students were more likely to identify organisational or underlying factors. In addition there was a general tendency to identify precipitating events or contributory factors rather than 'causes' in the scientific sense and a general disregard for underlying factors was evident. Although the largest single category of responses was of individual factors, these were mainly attributions of negligence or blame. Whereas a knowledgeable group of safety practitioners managed a total of 35 factors which contributed to the accident, the average number of factors identified by the students was just over eight. This example again demonstrates the importance of relevant learned knowledge and skills applied to a situation involving hazards. It might also be taken as an indication that those whose future engineering skills might well be applied in such an environment, could benefit from greater insight into behavioural aspects of accident aetiology.

Despite the importance of the process of predicting failure modes there has as yet been very little systematic research of the process by which people make and evaluate these predictions (37). Manuals on risk assessment methods stress the importance of discussion between experts in plant operation, systems design and human factors about possible failure modes (81,88), but the process seems to be left at present largely to the lottery of group dynamics. Textbooks on design methods stress the value of a combination of creativity, thorough research and the use where possible of testing of prototype models or mock-ups on samples of the eventual user population in trying to anticipate problems of misuse of products and equipment (89). However, the way in which these should be used and combined to predict hazards does not seem to have been studied systematically.

In the construction of conventional fault trees there is also an important element of divergent thinking in imagining ways in which the plant operations could move outside designed normal working, and the circumstances which could give rise to that. Great reliance is rightly placed upon past experience of plant operation and upon logical and auditable methods, (based upon checklists such as Hazard and Operability Study, 90). However, in the end recourse is invariably made to engineering judgement to assess what are 'credible' accidents or occurrences (79).

In all of these cases subjective judgement lies firmly at the base of attempts to predict hazard and failure, whether of the human or the hardware elements of the system. The so-called objective methods used in Probabilistic Risk Assessment are no more (and no less) than systematic ways of working through and recording in an auditable way the experience and expectations of a group of experts. Use of computer-aiding to generate fault trees does no more than automate this systematic process. It adds no certainty of its own, but unfortunately is sometimes treated as though it did. The mystique of the computer provides an aura of credibility of its own.

Probabilistic risk assessment techniques are no less valuable because of this limitation but their proponents should never claim them to be right in any logical or mathematical sense, nor that they are able to predict anything with absolute certainty. Claims to the contrary may come from a confusion of two sorts of fault tree, one which analyses with hindsight after an event why it did happen, and one which attempts with foresight before the event to predict all the ways a given event might happen. The former can and should be objective and accurate, the latter can never be.

But as Fischhoff (91) has shown, people confuse hindsight with foresight and consistently overestimate the accuracy of the latter.

The element of creativity postulated above often appears under the title of 'engineering or expert judgement'. Reviews of the literature on this topic (92) indicate the importance played in the accuracy of such judgements by the mental models which the experts have of the processes about which they are being asked to make predictions. (Considerable stress is also laid on the biases present in all expert judgements, which will be dealt with in Chapter 5). A practical example of the influence of these mental models appears in the peer review (81) carried out for the US Nuclear Regulatory Commission of the handbook produced for it to calculate human factors reliability (93). This peer review contained a sample calculation that the reviewers were asked to carry out using the method proposed in the handbook. The results revealed a marked difference between individual reviewers in their estimates of failure probability, and an even greater difference between the reviewers and the authors of the human reliability guide. The differences would appear to be mainly the result of significant differences in the range of potential causative factors considered. These variations were not just the effect of differing experience of the nuclear industry, but of what looks more like different definitions of what were credible failures (83).

Another study on the use of fault trees makes a similar point (94). The researchers were interested in the effect of varying the amount of detail given in a fault tree on the estimation of the probability of the failure analysed in it. They took the simple case of a car engine failing to start. Failure can be due to a number of qualitatively different and independent failures - for example, failure of the starter motor, lack of petrol, lack of spark. They drew a number of different fault trees, which differed in the number of failures specifically mentioned. Each tree had a catch-all 'other failures' branch into which any factors not specifically mentioned were described as falling. Subjects, who were either 'experts' (garage mechanics) or laypeople, were asked to estimate the probabilities of the overall top event (the car failing to start) and of each of the separate failure branches given, including the catch-all category. The results of the study showed consistently greater underestimation of the probability of the top event and of the 'other failures' category the more specific branches were left out. This was interpreted as evidence that people did not use their imaginations sufficiently to consider what important 'other failures' there might be which were not specifically included in the tree. This underestimation was found as much among the experts, who might have been expected to be able to use their experience to fill in the gaps, as among the laypeople.

The last-mentioned study is evidence both that divergent thinking is necessary in the prediction of failures, and that it can be restricted by presenting a partial solution to the problem. This is akin to findings in the field of problem solving (95) which show the strong tendency to move too rapidly from the divergent solution-generation phase to the convergent solution-evaluation stage before the true nature of the problem has been discerned. In other words people may tend to retreat from the demanding knowledge-based level of operations to the rule-based level of solution application too soon (96).

4.6 KNOWLEDGE OF CAUSAL NETWORKS

Underlying the discussion of all three types of hazard detection (alerting to, inspection for and prediction of danger) has been the idea of mental models of the way in which events happen and systems develop (82,97). People are alerted to danger when their expectations (predicted model of how things should turn out) are not met. They use their models again to create the hypotheses that they test about what hazards might arise and how failures might occur. If these mental models are incomplete or wrong they can lead to inappropriate behaviour in the face of hazards.

We begin this section with some illustrations of the ways in which models of the causal mechanism associated particularly with occupational disease hazards can err. Some evidence comes from two small field studies (98,99). The studies were conducted to discover how people working with particular hazards perceived and understood them. Groups were chosen who worked with one of the following hazards; radioactive sources, benzene, asbestos, trichlorethylene, cyanides. They were asked a series of questions starting with a very general one about how they could get sick or injured as a result of their work. The questions then narrowed down to the particular hazard of interest. Here they were asked how it could hurt them, how they knew that danger was present, and whether the risk worried them. In this way insight was gained into the concept or mental model that these workers had of the hazard they worked with and the cause-effect links perceived between presence of the hazard and the occurrence of harm. While the majority of the interviewees had a reasonably accurate picture of the mechanism by which harm occurred, there was a significant minority whose picture was dangerously inaccurate. Accuracy was defined here not in purely scientific terms, but in terms of whether the model would lead the individuals to adopt the appropriate behaviour to protect themselves from the hazard. Examples of such significant inaccuracies were:

- men sawing asbestos cement sheets who thought that the worst that asbestos could do to them was give them a dry smoker's cough, and others who said that they only wore their face masks when they could see asbestos particles in the air. (Yet it is the microscopic, invisible particles which are the most dangerous because they are in the size range which can penetrate to the lung);

- two men working with trichlorethylene who ignored the smoking ban; they claimed that it was an unnecessary rule because 'trike' was really not very flammable in their experience. They had on one occasion dropped a lighted match in it and it did not catch fire. (A major danger from smoking is the breakdown of trike into toxic gases in the heat of the burning cigarette end);

- a group of a dozen chrome plating workers using cyanide who said that they had no worries about its effect on them because they had a weekly medical examination from the doctor. (This was in fact for chrome ulcers. Ingestion of cyanide produces symptoms in minutes).

Hale & Else (100) quote inadequacies in the cause-effect model of people working in noise. A number fail to incorporate the notion of time weighted average exposure in their concept of what constitutes dangerous noise. Hence they fail to realise that prolonged exposure to noise levels around 85-90 dbA or very short exposures to high noise levels can result in a dose above the recommended limits. The former misconception results in total lack of wearing of ear protection; the latter results in a failure to realise that 'just taking the ear-muffs off for a few moments to let the ears breathe' can negate much of their protective effect. In the case of noise this problem of the inadequacy of the mental picture is made worse by the fact that the scale of subjective loudness does not correspond with the scale of energy immission which determines the degree of damage. Noise energy doubles approximately with every 3db increase, while subjective loudness doubles only with every 10db increase. When this is combined with the habituation to constant noise levels, which makes them appear lower anyway, the danger from higher noise levels is seriously underestimated.

Mason (101), in a study of training in good working posture and movement also showed misconceptions among his trainees (workers and managers alike) about the link between posture and musculo-skeletal damage. Misconceptions included labelling postures as 'relaxed' and therefore good when they showed the body and notably the spine in a slumped position (which in fact puts extra load on the back muscles to stabilise the spine in that position); others believed that postures which showed great effort being put into applying force were good, when in fact minimum damage is done when force can be applied without showing effort.

Svenson (30), in his review of factors relating to road safety, cites examples of erroneous beliefs among drivers and pedestrians about mechanisms of harm. For example, occupants of cars believed that they could hold themselves away from the windscreen with their arms in crashes at up to 25kph (this is not possible even at 7kph); pedestrians believed that they were visible to drivers much further away than was the case (20% of those who were absolutely certain they were visible were in fact totally invisible); drivers would overtake on a curving road with no traffic in sight, not realising that they had less time for the manoeuvre (because of the possibility of traffic hidden by the curve) than they would accept on a straight road (indicating that the decision to overtake was taken on a seen/not seen decision, not a safe/not safe one).

At the level of engineers and designers, Kletz (102,103,104) shows that equivalent misconceptions or myths about the causes of accidents and incidents are just as prevalent. For example, they tend to underestimate the dangers of implosion of storage tanks if the provision for pressure equalisation is inadvertently blanked off and the tanks are run off or subject to cooling; they tend to assume that overpressure and relief valve failure are the only credible causes of vessel rupture, forgetting the fact that yield point is reduced when vessels are locally heated.

Burton et al. (105) showed that the absence of readily comprehensible explanations for natural disasters could lead to the adoption of supernatural explanations for them. These tended to be deterministic (either that lightning would never strike twice in one place, or that one disaster meant that another would certainly strike). These 'explanations' conditioned the behaviour that people showed towards future disasters (total unconcern v flight to another area respectively). Other studies report similar attitudes about the unpreventability of accidents, belief in accidents as punishments of Fate or some supernatural being(s), or as an inevitable part of a technology or activity (3, 106).

Accidents are a powerful incentive to the creation of myth (32). They demand explanation in order to set people's minds at rest (107). Gouldner (108), in his classic study of the beliefs of workers in a gypsum mine describes graphically the myths which miners had about some warnings of danger (that rats would leave the mine just before a disaster) and some protective devices (wood props being able to hold back the roof, when mine engineers regarded them only as early warning systems which would give signs by bending and cracking of pressure build-ups before collapse occurred). Guedeney & Mendel (109) in their study of attitudes to nuclear power demonstrated the potency of such myths, which tended to be very simple, if not primitive, and to be borne by rumour, particularly among people living some distance away from the hazard.

Many of the errors in models of the causal mechanism of harm which we have mentioned tend to be simplifications which leave out some vital element or influencing factor. This simplification comes in part from limitations in the processing power of the human brain. It cannot cope with the simultaneous processing of many variables especially if they are interconnected (cf Chapter 5), and so makes simplifying assumptions, or only processes part of the problem at a time. A study of bus drivers illustrates this point (110). They were asked to judge whether they could drive their buses through specific gaps. A small number were quite able to assess the width of the gap accurately, and knew the width of their bus, and yet failed to put the two facts together when making a judgement about whether they would attempt to drive their bus through the gap; they were willing to try to drive through a gap they knew was narrower than the bus. A more bizarre example is quoted by Kano (111) of a suicide attempt in which the person chose to gas himself, turned on the gas tap, then had second thoughts and decided to have a further think about his situation; the better to think he lit a cigarette and suffered severe burns when the gas exploded around him. Such examples of bounded rationality and short circuiting of the reasoning process are not uncommon in industrial settings (5,112), especially where action is being taken to put right a preceding problem which has disturbed the normal flow of work (see also 113).

Many writers on large-scale disasters talk of the enormous complexity of the events leading up to the incident - for example, the Aberfan tip slip 1966 (41,114), aircraft and nuclear incidents (115,116), and shipping accidents (7). The complexity is sometimes so great that it is hardly reasonable to expect any one party to penetrate it, except with hindsight. Information is buried among other material, often in several different organisations; there may be distrust of some of the organisations by others and information may be wilfully withheld; attention may be distracted elsewhere, or the whole culture of an organisation may allow no place for the vital information (115). At no point before the accident does (and perhaps can) anyone form a complete mental model which contains the possibility that the accident could occur. This leads Perrow (115) to talk of 'normal accidents' which are so embedded in the technology and so much a result of the close-coupling of widely different system elements that they cannot be considered in any reasonable sense preventable.

We have given copious examples here of errors and limitations in causal models of the harm process in particular cases. Because the harm process for most occupational diseases is more complex and less visible than that for simple injuries, the correction of models presents a greater problem for occupational health than for everyday industrial safety (117). For complex contingent hazards (such as occur in many process industries) it is also a problem. The next chapter takes up the topic of how the models are used, and we shall return in Chapter 9 to the question of learning and of modifying the models.

4.7 CONCLUSIONS

We have described three processes by which people detect that they are in danger:

1. A more or less automatic monitoring of action sequences at the skill-based level, which detects quite efficiently deviations in the execution of the plan, but which is less efficient at picking up deviations of the plan from the goal set for it.

2. A conscious search and matching process at the rule-based level, in which hazards are recognised by a process of comparison with learned signs, usually related to the physical characteristics of the hazard. Two strategies were described, a systematic detailed scanning and a global impression formation.

3. A process of hypothesis formation and testing, where activities or possible future developments of the system are projected onto the current situation in order to predict what might go wrong. This operates at the problem-solving, knowledge-based level, and amounts to a decision-making process.

According to Reason's theory (118, see also 96,119) an individual shifts from method 1 through 2 to 3 as more signs appear that the more automatic 'lower' levels of behaviour are failing to cope with the problem. This is done by concentrating steadily more attention onto the problem. This means that the active (and time consuming) hypothesis forming and testing mode is only occasionally engaged and is hard to sustain for long, especially if the person is trying to do other things at the same time. Active search for hazards can only be done as an exclusive task, and therefore needs to be planned as such at appropriate times. The only hazards which can be kept under control at lower levels of attention are those which are a normal part of the activity concerned, and for which there are well learned control routines.

Behind all the levels of hazard detection lie mental models of cause-effect sequences which people use to make their predictions of what should happen, and so what could go wrong. At the skill-based level these are expectations of what will be the result of particular actions; at the other levels they are models of the mechanisms by which harm could occur. We suggest that these are the building blocks used in the monitoring process. How they are used is the subject of the next chapter.

A general conclusion from this chapter is that our understanding of the process of detection of hazards is still very patchy. We do not know clearly what features of a situation are effective, and what ineffective in alerting people to danger. Nobody has studied in sufficient detail the process of active search for hazards, in order to discover whether it comes up with the problems which are important, and what could be done to enhance its effectiveness. When we return to the question of training as a method of changing behaviour, and the process of learning about danger (Chapter 9) we shall have something more to say about this. Studies of recovery from deviations (near misses) could throw much more light on these questions.

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CHAPTER 5

DANGER LABELLING AND ASSESSMENT

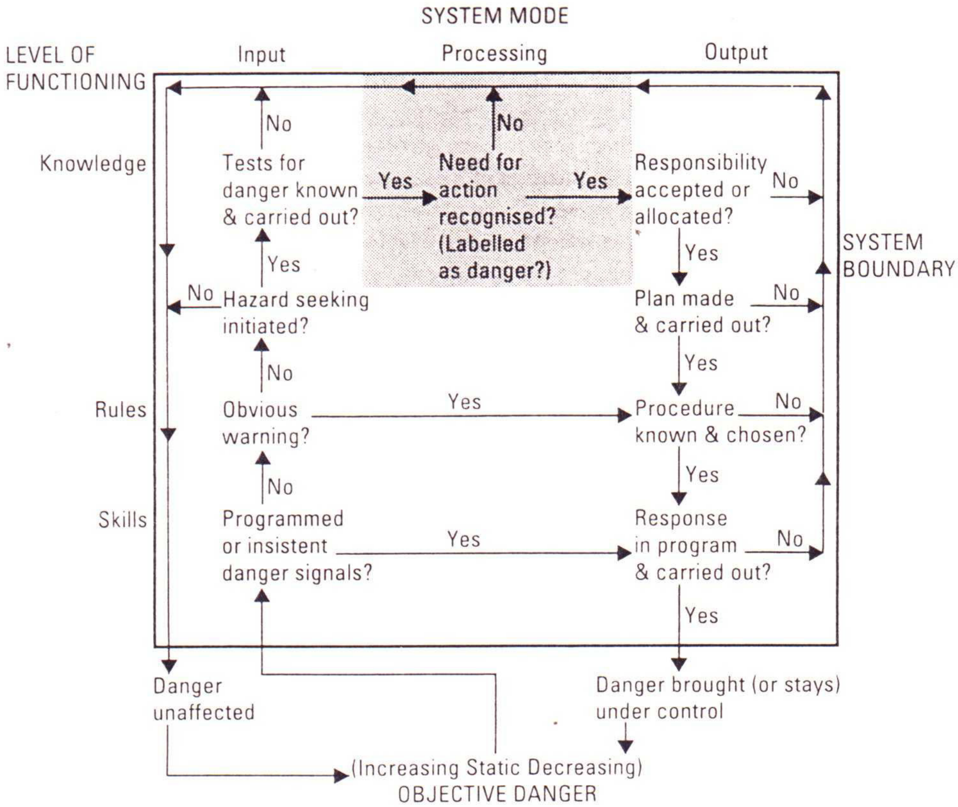

Figure 5.1. Behaviour in the face of danger model - labelling & assessment

5.1 INTRODUCTION

In Lawrence's study of gold mining accidents (1) 17.5% of the victims made no attempt to avoid or to escape from the danger despite having perceived it. This was largely due to an underestimation of how great the risk was. In Abeytunga's study of construction site safety (2) supervisors refused to accept that 8% of the items on a list of hazards drawn up by a construction safety expert were indeed hazards, and regarded another 10% as being hazards, but ones which nobody need do anything to remove, in other words as just a part of the normal and acceptable risk of construction work. In this chapter we discuss the factors which influence the assessment of hazards, and lead to a decision that something must (or need not) be done about them. Two types of error can be made in this respect. The most obvious is that nothing is done, when in fact the situation is out of control and action is required. Here we talk in common parlance of negligence or complacency, or of blindness to the realities of the situation. The second type of error is where nothing needs to be done, but people still believe that something is wrong and that action should be taken. Here we talk about scare mongering, anxiety or anti-technological biases.

The research which we shall review tackles both issues, but much of it has done so from a very specific viewpoint, the assessment of nuclear power and related technologies, which present low probabilities of harm. Such technologies present an almost perfect test case for the arguments about assessment of danger. On one side are ranged the supporters of nuclear power who stress its advantages, the dearth of realistic alternatives, the vanishingly small probabilities of serious accidents (large releases of radioactivity from core meltdown), and the professionalism of the staff designing and running the plants. On the other side are the opponents who stress the consequences of an accident should it happen, the difficulty of disposing of nuclear waste, and the concomitant threats to general security of the production, transport and storage of the waste material which could be used for making nuclear weapons. Each side castigates the other with the abusive terms we have just suggested. Such diverse viewpoints require explanation which goes beyond simple differences in the level of knowledge about nuclear hazards by the two parties (3). It must be sought in the way in which people assess the different factors which comprise a hazard.

A decision about the need for action is in many circumstances not easy. In the context of occupational disease threats, it requires considerable epidemiological research to establish whether there is a level of exposure to the substance or physical environment which is safe, and if so, what that level is (4,5). There are few substances where there are no objective controversies over the quality of the evidence and/or how it should be used to arrive at exposure standards. Even if the research evidence were to be clear cut about what objectively is dangerous, we are left with the problem of whether people will accept that evidence and regulate their behaviour according to it. The same is true with contingent dangers; the hazards which only manifest themselves when something gets out of control. We pointed out in Chapter 4 that the process of recognising when a deviation from normal is great enough to constitute a danger is unavoidably subjective. Even with comparatively simple machines or processes it is never possible to claim that all possible failure mechanisms and processes are known with certainty. This means that there must be an element of trust involved in accepting that they are really under control.

5.1.1 Labelling

We have used the word 'labelling' in the title of this chapter. This reflects the fact that the very complex situation described above is ultimately reduced to a yes/no decision related to some action or other; to put on protective clothing or not, to include an interlock between the motor and the inspection cover in the design of a machine or not, to accept a job as a steeplejack or not, to join a protest demonstration against the siting of nuclear reprocessing plant or not etc. It is as though a label 'dangerous' had been attached to some situations and not to others. A complex, multi-facetted continuum has been reduced to a dichotomy.

The concept of labelling has been used widely in the discussion of disease and the seeking of medical treatment. Doctors have long been interested in what makes some people seek their help with a given set of symptoms, while other people with the same symptoms will not even consider going to see them. The idea of 'subjective health' as an explanatory concept has been developed (6,7), which overlaps only partially with objective health (the presence of actual pathological changes or disabilities). Subjective health has to do with feelings of being in control of symptoms, feelings of underlying resistance to disease, feelings of what one should expect to feel and be able to do given one's age and general physical state. Only if these feelings are threatened do people seek medical help. To do so they must label themselves as sick, and surrender some of their freedom by placing themselves under the doctor. Many people will not do this for diseases they regard as temporary, or if they do not believe that the disease is curable (8,9). On the other hand some will attach the label 'sick' to themselves very easily. Colligan and his colleagues in the USA (10,11) have investigated a number of incidents of what has come to be called mass psychogenic illness in factories. This is typified by an epidemic of absence particularly among women associated with diffuse symptoms, no detectable pathology, no traceable toxic substances, and complaints of a generally non-specific nature about smells, or 'bugs in the air'. While it is never possible to say that such outbreaks have no organic cause, it seems likely that they are the result of premature labelling of vague symptoms as a disease, which then acts as a focus for general feelings of dissatisfaction with the environment, which are shared by the whole group which works there.

5.1.2 Acceptability

In much of the literature on high technology hazards the name given to the danger label has been 'acceptable v unacceptable', and a large body of research and discussion has grown up around the issue of the definition of acceptable risk (12,13,14,15,16, 17,18). As we shall see in this chapter the debate has been marred by fundamental misconceptions about the way in which people assess hazards. Two issues in particular have caused confusion:

1. The connotation in the word 'acceptable' that people are, or should be content, or even actively happy with the situation. The word 'accepted' gives a better assessment of the situation, since it carries with it an idea that the opportunity to do something about the hazard is a relevant factor in the decision. If I perceive that I can neither do anything to reduce the risk, nor persuade others to reduce it, nor move away from it, the only course open is to accept it; this does not mean that I am happy about it, or would not grab any opportunity of reducing it should one come along. The work of Green & Brown (19) showed in particular that people would always be happier if the risk from a hazard was lower than it is now.

2. The idea that an absolute level of probability of death can be fixed which can be labelled 'acceptable' for any hazard. We shall return to this issue later in the chapter in detail, but one point needs to be made now. There is overwhelming evidence that people do not consider the risk attached to an activity or technology in isolation from the benefits to be gained from it (18,19). Therefore no absolute 'acceptable' level for a wide range of different hazards can be meaningful, since the benefits which go with them will vary widely.

A clear distinction has emerged from the research between threats to personal safety, threats to health and threats to societal safety (20,21). The factors which people use in assessing each of them appear to weigh differently, and this is likely to be related to the sort of action which people perceive they can take against the differing threats. For example, moving house or changing jobs will solve the threat to an individual's safety from a particular chemical plant, but will do nothing for the threat to societal safety from that same plant.

All of this underlines the importance of being clear what question we are asking people when we try to measure their assessment of hazards. If we ask them to compare a wide range of disparate health and safety hazards (from smoking to driving a car to living near an airport or a nuclear plant), they will usually reply in terms of the threat to society and to general health, but not in terms of threat to personal safety (20,22). If we ask them to respond to hazards of one type (for example physical dangers) which are all present in their own environment, they will be more likely to respond in terms of personal safety. If we ask them questions related to the need for laws and regulation of hazards they will respond largely in terms of societal safety (16). If the questions are related to the need for protective devices at work, personal safety and/or health will dominate.

Despite these differences there do appear to be common dimensions or factors which people use to make assessments of danger and to apply a label to a situation indicating that something must be done about it. What varies between types of hazard and between responses to different questions is the weighting given to the different factors. The first part of the chapter discusses the factors which have emerged from research; the second part considers the biases and errors which people make in assembling the evidence and in making decisions on hazards. Since most hazards which people face have, for them, a low probability of occurring, the latter discussion will centre on the biases in dealing with small probabilities.

5.2 CLASSIFICATION OF HAZARDS AND 'SUBJECTIVE RISK'

A large amount of research since the mid 1970s has looked at the way in which people evaluate hazards; the constructs which they use to classify them, and the way in which these relate to their overall assessment of hazards. This has unfortunately become known as the 'subjective risk' literature. This is unfortunate for two reasons. First because the word 'risk' is being used in the sense that 'danger' is used in this book. The literature deals with far more than the assessment of probabilities. Indeed, as will be seen, probability is found to be a relatively minor aspect of subjective hazard assessments. Second, the use of the word 'subjective' implies that there is an 'objective' alternative. It would be better to replace these words with 'lay' and 'expert', since the so-called 'objective' assessments are no more (nor less) than the results of systematic assessments made by particular groups of people using a particular range of analytical instruments; instruments which involve significant subjectivity, as was shown in Chapter 4, and will be demonstrated again in the second part of this chapter. In particular the word 'objective' carries the connotation that it is the right way to do something, and hence that 'subjective' must be wrong. The controversy which still rages around what are relevant dimensions for making policy decisions about hazards shows, however, that it is not possible to talk of one right way in this field (23,24, 25).

5.2.1 Expressed preference research

Much of the research carried out by social scientists in this area has concentrated on demonstrating the futility of searching for one level of risk expressed in terms of probability of death per year which could be used as a test criterion to allay the fears of local residents and the public at large about the use of high risk technology. We do not wish to imply that such a figure, or an equivalent probability using some more comprehensive index of type of harm than death alone, cannot or should not be used as a design criterion; merely that any such figure can never be expected to correspond to the dividing line between what the public does and does not find worrying.

The research has demonstrated that people use a more sophisticated assessment process in making acceptability decisions, which depends not just on probability of harm, but also on a wide range of other factors, which are demonstrably relevant to the debate about safety. A number of reviews of work in the area have appeared in recent years (15,16,18,26,27, 28,29,30). While some of the reviews have been critical of the small numbers of subjects involved in the studies, and the artificiality of some of the experimental methods, the results are remarkably consistent in their main features, which gives confidence in their general accuracy.

This research has sprung largely from what has come to be known as the 'Expressed Preference' approach which studies the way in which people think about, classify, or rate situations which contain danger. Before describing the results of the studies we shall describe the methodology of this approach which has three stages; hazard elicitation, scale elicitation and scale analysis. These need to be distinguished, since some of the studies have used different techniques at each stage which may have affected their results somewhat.

1. Hazard elicitation.
To be a true study of subjective assessments the subjects should themselves define, as part of the research, the situations which they consider to be dangerous - that is, the hazards. This can be done for example by keeping a personal note of them (31,32,33), pointing them out to another person during a site inspection (2), or by using specially prepared hazard pictures as the stimulus for a list (as described in Chapter 4, 31). In other words the individuals whose classification of hazards is being studied must themselves go through the processes described in Chapter 4 and come up with a list of hazards which are meaningful to them. If this is not done there can be no guarantee that what are called hazards by the researchers are accepted as such by the participants.

The implication of this approach is that the pure study of hazard dimensions can only be carried out on individual subjects, since each person is likely to end up with a somewhat different list of hazards, even from the same stimulus picture. This makes comparisons between people difficult at later stages in the experiment. For this reason most of the research has used grouped lists of hazards elicited from all subjects in a study, or has presented them with a list prepared by the experimenter (18,19,22,34,35). In the latter case the results must be interpreted with greater care. In any event the range and diversity of the list of hazards used will affect to some extent the scales which are elicited at the next stage. Hence no one study is likely to elicit all the relevant dimensions, and the available research needs to be aggregated to gain a comprehensive picture of how people classify the full range of possible hazards.

2. Scale elicitation.
The second stage is designed to get subjects to reveal systematically what factors they use to differentiate between the hazards on the list. A convenient technique which has been devised to do this is known as Kelly's Repertory Grid (36,37). This was used by both Green & Brown (38) and Pérusse (31,33) in their hazard perception studies. In this technique the list of hazards is divided into groups of three, called triads and subjects are asked to look at each triad in turn and to state how two of the three hazards are alike and different from the third. For example, a triad from the picture of the kitchen on page 4.13 was:

1. 'cooker switches placed so that you have to lean over the stove to operate them'
2. 'fat boiling over'
3. 'kettle flex in water'.

This triad generated among others the scales;

'It takes a specialist to put this right (1) v anyone can put this right (2 and 3)', and
'This is the result of untidiness (3) v not (1 and 2)'.

The technique offers a simple and convenient method of generating in a direct but meaningful way the scales which a person uses for classifying the hazards. Ideally this stage should be carried out as an individual exercise, with each subject using only their personal list of hazards generated. More normally it is done as a group exercise to produce a pooled set of scales (known in Kelly's theory as constructs) in order to make it easier to compare the results obtained by different individuals in the final stage of the method. This again introduces some blurring of results (31). This pooling of results has also meant that the existing research has not considered individual differences in hazard perception which might be related to differences in behaviour towards the hazards.

This scale generation exercise typically produces between a dozen and thirty scales (or constructs) relating to the more abstract and generalisable aspects of hazard classification. Great care needs to be exercised in defining with the subject(s) what the endpoints of the scales are, and making sure that they are all unidimensional, so that they can be used for the third stage of the exercise. Figure 5.2 gives the list of scales generated in one of Pérusse's experiments which used the kitchen picture already mentioned. In most research studies in the area this elicitation process has not been used, but the scales on which the hazards are to be rated are given to the subjects by the researchers (18,34,39). This is frequently done to save time, but introduces a more serious drawback in the studies than the provision by the experimenters of the lists of hazards. Unless the range of scales given is very broad it is highly likely that important scales will be left out.

1	consequence of another hazard v not
2	a hazard v not a hazard
3	due to inadequate maintenance v not
4	hazard is only temporary v permanent hazard
5	result of untidiness v not
6	in order to call this a hazard one has to make assumptions v not
7	caused by lack of knowledge v not
8	sufficient on its own to cause injury v not
9	result of hurrying v not
10	it takes a specialist to put this right v anyone can correct it
11	arises from something that is in use v not
12	the result of poor planning v not
13	a multiple hazard v single
14	arises from something that has not been done v not
15	due to bad design v not
16	result of someone's action(s) v not
17	hard to see v easy to see
18	hard to remove v easy to remove
19	hard to avoid v easy to avoid
20	hard to put right v easy to put right
21	could cause a very serious injury v only a very trivial injury
22	very likely to cause an accident v very unlikely
23	could be a direct cause of an injury v only indirect
24	a very large hazard v very small
25	very dangerous v not dangerous at all
26	one comes across this very frequently v very infrequently
27	very likely to cause death v very unlikely

Figure 5.2: Hazard scales generated by one group for kitchen pictures on page 4.13

3. Scale analysis.

As can be seen from the list in Figure 5.2 the scales produced by step two are varied in nature, and on the face of it often appear to overlap. A final stage in the methodology copes with this problem by testing how the subjects use the scales generated. This is done by getting them to rate each hazard from the original list on each scale to produce a two way matrix. This process will show up whether two or more scales are used in the same or similar ways to rate all hazards, thus implying that there is some underlying common feature in the scales. For example, if a subject rated all hazards which were very large (scale 24) as very likely to cause death (scale 27) and all hazards which were very small as very unlikely to cause death, this would be evidence that, for that individual, there was only one idea underlying the two scales. The matrix is then subjected to principal components and/or cluster analysis to reveal the much smaller number of superordinate constructs (typically two or three and almost always less than ten) which explain more clearly how the subjects make sense of the defined field of hazards. The constructs which emerge from the analysis can be represented in multi-dimensional space. The analysis also shows which scales and which hazards cluster on each dimension in this space. The technique thus draws a mental map of each person's own way of making sense of this area of experience. Because of this multi-dimensional mapping technique the superordinate scales are often called 'hazard dimensions'.

The researcher must then examine the way in which the scales and elements have clustered on the hazard dimensions and decide on an appropriate name to give to each dimension. Figure 5.3 shows the scales loading on one dimension in Pérusse's study (31). (N.B. this is not the same group as the one which produced the scales in Figure 5.2, but, as can be seen, there is considerable similarity between the scales despite the fact that in this case they were generated from hazards spotted by the participants during their normal work at a beer-kegging plant). The order in which the scales are presented indicates the importance of their contribution to the factor. Pérusse, on the basis of this table and of an analysis of the way that hazards cluster on the dimension gives it the label 'scope for personal control'.

easy to avoid consequences of danger v impossible
danger has nothing to do with design v due to bad design
operator’s fault v nothing to do with operator
danger not a necessary result of process v is so
due to indicate training v not
preventable v not preventable
nothing to do with management v management’s fault
anyone can put it right v takes a specialist
temporary danger v permanent danger

Figure 5.3. Scales loading on one hazard dimension from principal components (source 31, Pérusse 1980)

This last, labelling stage in the methodology introduces a subjective factor which makes comparison between studies somewhat difficult. Different researchers may give the same label to different dimensions or may use different labels for what are essentially similar dimensions, depending upon how they interpret the results. This fact must be borne in mind when reading the remainder of this section, where we have had to place our own interpretation on different studies in arriving at the list of headings under which to discuss the results.

5.2.2 Other research approaches

The research method described above concentrates on the internal processes of subjective assessment and hazard classification. Attempts have been made by some authors to relate these assessments to some external scale. For example, Green & Brown (40) used psychometric scaling techniques to generate from their subjects, scales of their assessment of the range of hazards on such factors as probability of occurrence and conditional probability of death given the occurrence. They then used multiple regression analysis to determine which combination of the scales best predicted the rating of the hazards on a scale of seriousness.

Additional insights come from the parallel approach of 'Revealed Preference' whereby actual behaviour in respect of different hazards is considered. In the sense in which this term has been most used it refers to the approach pioneered by Starr (12). He calculated the probability of death during a range of well established activities (such as air transport or coal mining). He then made the explicit assumption that these current levels of risk were a good measure of an 'acceptable' level because they must have resulted from an accumulated process of decision making and action which had levelled off when a point of indifference had been reached. He thus arrived at a relationship between the probability of death during the activity, the benefits derived from it and acceptability. He has been strongly criticised for making the assumption that current levels of risk in established technologies are acceptable. Subsequent studies have shown that people are far from content with current levels of risk (29,34, 41). Nelkin (42) also points to a basic contradiction in his approach. If it is true it means that the market is an efficient means of regulating safety, since the level will always eventually reach an acceptable one, and hence there is no need for external regulation. On the other hand, if the market is not an efficient means, one cannot use information from it to calculate acceptability, and there is no need to define an arbitrary acceptable level. While accepting this criticism as valid, it attacks only Starr's use of the revealed preference approach to assess acceptability. The use of observation of behaviour as a way of showing differences in the ways in which people respond to different types of danger is quite different (43). Indeed, as the Royal Society (15) in its report on risk assessment points out, studies of real behaviour are needed in this field in order to lessen the potential bias from using only subjects' uncorroborated reports of their own beliefs.

5.2.3 Structure of the section

From the research stemming from the various approaches we have derived a list of four factors which appear to influence the assessment of danger and behaviour towards it. Under each factor fall a number of sub-factors. As stated earlier the fine detail of the picture is not entirely clear, although the major lines can be discerned in the majority of the studies. The semantic problems arising from the labelling of the dimensions by different authors also mean that our list differs somewhat from others proposed (15,30,31,44,45).

1. Whether the victim has a real choice to enter the danger or not, or to leave it once exposed. This includes the equity of the process; whether those who are the potential victims are also those who gain from the hazardous activity.
2. Whether the potential for harm in the situation is under the control of the potential victim or of another person or group, or outside any human control.
3. The foreseeability of the danger, which includes such ideas as the degree of uncertainty about possible future states of the system which might result in danger and the complexity and plausibility of the combination of circumstances which would need to occur for the potential of harm to be realised.
4. The vividness, dreadfulness and severity of the consequences.

We then use these basic factors to look at the differences which exist in the ways in which people respond to hazards leading to different types of harm. Whether the damage is to long or short term health, or to some other attribute of the person, or whether some other system element is threatened. How responses differ when different people are victims of the harm; whether the threat is to oneself as opposed to others - particularly when those others are specially vulnerable - for example, children or future generations - or alternatively are perceived to be skilled or expert in some relevant way.

5.3 MAJOR HAZARD ASSESSMENT FACTORS

5.3.1 Choice to enter and leave danger

Voluntary activities. A frequently suggested dichotomy in attitudes to danger is that between voluntary and compulsory activities (12). One of the differences lies in the freedom to choose whether or not to expose oneself to the dangers of the activity. This is a dimension which emerges from Green & Brown's studies (35) as a predictor of perceived safety and which is also an important element of the concept 'Scope for human intervention' in Pérusse (31). The interpretation which can be put on this dimension is that those who choose to engage voluntarily in activities which they know to be dangerous can be assumed to know what they are doing, to realise the nature of the hazards and to have accepted their own responsibility to control them. The problem of accidents or disease is then seen as their affair, and they are presumed to be in control of the hazard. On the other hand if there is no choice about exposure to the danger there can be no meaningful discussion of an acceptable level of risk for that hazard. The situation is seldom absolutely clear cut, since there are varying degrees of voluntariness (46). Can the choice of a person to take a job on a construction site in an area of high unemployment be called a voluntary acceptance of risks associated with that job? Is use of a car to drive to work a voluntary activity? What about taking the car to go and visit parents or children at a weekend? To what extent, in the days of consumer testing of different brands of home appliances, can purchase of the less safe ones be called voluntary acceptance of the extra risk? Can refusal to move away from a flood plain or earthquake region be construed as voluntary acceptance of the hazard (47)? All of these decisions depend upon the other options open and the costs and benefits associated with them. Decisions about purchase of goods, choice of transport means, choice of job or of place to live are seldom, if ever, taken on the basis of the hazard alone; the hazards come as part of the package.

This is an issue upon which the law has changed over the decades. In the early years of the industrial revolution workers were deemed to have accepted voluntarily the hazards of the job that they accepted. Therefore they were deemed liable for their own accidents. This view had to change before the concept of employer's liability insurance could be introduced (48). Now the employee is not considered to accept occupational hazards voluntarily, unless there is talk of some gross deviation from normal carefulness (28,49). Legal interpretation aside, research results show that the level of risk that people are prepared to accept, both for themselves and for others in more voluntary activities (such as sports and leisure pastimes) is greater than in less voluntary activities (34).

Attraction of danger. There is some evidence that dangerous activities which are voluntarily chosen are positively valued partly because of their finite element of danger. The element of apparent loss of control is one of the attractions of fairground rides such as roller coasters and the 'wall of death'. But the fascination seems to go further than this. There is evidence that there is an increase in popularity of such places and rides after a fatality or accident. Allen (50) reviews evidence from people's reactions to accidents, to vandalism, and to horror movies, as well as to the greater crises of war, and suggests that there is a common element in all of them. Greater danger is associated with greater group friendliness, shared feelings, sense of purpose and competence which makes the danger positively valued, or at least willingly accepted. While some of his list are clearly not voluntary activities, his conclusions may account for some of the attraction of dangerous sports. Similar effects of dangerous jobs on group cohesion have also been noted (51). Drasdo (52) argues along similar lines that mountaineers choose to attempt different climbs of increasing difficulty as their skill increases, finding the old ones tame. There is an element here of testing the degree of control which one has over a situation to check that it is real. These two elements of fascination for danger and testing of control appear again in the figures for fire injuries in children (53). Injuries from self started fires start at the age of three, peak at five and are practically non-existent after eight, yet 45% of boys between the ages of five and eleven interviewed in the study admitted to starting fires. The danger is at its highest when the fascination for the fire is high, but the ability to control it has not yet developed.

The idea of a positive value for risk is to be found also in the theory that people compensate for increases in objective safety by behaving more dangerously (54). We shall discuss that theory in detail in Chapter 9.

Equity. Green (55) and Lathrop (26) point out that people come to very different assessments of hazards if the person who is risking getting hurt is also the one to gain the benefits of the hazardous activity, as opposed to situations where the potential victim must accept the hazard as part of an activity from which someone else is the main winner. This particularly differentiates hazards in paid work from hazards in leisure time. McClelland & Rohrburgh (56) found that a quite common feature in negotiations between parties to a decision was the desire to spread the negative outcomes evenly and fairly. This often took precedence over maximising the outcome of the negotiations for the two parties taken together. This amounts to saying that people are happier accepting a smaller total wage packet for the group with an even spread of the dangerous work over all its members, rather than a bigger group wage packet at the expense of one person taking all the risks. Green & Brown (19) also found that the demand for increased safety was stronger if the risks and benefits were inequitably shared.

5.3.2 Controllability

This is the primary dimension which emerges from Pérusse's analysis (31) and which he calls 'Scope for human intervention'. It also emerges in much other work under other names such as personal responsibility (45), or organised safety (18).

Personal control. The largest element in this dimension seems to be the feeling of personal control. Those who believe themselves knowledgeable about and in control of a dangerous situation, even where the magnitude of the consequences is potentially great, show little fear or concern about it (57,58,59,60). It has also been found (61) that people who live very close to hazardous chemical or power plants are less concerned about them than are those who live a little further away. The suggested explanation is that the very visual contact, plus the fact that they know people working at the plant give those who live near a sense of control that those a medium distance away do not feel. (There is the added factor that they may derive more benefits from the plant because they or their family work there). When people are asked to think about hazards that will affect others and not themselves they seem to take a great deal of account of this dimension. Abeytunga (2) studied the attitudes of construction site supervisors to hazards on their sites and to the responsibility for their removal. Where the supervisors considered that the hazards were under the control of skilled craftsmen, they did not personally concern themselves with them, even when they saw that that control was not being fully exercised. Green & Brown (62) asked people to recommend allocation of public funds for fire prevention between different types of fire. They found that people did so not on the basis of the frequency of each type of fire, but on the basis of their beliefs about control, allocating most to fires which they thought were beyond the control of the victim - for example, faulty electrical installations.

The literature on attribution theory which is reviewed in more detail in Chapter 6 suggests that there is a general bias in the way in which people think about dangers which threaten others rather than themselves. There is a tendency for people to recommend less 'risky' actions for others than they accept for themselves. This applies unless the other people are considered to be greater experts than the person making the judgment. The reasoning for this is somewhat complicated. It is known that people have a general bias to attribute accidents which happen to other people to failures in their personal care or skill, while one's own accidents are attributed more to misfortune or external circumstances (63). Hence others are seen as intrinsically less skilful than oneself when it comes to avoiding accidents. Hence one should recommend less risky undertakings to them.

Skill v chance: illusions of control. If the assessment of personal control is such an important factor in evaluating hazards it is very important that the assessment is accurate, and that people do not believe they are in control when they are not. Believing that one cannot exercise control when one in fact can could also have bad consequences, since it might result in feelings of anxiety and also in not attempting to control a danger, which might then really get out of hand. The evidence on this point is complex, and comes from a wide variety of different sources from gambling to mental illness, with only a smattering of studies directly related to health and safety. We deal first with the distinction between being in personal control versus being the victim of chance events; events seen as being outside any (human) control. This is identified as a dimension particularly in studies of natural disasters (39,47), but also surfaces in studies with industrial hazards (64), often as a dimension labelled 'active v passive' hazards.

Eyssen et al. (65) correlated the safety records of departments of a telephone company with the attitudes and beliefs of their managers. They found a clear link between a manager's belief that the safety problem as controllable and a low accident record in the department. Those who felt that the problem was largely due to chance presided over higher accident departments. The causal link could go either way, but it seems rather more plausible to believe that feelings of controllability led to (successful) attempts to control and so to fewer accidents. Tourigny (66) reports that those who felt that occupational deafness was within their own control were more likely to wear ear defenders. Genuine feelings of control and responsibility are likely to be a necessary precursor to successful action.

But there is ample proof that people can have illusions of great control where none or less exists. Svenson (67) quotes a number of examples from the field of driving. For example between 75 and 90% of drivers believe themselves to be better than average when it comes to driving safely; logically no more than 50% can be better than average. A study of those trained in cardiopulmonary resuscitation (68) found that 88% felt confident after an interval of several months to perform it, while only 1% actually performed adequately. Burton et al. (47) quote another extreme example. Inhabitants of Chicago were asked about what they thought would happen if an atom bomb fell on the city. The mean estimate of the numbers who would die was given as 97%, yet 90% of those questioned thought they would personally be alive after the blast, a remarkable triumph of wishful thinking over personal belief.

Bus drivers in a study by Cohen et al. (69) overestimated their ability to drive through narrow gaps (although they underestimated their skill at driving through wide ones (see also 70,71). There seems to be a relationship here with skill and experience. The more people have had the personal opportunity to experience hazards the more control they feel over them and the less they consider them to be a serious risk (72). This is particularly remarkable in the studies of the survivors of severe injury or of serious disasters - who tend to rate them as less serious than do those who have never experienced such an event (38,73,74). The feeling in these cases may come from the sense of relief that people have survived an experience that they did not expect to, and hence that their capacity for resistance and resilience is greater than they thought.

Feelings of increased control coming from experience are clearly partly justified in many cases. The danger comes when they become too generalised, and when specific knowledge, for example of a theoretical nature, about a process is taken to mean control over the whole activity involving that process. This can be a serious source of overconfidence in skilled personnel such as research chemists or toolroom personnel, most of whose accidents in fact come from the everyday hazards of the machinery or the laboratory which have little to do with their speciality. Some of Svenson's examples (67) also reveal this process at work. He found that drivers who drove more at night were inclined to rate night driving as less risky than day driving; yet it is objectively far more risky than day driving. Orcutt & Biggs (75) found a comparable effect among marijuana users; the more they used the drug the less they considered it a hazard. The problem comes in recognising the overconfidence. Maybe night driving was safer for Svenson's subjects because they took greater care and because most night driving accidents happen to drunken drivers. We are here up against the problem of when it is permissible to use aggregate risk figures to assess the objectivity of an individual's estimate of personal risk.

Glass et al. (76) illustrate a related effect in a series of experiments in which they measured the rated seriousness of noise for people who were either in direct control of the noise (could turn it off if they wished) or who were not. The former considered the noise far less of a problem; a result found also when mild electric shocks were used as the hazard (77). Despite being able to turn the noise or shock off, the subjects in the experiment did not in fact do so. The feeling of control in this case did not lead to extra preventive action. This sort of overconfidence seems particularly likely to occur with chronic hazards or ones which only rarely lead to harm, since there is no feedback to teach people the inaccuracy of their beliefs and they can maintain the belief that additional action can be taken later (78).

A much more clear cut situation exists when it is possible to say objectively that a situation is governed by chance (such as roulette or dice throwing) and yet people persist in believing that they can influence the outcome (79,80). The literature on gambling shows that erroneous beliefs about the susceptibility of chance events to human intervention are rife in that field (81,82). Cohen suggests that this may arise from a confusion in the mind of gamblers between predictability and controllability. Just because it is possible to predict accurately that, in the long term, a coin will fall heads and tails an equal number of times, it does not mean that there is a controlling power which will 'correct' a long run of heads and make it more than 50% likely that the next few tosses will come down tails. Yet studies of gambling show that gamblers will frequently bet on this fallacy. They will also indulge in small 'magic rituals' to influence that power, or will talk to the dice or cards to try to influence them directly (83). People will also bet more money on the outcome of dice if they bet before the dice are thrown than if the bet is placed after the throw takes place but before it is revealed (79).

The prevalence of these sorts of beliefs has been interpreted as evidence that there is a very strong need present in people to believe that they are in control of situations. If they cannot exert that control in any other way they will attempt to do so by beliefs in magic and rituals to propitiate the fates or gods who are thought to be behind the capricious events which overtake them. Several authors have reported such attitudes to large disasters among miners (84,85,86,87) and also among inhabitants of some developing countries (88).

Such beliefs about divine intervention in accidents often go hand in hand with the belief that those accidents which do happen are a punishment for failure to make the appropriate propitiation, or to live the sort of life which is pleasing to those powers. Suchman (89) found that 58% of sugar workers in Puerto Rico had such beliefs. This does not prevent behaviour directed at prevention but may direct it into non-scientific pathways.

There is certainly evidence that more people prefer to take part in an activity that has at least the impression of being skilled than one which is a chance event. Activities which give the impression of being controllable are those where choices have to be made (such as betting on roulette) and where there is an element of competition (such as bingo). When confronted with the choice people will even prefer moderate probability of success on a skilled task to a higher one on a chance gamble, believing that they can always influence the outcome on the skilled task by trying harder (67). The literature on gambling also shows that people take much more extreme chances on gambles than on skilled tasks; either being very cautious or very extravagant according to their personality (90). The situation is complicated by the circular nature of some of the beliefs; Cohen (91) cites examples of people who seem to use an attribution of chance or luck as a salve for a failure which is really due to their own incompetence. Fitzpatrick (51) found that the escape of an inexperienced miner from danger was attributed to luck, of an experienced one from the same danger to skill.

Trust in others. The above paragraphs have already suggested that personal control is not the only aspect of controllability. Trust may be placed in others to keep the situation safe. Again it is a question of whether the assessment is accurate and whether the trust is justifiably placed. Hale & Pérusse (88) quote an example of chromium workers who showed little concern about a dangerous situation because of a misplaced trust that medical monitoring was keeping them safe from it. The work of Vlek & Stallen (18) can be interpreted to suggest that one of the clusters of beliefs characterising those who oppose large nuclear, transport and chemical plant developments is personal insecurity and lack of trust in those controlling the technology. Fischhoff et al. (3) also refer to this credibility gap between the general public and those responsible for such technologies. The situation is made worse by the spectacle of experts disagreeing violently with each other about the safety issues of the developments in question. This leads to a reaction among the public of the form: 'if the experts cannot agree, who can I trust?' This indicates a lack of appreciation among the public of the adversary process by which scientific theories are tested, a distrust echoed by politicians who plead loudly to be rid of 'two-handed' scientists (on the one hand this, on the other hand that) who will come to no clear decision.

Control, susceptibility and efficacy. The field of health and health education has produced a number of concepts which are relevant to controllability. Studies of attitudes to a number of serious diseases have come up with the idea of 'personal susceptibility' as a very important factor in determining how people respond to a given disease in others (92). If they feel no 'personal susceptibility' they are inclined to consider the disease less serious and to have less sympathy with its sufferers. The same idea appears in people's attitudes to threats to their own health. It has been embodied in an influential theory in the field of health promotion - the health belief model (93). This theory puts forward the idea of a series of psychological action thresholds which people must get over before they will embark wholeheartedly on an action designed to improve or to conserve their health. One of the main thresholds is to admit that they personally are susceptible to the health threat, for example, from smoking, alcohol, drugs, or heart disease. This amounts to a willingness to label themselves as potentially at risk, in other words as having potentially lost control of their own health. The other side of this coin in the health promotion process is the need to believe in the efficacy of the preventive action being proposed (94). This means believing that the proposed action would restore that lost control; that giving up smoking would reduce the risk of cancer and heart disease, that wearing the protective earmuffs would reduce the hearing loss and so on. The opportunity to prove for oneself the effectiveness of protective devices is therefore important in persuading people to wear them (95). We shall return to this idea in Chapters 7 and 10 when we talk about the decision process around the adoption of prevention measures.

Conclusion. The concept of control and controllability is a complex one, which is still far from understood in its application to behaviour in the face of danger. We have introduced some of its aspects here in order to demonstrate its relevance to the labelling of a situation as dangerous. The picture which emerges is of a delicate balance to be struck. If a situation is regarded as under control there is by definition no further action needed. Hence any attempt to get people to change their behaviour and to adopt new procedures or precautions must disturb that feeling of overall control. Working against that is a strong underlying need that people have to feel in control of what happens to them, and to operate within a margin of safety or control (96,97). Mild challenges to that feeling of control, which test it but do not seriously threaten it, are even pleasurable, but serious threats are highly unpleasant. If they are repeated over a long period and in important areas of life they can lead to serious breakdown, which goes under the name of 'learned helplessness' (98) - a disabling condition in which the individual gives up all attempts to cope with life and its problems. Above all, the disturbance of the feeling of overall control must not challenge the feeling that the restoration of the situation still lies within the possibilities of personal control; the individual must be offered the lifeline of an effective way of winning back overall control. This is true also at the level of trust in organisations to control danger. Green & Brown (19) showed that the extent to which people demanded increases in the level of societal safety depended upon their assessment of how controllable the technology was; the more controllable the higher the demands. But if controllability is seen as too low the reaction may be an outright rejection of the technology.

The concept of control is so central to the theme of this book that it will return in several other guises in the chapters on attribution of responsibility, on preventive action and on learning about danger (Chapters 6, 7 and 8).

5.3.3 Foreseeability

Foreseeability is a word familiar from the case law of the English legal system relating to health and safety. It has been defined by judges with reference to what the 'reasonable man' would expect to happen given access to the current state of knowledge at the time of making a decision (49,99). It is used to draw a dividing line between situations in which people should have taken action to prevent an accident, and those for which it is not reasonable to hold them liable.

A concept central to the technique of Probabilistic Risk Assessment used in high hazard technologies is the 'credible accident'. Only those events which are considered by experts to have a realistic chance of occurring are included in the quantitative analyses (100). As we have seen in Chapter 4 a similar cut-off seems to be applied by people in searching for hazards in more everyday circumstances. Pérusse's subjects (31) would sometimes reject a hypothesised sequence of events with statements such as: 'that's too far-fetched'. This is an example of 'bounded rational choice' (47,101), where certain simplifying assumptions are made about a situation before any detailed assessment is carried out.

Other hypotheses in Pérusse's study seemed to be rejected for reasons which looked far more like an unwillingness to believe that someone could possibly act in a particular (usually stigmatised) way; 'nobody would be that crazy, surely'. This is a slightly different meaning of the word credible, which emphasises a moralistic notion that people are not irredeemably careless. It amounts to an unwillingness to believe in the formulation of Murphy's Law which states that 'anything which can be done wrong will be, and usually at the most awkward moment'.

Fischhoff & Slovic (34,46), in their studies of attitudes towards a wide range of hazards, found that the most important factor was one which they called 'technological risk'. It loaded heavily in their factor analysis on constructs such as 'known to science', 'known to the exposed', 'newness' (as well as 'controllability' and 'voluntariness'). There would appear to be a strong element here of foreseeability. There is also an element of how commonplace as opposed to unknown the risk was. Pérusse (31) also found a factor relating to obviousness of hazard.

From Pérusse's study and also from the work of Burton (39,47) come dimensions which they called 'natural v man-made', 'stable v unstable', 'relevance of planning' and 'static v moving'. The studies from which these came included in their list of hazards a number of natural disasters such as floods and hurricanes. Viewed in the context of the stimulus material the constructs seem to refer to the predictability of the hazards, the complexity of the factors which led up to them and the certainty with which they could be planned for.

A common feature of all of these reported dimensions appears to be the degree to which respondents felt that they or anyone else fully understood the potential effects that the hazard could have in the future. They would appear to be making a judgement about the degree to which the map of future states of the system contains significant areas of 'Unknown Territory' which might need to be labelled, in the manner of old charts; 'Here be dragons'. The issue of trust and confidence may also enter at this point, since lack of certainty might not be a problem if respondents felt that some trusted person in control of the area was guaranteeing to guide them through the uncertainty. The comments made in the section on 'Control' could therefore apply here also.

What underlies much of what has been argued in this section is the need that people have for a large degree of certainty in their lives. Tversky & Kahneman (102,103), in their studies of human decision-making, point to the fact that certainty has a value of its own; a fifty percent chance of a given loss is much less than half as bad as a certain loss. People are motivated to avoid uncertainty in many circumstances. They can sometimes do so by denying that a small possibility exists at all. Kates (73) found this in his study of flood plain dwellers which he carried out just after a large flood. Many of them believed that there was absolutely no chance of a similar event happening again. People also seem to use a different style of reasoning in cases where they believe there is significant uncertainty; they use the so-called 'minimax' strategy. This means that they try to minimise their chances of incurring a large loss rather than trying to maximise their gains. This is a strategy which plays safe by rejecting options which, although they might have obvious attractive advantages, also have very large disadvantages which may be very unlikely, but about whose probability people are uncertain. Nuclear power fits this description well (104).

The need for certainty also leads people to try to simplify the choices in front of them, to adopt the 'bounded rationality' mentioned above. This reflects a belief that the simultaneous or consecutive occurrence of a whole series of unusual events presents a picture of the world which is too complex and serendipitous to be true; that there really is some guiding principle which ensures a predictable and just world (105). It also limits the amount of time and effort people must expend in playing the 'what if' game described in Chapter 4.

Daniel Defoe captured the motivation well in his description of the discovery by Crusoe of the footprint in the sand on what he had thought to be an uninhabited island: 'How infinitely good that Providence which has settled in its government of mankind such narrow bounds to his sight and knowledge of things; and though he walks in the midst of so many thousand dangers, the sight of which if discovered to him would distract his mind and sink his spirits, he is kept serene and calm, by having the events of things hid from his eyes and knowing nothing of the dangers which surround him' (106, Chapter 14).

Individuals differ in their tolerance of uncertainty and ambiguity, and the work of Hudson (107) shows that this is associated with people's choice of discipline and career. The convergent thinkers (who are more systematic, but less creative in thinking outside system rules - see Chapter 4 - also tend to be less tolerant of uncertainty. They tend to end up more in the mathematical and engineering disciplines, and it is tempting to suggest that this combination of factors may account, at least in part for the view frequently voiced by engineers working in risk analysis that the whole of human behaviour is so complex and apparently unpredictable that the only practical solution is to design it out of the calculations altogether, or to include it through an arbitrary simplification.

As with the factor controllability, we are faced with an apparent paradox with the factor foreseeability. If an event is not foreseeable or credible it is treated as though it is not there. Yet, if it is uncertain it can in certain circumstances attract what might seem an unreasonable cloak of dread. The solution to the paradox may lie in the interaction of 'dread' with 'controllability' and 'severity' (which we discuss below). If uncertainty is present in combination with severe consequences and a feeling of powerlessness in the face of the threat, the reaction may be extreme. If both of the other two elements are not present the problem may be dismissed. Such a hypothesis suggests that evidence that a new hazardous technology is not as much under control as previously thought will have a profound effect on people's beliefs, shifting them rapidly from indifference to strong opposition. This is somewhat the effect which the Three Mile Island incident (and perhaps the contemporaneous film 'The China Syndrome') had on nuclear power, the showing of the film 'Alice, a fight for life' in the UK (108) had on asbestos, and would be the result of any major publicised mishap in the field of genetic engineering (109).

5.3.4 Vividness, dreadfulness and severity

Severity of the consequences of an incident emerges from both Fischhoff's and Pérusse's studies (31,34) as the second most important factor. In other studies it is also to be found (18,19,92). Green & Brown developed a ratio scale on which to measure the dreadfulness of different injuries. They report that their respondents found it meaningful to generate such assessments and could do it consistently (38). The results showed that there were some injuries (quadriplegia and brain damage) which were consistently rated as worse than death (see Figure 5.4).

	GEOMETRIC MAN		GEOMETRIC STANDARD DEVIATION
Being unhurt by the accident	10		1
Bruises	16		2
Sprained ankle	21		17
Concussion	40		35
Simple fracture of an arm	44		21
Broken ribs	79		23
Compound fracture of an arm	80		28
Internal injuries	197		377
Fractured skull	225		279
Carbon monoxide poisoning	286		501
Multiple facial lacerations	310		551
Loss of one eye	349		438
Loss of right arm	559		595
Severe burning over 1/3 of the body	683		1094
Loss of one leg	735		717
Radiation sickness	780		1064
Paralysis from the waist down	1643		1086
Loss of sight of both eyes	1917	*	920
Death	5676	*	5070
Paralysis from the neck down	6213	*	1679
Brain damage	7243	*	2340

* Injuries which at least one respondent rated as infinity. Technically, therefore, both means and standard deviations for these hazards are infinite.

Figure 5.4. Perceptions of injury severities (source 19, Green & Brown 1978)

Similar scales have been developed for diseases (110). The ratings on these scales do not always correspond with those made by 'experts' (such as doctors) who may be more influenced by the costs of, and prognosis for treatment. The potential victims tend to place a less negative value than the doctors on outcomes with diffuse symptoms, such as sleeplessness and general pain, and a more negative value on specific symptoms such as loss of an eye or kidney failure. The potential victims also give much greater negative value than the 'experts' to socially unacceptable diseases such as venereal or mental disease.

Dunn (111) found that assessments given by chainsaw operators of the likelihood of different types of injury was a poor match with reality in certain respects; for example leg injuries were overestimated and hand and back injuries underestimated. He interpreted this as reflecting a bias caused by different seriousness or saliency of the different injuries. Laitinen (71) found that the accidents and near accidents which people remembered were the dramatic ones, such as falls, rather than handling injuries and dropped objects. Lichtenstein et al. (112) found that people consistently underestimated the probability of certain diseases and accidents and overestimated others. They interpreted their results in the light of the research of Tversky & Kahneman (102) who describe the bias of availability, which tends to make people believe that the events will be more likely to occur again if they have happened recently or if they are in some other way memorable (19). Combs & Slovic (113) investigated the issue directly by showing that subjective assessments of frequency of a range of hazards correlated better with the amount and intensity of newspaper reporting than with objective frequencies. They speculate that discussion in the media even about the unlikelihood of given accident scenarios may trigger off the availability bias and perversely make people believe the accidents to be more likely than they did before.

An important element in memorability is 'kill size', the number of people who either actually do, or potentially could get killed in an incident. The latter is sometimes also called 'catastrophic potential' and can differ very considerably from judgements of the average number of people who would be killed in such incidents. For chemical and nuclear accidents potential kill size was judged 1000 and 5000 respectively, while the average numbers of fatalities per incident were judged by people to be 5 and 2 respectively. It is the catastrophic potential which predicts the dread in which people hold these technologies compared with other hazards (114). Green & Brown (115) also found that multiple fatalities were much less likely than single fatalities to be attributed to the fault of the victim. Therefore concerns about equity or about innocent victims being struck down through no fault of their own may inflate the feelings of concern about multiple fatalities.

As a small postscript, the greater importance attached by people to a 'named' life rather than an anonymous one in assessing hazards and may also be explicable in terms of availability (15). This phenomenon includes the huge response to television appeals for particular disease victims compared with the success of general appeals in relation to the same disease, and the great attention paid to rescue of identified victims after disasters, compared with prevention of future disasters to hypothetical - and so unknown - victims. It also explains the value of using named, even if otherwise unknown, people in sales or safety propaganda efforts.

The dimension of judged seriousness crops up in the study by Eyssen et al. (65) of the correlates of good and bad accident rate departments in a telephone company. They found that managers who regarded the accidents in their department as a serious problem and a high risk were more likely to preside over safe departments than those who considered the problem a small one. This is some indication that problems which are salient for managers get solved. On the other side of the coin there is evidence (116,117) that individuals who have had more accidents in the past underestimate the seriousness of the injuries (or offences) that result from them (or in them).

5.4 HAZARD ASSESSMENT FACTORS AND TYPES OF HARM

Chapter 1 considered the definition of danger and raised the question of the range of types of harm which should be included in this book. We cited different disciplines and groups who advocate grouping different clusters of 'hazards' for different purposes. For example, Loss Control (118) starts from an organisational viewpoint and clusters all loss resulting from non-speculative (and insurable) causes, thus grouping property damage and theft with physical injury. Psychologists (119) often group situations using the causal factor of human error, paying no attention to the outcome of error. One influential tradition in safety (120) places emphasis on the 'near-miss' as a member of the same family as the accident, having the same causes and lacking only the physical damage. More recently there has been debate about the grouping of hazards to safety with those to health (121,122) in defining the jobs of experts in the field.

The viewpoint of this book is largely that of the mythical 'average person' and the way that he or she groups hazards and makes sense out of them. This issue becomes important when people are asked to make comparisons between hazards. Tables of the comparative risk of different hazards are used widely in papers in the debate on 'acceptable risk' (12,15,123,124,125, 126). Many of the tables contain hazards drawn from a wide range of activities - for example, smoking, coal mining, being struck by lightning, living next to an airport, working in the chemical industry, and rock climbing. The main point made in these discussions is that different activities involve very different risks of death per year of exposure. This is indisputable. What is far more contentious is the inference that this is illogical and that risks which fall at the bottom of the league table should automatically be considered as more acceptable than those at the top. This rests on the assumption that people regard the different hazards as legitimately comparable, (or as Green & Brown (127) put it far more colourfully in the title of one of their papers 'Certainly one football team = three cabinet ministers = one princess of the blood royal?'). If hazards which lead to cancer are not regarded as being comparable with hazards which lead to explosions, the fact that the level of risk of death per year of exposure to one differs from that to the other tells us nothing significant about acceptability of a given level of risk of death in the abstract. Indeed it is far more logical to argue the other way round. If people will pay more for a given quantity of apples than pears, we have no difficulty in concluding that they prefer apples; nor would we regard them as irrational for doing so (even if we disagree with them). Similarly, if people say that they would be happy with different levels of risk of death from different hazards, we should conclude that the circumstances in which people die and the way of dying matter as well as the chance of dying; that it is preferable to die from cancer brought on by smoking than by cancer from the increased radiation from nuclear power stations. This implies that hazards are clustered into groups which are distinguished from each other when people make judgements and that comparisons are more valid within groups than across them.

A number of studies throw light on how in practice people group various hazards. Steiner (128) showed marked differences between individuals' responses to 'risks' in the differing spheres of physical injury, social embarrassment, and financial loss. Many others have also criticised the attempt to draw analogies between behaviour towards physical damage and towards financial or social loss (60,129,130,131). This is one reason why such non-physical damage has not been included in this book.

Green & Brown (132) showed consistent differences in the factors which people use to consider acute, immediate hazards such as explosions compared with chronic (delayed-in-effect) hazards such as carcinogens. They argue therefore that straight comparisons between the two types of hazard are invalid when assessing priorities for action. They also found (19,132) that people use different criteria to assess situations with a potential only for minor injury compared with those with a potential for 'nearly as bad as death, death, and supralethal injuries' (quadriplegia and brain damage).

A look at the four major factors which we have derived from the research suggests why the hazards cluster as they do. 'Delayed-in-effect' hazards tend to be seen as unfamiliar and generally as less controllable than acute hazards. There is less certainty about both their presence and their effect. Hazards which affect future generations (such as teratogenic hazards and the storage of long-life radioactive waste) engage feelings of inequity, since the future generations have had neither say in, nor benefit from the hazard which is bequeathed to them (25,133). This represents a fundamental breach of the 'democratic imperative' which deems that people should have a say in events which affect their life and death. More concern is always expressed for those who are considered particularly unable to exercise control on their own behalf. This view is also reflected in the way in which the law on health and safety has developed. In the UK, intervention of the state in working conditions was justified in 1833 on the basis of the belief that those protected (children and later, in

1844, women) could not choose for themselves (134,135), while it is only in 1974 that self employed persons in the UK were required by law to protect themselves.

In marked contrast to chemical and nuclear hazards are those from cars, bicycles and home appliances, which are regarded as controllable, familiar technologies, which produce harm only in small doses.

If people do indeed tend to divide up their mental map of hazards into distinct regions which they only reluctantly compare with each other they will have difficulty when asked to think about activities which involve hazards falling into more than one of the groups. This is why people have such difficulty in contemplating the total picture of the potential harm from, for example one given energy source compared with another. The use of coal energy involves the acute hazard of mining accidents ranging from single injuries to explosions and collapses which kill many, the chronic health hazard of pneumoconiosis, the chronic injury hazards involved with heavy physical work both in the mines and in transport of coal, a share of the risk of road and rail transport fatalities from crashes, and the chronic health and ecological (acid rain) hazards from exhaust gases from coal-fired stations and domestic fires. Hazards from the use of nuclear energy are more concentrated in the mining, refining, use and disposal of the radioactive material, and are perhaps of less variety. This may mean, as Fischhoff et al. (23) argue, that the former energy source is seen in a better light than the latter; its harm comes in more small chunks (as well as being more conventional and well known).

5.5 DIFFERENCES IN GLOBAL ATTITUDES TO HAZARDOUS ACTIVITIES

The previous sections have considered evidence related to factors which influence widely different groups of people in their assessment of danger. Within many of the studies there is also evidence of significant individual differences in the relative importance of the various factors, and the way in which particular hazards are classified.

Pérusse (31) found that the order of importance of his factors was reversed in some of his subjects. For a few 'dreadfulness' (severity and vividness of the consequences of a hazard) seemed to swamp 'controllability', which in the majority of subjects was the most important. The minority might be labelled as having an emotional as opposed to a rational response to hazards. Individuals whose whole mental map of hazards is dominated by potential consequences with little or no regard to the possibility of steering the system away from them (and thus of reducing the probability to vanishingly small figures) might have no rational course open to them but to try to suppress the hazards totally by banning technologies or by shunning them personally. Vlek & Stallen (18) showed that people who were generally less at ease with technology were more inclined to stress the severity dimension in their hazard assessments. Jenkins & Zyzanski (92) found some people in their study of serious diseases (polio, cancer and mental illness) reacting in the same way, and not considering the rational preventive or curative possibilities open. However, such extreme mental models were relatively uncommon in the groups studied, and most people showed a clear tendency to consider the issue of controllability as more important than that of severity.

Other individual differences in assessing specific hazards will depend upon differences in experience, for example of how controllable the activity is or how severe the consequences of deviations are. Much more research will be needed to see how far such individual differences can account for, or be useful in predicting, differences in behaviour towards those dangers. However, it is already clear that assessments cluster within an individual in ways which suggest global cognitive styles (18,28, 136,137). Different attitude clusters or ratings on dimensions have been found to characterise opponents and supporters of the development of 'hazardous technologies' such as nuclear and chemical plant. The differences are not so much in the factors that people use to make assessments, or in disagreements over what the consequences of using the technology will be; they are in the weight given to different factors in arriving at the decision about a pro- or anti-stance. Opponents attach more importance to the risks, to conservation, to the damaging effect of uncertainty, and lack of control; supporters more to the positive value of the technological way of life, to the benefits of the specific technology and to economics. In some cases there is a complete reversal of beliefs between two groups; some people in Vlek & Stallen's study thought that large scale benefits outweighed large potential harm to produce a more acceptable technology, others felt that this made matters worse, and that it was best to settle for small risks associated with small benefits. There is some evidence that the attitude clusters link in with more fundamental personality factors and beliefs about conservatism, the role of rules in society and the place of authority (138). If this is so it raises questions about the direction of cause and effect in this area; to what extent are ratings on the individual hazard factors derived from, rather than combined to form an overall rating of the dangerousness of the situation. For example, do people first arrive at an assessment that a situation is dangerous and then infer that it must be out of control, or do they first judge that it is out of their control and then conclude that it is dangerous? Are they in favour of new and challenging high technology and therefore think it is safe, or do they first judge that it is safe and therefore conclude that they are in favour of it? The direction of cause and effect is vital when considering attempts to influence opinion; what is needed is longitudinal research to unravel the process of attitude formation in this area.

Further discussion of the sociological factors which relate to these differences, and the consequences which they have for the organisation of political and social decision-making about hazards is beyond the scope of this book. It is a burgeoning area of research and debate which can be followed up in many publications, (3,16,23,43,139,140).

5.6 CONCLUSION

5.6.1 The classification of hazards

We have traced four major factors which people seem to use to classify hazards, and which allow us to draw a mental map of a space in which people plot the similarities and differences between hazards. We could reduce those four to two rather different clusters. The first is made up of the choice to enter the danger, the controllability of it once entered, and the foreseeability of the consequences of carrying on the hazardous activity. Those could all be said to have an element in common, the scope for human intervention (31) to keep the system on the straight and narrow. Can I influence it? do I understand how? do I trust the people in control? who is getting the benefit out of the situation? am I just a cog in the system? The second cluster revolves around the consequences of things going wrong (dangerousness, 31): how bad would it be? who suffers? how reversible are the consequences? how likely are they? Figure 5.5 shows the way that the constructs from Pérusse's research cluster broadly into these two main concepts and their sub-factors. The clustering is shown by the tree branches in Figure 5.5.

The first of these two factors corresponds in many ways to the questions discussed in Chapter 4. Events are perceived and understood in terms of a number of causal webs or maps which allow a person to plot where they are and what could happen next. Those maps are looked at and tested against a number of criteria, notably to what extent the paths that the system is being pushed down are determined by forces which are understood and controlled by the person making the judgment. It is likely that only a proportion of the possible future states of the system are considered; when really pushed to seek out danger people can come up with a great many more conceivable futures. If the maps are known to be incomplete this creates concern, which turns into a much stronger awareness of and worry about danger if there is known to be a source of major harm present in the system. Equally if the predictions made indicate that the system is not being or may not be controlled and steered away from danger because of forces outside the individual's control, the feeling of personal safety is threatened. Last but not least, where the individuals consider that the system is controllable by themselves, it is a question of their confidence in their own ability to control it. The system may be looked at from two points of view, from inside as an element of it, or from the outside as a potential entrant into it. These two views may give very different perspectives. For example, the subjects in Green & Brown's study (19) thought that they had considerable choice over whether to expose themselves to the risk of plane or train crashes since they could choose fairly freely whether or not to use that form of transport; but having made the choice, they felt that they had little control over whether a crash occurred. In contrast, with travel by car they felt that they had less choice about whether to use a car, but more control over the occurrence of an accident.

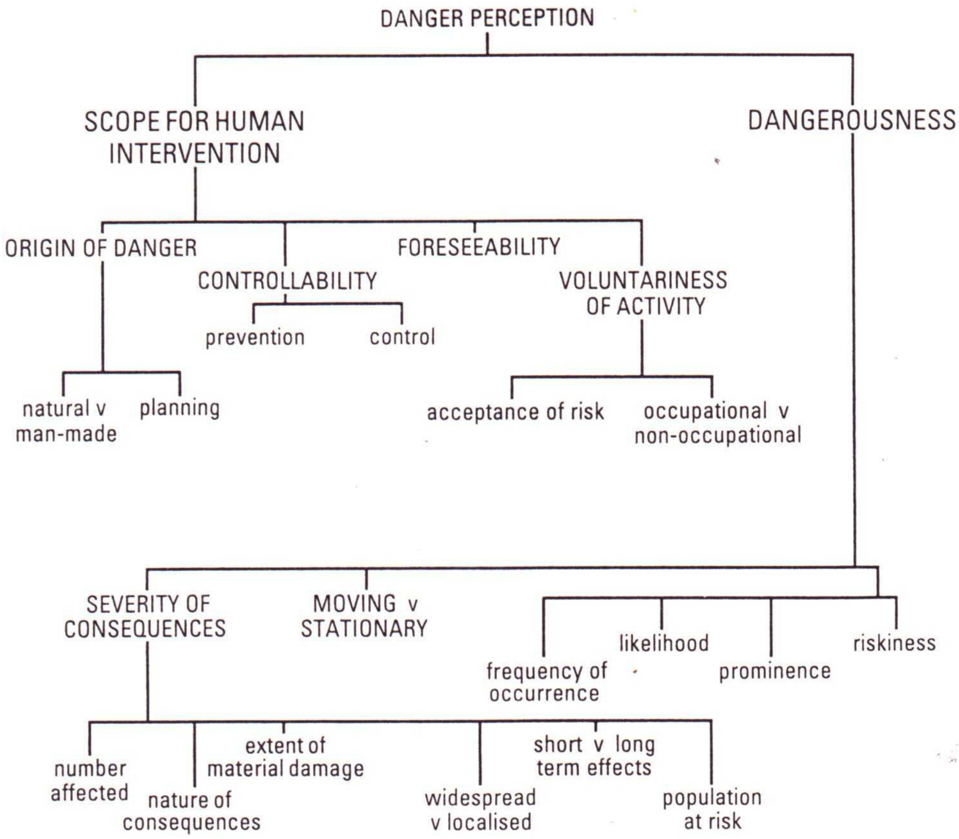

Figure 5.5. Summary of concepts and sub-factors in perceiving hazards (source 31, Pérusse 1980)

It seems likely that questions related to the second cluster (severity) only get asked if the individual has given an unsatisfactory answer to the first group; in other words has decided that things are, or could go out of control, and so there is something to worry about. By that time the question of risk in the sense of probability has been partially answered: things are not wholely under control, so the harm could happen and what matters now is how serious it could be.

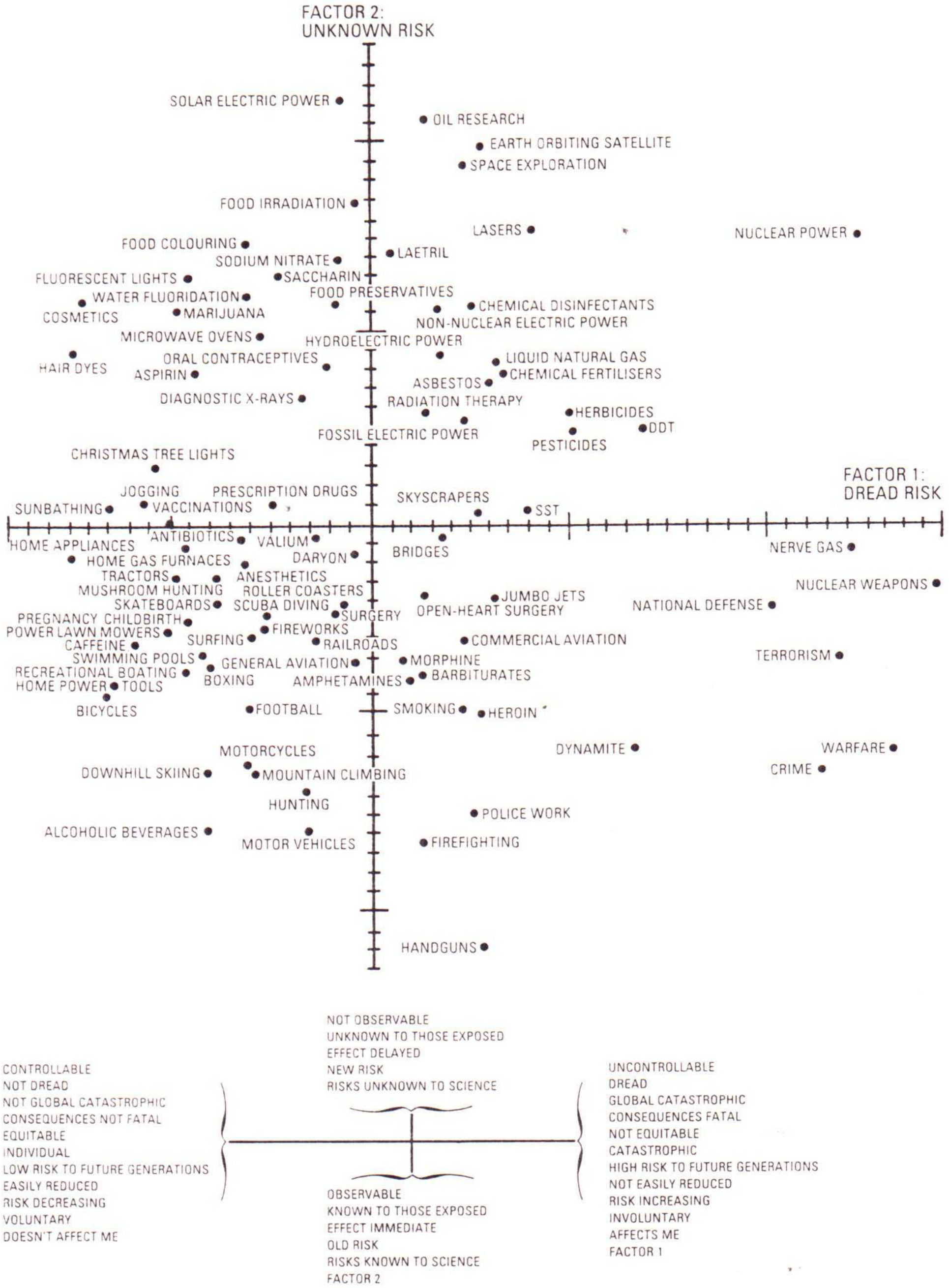

Figure 5.6. Location of hazards on two dimensions (source 141, Slovic et al. 1982)

Other studies which have attempted to put some order into the dimensions through factor or cluster analyses (18,34,46) all show a similar overall structure, with two main dimensions. Usually one has the flavour of controllability/intervention and the other of seriousness, but sometimes elements are mixed between the two as in the case of Figure 5.6 from Slovic et al. (141). This shows two dimensions, 'unknown risk' and 'dread risk', and the constructs which loaded on them in the factor analysis. The hazards which were used in the study are plotted on the resulting two-dimensional mental map, as they emerged from the analysis. For example, nuclear power loads very highly on both dimensions, while nuclear weapons are considered more well known, though very high on dread, and DNA research is unknown but not particularly dreadful.

Vlek & Stallen (18) carried out parallel research looking at the way in which people construed both the hazards and the benefits arising from a number of hazardous technologies. A two-factor structure of benefits emerged from the analysis; giving dimensions which they labelled 'personal necessity for the benefits' and 'scale of production or distribution of the benefits'. They then considered the judgements that their subjects made of their overall attitude towards the acceptability of the technologies. They found that this correlated more with the picture gained from the analysis of benefits, with attitudes to risks playing a much smaller part. In other words gains weigh more strongly with people in their final assessment of the acceptability of technologies than do losses. This emphasis on the importance of considering benefits from actions and activities drives a final nail in the coffin of the search for absolute and generalisable acceptable risk levels in terms of probability of death alone.

If safety can be equated to an important extent with control of the system, health is rather more complex. It is also an asset which people believe themselves to have. Herzlich (6) distinguished two kinds of health in practical situations (in addition to a more abstract concept of health as simply absence of illness). The first was called a 'reserve of health', which amounts to physical (and mental) robustness and the potential for resistance to disease should it arise; the second was called 'equilibrium', which carries the connotation of control, wellbeing, freedom of movement, good relations and effective action. The interplay of these leads to the feeling of subjective health, which has a large element of expectation built into it. For example, people who are basically very fit (have a good reserve of health) feel more threatened and so less healthy during a given disease (loss of equilibrium) than those who are basically less fit; the elderly may have better perceived health than young fit firemen because they have lower expectations (8,9). Actions to improve health, such as going to the doctor or taking exercise are more related to perceived health than to any objective measure of symptoms. So, in relation to both health and safety, feelings of control and expectations about their loss play vital roles in the labelling of a situation as dangerous and as requiring action.

5.6.2 The place of probability

Throughout the discussion so far in this chapter there has been comparatively little use of the word probability (or relative risk) as a factor which people use to assess hazards. As Pérusse (31) noted in his conclusions: 'A great deal of attention has been devoted in the literature on hazards to the assessment of likelihood. However, there were indications that perceived likelihood may be only a minor aspect of hazard assessment'. His own study found a construct labelled 'likelihood' subsumed under 'dangerousness' as a concept. That can perhaps be interpreted as a rather specific sort of probability: given that some sort of harm is going to occur because the situation is out of control, what is the probability that the harm will be serious (that a broken neck will result, as opposed to a sore one). Slovic (141) also found this factor closely associated with dread. Green & Brown (19) found that this conditional probability of death or injury was present in their subjects' assessments, but was a rather minor factor. Subjects asked to consider accidents '...self-define an accident as a near or supra-lethal accident and do not include less serious injury or non-injury incurring accidents'.

What then has happened to 'probability of the accident occurring' as a factor in determining attitudes to it? This factor is used in every article concerned with risk assessment. Probability and consequences (in our case the severity of outcome) are the two factors incorporated by all economists in making decisions between courses of action on what they consider a rational and logical basis. Utility theory looks at each course of action, plots the costs and the benefits accruing from it, multiplies each by the probability of the cost or benefit arising and sums across them to arrive at a total value for that choice. Risk analysts proceed in the same way by calculating probabilities of events through a fault tree to arrive at the probability of the top event, which they can then multiply by the consequences of the top event (in deaths, or any other outcome). The whole edifice of logical analysis seems to be built on and to require the concept of probability. Yet none of the studies we have reviewed gives it any prominence, except to say that people are not good at assessing it.

This paradox is soluble if we accept that for the average (and perhaps we might be forgiven for saying the normal) person, probability is not a concept that comes naturally. (This is an idea which will be readily accepted by anyone who has tried to learn, or to teach others the fundamentals of statistics). It must be manufactured when asked for, and the building blocks the person uses are those which go to make up the two main factors which we have described and their sub-factors. To most people it is meaningful to think about whether a system is under control. If it is, then it is not likely that an accident will occur, unless something unexpected happens. If it is not under control, or they are not sure whether it is or not, then it is quite likely that things could go wrong. Such judgements are qualitative, and are usually accurate enough for most situations. Above all they focus people's attention onto the vital factor for prevention of harm, the regaining of control. Judgements of numerical probability as an end in themselves are a requirement of what can be regarded as a highly specialised need, the problem of regulating the activities of a small sector of the population who are in the process of designing and building plants which will have far reaching effects on many others. Most normal people have little need for such judgments and little practice in making them. Individuals are therefore normally rating a personal probability of things remaining under control; 'objective' measures of probability are the accumulation of historical experience relating to a group of people, factories or processes. It is not surprising therefore that individuals come to a different assessment. They know that they are different from the rest of a group, and they know that the future can be different from the past.

In sketching the range of factors that influence the labelling of a situation as dangerous we have so far concentrated on the factors which go into the equation. Along the way we have indicated some of the biases which influence the judgements. In the final part of this chapter we shall concentrate on these biases, and on the process by which they arise. This leads us into the dynamics of decision-making. Because the decisions which are important for health and safety deal for the most part with events that have a low probability, and because much of the research has started specifically from an investigation of judgements of probability, this will be our focus. We shall explore the process which we have suggested can occur when necessary, of deriving probability from other information. In particular we shall explore the situations in which people have a false sense that things are under control, but where systematic experience or logical analysis indicate that the probability of deviation is significant.

5.7 EXPECTATIONS AND BIASES: JUDGEMENT IN UNCERTAINTY

Research on the biases in decision-making owes much to the pioneering work of Tversky & Kahneman (102,142,143,144). This was taken up and applied to the field of safety and risk by Slovic, Fischhoff and their colleagues (29). The results of the studies have been applied to Rasmussen's three level model, which we make use of in this book (145,146). The theme of much of the research in this field is that people are not natural processors of probabilistic information, but have certain built-in biases in the way in which they collect and process information. These work in favour of clear and simple decision making most of the time in the sort of situations which people meet from day to day. However, they occasionally break down, and in certain situations which are characteristic of technological hazards they are very inadequate. Before considering the biases and sources of error we examine just how bad people are at assessments of probability.

5.7.1 Probability assessment: absolute and relative

Slovic and his colleagues (133) find what they call a good relationship between 'perceived riskiness' and the known (that is, based on past experience) fatality rate among 'expert risk assessors', but not among lay groups. In contrast, Green & Brown (147) conclude that 'perceived personal safety' (PPS) for their lay group is well predicted by perceived accident frequency rate and that in turn relates well to the known fatal accident frequency rate or FAFR (Log PPS = 2.18 + 0.17 log FAFR for risk of fires). This disagreement as to whether people (and which people) are good probability assessors is typical of the literature in the area. The differences are partly a matter of defining what is a 'good' prediction, and partly of specifying what assessment is being compared with what 'objective' measures.

Figure 5.7 shows the subjective assessments by one group of subjects (members of the League of Women Voters in Oregon) of frequency of deaths per year compared with the national US statistics available for those causes of death (112). As can be seen the subjective scale spans only three orders of magnitude, while the objective one spans six. Green & Brown (19) found a similar compression of the scale for their subjects (students of architecture in the UK). The subjective scale range was 1 to 500, the objective range 0.1 to 2500. It would seem therefore that the subjective and 'objective' scales are lawfully related and can be translated into each other (as the equation above shows), but the relationship is far from one to one. Such a compression of a subjective scale in relation to an objective one is typical of human functioning. It can be found, for example, in comparing subjective scales of loudness with scales of noise energy, subjective and objective scales of weight or of temperature.

Green & Brown (19) demonstrated that three different equations were necessary to convert assessments of personal safety, societal safety and threat to health into objective measures. These are:

personal safety = (f) probability of accident x conditional probability of death
societal safety = (f) frequency of lethal accidents x maximum potential kill size
threat to health = (f) rate of cancers/heart disease/genetic effects.

The fit between objective and subjective probabilities of death is in some ways remarkable given the sources of information people have. It is not at all obvious that the comparison statistics should be the national ones in each case, and not the local, or, for some hazards such as air crashes, even the world figures. Most people have only highly selective media sources and personal experience to go on in building up their picture, which will give some mixture of those three levels of information depending upon the breadth of their horizons and of their reading or viewing habits.

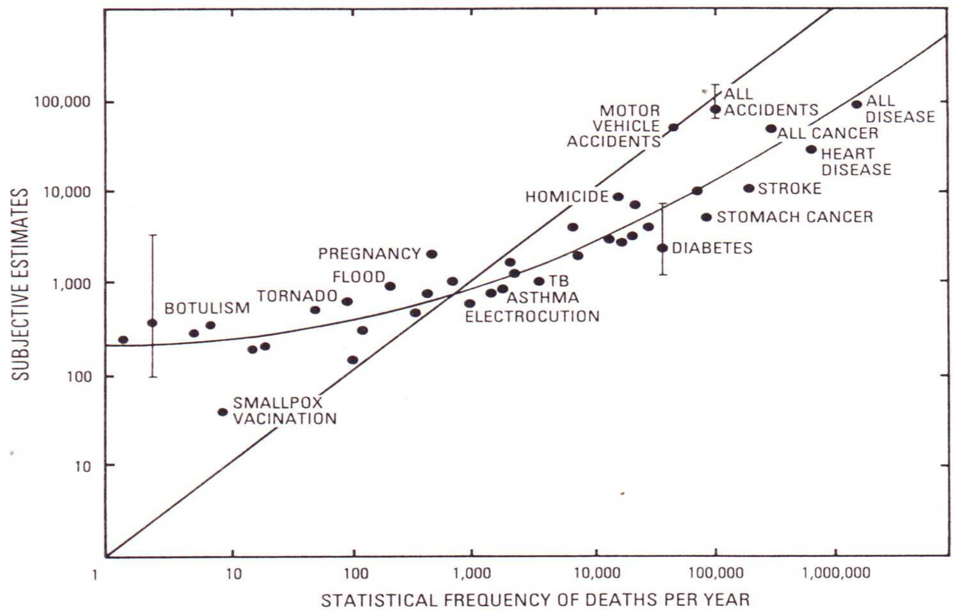

Figure 5.7. Subjective estimates compared with frequencies of deaths per year (source 112, Lichtenstein et al. 1978)

Slovic et al. (133) show that experts' subjective judgments of probability match the objective scale better than do those of lay groups when the question asked is to 'assess risks'. However, if laypeople are specifically asked to assess the chance of fatalities their assessments come to resemble the experts far more (29) although both groups still have the typically truncated range. Tversky & Kahneman (102,103) summarise the relationship of subjective to objective probabilities across the full range of values for both positive and negative outcomes (wins and losses). Small probabilities are overestimated and large ones are underestimated.

A review of the field of expert judgment (148) finds weather forecasters very good (highly motivated because promotion depends on it, and highly practiced at a well defined task at which they get feedback), medical specialists generally good apart from the tendency to overestimate the probabilities of serious complications (perhaps because of the strong wish to avoid them), and business risk assessors largely very poor (mainly because of the intrinsic variability, unpredictability and vague definition of what they are trying to predict). Expertise, motivation and the difficulty of the task combine to determine success.

Within the overall picture of a good relative ordering of hazards by probability, but a less good absolute one, there are some clear anomalies. For example, dramatic hazards are considered relatively more common than everyday ones (19,112). Green (149) reports some specific illogicalities in relative risk estimates; his subjects regarded civil aviation pilots as being at less risk per mile flown than passengers, which is impossible, given that they sit in the same plane. This means people must either be biased by the feeling that pilots are more skilled and in control of the aircraft than passengers, or that the assessment for passengers in some way incorporates the idea that they get killed in large groups, while there are seldom more than two pilots on one plane.

Kates (73) also reports large discrepancies among flood plain dwellers in estimating future flood probability despite personal experience and high media coverage. This seems to be strongly influenced by the need for feelings of security in the face of a very severe alternative (selling up and moving).

5.7.2 Biases and errors

Tversky & Kahneman (29,102,103) consider the following biases: - availability (considering recent and dramatic events as more probable)

- representativeness (considering small samples as representative of large populations)
- overconfidence (being surer of estimates than the data warrants)
- anchoring (not changing estimates enough with new information).

Although they were the first to study these biases systematically the list is certainly not a new one. Francis Bacon in his Novum Organum of 1620 (150) discussed the 'Idola tribus', giving the following list:

- assuming greater order, purpose and regularity for nature than exists
- generalising from small numbers
- using man as the measure of the universe
- supporting assumptions by quoting affirmative instances and omitting negative ones.

He concludes: 'take this as the rule, that whatever his ...(the common man's)...mind seizes and dwells upon with particular satisfaction is to be held in suspicion'.

We shall discuss these and other biases under three main headings:

1. Availability
2. Value of certainty
3. Overconfidence

1. Availability. The bias of availability refers to the greater role played in the process of assessment of probability by information that is regarded as important and salient. This means that people are more influenced by events which have happened recently or frequently or which are particularly vivid. A practical demonstration of this is the way that drivers on a motorway will slow down on seeing an accident as this triggers immediate thoughts of a possible accident to them. After a few kilometres the effect of the event gradually wears off as it is overlaid by other experiences.

Research on the 'severity' dimension, reviewed earlier in the chapter, demonstrates the importance of kill size as a factor which concentrates attention on a hazard and makes it more dramatic. This increases its 'availability' and so biases the assessment of probability (149).

We can see this bias in the context of the rules and expectations which we described in Chapter 3 as the guiding forces of behaviour. Sequences of action are built up from experience. They evolve to cope with the situations which people come across regularly, and it makes sense to organise behaviour on the basis of first checking to see if we have met a particular situation before and so know how to respond to it. When confronted with a situation we therefore first compare it with the most familiar rules and plans. Given the fact that this checking is sometimes rather summary, and only looks at the main features of the situation (and given the bias which is described below to concentrate more on confirmatory than negative evidence) it can lead to a mistaken decision that this is indeed a familiar situation, when in fact it is not. When asked to assess probabilities these familiar rules and situations surface first and get more attention than they deserve. The availability of the rules will be roughly equivalent to the number of times they have been used, but with a bias towards recent use, which will have put them in a state of activation which takes some time to decay.

The experience on which the rules are built comes not only from what individuals have themselves experienced, but also from what they hear from others. In modern, media-oriented society television, radio and newspapers have taken over part of the information provision function that was previously largely fulfilled by friends and acquaintances. As a result, subjective assessments of risk bear a closer relationship to the percentage of media coverage than to objective death statistics (113). Concerted media campaigns can therefore be expected to raise the availability of information about particular hazards. However, personal experience will still form a limiting factor in some cases, as Kates (73) found in a study of people living in flood plains. The upper bounds of the size of loss which people expected was set only a little above what they had personally experienced. Experience and personal recommendation also strongly influence choice of action (151). Another influence on availability will be personal interest (148). Things which individuals find salient and fascinating will bias their assessments.

In the decision making literature the lack of symmetry between assessments of past and future probabilities is also clearly demonstrated. Fischhoff (152) asked people to give estimates of the probability of the different outcomes of events such as elections which were about to happen. After the event he went back to the same people and asked them to remember what their predictions had been. He found characteristic distortions. They remembered giving higher probabilities to the outcome which actually occurred than they had in fact done. In other words outcomes always appear with hindsight to have been more probable then they actually appeared with foresight before the event, or in every day terms; 'I always knew it would turn out that way'. This is another availability bias.

2. Value of certainty: confirmation, closure, symmetry and meaning. When we discussed the dimension of controllability earlier in this chapter we commented upon the need people have for a feeling of control and of certainty. People find the process of thinking about hazards an uncomfortable one, and they want to round it off as fast as possible; therefore they seek closure, and once a decision has been made they resist attempts to go back and reopen the issue, even to consider more evidence (46). In order to achieve closure people will oversimplify situations by leaving out all but a few factors (146) or accept some action which gives at least the semblance of certainty, rather than tolerate the ambiguity. Insurance can give this 'pseudocertainty' despite the fact that it does nothing to reduce the risk of harm occurring (29,153). However, it is interesting that insurance is seen in general by people as an investment rather than as a reassurance. They are much more willing to insure against small losses of a relatively high probability (where the claim functions as a sort of dividend on the premium) than against large losses of a small probability. This directly violates rational economic theory. What seems to happen with the latter type of potential loss is that people gain their certainty by ignoring the risk altogether.

Even semantic changes in information can provide a significant increase in respect of certainty (29). It is more effective as an argument to get people to be vaccinated to tell them that a vaccine offers total protection against one strain of disease that accounts for half of a given sickness, than to tell them that the vaccine offers 50% protection against the sickness; the presence of the word 'total' in the message gives the illusion of certainty.

The research on gambling by Cohen (81,91) showed the importance of symmetry, pattern and meaning. The famous gambler's fallacy, that your luck will hold if you are winning and break if you are losing is built partly on this belief, and partly on a bias towards believing that the outcome you want will occur. People faced with a long run of heads tossed on a coin will bet strongly that the sequence will break, that the next toss will be a tail, when it never varies from a fifty-fifty chance (if the coin and the mode of tossing are fair). This comes about because people confuse long-run probability with short-run patterns, and believe that the latter is, or should be representative of the former. Another explanation of the fallacy lies in the comment in brackets above: people always have in the back of their minds that the real world has its share of crooked coins and crooked tossers, which mathematical and economic theory ignore.

The importance of pattern and symmetry has been shown by the Gestalt school of psychology (154) which found that people were always able to distinguish symmetrical figures from jumbled background, and would miss detecting small flaws in symmetry if they quickly glanced at shapes. This need for symmetry is repeated in non-visual patterns. People asked to assess the probability of finding particular birth orders of boys and girls in a family of a given size rate orders such as BGBGBG more likely than BGGBGB (where B = boy and G = girl), when, in fact both are statistically equally likely. Both configurations are regarded as more likely than BGBBBB because it is more representative of the expected long-run pattern (143). For children in particular symmetry is a strong bias (81,155).

Finally under this heading falls a major bias in the way that people go about checking their initial assessments. They are strongly inclined to formulate a hypothesis, draw conclusions as to what they should see if the hypothesis is true (If P is the case I would expect Q) and then look for evidence that Q is present (156). People do not formulate negative predictions (If P then X should not be there), nor are they so impressed by the absence of some expected positive signs provided others are there (157). Taken with the tendency (mentioned above) to seek closure and to get on with carrying out a plan of action this leads to the short-circuiting of the assessment stage of the decision process, and to attempts to implement a plan which is not appropriate to the whole problem (see also 158 for a specific application of this concept to a general methodology for the solution of health and safety problems).

This bias leads to the following logical anomaly. People can be fed specific pieces of information which lead them to a particular conclusion; all the individual pieces of information can then be systematically shown to the satisfaction of the subjects to be wrong, but they will still continue to hold to the conclusion. Ross (157) called this process 'hysteresis', drawing an analogy from the effect of electric current on the magnetic field of a piece of metal; the metal does not lose its magnetism so rapidly as the current is reduced as it gained it as the current was increased.

The problem here is not that people do not know how to make appropriate predictions. If asked whether X should be present or not given P, they can often answer correctly. However, it does not occur to them to make this prediction unprompted. Negative instances are not so 'available' as the positive ones. The same is true of factors which are not specifically named in the problem. People do not think broadly enough to import logically derivable but unstated facts into their reasoning. All this amounts to the conclusion that people are not natural users of the Popperian scientific method, which lays its main stress upon the formulation of hypotheses which one should specifically attempt to disprove.

3. Overconfidence. The final source of bias that we describe is that of overconfidence in the quality of the knowledge at one's disposal. A number of studies and reviews emphasise this point (29,148,159). If asked to estimate the probability of an event and then to estimate a range around that figure within which they are 98% certain that the probability will fall, people typically produce ranges which fail to include 20 to 25% of the actual values. This figure should be 2%. Experts are just as prone to this sort of error as lay people, and intelligence is no protection against overconfidence. The bias tends to operate most in judgements where people are high in confidence; in other words, the more confident people are of their judgment, the more over-confident they are likely to be. The bias may even work in the opposite direction at the opposite end of the scale (being underconfident about wild guesses, 160).

At one level humans function by simplifying differences between events by grouping things into categories which are then handled as homogeneous units. This process involves emphasising boundaries between certain things and ignoring those between others. This leads inevitably to the sort of result described above, where grey shadings around estimates are transformed into black and white.

People are also far too prepared to draw firm conclusions from small samples of behaviour or information. They treat them as being as reliable as large samples. Even providing information about the unreliability of figures does not have as much influence as it should on the confidence with which conclusions are drawn.

5.7.3 Effects of the biases

Framing

The result of all of these biases is that the result people arrive at in making an assessment is very dependent upon the way in which the question is posed, and the information which is made to appear salient or available. This was demonstrated graphically in an experiment in which comparable questions were asked about deaths from various causes (161). Four groups were given four differently formulated questions which all logically require the same or compatible answers:

1. For each 100,000 people afflicted how many died?
2. X people were afflicted, how many died?
3. For each person who died, how many were afflicted but survived?
4. Y people died, how many were afflicted but did not die?

The answers given differed dramatically. The comparisons between 1 and 2 and between 3 and 4 show the effect of anchoring the judgement with the actual numbers afflicted or surviving, while those between 1 and 3 and between 2 and 4 show the effect of framing the question in terms of survival rather than death. The results converted to an estimated death rate per 100,000 afflicted are given in Figure 5.8.

MALADY	DEATH RATE PER 100,000 AFFLICTED				
	Estimated lethality rate (1)	Estimated number who die (2)	Estimated survival rate (3)	Estimated number who survive (4)	Actual lethality rate
Influenza	393	6	26	511	1
Mumps	44	114	19	4	12
Asthma	155	12	14	599	33
Venereal disease	91	63	8	111	50
High blood pressure	535	89	17	538	76
Bronchitis	162	19	43	2111	85
Pregnancy	67	24	13	787	250
Diabetes	487	101	52	5666	800
Tuberculosis	852	1783	188	8520	1535
Automobile accidents	6195	3272	31	6813	2500
Strokes	11011	4648	181	24158	11165
Heart attacks	13011	3666	131	27477	16250
Cancer	10889	10475	160	21749	37500

Figure 5.8. Lethality judgements with different response modes
(source 161, Fischhoff & MacGregor 1983)

The contrast in the figures is striking, with the greatest overestimation caused by question 4 and the most underestimation by question 3. These two questions were judged by the subjects as being a more unnatural way of framing the question than in terms of deaths. In other words they had to do the most translation of the data as stored in their heads.

What seems to happen here is that the form of the question sets a frame or script (162,163) within which it is interpreted; in other words it activates a particular mental model. This model has a particular structure with gaps which need to be filled in from the information given in the problem. If there is no information there to use for a particular gap the frame provides its own default values which are used without further questioning as though they had come from the problem itself. Once this frame is set the problem is analysed within it. In particular, when it comes to estimates and calculations the default values in the frame act as anchors, and people reason in terms of differences from these anchor points. In doing so they tend to be conservative. This problem of leading questions is well known both in research and in the legal context of witness cross-examination. For example, far more people will report remembering seeing broken glass at an accident site if asked to recall the 'car smash', than if asked to recall the 'collision' or 'contact'. Language is a powerful setter of frames of reference.

Conventionally 'risk' estimates are quoted on an annual time base (for example, accidents per year of exposure), or over a convenient 'life span' (for example, an average human working life of forty years, or the life of a plant or machine). Framing appeals to seatbelt use in cars in terms of the probability of accidents over a lifetime of use (probability of death - circa 0.01 - and of disabling injury - circa 0.33 - both over 50 years and 40,000 trips) is much more convincing to people than the probability over one trip (probability of death circa 1 in 3.5 x 10, and of disabling injury circa 1 in 10). The former message resulted in greater seat belt wearing than the latter (29).

People do not give sufficient weight in their calculations to events which will occur a number of years after the decisions they take. Perhaps there lurks behind this finding beliefs that such events can always be influenced by later decisions, and hence can be discounted to an extent at least for the moment. People feel that there is scope for later intervention. For example, Jones & Johnson (164) found that students asked to take part in an experiment to test the side effects of a drug would agree to take more of it if they were told that the experiment would take place in three hours compared with being told that it would begin right now.

A priori probability. Something which frequently gets left out of the frame of the problem solution is the a priori probability of an event occurring. If a problem is phrased as follows people pay no attention to it a priori probability:

'Imagine a city where 85% of the taxicabs are green and 15% are blue. A witness sees an accident happen to a cab and claims that it was a green one. Later tests show that the witness correctly identifies the colour of a taxicab on 80% of the occasions but gets it confused with the other colour on the remaining 20%. What is the chance that the cab was green?'

Most people give an answer of 80% ignoring the fact that the a priori probability of the car being a green cab is high, and therefore the final probability should be nearly 96% that the cab was indeed green. If on the other hand the story is phrased in terms of 85% of the cab accidents happen to green cabs people get much nearer to the right answer. The a priori probability has then been made salient as part of the frame (165).

Ignoring the a priori probability of events leads also to fallacies in the medical sphere - for example, in interpreting the results of mammograms to see if breast tumours are cancerous. Doctors frequently do not take account of the fact that only a proportion of tumours are cancerous (the a priori probability) and base their judgement only on the known probability of the test itself being in error. As a result they are too eager to operate (166).

Dependency. Another factor which stays outside the frame in making judgments is the dependency between different sources of information. Logically, evidence from independent sources strengthens a conclusion, while evidence from two related sources is little stronger than that from only one. However, when presented with evidence from two or more sources people sometimes treat them as totally independent when they are clearly not. At other times they undervalue corroboration. Which occurs seems to depend partly upon the assessment that people make of the trustworthiness of the sources of evidence (91), but in general people were found to be more confident of judgments based on dependent than on independent evidence. For example, they were more confident of their predictions about a person based upon the results of psychological tests which they were told were highly inter-correlated, than on results of tests which were independent; a result which is precisely the opposite of what should occur (167).

People also arrive at higher probabilities when presented with many separate (but not necessarily independent) pieces of information. Thus, decomposition of a problem into a large range of possible contributing component failures (the standard fault tree method) leads non-experts to estimate a higher failure probability than stopping the analysis at a generic level of sub-system failures (168). The same review also reports that half of the highly educated sample in the study always violated the law that the probability of a conjunction of events can never exceed the probability of its least likely member.

5.8 CONCLUSIONS: STRATEGIES OF JUDGMENT

The end result of the biases and expectations which operate in the labelling of danger is that people are poor at making assessments about unusual or improbable events. They are over-influenced by the features which they see as salient in a situation. They are more inclined to see a problem as an example of a familiar one than as an unusual or a unique one (the now familiar problem of preferring to operate at the rule- rather than at the knowledge-based level). Problem definition is conditioned by the solutions which a person has available and has experience of; 'to a person with a hammer, every problem looks like a nail'. A simple example may serve to clarify the problem:

If I dial a number on my telephone and get a ringing tone but no answer there are a number of possible explanations: I dialled the number incorrectly; I remembered the number wrongly; the number has changed; the person is not at home; his or her telephone is not functioning properly; the apparatus in the exchange is faulty. I will almost certainly not think of all these at the time, but, depending upon my experience with the 'phone system, my view of how good I am at dialling numbers, my knowledge of my friend's social habits and the time of day, I shall make a diagnosis of the cause and take action. If I know that my friend's phone was out of order a few days ago, but has been repaired I may immediately 'phone the operator and report it out of order again. This will almost certainly be a biased judgment influenced by availability. By matching the symptoms with available frames I will have short-circuited the full problem analysis and made an error. In this case the 'phone operator may rapidly disabuse me of the error, and I can try again, but there are many problems where the evidence to challenge the first judgment made is not so readily available or so clearly expressed. Sometimes also there is no second chance because the dynamics of the harm process have progressed too far.

Only if this 'symptomatic' strategy of fault finding fails will a person move from the rule-based to the knowledge-based level of functioning in order to try to break out of the strait jacket of the learned scripts and frames (145), which De Bono (169) called 'monorail thinking'.

The power of the frames of reference which people have of health and safety problems is very great. Nelkin (43) traces the difference between a number of these frames of reference. She cites as examples the consensus-based mainstream frame of labour inspectorates and designers with its high value for scientific evidence and bureaucratic procedures, compared with the conflict-based frame of what she calls the advocacy press which stresses workplace involvement, the place of subjective feelings and the need for societal and system change. Certain key information seems to engage different frames. Thus, MacGregor (170) found that the attitude of people towards the appropriateness of risk analysis as a technique was profoundly affected by the presence or absence of the step in which a value is placed on a life lost. Without that step it was viewed favourably as a technique; with it the view swung against, because it offended against ideas of ethical decency and engaged a totally new moral frame for the judgment.

The range and influence of the biases we have described is so great that it has led to considerable efforts to find ways of countering them. Training in problem solving methods and in the presence of and reasons behind the biases has shown some promise for both experts making estimates and operators in process control plants who have to make fault diagnoses (148,171,172). A great deal of attention is now being given to the way in which estimates of probability should be extracted from experts in order to avoid or to minimise bias (148,159,173). This requires great care in the motivation of the judges, in structuring both the problem and the questions in a meaningful and precise way. It demands specific attention to the process by which people arrive at the estimate, care in obtaining the response in a way which is meaningful to the respondents, and built-in checks for consistency within a set of estimates.

The same issues occur at a policy-making level. There needs to be careful separation of the process of defining the facts and of the allocation of values, so that the definitional problems do not become confused at too early a stage with emotional value judgments (29). Individuals' judgments about risk are so subject to bias and so labile that it is not permissible to leave decisions of that sort to market forces and individual negotiation. Individuals are too easily misled, hoodwinked and bamboozled. Therefore there must be state regulation of the process, in order to impose the rules by which decisions are reached.

At the level of the individual faced with personal dangers the research has only the negative comfort of state regulation to offer, together with the suggestion that information technology may be able to support and guide decision-making in some areas by pointing out to people the biases and prejudices which they are about to fall victim to in the decisions they are proposing (146). A more positive approach might be to see if there was more that could be done to present information about hazards and the activities in which they occur in a way which made the dangers stand out more clearly, and to pay more attention to the benefits derived from both safer and more dangerous courses of action. Both of these themes will return in later chapters. Meanwhile we would stress again the importance of the concept of control which emerges from so much of the research. Future attempts to influence individuals in this area need to concentrate on this concept rather than 'probability' and its judgment.

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CHAPTER 6

SAFETY AND RESPONSIBILITY

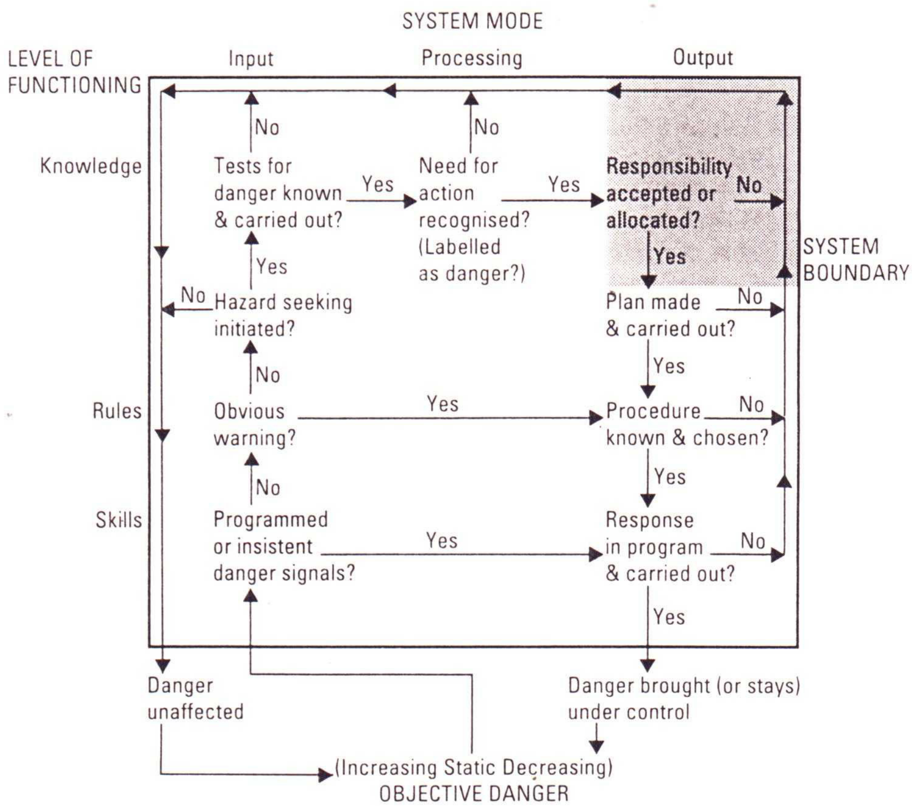

Figure 6.1. Behaviour in the face of danger model - safety & responsibility

6.1 INTRODUCTION

Chapter 5 dealt with the processes by which people reason about danger and decide whether it is present to such a degree that something needs to be done about it. We concluded that such a question was tantamount to deciding whether the situation was under control, and if not whether any serious consequences could follow. Disturbing this sense of control enough to make people think that action is needed is not always easy. There is a strong need for people to believe that they have things under control. They can ignore evidence to the contrary or interpret it in other ways if the situation allows (for example, if the evidence is not absolutely clear-cut and insistent). Even the occurrence of accidents, at least if they happen to others, is compatible with feeling that things are still basically under control. We can hear or read about accidents, even in our immediate surroundings, without feeling more than a passing urge to do anything about them. Bucher (1) documented this in a study of people living around an airport where three crashes occurred in rapid succession. After the first accident there was very little concern expressed by the residents. They were quite prepared, when asked, to say what they thought should be done to prevent the accidents, but there was very little active concern in the sense of letters or protests. People simply talked about the incident, and explanations tended to be phrased in terms of 'one of those things', 'to be expected now and then'. They had explanations ready which did not demand any change in the way in which things were controlled at the moment, apart perhaps from a bit of tightening up of procedures. When the second and third accidents occurred the response was very different, and people began actively to think in terms of new theories. Only then did significant talk of responsibility and blame emerge. When it did it was couched in terms of the individual's (new) theory and came out as anger that someone (usually in authority) had not yet acted to alter the system along the lines that the theory would suggest (for example, the state authorities were blamed for not moving the airport, if the individual felt that that was the only solution to the problem).

Here we see a process where a problem is first treated as 'normal', then an 'unexpected' element enters, and a threshold is passed where people feel something must be done. In this case they perceived that they personally could do nothing to control the accidents, but that others could; which others depended upon the way people reason about the cause of the accidents. Then they allocated responsibility, and if nothing was done, they translated that responsibility into blame.

The concepts of cause, control, responsibility and blame are intimately connected in this dynamic process. If people believe that there is nothing they can do, even by trying to stir others to action, the process can be short circuited with the result that the problem is put out of their minds. A quotation from a book written by the Principal Lady Inspector of the British Factory Inspectorate referring to the early years of the twentieth century shows that this is a problem which has long been recognised:

'Miss Paterson wrote, in 1902, that the indifference of the employer had resulted in a corresponding indifference on the part of the worker, who, "acquiescing at first in conditions which she feels powerless to improve, gradually ceases to feel them an offence to her. There is no doubt that one loses sensitiveness to indecent arrangements just as to impure air, but the moral effect in the one case is much the same as the physical effect in the other".' Anderson (2) p41. (The quote within the text comes from the Annual Report of the Chief Inspector of Factories for 1902, p154, 3).

Fischhoff et al. (4) cite evidence of this process of habituation occurring, particularly with natural hazards, which people often see as uncontrollable. It also tends to happen if a person can see no viable alternative which is safer, if nobody else seems to be worried, or if nobody seems to be in a position to act. In other words people naturally make judgments of 'reasonably practicable means' of action, just as these are made by judges in deciding compensation or prosecution cases, and by labour inspectorates in assessing accidents and bringing those prosecutions (5,6). Such judgments are affected by experience; people may try to get hazards removed by reporting them to management, but if nothing happens after several reports they may adopt a fatalistic attitude and stop trying (or they may take stronger action such as a strike, 7). The choice will depend on many other circumstances, such as the history of labour relations and militancy of the organisation, the personality of those concerned and the seriousness of the threat.

The three processes which appear in the upper right-hand section of the model are therefore not three independent processes, but a single iterative one, which we have divided up into three chapters for the sake of ease of explanation. The last chapter looked at danger labelling, this chapter focuses on the question of responsibility, while the next looks at planning and action processes. However, we first say something about the options which are open for action in order to provide a meaningful context for discussion of responsibility.

6.2 OPTIONS FOR ACTION

This chapter, like the last, considers actions at the knowledge-, or in some cases, the rule-based level of activity. We are therefore not concerned here with actions which are built into learned procedures. There the question of who should carry out the action does not arise, since it is an automatic part of the procedure. Here we are dealing with more or less conscious choices of who should do what. Individuals are faced with the choice of doing nothing, of choosing personally to carry out one of their repertoire of action programmes and plans or of stimulating others to act. There would appear to be three factors relevant to these potential actions. One dimension (X) can be based on the model of danger which we presented in Chapter 1, namely at which point in the process leading to harm can the intervention take place; a second dimension is action to protect oneself as opposed to doing something to protect others (Y); logically a third distinction (Z) can be made between taking direct action oneself and trying to get others to intervene. These dimensions which we propose are set out in Figure 6.2.

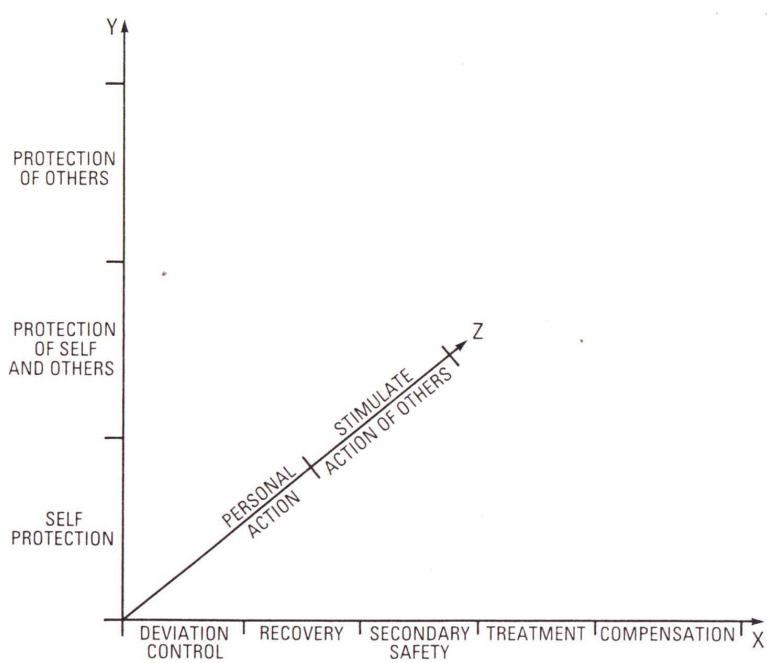

Figure 6.2. Options for action

Different actions can be plotted in the three dimensional space. For example, moving away from an area where a radioactive waste treatment plant is to be built or running away from a fire are personal actions to save oneself, the first in anticipation of, and the second during the unstable phase of an incident when control is no longer possible (secondary safety). Entering a burning house to rescue someone is a personal action to protect someone else at the secondary safety stage. Instructing someone to replace the frayed wire on electrical apparatus before using it is a personal action to protect others at the stage of recovery from a deviation.

In some circumstances there are many options for action open, as for example when travelling from A to B the traveller can make choices between different types of transport and times of travel, and once having chosen to drive, between different routes, speeds and headway to other vehicles, all of which will affect the level of risk. In other circumstances the choice may be very limited or even non-existent, as for example in response to the building of a chemical or nuclear plant in one's neighbourhood, where the only direct actions open to the individual may be to move away or to attempt to sabotage efforts to build the plant, and where indirect actions to stimulate others to act may be limited by ignorance of how to influence the local press, public enquiries, local planning processes or national lobbies. Given the difference in the range of potential actions which may be possible in any given circumstances it is not to be expected that people's feelings about responsibility for action would be the same for all of them. Unfortunately the research which has been carried out in this area is still limited. Only some of the areas on the diagram have been studied directly, and much of the research has not looked directly at responsibility for safe or dangerous actions, but at feelings of responsibility for such outcomes as job or examination successes or failures, or achievements at business or in games. What is worse, many of the lines of research and theories in the area have not made clear distinctions between the range and type of different potential actions (8,9). Theorists have often tried to generalise unquestioningly from one to the other, and have thus become tied up in apparently contradictory results. In the remainder of this chapter we shall try to trace what seem to us coherent themes running through this confusion. However, before doing so we shall describe in more detail some direct studies of safety responsibility in order to give a clearer view of some of the issues.

6.3 FIELD STUDIES OF RESPONSIBILITY FOR SAFETY

6.3.1 Construction site supervisors

Abeytunga (10) studied the perceptions that 70 construction site supervisors had of the hazards on the 50 sites for which they were responsible. During the research he conducted site inspections with the supervisors. The declared aim of the surveys was for him, as a novice, to learn from the supervisors where the hazards were and what problems existed in removing them. This cover story was devised so that supervisors would not realise that he was a trained construction site inspector and so would not go out of their way to alter their behaviour so as to project a false impression of safety. The supervisors were simply asked to point out every hazard they saw as they walked round. Where Abeytunga saw a hazard which the supervisor had not pointed out he stopped and pointed it out himself, asking whether the supervisor thought it was indeed a hazard, and if not why not. For all of the hazards he then asked a standard series of questions. These are set out together with a summary of the number of 'yes' and 'no' answers in Figure 6.3. The questions were asked of 659 hazards found during the inspections.

The findings from questions one to three (on hazard recognition) have already been discussed in Chapters 4 and 5. The questions of interest here are those relating to acceptance as a hazard and allocation of responsibility (questions four to eight).

The 'why' questions gave information about the reasons used by supervisors to justify their answers. From these, Abeytunga identified fifteen factors which were mentioned, usually more than one per answer.

A. Limited resources to remove the hazard
B. Beyond supervisory duties (limited, attributed to others, undefined)
C. Incompatible demands (production, quality, cost etc. v safety)
D. Accepting hazards as inevitable (risk-taking necessary part of the industry)
E. Social climate influences (workforce pressure and autonomy, low authority of supervisor)
F. Industry tradition (accept certain hazards, changes needed to remove hazards would not be acceptable)
G. Lack of technical competence to remove the hazard
H. Dependence upon individual worker (skill of others, hazards seen to be under specialist's control)
I. Lack of authority to do anything (authority surrendered to others to achieve work goals, unclear authority structure)
J. Contingency situations (rapid planning required, unexpected breakdowns or arrival of material and personnel, risk taken to cope)
K. Safety management system factors (inspections, permits to work, no facilities, provisions, personnel or communications)
L. Task overload (deal with immediate tasks, pressure of other duties)
M. Company rules, policies and practices (follow instructions, unclear instructions, not held accountable)
N. Lack of information (communication breakdown)
O. Legislation (no need for action unless legislation breached, higher priority to other legislation breaches, shifting onus of responsibility to others).

The reasons given will certainly have reflected some attempt on the supervisor's part to find post hoc justifications which appeared to them to be acceptable explanations for their lack of action. As such they should not be taken as a complete, nor necessarily an accurate list of the factors which actually influenced behaviour. However, they do give a good picture of the way in which the supervisors saw their workplace responsibilities for safety, and the factors which constrained the range of decisions they could make (reasons A,B,G,I,J,L,N), or should make (D,F,M,O,) and the other criteria apart from safety which weighed upon their minds (C,E,H,K).

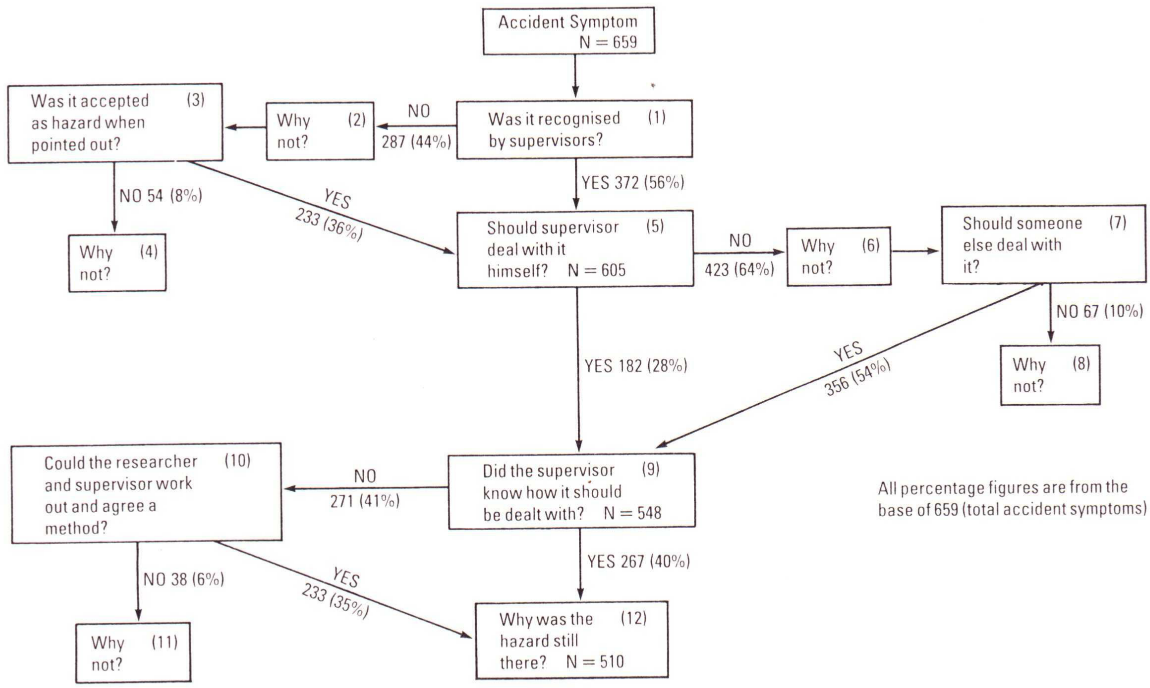

Fig. 6.3 Perceptions of hazards (accident symptoms) by construction site supervisors (source 10, Abeytunga 1978)

From Figure 6.3 it can be seen that eight percent of the hazards were not considered as real by supervisors (question 3) and that a further ten percent were felt to be nobody's responsibility to remove (question 7). The reasons given in the two cases were very similar (reasons C,D,F,H,J,M,O, above). They reflect a level of acceptance of some hazards as part of the job or the industry, so much embedded in the way that it works that there is no way that they could (or by implication should) be removed. This is partly due to the complex and rapidly changing nature of the work and its demands. In the background is a belief that 'if it is not defined in the law or in the company rules as a hazard, then it is not worth further thought'. The answers reflect a degree of acceptance of inaction by the supervisors. The fact that such responses fell into two groups is some indication that there were two levels of acceptance; in one the situation was so much a part of the system that it was not even labelled as a hazard; in the other it was labelled as a hazard, and the need for action was presumably considered, but was then rejected.

For the remaining 82% of hazards, action was considered to be necessary, but was allocated roughly in the proportion of two to one to other people compared with the supervisor himself. Under the 28% accepted by the supervisor as his responsibility fall both direct action to control or to remove the hazard and action to warn either the people at risk or those seen to be in control of the hazard. All fifteen factors were given as reasons for rejecting supervisory responsibility, with 'resource limitations' and 'being outside the boundaries of supervisory duties' (reasons A and B) prominent among them.

Analysis of the type of hazards for which responsibility was accepted and rejected showed that the supervisors felt significantly more control over the work setting (site layout) than over the work methods being used or workforce quality or quantity or of the plant and equipment provided for the work (11).

Supervisors' safety role problems can be summed up under three headings:

1. range and complexity of required tasks beyond capability (overload)
2. incompatibility between expectations concerning safety and other role expectations (ambiguity)
3. conflict between relevant other roles and the safety function (conflict).

As case studies, Abeytunga interviewed three supervisors in detail about hazards on their sites. He also questioned the corresponding site agent, project manager and safety officer of each site about the same hazards. He found that these relevant others were progressively less likely to accept the supervisors' perceptions of their safety functions, as Figure 6.4 shows.

The data in Figure 6.4 highlight conflicting expectations between safety responsibilities attributed by safety officers and line management and those accepted by supervisors themselves. As the interview findings from this study were not validated by observing actual control actions by supervisors, the findings may be conservative. Supervisors would have been likely to say that they would accept responsibility for more things than they in practice did. Neither is it necessarily the case that those hazards which were attributed to the responsibility of another party, such as subcontractors, would be accepted and acted upon by the other party. The figures cited here, therefore, may give a rosy picture of how responsibility is allocated and accepted. Even in this picture there are clear signs of conflict and disagreement. If these beliefs were acted upon they would lead to significantly different courses of action; the supervisors sitting back attempting no control over workforce or work methods and expecting management to provide better equipment, the headquarters staff castigating supervisors for failing to supervise.

	Hazards regarded as outside supervisor's responsiblity	Reasons given for non-action by supervisor
Which were:	N = 49	N = 184
- in view of supervisor	32 (65%)	184
- agreed by site agent	21 (43%)	131 (71%)
- agreed by project manager	14 (29%)	97 (53%)
- agreed by safety adviser	4 (8%)	36 (20%)

Figure 6.4. Differing perceptions of the supervisor's role
(source 10, Abeytunga 1978)

6.3.2 Financial responsibility

Lancianese (12) reports the findings from a large scale US survey in which a cross-section of the public (N=1500) as well as opinion leaders (N=553 representatives from Congress, top executives and financiers) and Government regulatory officials (N=47) were interviewed. Respondents were asked who they felt should have primary financial responsibility (employee, employer or shared) for injury or disease occurring in three circumstances. Figure 6.5 shows a sample of the results:

CIRCUMSTANCES	Party responsible	% OF GROUPS JUDGING RESPONSIBILITY TO LIE WITH SPECIFIED PARTIES		
		Public	Regulators	Other opinion leaders
Employee injured through employee negligence	Employee	55	47	61
	Shared	24	45	29
Disease by exposure on job to dangerous substance	Employer	83	85	72
	Shared	10	11	20
Employee injured on job known to employees as dangerous	Employee	26	18	11
	Employer	32	30	40
	Shared	39	51	45

Figure 6.5. Financial responsibility judgements (source 12, Lancianese 1980)

Across the three situations, the financiers and the general public were most willing that the employee should bear financial responsibility for occupational injury and disease while Congress and Government regulators showed the greatest tendency to make employers financially responsible. However, within this generalisation lies a great spread of opinion not only between groups, but across situations. Responsibility in this study was specifically defined as financial, though there is no guarantee that people did not import some element of moral judgement also.

6.3.3 Responsibility for safety and accident prevention

In a series of small studies based on findings by McKenna (13), Glendon (14,15,16) asked different groups of people concerned with health and safety who they considered to be responsible for safety, accident prevention, health at work and prevention of occupational disease. Respondents were asked to place different groups in order of decreasing responsibility; for example, Figure 6.6 shows the results of asking workers, supervisors and trade union safety representatives the question 'who could do most to prevent an accident happening to an individual worker?'

RANK ORDER	Workers	Supervisors & Managers	Safety Representatives (small sample N = 10)
1	Worker self	Worker self	Worker self
2	Other workers	Supervision	Trades union
3	Supervision	Other workers	Supervision
4	Management	Mangement	Other workers
5	Trades union	Trades union	Management

Figure 6.6. Responsibility for accident prevention (source 13,14, McKenna 1979, Glendon 1980)

The groups agreed overwhelmingly on the top position, of the individual worker (as the person nearest to the problem), and only differed among themselves in promoting their own group about one rung further up the scale than other groups had put them.

When the question was changed slightly in wording and groups were asked about responsibility for safety the order was greatly changed. Management and supervision came to occupy the first two places for all groups asked, including health and safety professionals (15). Responsibilities for health and for prevention of occupational disease were not distinguished in the way safety and accident prevention had been. In both cases management occupied the top place followed by occupational health professionals. Factory inspectors and insurance company risk inspectors gave a quite different order of responsibility from other groups when it came to responsibility for accident prevention, making little distinction between that and safety. Glendon (15) suggests that responsibility was probably interpreted legalistically by these two groups, namely in terms of incurring liability or penalties. Groups within the workplace are more likely to have interpreted responsibility in either a managerial or a technical sense, depending upon the question wording. For example, managers may be seen as responsible for providing protective equipment and machinery guarding while workers are seen as being responsible for 'working safely'.

Some support for these notions was obtained from a more detailed analysis of the data (16). Subjects identified in rank order what they meant by 'responsibility for safety' and for 'accident prevention'. Safety, attributed by all groups, above all to management and supervision, meant:

1. physical safety (for example, guarding, personal protection, maintenance, housekeeping)
2. communication (discussion, representation, persuasion, liaison)
3. internal regulation (plant rules, procedures, and their enforcement)
4. external regulation (legal requirements)
5. organizational and policy arrangements (including monitoring and implementation)
6. ensuring a generally safe environment.

Responsibility for accident prevention - attributed first and second to the worker and to supervision, was held to mean:

1. adherence to safety rules, practices and methods
2. implied control by the worker (safe attitudes, being a safe person, taking care, not being negligent)
3. education (training, provision of advice and information)
4. monitoring (checking, reporting, identifying hazards)
5. physical protection of the worker (by protective clothing or equipment)
6. safety devices - relating to machinery or environment
7. provision of safe conditions, workplace or methods.

There are parallels between these views and those of the construction supervisors in Abeytunga's study. Abeytunga's subjects saw only the layout of equipment as their responsibility, with its provision and the question of policy and rules being displaced onto management. A similar split occurs in a study where different groups were asked to describe what factors they felt were most responsible for accident causation. Those in management pointed to regard for safety rules, lack of care and attention and experience; those lower in the hierarchy, including shop floor workers, pointed to poor safety provision, faulty materials and bad working conditions (17). There are also parallels from a study of workers and managers in the public and private sector building industry (18). In the public sector, hazards were attributed far more to organisational factors (especially the bonus system) than in the private sector, where individual factors were considered to be dominant. Although the work differed somewhat in the two sectors this is unlikely to have accounted for all of the differences found, which probably reflect the working cultures in the two sectors.

6.3.4 Responsibility in other environments

If such a range of meanings can be ascribed to responsibility in the relatively constrained context of the work environment, where clear contractual relationships apply, then it is likely that the range of meanings (and of parties involved) in other environments will be even greater. In a community survey (19,20) respondents were asked who they considered to be responsible for their safety and who could do most to stop them being injured in their own home, in the street and at work. Greatest personal responsibility for safety was accepted for safety in the street, then in their own homes and least of all at work. Others were much more likely to be perceived as responsible for safety at work than in the other two environments. Asking about injury prevention produced almost equal percentages who saw themselves as personally responsible at work as at home, while lower percentages - but still the majority - perceived the prime responsibility in the street to be their own. As well as these overall patterns there were complex patterns of differences between individuals. The explanations for these variations are likely to come from differences in perceived controllability (greatest at home and at work), contractual obligation of others (greatest at work), and complexity and unpredictability (greatest in the street).

6.3.5 Communication and intervention in the safety of others

Canter (21) and his colleagues in their study of fires have measured what people do when faced with the signs that there is a fire in a building. They found that most people initially do not believe that there is a fire, and simply carry on doing their normal tasks. Only after a threshold is reached do they stop, often go and investigate and then accept that fire is present. The reaction of the vast majority is then either to escape, especially if the fire is serious, or to fight the fire. Warning others comes much lower in frequency. Women are more inclined than men to warn others and show more concern for personal safety (both their own and others'). Experience of fires does not increase the amount of warning given, and it takes specific training to do so. This applies both to warning others in the building and to calling the fire brigade; there is even some evidence that experience of fires makes people more inclined to tackle them rather than to call for assistance.

A number of explanations can be given for this lack of warning; that people become fixated on their own safety, that they try for too long to retain control of the fire and then have no time to warn others, or that they do not like to interfere and assume that others must have seen the warnings which they themselves have seen.

Reluctance to interfere and to tell people that they have made a mistake is documented in the analysis of aircraft accidents (22). Burrows cites cases of incidents where one member of the crew did not intervene in a dangerous manoeuvre, and blames personality clashes and the dominance of one crew member (usually a senior captain) over less experienced or younger crew. Edwards (23) called this phenomenon a 'cockpit gradient'; too great a difference in age, experience, rank or personality creates a slope which is too steep for the junior member to climb, and so he does not dare to intervene even though it is quite clear that the senior party has made a mistake. Even if this gradient delays intervention only for a few seconds it can be vital in a system where the time between the start of an accident sequence and a crash can be only a few seconds (for example, the crash of the Trident aircraft at Staines 1972, in which just such a failure to intervene may have occurred, lasted less than 2 minutes from the first error to impact).

Robinson (24) gives broader examples of an individual's reluctance to interfere in another group in a factory in order to correct faults in the production process which were leading to both poor quality and hazards. The preference was to try to correct the errors once they came into the individual's own territory rather than intervening to get them put right at source.

A final piece of evidence comes from so-called 'bystander' research (25,26). This set out to investigate helping behaviour among passers-by who witnessed a problem. The research was triggered off by a widely publicised murder in the USA in which a number of individuals from their apartment windows witnessed a lengthy beating and finally murder of a victim, without any of them either attempting to intervene or 'phoning the police. Studies of behaviour of witnesses to a simulated epileptic seizure and to a theft confirmed the reluctance of people to intervene, especially if they were in a group (why should they be the first to step out of line?). Intervention only became more common if the individuals perceived that they were the only source of help, if they knew the victim at least slightly, and if the victim was perceived to be in some way vulnerable (for example, female rather than male).

6.3.6. Discussion

The purpose in giving these detailed descriptions of studies is first of all to illustrate the complexity of the factors which influence judgments about responsibility. Apparently small changes in the wording of a question can have significant effects on the answers which are given by the same group of people.

Contextual factors are vitally important in determining whether people will consider it their responsibility to take action. As with probability judgments, discussed in Chapter 5, attributions of responsibility are strongly affected by the frame of reference within which the question is set. In trying to make them, people draw upon the same mental models of the system or process they are being asked to consider, and there is evidence that similar factors influence the final outcome. We have identified above the factors of control (what contribution can I make, who has control over what, who can afford to pay), complexity and uncertainty (is the situation unpredictable and so do I need to keep my eyes peeled for trouble?), and equity (is someone else employing me to do this, and so should look after me? is the potential victim particularly vulnerable?), which also featured prominently in Chapter 5.

However, evidence from a small number of field studies is hardly enough on which to base firm conclusions. We therefore turn in the remainder of the chapter to research literature in the social sciences to see what information we can derive from there.

6.4 ATTRIBUTION

6.4.1 Origins of attribution theory

A major objective of psychology is to explain why people choose to behave in the way they do. Since the 1960s this question has come to be looked at increasingly from a new perspective. Instead of treating the human research subject much as a rat in a maze, as a sort of black box to be experimented on through manipulation of the environment, researchers have tried to get inside the heads of their subjects to find out how they experience the world around them and how they make sense of it. A central assumption of this approach is that people actively seek to find meaning in their environments. They process information like scientists with hypotheses (27) rather than like automata (28). This idea of people being 'naive scientists' trying to make sense of their world has given rise to a meta-theory, which has come to be known as attribution theory. Meta-theory means the construction of theories about how people construct theories. The argument runs that scientists develop theories about the world, and guide their future research and behaviour on the basis of the tests they make of the theories. If people are essentially acting like scientists, then the study of people (psychology) must be the study of how and why they make theories and test them out, and where they go wrong in doing so. Attribution theory therefore emphasises perception (how is the information about events taken in), understanding of cause (what relations between events are inferred) and the interaction between the individual an environment (did the individual's action produce the effect observed).

Because of its status as a meta-theory, attribution theory has had a very wide field of study. Only a small proportion of the studies have been directly concerned with attributions of responsibility for safety, health and their control, or accidents, diseases and their prevention. Hurry (29) argues that accidents per se cannot be a legitimate subject of study for attribution theory, since it concerns itself with the intended results of rational events, and accidents are by nature neither intended, nor often perceived as rational. However, there is considerable evidence that people do attempt to rationalise, predict and explain accidents, and so try and force them into their attribution frameworks. We shall therefore consider what it has to say on the subject. However, the majority of attribution studies have looked at success and failure in examinations, gambling, skilled games, finance or business. The field has also spawned several competing theories. The points of departure from which these theories have been developed and the areas of behaviour which they have studied have been widely different. Much of the early research suffered from a lack of clear definition of the factors being studied and the conditions under which the subjects were being asked to make attributions. The result has been a complex and confusing mass of specific findings which often appear contradictory, and a series of parallel explanations for the findings whose theoretical and practical differences are often not clear. For a detailed study of the whole field the reader is referred to one or more of the major texts (30,31,32,33,34).

6.4.2 Attribution of cause and responsibility

A central activity of science is the study of cause; what events and actions lead to what results. Therefore a central theme of attribution theory has been to study how people attribute causes to events; to look at where they seek information and what they do with attributions once they have been made (30). We shall mention particularly the work of Heider (35), who has been called the father of attribution theory, and who studied the evidence upon which cause is assigned. His work has many links with the philosophical study of cause by such philosophers as Locke, Hume, Russell, Wittgenstein and Popper. One theme of this approach is that people impose a sense of cause and effect by subjectively dividing up what would otherwise simply be a stream of events (36). Sometimes the events and the links between them are clear, as when a fork lift truck collides with someone and knocks them down. At other times they may not be, as when a person grasps a piece of metal and falls down. Only if we know that there is an electric current running through the metal does the link become clear; otherwise the link could have been purely fortuitous or indeed reversed in order (the person had a heart attack and grasped at the metal to try to avoid falling).

Reviews of the research literature on attribution (37,38,39) have emphasised a number of common features in this process of drawing conclusions about cause. People look for patterns and consistencies in events. If the same person or machine is linked on several occasions with the same event, cause will be attributed to that stable element. This tendency is strengthened if other similar people or machines are not associated with the same event. Hence, if the same person has accidents repeatedly they will be likely to be labelled 'accident prone', especially if the accidents happen on several different machines, or other people doing the same job do not have so many. Only if several people have accidents on the same job will the job stand out as the common element, and be held responsible. If there is more than one element which is stable - for example, the same person always has the accidents on the same task or machine - there is more than one option for attribution of responsibility. In general, which one is chosen will depend upon the mental model which the person making the attributions has of the process under consideration. As we shall see below (Section 6.4.4) there are biases at work within the attribution process which make people more likely in such cases to choose the people rather than inanimate objects as the cause.

Where people are faced with isolated events, in other words where there is no possibility of looking for a pattern, they have to rely entirely on their mental models of the process they are trying to understand. From these they develop hypotheses, or expectations of why events have occurred. What then becomes important is whether there are other causes which could account for the event, and whether there is any countervailing evidence to reject the cause they have proposed. In this process of judgment other factors are also considered:

- the incentives operating in the situation; did the person want the result which occurred? was there a particular reward for the action taken?
- the controllability of the process; is it subject to skill, or only to luck? who or what could influence the outcome?

A dilemma occurs when there is apparently no plausible other cause for an event, yet there is countervailing evidence. This occurs when a person clearly took an action when there were good reasons why they should not have done - for example, an action which immediately prompted a personal injury. Research shows that this state of affairs strengthens the attribution of responsibility to the person rather than weakening it (37). The reasoning seems to be 'If X did that in those circumstances, they really must have meant it'. If the event in question is an accident which clearly resulted from a person's action, this attributional bias leads to an inference of at best carelessness, if not gross negligence or even unconscious desire to hurt oneself.

Russell (39) summed up the important dimensions in attribution under three headings:

- controllability; subject to control or to chance
- locus of control; controllable by the individual or not
- stability; features constant or variable over time.

The first was dealt with in Chapter 5; the last has been sketched above. Both will return in our discussions below, but our focus in the rest of the chapter is on the second, the question of individual responsibility through control. We shall concentrate on what the literature has to say about attributions of responsibility between three possibilities:

1. individualistic; the skill or fault of the individual concerned
2. societal; responsibility placed on other groups or society
3. fatalistic; attribution to external (uninfluenceable) factors.

This classification incorporates some elements of Russell's 'controllability' dimension as well as his 'locus of control' one.

6.4.3 The meaning of 'responsibility'

Several writers have noted the confusion in the attribution of responsibility literature due to failure to define consistently the term 'responsibility' (9,33,40,41). Three different frames of reference have been suggested (42):

1. Concern with underlying physical, psychological and social causes of events in a scientific sense (causal-genetic viewpoint): a person is responsible if their action caused an incident, or could have prevented it.

2. Evaluation of behaviour against norms of what is appropriate or admissible (situation matching): a person is responsible if their behaviour did not conform to the rules and so led to the incident.

3. Concern with supporting one's own beliefs and view of the world (value maintenance): a person or organisation is judged responsible because of their position, or because it reassures the person making the attribution to assign responsibility there. For example, the government of the day is judged responsible for the economy, or immigrants are blamed for unemployment. A common bias under this heading is to assign as much responsibility for pleasant events to oneself as possible in order to bolster the belief that one is in control of what happens (see also Chapter 5).

Attribution of responsibility under 2 above frequently leads people to imply that the responsible individual group or factor must therefore change or be changed in order to prevent the accident happening again. In other words responsibility in the sense of 1 is inferred from attribution in the sense of 2. However, these two senses need not go together. An example is the attribution of responsibility to children for road accidents in which they are injured (43). Studies show that adults regard the children as in large part responsible for causing the accidents (44), by dashing out into the traffic (which contravenes the norms of adults). Yet observation shows that it is the children who do most of the active avoidance in traffic conflicts of this sort. Drivers do little to avoid children who do run into the road, or to adjust their speed in areas where, and at times when, children can be expected to be about. In other words drivers have much more control than they choose to exercise. Howarth & Gunn (43) conclude that the inference of causal responsibility to the children is false, especially in the light of the fact that children of that age are regarded as not legally responsible for their actions, and are generally known to be less predictable than adults. This use of a situation-matching frame of responsibility instead of a causal-genetic one has lead to too much emphasis on attempts to teach children to act differently, and too little on encouraging drivers to take a more active avoiding or preventive role.

Accident investigators can easily become entangled in this same confusion, and see no further than behaviour which was a breach of a rule, rather than asking whether the rule was a reasonable one. In a thorough and scientific accident investigation, responsibility should be allocated on the basis of an analysis of cause, and not vice versa. However, as Lloyd-Bostock points out (41,45,46), the tendency is to work the other way round. People make judgments about who they think was responsible for a given situation, and then infer that their action or inaction must have caused the accident that occurred in it (a situation-matching approach). People only adopt a causal-genetic frame of reference for attribution of responsibility in special circumstances, either when specifically asked to do so (as on a jury), or when their situation-matching attributions cannot cope or lead them into problems (for example when those initially considered responsible cannot pay compensation). This finding can be interpreted in terms of our three level model: attribution within the causal-genetic frame of reference is equivalent to knowledge-based activity, whereas the situation-matching and value-maintenance frames correspond to rule-based activity. We have already said in Chapter 3 that the knowledge-based level is only engaged when it is consciously selected or when the rule-based level is seen to fail.

What lies behind this confusion of meanings and uses of the concept 'responsibility' is often a confusion between consideration of the past and the future, between what has happened and what is expected to happen. In looking at past events people in many circumstances do not look simply at objective cause-effect links between antecedent events or actions and subsequent occurrences; they are more inclined to look for reasons for the occurrences and to look for meaning in what has happened. Meaning and reasons have more to do with what should have happened and what people intended to happen, than with what actually happened. However, influencing what will happen in the future relies upon having a very clear understanding of what factors actually have (and had) an influence. Problems arise if causes are confused with reasons and if future actions are based on judgments of responsibility from situation-matching or value-maintenance frames of reference rather than from a causal-genetic one.

We consider next what research can relate about these confusions and biases in attribution and how they affect behaviour. We shall consider them under two headings: attributions of own and other people's behaviour, and attributions of the causes of accidents.

6.4.4 Attributing responsibility for own and other's actions

Early in its history attribution research uncovered a major difference in the way people explain events which happen to them as opposed to those which happen to others (47). An overall tendency has been found to attribute what happens to other people to their personal responsibility, but to place much more emphasis on the role of external circumstances when explaining what has happened to oneself. In the field of health and safety there are a number of studies which show this bias. Abeytunga (10, see also Section 6.3) showed that supervisors reject their responsibilities for hazards because of the many external constraints under which they work, while management continues to attribute personal responsibility to them; the further distant in hierarchical terms the more personal responsibility is attributed. Kouabenean (48) found that those on the shop floor (and thus subject to accidents) attribute accident causes to poor working conditions, while those higher in the hierarchy attributed accidents to lack of attention or care (personal responsibility). Consistent differences are found (49,50) in attributions made for one's own accidents (unusual circumstances, not noticing things) and those of others (risk taking, aggression, carelessness). Green & Brown (51), in a study of attributions made by students for accidents they read about, found an overwhelming attribution of responsibility for fires to the victims themselves, despite the fact that objective evidence presented in the accident descriptions showed that the victims often could not have influenced the fire.

The implications of this bias are that the blame for accidents tends to fall by default on the victim. 'Accident proneness' is therefore regarded as a common sense 'fact', which requires no support from scientific research and which is therefore highly resistant to disproof by such evidence. It also means that accident investigators, unless they take specific steps to counter the bias, tend to start out from a hypothesis that the victim is to blame, while the injured parties tend to start from the hypothesis that they are the victims of circumstances. This lays the ground for acrimonious miscommunication.

In more general terms this bias leads people to underestimate the influence of external circumstances on other people's behaviour, and to be surprised that they do not stand up to those circumstances. People are therefore surprised by the results of some experiments in social psychology where subjects behave in antisocial ways which go against the subjects' own expressed beliefs (37,52). An example of such experiments are those of Milgram (53) in which subjects consented to take part in a study in which they had to give electric shocks, which they were led to believe could be dangerous, to other volunteers. They did so simply under the constraint of being placed in a role as subordinates to an imposing experimenter in a white coat, who constantly assured them that they should carry on, even in the face of signs of distress from the guinea pigs. The overwhelming majority of people asked to predict the results of such an experiment said that only a tiny minority of the subjects would go through with it. In fact all but a handful did impose shocks which they had been informed could be harmful. The actual constraints imposed on the subjects by the situation far exceeded the expectations of those asked to judge the outcome.

Similar underestimates by managers of the effects of time pressure, group norms and work layout on the safety of worker behaviour are commonplace.

Various reasons for this 'actor-observer' bias have been provided by different theorists. Buss (8) points to the different information available to people as observers of others, and as actors themselves. In the latter role they have access to their reasons for doing things (their intentions), while as observers they must infer intentions from what actually happened. As actors, people are also aware of the constraints imposed by circumstances, while as observers they can only infer the strength of such constraints. As observers, people can really only talk of causes; reasons must be inferred, and in order to make that inference people will need to empathise with the person being observed. If empathy can and does exist, people will then tend to project their own intentions onto events and judge the other person as if he or she were themselves.

In making attributions of responsibility for an accident, victims have two sources of information. They 'know' that they did not intend the accident, and are aware of the external constraints on their own behaviour; hence they are inclined to attribute it to those external circumstances. As observers they can only observe directly the circumstances; they start with the bias that people intend the things they do and while they may make some allowance for the external constraints, this is not usually sufficient (see Chapter 5 and the concept of anchoring of judgments). Having failed to find sufficient explanation for the behaviour in external circumstances, the only explanation left is that it must, at some level, have been intended. If there is empathy with the victim (they are alike in some way, do the same job, etc) complex feelings seem to be engaged. On the one hand people believe that such a person could not have intended an action which led to an accident, and hence responsibility must lie elsewhere. On the other hand observers feel the need to protect themselves from the belief that such an accident could happen to them as it did to the victim. This sometimes results in trying to find characteristics of the victim which distinguish them from the observer, and then blaming those - so intensifying the blame allocated to the victim (32,37,54,55,56). This distinction between explanations in terms of causes and of reasons recalls the distinction in Section 6.4.3 between causal-genetic and situation-matching frames of reference for allocating responsibility.

Coping with accidents. We have said that people have a tendency to blame external circumstances for their own accidents. There is an interesting sidelight on this issue which is cast by a small number of studies of the victims of serious accidents and diseases (and of their close relations) (57,58). These studies found that those who accepted personal responsibility for the accident or disease coped better with the aftermath, and adapted their lives better. Those who felt that they had been the victims of fate, unusual circumstances or of others' actions coped poorly. The studies also showed that self blaming increased over time, and was more prevalent among those who had religious convictions. Often the amount of blame accepted was greater than a more objective analysis would have allocated. Brewin (59) confirmed these results with victims of minor accidents and concluded that the effect was linked to a need to affirm personal control, and to believe that therefore further accidents could be avoided; 'it was a slip that will not happen again'.

6.4.5 Locus of control: externals v internals

The term 'locus of control' has been given to two distinct things; first, a situation-dependent factor (for example, do people attribute injury accidents more to external factors than they do 'happy accidents', such as wins on the horses); second, a personality dimension which measures the tendency of individuals to ascribe the causes of all things that happen to them more to external or more to internal events (60). A small number of research results point to the relevance of this dimension to behaviour in the face of danger. Internals are more likely to seek information about a problem or issue and to attempt to control it themselves; externals are more likely to attempt to get social action (or action by others) started (61). Internals buy more insurance and make more plans against natural disasters (62). There is some evidence that smokers are more external than non-smokers, and that those who attempt to stop smoking are less external than those who never make the attempt (63,64).

Research on the use of safety precautions such as seat belts is far from clear, with contradictory evidence from different studies (66,67). It seems likely that the confusion over the applicability of the dimension in relation to the control of danger is at least partly because hypotheses have not been clearly formulated which indicate why certain control behaviour would be expected more from externals than from internals. It seems a priori that one can argue in two contradictory ways: either that internals should be more prepared to do something themselves to control the risk of accident and therefore would be prepared to wear seat belts; or that internals will regard themselves as more in control of the whole driving task, and that the risk of accident is therefore very low and hence no seat belt is necessary. Externals could, on the other hand regard the chance of an accident as being largely outside their control, and therefore the need for protection against injury as being the only possibility for them. Joe (61) found, for example, that if they regarded themselves in control of them, internals were more prepared than externals to take risks in skill situations. Until studies are carried out which probe more deeply into the way in which this personality factor links with the way of construing the problem of controlling danger this confusion is likely to continue.

6.4.6 Attribution of causes and responsibility for accidents

Walster (67) describes an experiment in which she asked students to attribute the responsibility for accidents given to them as brief written descriptions. She manipulated the severity of the outcome, and found that the tendency to attribute blame to the victim increased as the seriousness of the accident increased. She interpreted this as showing that the students were biased by the desire to avoid the idea that the accident could happen to them. If the victim was to blame, and not the circumstances, someone else finding themselves in the same circumstances would not have the same accident. The worse the accident the more the bias would apply. This so-called 'defensive attribution' hypothesis stimulated much research, most of it coming to different conclusions from Walster (9,55,68,69,70,71,72,73). The research indicated that there were far more factors playing a role than had appeared in the first studies, and proposed an explanation (74) in terms of a model of causation first proposed by Heider (35). Heider described a hierarchy of five levels of causality which can be adopted to reflect five levels of responsibility. The levels, with Shaw and Sulzer's adaptations (74) in brackets, are shown below:

1. Association (global association). Contextually close events are seen as causally linked so that a person who happens to be present at the time is regarded as responsible - guilt by association. The boss of a company or the leader of a country is held responsible at this level for all that happens therein.

2. Commission (extended commission). This requires a causal mechanism to link the action or event and the outcome. A person influential in producing an effect is held to be responsible for all results of their acts even if the outcomes are not foreseeable and is responsible for them even if no motive exists. An example at this level might be a child who finds an old gun, and, not knowing it to be loaded, points it at a friend and pulls the trigger.

3. Foreseeability (careless commission). This requires the causal link to have been foreseeable. A person would be held to be responsible for foreseeable consequences or effects of their actions, even if these were not intended. The father who left the gun in the previous example in an accessible cupboard where the child could find it may be responsible at this level. Foreseeability is also a test criterion in cases of manslaughter and causing death by reckless driving, and in cases of accidents at unguarded machinery under UK legislation (5).

4. Intentionality (purposive commission). This requires proof that the action was not only foreseeable but was also intended to produce its results. A person would be responsible at this level for any effects of actions which were both foreseen and intended. Both these elements must be present to prove murder. Motives are central at this level.

5. Justification (justified commission). Here the test of societal approval is added to all of the previous ones. Thus, a person responsible for an effect intentionally produced is exonerated from blame if the circumstances were such that most people would have acted similarly. This level may be invoked in approving actions which would otherwise attract severe punishment, such as killing in war or in the role of an executioner. The responsibility is passed up to the society which sanctioned the act. An example from the safety world is the 'sleeping policeman', the sharp hump in the road in residential areas which, if taken at speed can damage the car, but is justified on the grounds that this is a lesser evil than hitting a child at speed, who may be playing in the street.

Although intended originally as a basis for socio-legal attributions, a number of psychological studies have presented subjects with behaviours representing Heider's five levels of behaviour (74,75,76,77).

Shaw & Sulzer (74) showed that Heider's five levels corresponded with individuals' attributions of personal responsibility to actors in various situations. The higher the level of the description in the hierarchy up to level four, the greater was the personal responsibility allocated, with a slight reduction at level five. They suggested that levels 4 and 5 should therefore be reversed in Heider's sequence. Schroeder and Linder (71) showed that information about previous accidents involving the person in the description strongly influenced attribution to personal responsibility and acted as a test for foreseeability. The studies also showed an interaction effect between Heider's levels and seriousness of outcome. The more serious the consequences, the more personal responsibility was attributed for actions seen as foreseeable, intended or justified. Heider's hierarchy, or at least its first four levels seems to correspond with a scale of blame in people's minds (72). As each piece of information is added they become more ready to attribute responsibility to the person involved.

Vidmar & Crinklaw (9) concluded that the seriousness of the outcome of an accident acted as a stimulus to people to need to attribute responsibility somewhere. It made the event more salient and demanding of explanation (1,41,78,79,80). Once the desire to explain is engaged, evidence about foreseeability and control is important in determining where attributions are made, as are ideas of the role that people are expected to play (73,81). The defensive attribution which Walster (67) first postulated only seems to occur in a few cases where particular conditions of foreseeability are met.

Again it has to be said that the lack of conclusiveness of much of the research can be traced back to failures to define clearly the predictions of the hypothesis. If I am faced with explaining an accident which has happened to someone else, and wish to convince myself that it could not happen to me (the hypothesis of defensive attribution), the bias I introduce into my attribution will depend on circumstances. If I believe I shall never be faced with the situation in which the accident happened, it does not matter whether I blame victim or circumstances. If the circumstances are ones I could meet I need to blame the victim to reassure myself. If the victim appears at first to be like me, I either need to find evidence of a difference I can blame, or I need to go back and blame a feature of the circumstances which I feel I can control, or which will not be likely to happen again. No study has investigated all of those factors adequately in one research design in order to demonstrate conclusively whether such defensive attribution really does occur and to what extent.

6.5 DISCUSSION AND CONCLUSIONS

The evidence from the last two sections is far from clear cut, even when many of the inconclusive research studies are left out of the description. We also need to place the conclusions in context. The vast majority of the studies we have reviewed are attempts to get subjects (usually students) to assign responsibility for events after the fact - for example, to assign blame for past accidents. There has been very little study of the assignment of responsibility before the event, for taking action to remove hazards before they turn into accidents. Fischhoff (82) has shown that hindsight is always more clear-sighted than foresight. People find it easier to assign causes after the event than to predict them before it. It is likely that this applies also to responsibility.

Nevertheless at least three important features emerge:

1. When people are looking at their own behaviour they are biased towards believing that they can exercise control, and seem to take great (even too great) responsibility on themselves to act to control the situation and to prevent future accidents.

2. When people have personally suffered an accident, on the other hand, they are inclined to attribute it more to the force of external circumstances than to personal responsibility. However, they cope with the aftermath of injury better if they accept their own responsibility for it.

There is obviously feedback between these two features. Past accidents will affect the feeling of control and of ability to prevent possible future ones. If we wish to influence behaviour, attention needs to be focussed on the elements in the past accidents which were really controllable, and on the changes in behaviour which will bring them under control.

3. When people observe others' behaviour they grossly underestimate the effect that the situation has on determining it; hence they blame others unfairly for their accidents, and overestimate the control that they have over what they do. This can lead to a reluctance to intervene in situations to warn, instruct or help people (Section 6.3.5).

This chapter has explored the complexities of the allocation of responsibility both for actions to control danger, and for the consequences which arise from accidents and ill health. The discussion has been confined to a psychological level in order to explore the biases which creep into the process. This concentration on the circumstances in which judgments go wrong may have left an impression that people are very poor at making such judgments in all circumstances. It is important to emphasise that the biases only arise when there is some ambiguity in a situation which allows for more than one interpretation. Such occasions are most frequent in rapidly changing situations, and when people are trying with hindsight to reconstruct an accident of which they may have been a witness or about which they have merely heard reports.

In such situations the three biases mentioned above apply. If they are put together they go some way towards explaining the inactivity in accident prevention in a number of situations. Designers, who are usually considering hazards to others (the users of their products, machines or buildings), tend to think that the users can look after themselves, and so they, as designers, need not make special efforts to build in safeguards. Supervisors (as in Abeytunga's study, 10) place the onus for avoiding accidents on the contractors and workforce, and not on themselves; while their bosses think that it is the supervisors' job and so shuffle off their own responsibility for the climate of rules and priorities which they create. Both groups are subject to the third bias. If managers and designers sit round a table with workers from the shop floor who are talking about their own accidents (and so are subject to the first two biases), a great measure of agreement is possible. Both sides will agree that the main onus lies on the worker to prevent accidents. However, this agreement does not lead to any action, as both sides will also tend to believe that everything is under control and nothing needs to be done.

The above description may give too much of a caricatured picture of the true situation. Where danger is obvious or great this false sense of security is not likely to have much effect on behaviour, and everyone will be more likely to accept their appropriate responsibilities. It is only in situations of low, or less obvious hazard that the gaps will begin to appear. Butler & Jones (83) found this in studying accidents in naval units. In high hazard conditions the leadership style (acceptance of responsibility) of the supervisory ranks made no difference to accident rate; in lower hazard conditions the role of the supervisor, and the way in which responsibility was allocated and accepted was much more important in differentiating between high and low accident units. Feelings that hazards are marginal places special importance on the need to reinforce responsibilities actively.

The importance of considering the question of responsibility is shown by the studies we have reviewed, but the amount and type of research evidence available is still far short of what is needed to draw useful and complete conclusions. Too much has been confined to the artificial questions of uninvolved people (students) making judgments about hypothetical situations. The precise nature of the responsibility to be assessed, and the situation in which it is to apply have not been well enough controlled, nor whether the individual making the judgment is to do so from the point of view of the potential victim or that of a neutral observer, from the frame of reference of assessing cause and effect, or of allocating moral or legal responsibility. Much more research at the individual level of judgment is needed.

In view of the size of the difference in responsibility attribution between 'actors' and 'observers', more research needs to be done on that topic. There is an interaction here with the question of responsibility for one's own versus others' safety. Anecdotal evidence can be quoted of supervisors and group leaders who have placed their charges' safety well above that of themselves, and have endangered their own lives to save them from imminent or future harm. Presumably such altruistic motives in some form also play a role in the career choices of some of those who become safety representatives, safety practitioners or labour inspectors, often at the sacrifice of a high salary, or the cost of incurring social disapproval from colleagues with whom they must work. Individuals in such positions may be willing to sacrifice their jobs rather than accept what they consider to be unacceptable risks imposed upon others. An example is Sir Thomas Legge, who resigned as chief medical inspector to the British Factory Inspectorate in the early 1930s in protest at the government's refusal to ratify an ILO convention on lead hazards. The health and safety of others can therefore be a major motivation and responsibility which some people will accept gladly and value highly.

Other anecdotal evidence, and the 'bystander' research cited in Section 6.3.5 can equally point to cases where people place their own convenience, safety and peace of mind far above action to protect others. Little is known about when and why such different reactions occur, and whether and how those in positions of control and influence can be informed, trained or motivated to exert their control more effectively. Such questions touch the heart of self-reliance, self-regulation and mutual responsibility within society.

The rash of reforms of health and safety legislation which swept industrialised countries from the beginning of the 1970s rightly place great emphasis on allocating and defining responsibility. Legislation has begun to push more responsibilities onto those whose contribution to the harm process lies nearer its beginning (especially designers, 84). These organisational and legal issues lie outside the scope of this book, but the biases discussed here, and some of the theories and models touched on (for example, that of Heider, 34) provide a link between the two levels of analysis. Designers, managers, union leaders, judges and legislators are all also individuals subject to the same biases when thinking, talking and deciding about the way in which responsibility for health and safety should be allocated within the law. The changes in the legal definition of responsibility can also be seen to reflect changing views of individual freedom of action, the amount of control over hazards exercised by employers, employees and designers, the foreseeability of events, and the extent to which the causes of accidents and occupational diseases are to be sought only in the immediate preceding actions or events, or in the whole social, organisational and cultural system which conditions those actions. Clashes in these world views and in the way in which they influence judgments of responsibility can be traced in the debates surrounding accident compensation, product liability, introduction of works safety committees and the role of government inspectorates.

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CHAPTER 7

SAFE PLANS AND PROCEDURES

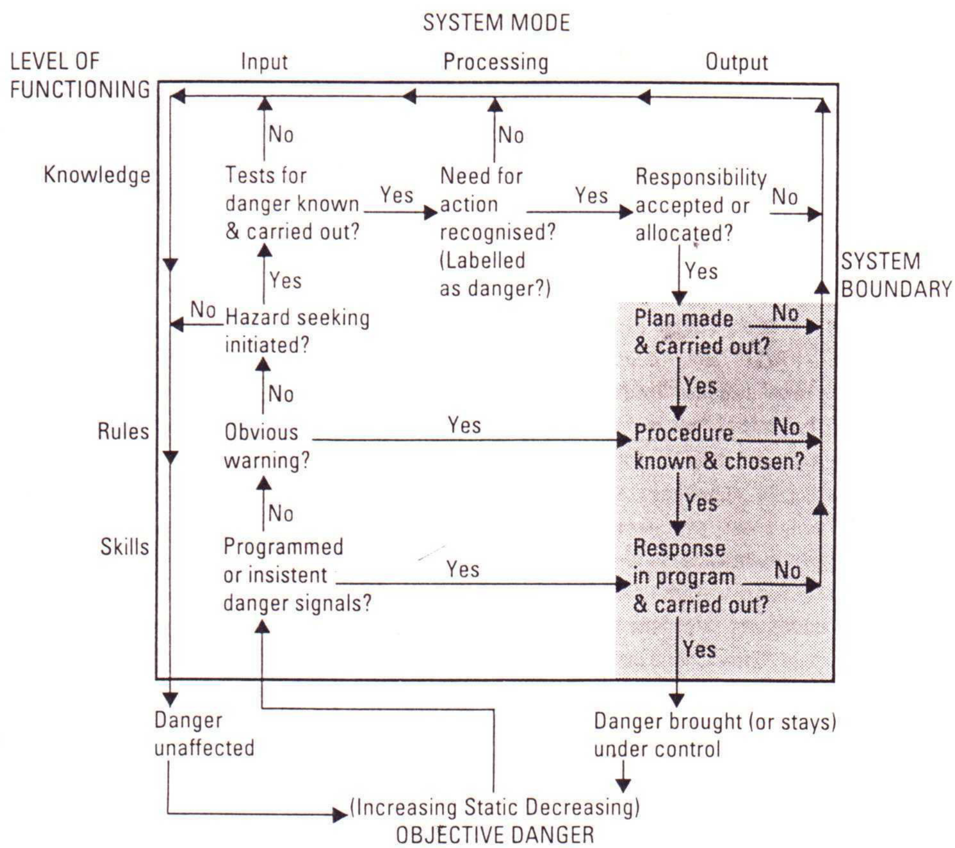

Figure 7.1. Behaviour in the face of danger model - safe plans & procedures

7.1 INTRODUCTION

This chapter completes the trio dealing with the planning and carrying out of actions against danger. We have arrived at the point where danger has been detected and assessed as important enough to try to deal with, and where responsibility for taking action has either been accepted personally or allocated to someone else. What logically remains is deciding what to do and then carrying out the action. Conceptually this is perhaps the simplest step to understand, since the preceding steps have provided all the necessary building blocks for it. There remain, therefore, comparatively fewer additional insights to discuss.

We must stress again that the three stages of assessment, allocation of responsibility and planning for action do not occur in a simple sequence, but should be seen as an iterative loop. Tentative conclusions about the presence of danger may lead to action to investigate, thence to a decision that the individual can do nothing personally to control the danger, and hence to a decision to escape from it; this is typical for behaviour in the case of fires (1). In other cases there will be attempts to control the danger, which may succeed, or at least appear to do so, and the individual will therefore consider the problem solved and turn to other things. In yet other cases the signs of danger will not be considered enough to justify any concern or action. The operation of these feedback loops tends to lead to a stepwise increase in activity as the danger is regarded as being or becoming more immininent or more serious. Such 'action thresholds' are described in a number of research studies and theories, and we shall review the evidence for how they work.

The choice of action to take depends upon an adequate diagnosis of the nature of the problem. This will depend upon the mental models, which were discussed in Chapter 4, of the causal mechanisms in the process or system which lead towards or away from harm. In addition, the knowledge and ability to solve problems will play a part in developing a good plan. In our discussions of danger in routine tasks in Chapter 3 the problem of short-circuiting the process of problem solving was discussed. People tend, in certain circumstances, to choose familiar rules and procedures as appropriate to solve a given problem without sufficient analysis as to whether the problem does indeed fit that familiar category. We shall review a number of factors which bear upon this problem, notably upon the availability of plans and procedures.

Finally there are issues of execution of the plans at the rule- and skill-based levels which complete the loop binding together all levels of behaviour. In particular we want to stress the question of coordination of activity between two or more people who are each trying to make and carry out a part of the plan.

Motivation is not discussed in detail in this chapter, despite the fact that one of the main points at which it has its effect on behaviour is in the choice of actions to take. While it is highly relevant to this chapter it also has considerable links with earlier chapters where we discussed the value attached to feelings of control and certainty, and the influence of fear and size of threat on the search for and evaluation of hazards. Therefore we have chosen to gather the discussion on the subject together and present it in a separate chapter (Chapter 10). Learning and feedback are also discussed briefly in the current chapter. They too have been mentioned in passing on many occasions already during the book, and as with motivation the threads relevant to them will be drawn together later, in Chapter 9.

7.2 ACTION THRESHOLDS

The study of construction site supervisors (2) which was described in some detail in Chapter 6, also looked at the interaction between the knowledge and perceptions of the supervisors. Figure 7.2 shows the results of the analysis.

SUPERVISORS' PERCEPTION OF RESPONSIBILITY

SUPERVISORS' KNOWLEDGE		**Recognises and accepts responsibility**		**Recognises and does not accepts responsibility**		**Not recognised, but accepts responsibility**		**Not recognised and does not accept responsiblity**		**Totals**	
		N	%	N	%	N	%	N	%	N	%
Knows Action	N	123	85%	103	49%	9	24%	32	22%	267	50%
	%	46%		39%		3%		12%		100%	
Does not know action	N	21	15%	107	51%	29	76%	114	78%	271	50%
	%	8%		39%		11%		42%		100%	
Totals	N	144	100%	210	100%	38	100%	146	100%	538	100%
	%	27%		39%		7%		27%		100%	

Figure 7.2. Hazard detection, responsibility attribution and knowledge of prevention among construction site supervisors (source 3, Abeytunga and Hale 1982).

It is clear that there is a great overlap between what the supervisor regards as his responsibility, knows how to deal with, and labels as dangerous during an inspection (the top left and bottom right hand boxes of the figure together account for about 45% of the hazards). In such a case it is difficult to know which is cause and which is effect; does he only look at things he can control? does he only learn to control things he notices? does he not bother to try and control problems for which he does not know the solution? A study such as Abeytunga's which takes a snapshot of a situation at one point in time cannot answer such questions. It is reasonable to suppose that the influences are mutual. We noted in Chapters 5 and 6 that people seek to order and regulate their world, and to find meaning in it. They seek consistency. It is likely therefore that knowledge, feelings of responsibility and distribution of attention will tend to adjust mutually until they become congruent.

In order to break out of this self-perpetuating circle of consistent beliefs something must happen to give the system a jolt. There must be an injection of new information which is sufficiently dramatic, such as the occurrence of an accident, a memo or sharp word from the boss, or new knowledge from a training course. Such an occurrence lifts the person over a threshold and initiates a new type of activity. Canter (1) and Tong (4) report this phenomenon in the initial stages of a fire, when new information coming to an individual may have apparently no effect for some time, despite the person being aware of it. At a given point enough signs that something is wrong accumulate and the person stops their normal activity and goes to investigate.

Over longer time scales the same effect can be seen. Burton and his colleagues (5) investigated people's responses to natural hazards, such as living on flood plains. They traced four characteristic responses divided by three thresholds. At the lowest level people were entirely oblivious to the threat and would deny its existence if the possibility was pointed out. At the time of the study, pollution fell into that category for the subjects (who came from a rural part of the USA). Above an awareness threshold there was no longer a denial of the possibility of the loss, but the response was entirely passive; no precautions were taken, and the planning was limited to the idea of evacuating should the disaster strike. Above the next - action - threshold, where the reality of significant loss became accepted, there were active precautions, such as installing pumps against flooding or actively campaigning for compensation. The action threshold was usually passed under the influence of recent, intense or frequent disasters (6). For some people such experience pushed them even further, beyond the final escape threshold and they packed and left the area.

Such clear cut thresholds and consistency between beliefs and actions have not been shown in all studies of natural and environmental disasters. Preston et al. (7) found that acute awareness of hazards could coexist with lack of action against them. However, this tended to be in cases where the individual was largely powerless to act. In these cases this conflict was often partly resolved by importing some other belief - for example, that science would come up with an answer in the long term - at other times the attitude was one of passive endurance.

In another area of research - health promotion - a similar idea of action thresholds has been suggested. The idea has come to be known as the Health Belief Model (8,9) and has been applied to the evaluation of health promotion programmes (10), and to the actions of departmental managers in controlling the health of their employees (11). The model puts forward a number of factors which influence the taking of action against a health threat:

- nature and severity of the eventual condition
- individual sense of susceptibility
- benefits (efficacy) of the proposed health action
- barriers to health action (physical or social side effects).

At the lowest threshold level new information may be received by individuals which changes their way of thinking about the health threat, and may result in it being rated as more serious, but without producing a change in behaviour. Baric (10) labels this the information threshold. In order to get over the next, psychological probability, threshold the individual must accept that there is a real chance of personal vulnerability (it could happen to me). This goes with a willingness to attempt to change behaviour, but still does not lead to action. The final action threshold is only breached when, in addition to belief in personal susceptibility and at least moderate severity of the disease, there comes a belief that the proposed action will indeed control the danger, and that there are no unpleasant side effects of the action. Even then action will usually not be triggered until some specific cue arrives, such as the death of a friend from lung cancer, a media campaign, or a visit to the doctor. Different individuals will pass the thresholds at different points, depending on personality factors such as anxiety level (12). Beliefs that the consequences of the threat can be very serious may cancel out some concern about side effects, but the theory claims that the order in which the thresholds present themselves remains the same for most people. This model is one which has received widespread credence in health promotion circles.

If the idea of action thresholds is attractively simple, it must not be allowed to conceal the fact that the range of actions that are appropriate to any given health hazard can be large, and that different thresholds, triggered by different information may influence each type of action. For example, Merriman (13), in discussing smoking and health points to the enormous difference between the actions of a non-smoker trying a first cigarette, of a smoker refusing a cigarette when offered, or deciding to give up smoking, or restarting after a period of non-smoking. The individuals in those circumstances have very different learned habits or action plans; a smoker may automatically light up when a cup of coffee is put in front of him or her, and must actively inhibit that plan, which a non-smoker does not have. The smoker may decide at a knowledge based level to give up, but not have the skill or awareness to refuse a cigarette from a friend (at the rule-based level). The (young) non-smoker may not have the information at the knowledge-based level to assess the consequences of starting to smoke. And for each person the weight attached to the different outcomes of smoking (such as relaxation, social image, long and short term health and fitness, effect on taste and smell) will vary considerably.

7.3 HEURISTICS, PROCEDURES AND PROBLEM SOLVING

The idea of thresholds at which behaviour suddenly changes quite markedly is also to be found in the literature about problem solving. We saw in Chapter 5 that the way in which people process information and try to make sense of it leads them to adopt particular frames of reference into which they try to fit the evidence before them, even doing minor violence to that evidence in order to make it fit the frame. Collection and evaluation of evidence is guided by the hypothesis which is governing that frame, and people will continue to use that hypothesis to guide their behaviour until they become aware that it can no longer be made to fit. At that point there may come a reevaluation of the evidence and, with hardly any new information, the behaviour will alter sharply.

Such a large effect from a small change in the environment is reminiscent of 'catastrophe theory' in mathematics which has been used to model sudden changes in apparently stable systems (as with earthquakes and volcanic eruptions).

The classic experiment in this area of problem solving was carried out by Luchins (14). He gave students a series of problems of the same form: how would they draw a given quantity of water as efficiently as possible from a well given three water jars of differing sizes. Figure 7.3 gives an extract of 16 such problems from the experiment. Before going further the reader should try to solve the series of questions, which all have the same structure. The size of the three jars in each problem is given in columns 1, 2 and 3, the amount to be drawn in the final column. Thus, in the first problem 99 litres must be drawn as efficiently as possible using jars of 14, 163 and 25 litres.

		JARS		
Problem	**1**	**2**	**3**	**Obtain**
A	14	163	25	99
B	18	43	10	5
C	9	42	6	21
D	20	59	4	31
E	13	83	28	14
F	56	90	12	10
G	43	93	20	10
H	8	61	6	41
I	24	52	3	22
J	19	42	3	17
K	23	49	3	20
L	15	39	3	18
M	18	48	4	22
N	14	36	8	6
O	19	42	4	15

Figure 7.3. Luchins' Water Jar Problem

The solution to the first problem is to fill the largest (163 lit) jar (2) from the well, measure 25 lit out of that jar into jar 3 and pour that back into the well, pour another 25 lit into jar 3 and 14 lit into jar 1. What is left in jar 2 is then the correct quantity (99 lit). The same procedure works for all the rest of the series of problems. What was not noticed by most of Luchins' students was that, as from problem K, there is also an easier solution which only involves using two of the jars in each case. Once a satisfactory plan for solving the problem type had been found, it was very resistant to change, and as a result behaviour was suboptimal. General warnings to look out for such blinkering had little effect, but more specific indications that there were more ways to solve the problem than one produced some reduction in those caught out by the experiment. In defence of the subjects it could be argued that their strategy was quite efficient when considering the experiment as a whole, since they could proceed rapidly with a tried and true solution, delegated to the skill-based level of functioning, without spending time monitoring their actions, or searching for better solutions.

A series of studies of airline pilot judgement (15,16,17) revealed a similar problem of not breaking a chain of reasoning despite the fact that it was leading nowhere in solving a situation. They traced such judgement chains in a number of accident investigations and incident reports, and reported a funnelling effect; as time became shorter and shorter to correct the problem, it became harder to break out of the set and go back on the initial poor decision. The researchers tried to relate the effect to personality factors such as attitude to rules, impulsivity, macho attitudes, feelings of invulnerability or of external control, and thence to personality tests, but they had only limited success. Risk analysts have seized upon this inverse relationship between time and fixation on incorrect diagnosis and have drawn the conclusion that the time available for a decision is the only important factor which will determine the probability of it being taken correctly (18). This is a gross oversimplification of the situation (19), since mental models, and the quality of disconfirming information available will also have a strong effect.

Ability to break perceptual set, and to adapt behaviour to the real situation rather than to a rule-bound representation of it has also been studied in the road traffic situation. Wilson and Greensmith (20) report that accident free motorists who nevertheless do a high mileage adapt their behaviour much more to changing driving conditions than do those with a higher accident rate. Quenault (21) described two groups of high accident drivers as 'dissociated' (one active, the other passive) based upon their lack of use of the driving mirror and other observations to keep abreast of changes in road and traffic conditions. The passive group differed from the active only in that they did not overtake other traffic much; both groups were involved in more accidents and close encounters than drivers whose interaction with the environment was more adaptive. Such descriptions are also reminiscent of the operators in the nuclear and process industries who carried on using procedures to control what they thought was the problem, even in the face of contradictory evidence (see Chapter 3, 22).

In all these cases control of behaviour is captured by an inappropriate rule, which then resists evidence to dislodge it. The solution finds the problem rather than vice versa. Experiments point to the need to learn not just the knowledge which is needed to solve a problem, but the techniques which will assist in putting that knowledge together in the most efficient way, and in particular in breaking out of previously promising approaches which have turned into blind alleys. Studies in the chemical and nuclear industries show the need for and effectiveness of such training programmes (23,24,25). Teaching of problem solving heuristics (ways of arriving at solutions by successive approximations) in addition to thorough knowledge of the plant produce far better diagnosis of novel faults than does plant knowledge alone. The heuristics help the operators plot their path through the cause-effect pathways from the symptoms facing them to the underlying cause of the fault. The difficulty of using plant knowledge alone was found to be that operators tended to reason in the opposite direction, from plant design and operation to symptoms. As a result they would either discover that their hypothesis did not match the symptoms, and have to start again, or they would sometimes fail to notice that some symptoms did not fit, because they became fixated on those that did.

Perceptual set, or what De Bono (26) calls monorail thinking may be the most prevalent problem in problem solving, but its opposite is also reported (27). This involves very rapid changes in hypothesis, which may be associated with discovering that a cherished hypothesis is after all wrong. The changes may be so rapid, and the subsequent analysis so poor that a very bad decision is taken, ignoring factors which had been perfectly well recognised in the assessment of the earlier hypothesis. Reason calls this 'vagabonding', and suggests that it may occur in some people under time stress.

Reason (22,27) discusses the opportunities offered by information technology for using intelligent decision aids in the form of expert systems to support problem solving activity in the process industry, where delay in diagnosing faults can have catastrophic results. He suggests, for example, the development of systems which can be interrogated by the operators based upon their own hypotheses, which the system could then compare with the ones predicted by theory in order to highlight the need for breaking set.

Such developments are a radical departure from the situation in which operators were placed before a sharp dichotomy; either there was a fixed procedure laid down for the specific problem which they could (or more normally were required to) use, or they were on their own with no assistance apart from their knowledge, experience and creativity, because the particular problem had not been predicted or analysed. These two contrasting approaches have traditionally distinguished the approach to safety in two types of task.

1 In routine and repetitive tasks it would seem reasonable to expect that the best way of carrying out the task should be worked out in order to act as a basis for training and day to day action. Generations of work study and methods engineers have operated on that assumption since the tenets of 'scientific management' were formulated in the early twentieth century by Taylor (28) and the Gilbreths (29). However, as they rapidly learned, gaining acceptance from the operator that this 'one correct way' was indeed to be learned and always used was quite another thing. Any field study of work methods shows differences with what is laid down in the job sheets or procedures manuals. These will be described by the operators as improvements they have made on the standard method to make it easier, quicker or more convenient (even safer). Seminara and Smith (30,31) for example, give copious illustrations of improvements made by control room operators in nuclear power plants which were discovered in surveys after the Three Mile Island incident. There are always several ways of carrying out any task, which are only more or less appropriate rather than clearly right or wrong. People carrying out a task will adapt and

modify how they do it until they feel comfortable with it. Even then there will still be variation from time to time to accommodate tired muscles, adjust to small changes in the task and the environment in which it is done, or simply to introduce a little variety. Even in repetitive tasks the operator does, and wants to exercise some creativity. The question must therefore arise as to how to avoid that creativity being used to embark on a course of action which is unsafe.

2. In non-routine tasks it is very difficult, but still possible with the expenditure of considerable time and resources, to analyse tasks and to lay down a 'best' procedure. But the analyses are limited to a defined set of credible potential situations, and there are always situations which go beyond the design base of the system for which the operator must improvise a course of action (32,33). The result of such detailed analyses is to be found in thick books of standard procedures or more recently in the form of computer information retrieval systems. In both cases there is a trade-off between the completeness of the information, and hence its bulk, and its accessibility and hence its usability by operators. The factor of effort to remember or to look up the 'right procedure' may thus play a role, alongside the need for variety and the fascination of solving a problem for oneself, in making operators rely frequently on their own reasoning rather than bothering to operate by the rules.

In all these cases the handling of the transition between the defined 'correct' way and the use of the operator's creativity to modify that method is crucial. It suggests that it is as important to teach operators about the limits within which modification of laid-down 'best' methods is safe or acceptable, and about the factors to take account of in modifying their actions, as it is to drill them in the 'one correct way', unless one of two conditions can be guaranteed. Either that no adaptation will be necessary or appropriate (a situation only likely to occur in the most routine of tasks); or that supervision is always on hand to enforce compliance and to cope with deviations, should they occur. This is a recognition that behaviour is, and m be a dynamic thing, which changes and adapts, and that it is better to recognise and to harness the forces which produce the change than to ignore or rigidly oppose them. It also points to the central role of the ultimate user or operator in deciding what procedures and work methods are used. Designers or managers who try to impose from above how a machine, tool or process must be used, or who do not take account of the user's likely modifications are laying a trap both for themselves and for the user.

7.4 AVAILABILITY OF PLANS

The previous discussion has shown that plans which are available in the repertoire can capture the control of behaviour, and so shortcut the necessary problem solving and planning process. This concept has already been discussed in Chapters 3 and 5 when we described the effects of availability of information and plans at the knowledge- and rule-based levels, and the greater availability of a particular 'strong habit' at the skill-based level which could hijack a plan during its execution. In this section we summarise a number of factors which affect that availability.

Physical proximity is an obvious form of availability. Winsemius (34) found in his studies of machine operators and craftsmen that he could trace the origin of a number of accidents to use of the wrong tool for a task. Many of these tasks were not part of the normal job, but were required to recover from some minor deviation, such as something getting jammed in the machine, or about to slip off the table etc. When this happened the person picked up the nearest handy item to put things right; for example, a chisel instead of a hammer to free a stuck component, or an oily rag to catch a falling red hot object. It was not just a question of physical, but also of psychological proximity; people would sometimes pass over a conveniently placed item which was seldom used in the normal task in favour of a less suitable one which was frequently used.

Availability can be social. People adopt much of their behaviour by copying from others; this is particularly so in childhood, but carries on throughout adult life. The training technique of 'sitting by Nellie' (watching an experienced operator and copying what they do) is based on this concept. In Chapter 10, where we discuss motivation, we shall return to this social control of behaviour in more detail. One example will suffice here. Svenson (35) noted that drivers and pedestrians at intersections were inclined to copy the behaviour of others even when it was specifically against the rules; for example, driving or walking across a road against a red light. A large group might be waiting until one person broke the rule, at which point most if not all would follow.

Availability can be a question of memory, of the strong habit muscling its way to the forefront and jostling the correct plan out of the way. It can also be that people think that they have learned a skill, but in fact have not learned it well enough, or have not used it recently enough to carry it out faultlessly when called upon. In such a case, the memory tends to set to work to reconstruct the plan from what is left, plus default values of what might be expected to be done. The person may be unaware just how much of what is being 'recalled' is in fact a reconstruction, and thereby may make many errors. Knowing what to do in theory and being able to do it adequately are poles apart as any tennis player knows the Saturday after the Wimbledon final. This problem arises particularly when the actions to control danger are only undertaken intermittently or rarely compared with the actions necessary for the normal running of the system. This means that they may be less practised and so less available to be called up when wanted, or may be in a rather decayed state when retrieved. As an example we quote a study of users of self-contained breathing apparatus (36). They are instructed to fit the mask of the apparatus and to test it before entering the danger area. The survey of users in industry found a large proportion who did not know how to carry out this apparently simple sounding instruction. In particular they had either never been taught, or could not recall the 'face seal leakage test' as a formal skill.

In some tasks the rhythm of the actions is critical and/or they must be synchronised with the actions of someone else or of a machine. Cardiopulmonary rescusitation is a classic safety-related skill which relies crucially on synchronisation. Heart compressions must be well timed and correctly interspersed with lung inflations. This is the most difficult technical aspect of the skill to learn and to retain. Studies of the decay of CPR skills following training (37) show that for half the trainees this part of the skill is no longer available after four months. The same research showed that the monitoring checks (of pulse and breathing) in the skill sequence were also subject to loss over time. This is in line with research on skill retention (38) which shows that memory of the order in which actions must be done is more subject to decay than memory of the actions themselves (see also Chapter 3).

In cases where the skill which is needed is not available, two things can happen:

1. If people overestimate their ability and think the skill is there when it is not, reality may catch up with the overconfidence with the result that there is an accident. In an experiment with a risk simulator (39,40) a machine feeding task was simulated with an electric shock being given if the hand was in the way of the 'tools' after placing the component. Subjects could choose the speed of machine, and got increasing reward from succesfully placed components the faster it went. The experiments found that the level of risk which appertained to a subject was determined by how good the subject was at estimating their skill at placing the component. Those who overestimated their skills had more accidents.

2. If on the other hand people know that they do not have the necessary plan or skill available to do anything, they will usually just carry on as they were or try to cope using old plans. Tong (4) found this inertia, or conservatism in the behaviour of people in fires, where he found that they would, either stay put or try to use known exits from a shop or building rather than the ones which were closest. The opposite, 'radical' response, namely panic, was very rarely found in fires analysed by any researchers (1).

7.5 WEIGHING PROS AND CONS

Where more than one plan of action is available in given circumstances a choice has to be made. We have already said that the relative availability and frequency of use of a plan will have a major influence in both skill- and rule-based behaviour. Where the choice of behaviour is more conscious the process involves a more specific assessment of the action plans against the criteria which are thought to be relevant at that moment. These will be the motives or objectives which the person is trying to achieve. We shall deal in Chapter 10 in detail with this process and how it can be influenced. Here it is sufficient to say that any course of action will have many outcomes, both short- and long-term, producing both positive advantages and negative drawbacks in relation to the relevant goals. The goals which are relevant will also differ between individuals in any given situation, and, to a somewhat lesser extent within one individual at different times. The scope for individual differences in response is therefore considerable. It must also not be expected that the weighing process is either complete or unbiased. It will not always be easy to predict in advance the ramifications of a given course of action, and individuals therefore adopt strategies of bounded rationality (Chapter 5) to simplify the decision. Different objectives in the same individual may also be in conflict (I may be both ambitious for money and lazy). In particular, where health and safety are concerned, very powerful motives such as fear and need for control may be evoked, which upset the smooth rational flow of decision making.

The end result of this complex decision process is the selection of one potential course of action, which will be set in motion. In the next section we look at how that initial decision is monitored and if necessary, corrected.

7.6 MONITORING AND FEEDBACK

Whether a given course of action will lead to control of the danger present will depend not only on whether the correct one is picked and available, and not usurped by another more readily available; it also depends on the action being monitored and correctly adjusted to achieve its purpose. We

shall discuss short term monitoring here, and return to the longer term monitoring procedures in Chapter 9.
Clearly, if the action has been learned wrongly it will not achieve the desired result, unless the error is picked up and corrected. This initial fault in the plan may have been built in at the stage when it was learned through, for example, an incorrect mental model of the harm process (see Chapter 4). The monitoring process requires the expenditure of some of the scarce resources of attention (see Chapter 3), and it will not always work effectively if the discrepancy between intent and outcome is (initially at least) hard to discern. If the harm process occurs slowly the error in the mental model may not be detectable until too late. An example of these problems can be found in research on manual handling. In much training in handling the instruction 'keep the back straight and bend the knees when lifting' is taught. The general correctness of this instruction can be questioned (41), but even in the cases where it is correct, the question must be asked whether it is understandable. Mason carried out a small survey asking people to draw a figure which had a straight back compared to one which did not. Broadly the figures fell into either pair A or pair B in Figure 7.4. In other words some interpreted straight as meaning erect, while others (correctly) interpreted it as the opposite of curved.

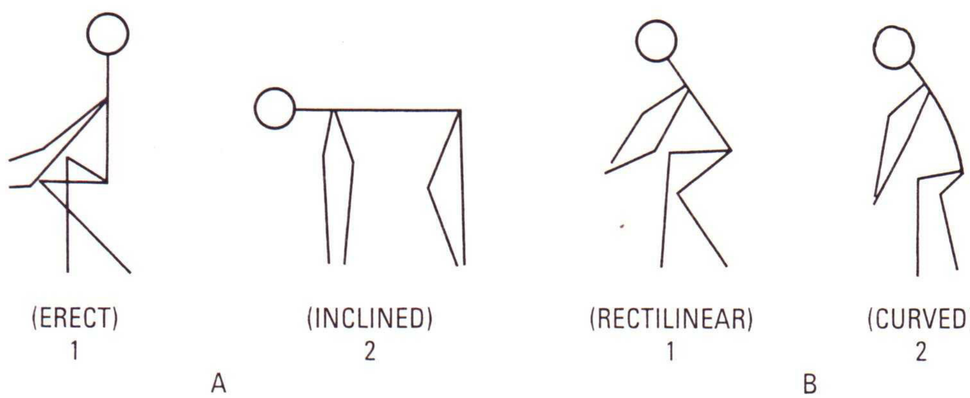

Figure 7.4. Interpretations of 'straight' back (source 42, Mason & Hale 1980)

Those with the incorrect interpretation could monitor their behaviour to their heart's content, thinking that all was well for many years before the effects of the poor posture would begin to have an effect. However, the situation in this case is worse still because the same research shows that people are very poor at monitoring posture in any case. In part of his research Mason showed people videos of themselves lifting, in order to demonstrate to them the problems they had. Many expressed extreme surprise at what they saw, and claimed that it was not at all what they thought they did and not what they intended to do. Here the problem was in understanding how to translate intention into a set of joint and muscle movements. The difficulty appeared to lie to a great extent in the lack of conscious awareness that people had of their posture. Hence there was no direct way of modifying that posture to translate an intellectual grasp of a new handling technique into postural reality. This can only be overcome by practice, with good external feedback of the results of the practice (for example, by use of videos) so that the person can monitor improvements and detect remaining inadequacies.

Monitoring requires a clear definition of what is adequate performance of either a step in an action sequence, a plan or rule, or a sequence designed to solve a problem. Where there are any ambiguities in the formulation of the 'test' in the sequence deviations, which are leading into danger can go undetected. Just as ambiguity over 'straight' causes problems at the skill-based level in handling, so can the wording of rules or laws cause problems at the other levels. Hale (43) pointed out the need for monitoring which is inherent in the wording of many sections of the British health and safety law and regulations. Such documents are scattered with words such as 'adequate', 'satisfactory', 'so far as is reasonably practicable', 'sound construction', and 'clean'. All of these imply points on a scale representing objectives to be achieved, and in each case those responsible for achieving them must know how to recognise and achieve that point. For example, does 'clean' mean it must be swept with a broom, washed with strong disinfectant or heated in a sterile atmosphere?

7.7 COORDINATION ERRORS

In all the chapters in the book so far we have been dealing implicitly with people as individuals, ignoring the fact that many of the tasks they have to do are cooperative ones. The task or action of one person must often come at the right point in a sequence which involves the actions of other people. Other actions require closer, coordinated action - for example, a two-person lifting task. Up to a point it is possible to analyse the errors that the different parties make as though they were acting independently, and simply responding to the actions of each other in the same way as to any other piece of information to be perceived and processed. Production line tasks generally fall into this category, although ergonomists (44,45,46) point out that even here the interactions can result in particular blackspots for accidents.

Where two or more people are engaged on sequential tasks which they must share and still get in the right order the problems become greater. Such tasks are typical of repair and maintenance activities where a piece of plant or machinery has to be isolated and made safe (47). They are also typical of monitoring checks, such as an aircraft preflight check. In these cases particular precautions have to be taken by the use of checklists, positive feedback of completed items, and permit to work schemes, to ensure that tasks do not get out of sequence or left out. There are some activities where even an extra thorough analysis resting on the principles discussed in earlier chapters still underplays the complexity of the situation. These are the situations where one person's behaviour affects another so rapidly that there is no time to react to it; it must be anticipated. Traffic and driving are examples where anticipation of the action of others is at a premium. Despite warnings from countless road safety campaigns to drive within one's stopping distance to allow for unexpected behaviour from other road users, driving in modern town traffic is hardly possible unless such advice is ignored. Every driver must make assumptions about what other road users are likely to do and plan and act accordingly. The alternative would be to slow down the pace of driving to something which is regarded as unacceptably low. Under such rapidly changing circumstances, accidents can be largely defined as breakdowns in communication between the different participants in the road system (48); in instances where someone does not stick to the expected rule, an accident becomes almost inevitable. This puts a premium on improving both communication of intentions and the accuracy of expectations about behaviour of all elements in the system.

At a more mundane level the combined lifting of one item by two or more people shares this need for clear communication and planning before the task is undertaken, and of clear signals to keep the actions synchronised.

7.8 CONCLUSIONS AND PREVENTIVE ACTIONS

Most of the issues raised in this chapter have found echoes in earlier chapters, or will be taken up again in later ones. The importance of frames of reference in confining problem solving into rigid and sometimes inappropriate blinkers has been stressed, as has the need for training and decision support in breaking out of that strait jacket. This is needed to avoid problems being passed too quickly from the knowledge- to the rule-based level before a good overall plan has been made. On the other hand problems can arise when the desired plans and rules are not available enough, for example in emergencies. Finally, coordination and monitoring of the progress of action sequences and plans is needed to keep them in line with both short term goals (is the sequence running properly?) and longer term ones (is the plan resulting in danger being controlled?).

The standard techniques used to overcome these problems are listed briefly below:

1. Training in problem-solving techniques, and deliberate attempts to 'break set' when faced with a problem. This can be done, for example by introduction of a new person into the situation who does not share the assumptions and prejudices of those deeply involved. Alternatively the set breaking can be given to an 'expert system'. Such ideas have been discussed in the nuclear industry as aids to solving diagnostic problems (22).

2. 'Overlearning' and the use of refresher training to increase availability of rarely needed plans. Overlearning is the continuation of practice beyond the point at which the person consistently gets the task correct. Early research on learning showed that such an expenditure of time was not a sterile exercise, but that the skill became gradually more deeply embedded and resistant to forgetting. Refresher training is simply another name for practice given with feedback of results to halt the decay of skill. Where the skill to be practiced is the response to emergencies the only way in which it can be safely given is in a simulated situation (4,49).

3. Checklists and standardised permit-to-work forms are two typical aide memoires to overcome the problem of forgetting a step in a long list of actions. They take the list of action steps (TOTE, see Chapter 3) out of the memory and place them on a sheet of paper where the test before exiting is recorded by a tick against each item. The activity is then less sensitive to interruption provided always that the sequence is only broken at the point after a successful test has been recorded, and not between the test and placing the tick.

4. Design and layout of the system in which people are working has a vital role which was stressed in Chapter 3 where we dealt with danger in routine tasks. The conclusion was that the world must live up to the expectations of it that people have built into their plans and action sequences.

5. Motivation will be dealt with in Chapter 10. The weight given by individuals to different goals may be hard to alter, except through long-term training, education and media propaganda, but it is often possible to introduce extra rewards or punishments to alter the balance in favour of particular (safe) courses of action.

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PART I

AFTERWORD

The previous five chapters have presented our model of individual behaviour in the face of danger and have used it to give a structured discussion of a large body of research which has looked at the topic from many different points of view. The emphasis in our discussion has been upon the way in which people process information and arrive at action decisions which either consciously, or more often unconsciously, influence their health and safety. We have taken an approach which has emphasised human cognitive functions, and the way in which danger is understood. So far our discussion has only touched in passing on the emotional aspects of human behaviour. Words such as motivation, fear, self-preservation, and risk-taking have not been central to our discussions. The result has been that the tone of the book has been rather rational, analytical and dry and has not represented the full diversity and complexity of real life behaviour. We have implied that people pursue goals in a systematic, if not logical manner, but we have not discussed what those goals are, nor where they come from.

The reason for the comparative neglect of these subjects up to this point is not because they are unimportant. The volume of text in the social sciences, let alone in literature, philosophy and religion, consecrated to motivation and the purpose which people strive to achieve is alone enough to show their central place in explaining and predicting behaviour in any sphere. We also referred in our introductory chapter to the almost reflex association in the mind of many people in industry between safety and motivation. The reason that the subject has not received specific attention in any one chapter in Part I is that it pervades the whole model. It is the motor which drives it, and which therefore has an influence at each stage; it affects whether people have time to look out for hazards, whether they accept high-hazard jobs, whether they take safety precautions or risks, whether they see it as their job to point out to others that they are behaving dangerously, and whether they monitor the routine task they are doing. To treat motivation as a subject under any one chapter would have distorted what we wanted to say about it. It therefore seemed better to collect all that needed to be said under one chapter. Since an understanding of a 'motor' allows one to influence it, and so to alter behaviour, it also seemed better to hold the discussion of motivation over until Part II of the book where our focus shifts to influencing behaviour.

We have also concentrated on the static presentation of the model in Part I. It is true that mention has been made at intervals of feedback loops, and of the role of learning in developing mental models, expectations and skills. However, these topics have also not received any detailed discussion. Again the reason is that they pervade and underlie the whole model. All behaviour must be learned, or modified from the potential with which people are born. That process of learning goes on very rapidly in the early years of life, and may slow down considerably in middle and old age, but it can never really be said to cease. The behaviour of an individual on one day is a good predictor of how that individual will behave in a similar situation to the following week, but it is far from a perfect one. By definition, therefore, learning is a process by which behaviour can be influenced, and we shall deal with it as such in Part II. The two topics of learning and motivation also interact fundamentally; without motivation there is little or no learning.

We must also stress, in conclusion that the behaviour we have talked about in Part I is not the only influence upon the increase or decrease of the level of danger in a situation. Behaviour intended and suitable to decrease danger may not result in the decrease if the dynamics of the danger process are already too far out of control. Other individuals, and other physical forces also have their influence in a complex interplay. The human being thus sits as powerful but not omnipotent in the driving seat. In Part II we shall turn to look at ways in which the behaviour of the driver can be influenced.

CHAPTER 8

GENERAL PRINCIPLES

8.1 INTRODUCTION

In the first part of the book we proposed a generalised model to describe the way in which people behave in the face of danger. We stressed the distinction between two types of question:

1. relating to behaviour at a routine level of operation which may lead people into or out of danger, without their being especially aware of danger as a salient feature, and

2. relating to behaviour which is consciously directed, at least in part, towards coping with danger.

Because our central focus in this book is on behaviour relevant to safety, this element has taken pride of place in our discussions. It is salutary to recall at this point that the conscious pursuit of health and safety is usually a very minor concern of the individual, which is generally only incidental to the pursuit of other goals, which may at times be in conflict with safety. Only comparatively rarely are the conscious plans mentioned in 2. above brought to the forefront of consideration.

The model we presented is incomplete. There are aspects which have received little study, and where we have only been able to speculate about how it works and what factors are relevant to it. What is more important is that our discussion so far has been largely directed at describing and, where possible, explaining behaviour. Only incidentally have questions about changing behaviour been discussed. The objectives of the theorist include analysis, understanding and prediction; the objectives of the practitioner go further. If analysis or prediction reveals a problem, the practitioner's objectives are to intervene, to modify the situation and to evaluate the intervention.

Previous chapters considered what is known about factors which influence behaviour in various situations relevant to health and safety. A legitimate response of the practitioner to such a discussion is; 'so what? What can I do to influence individual behaviour in order to reduce the number of people who suffer injury and disease at work?' In this part of the book the focus will be shifted more to such questions. We shall discuss the way in which people naturally adapt their behaviour to the presence of hazards, through feedback and learning; how their choice between different possible courses of action is influenced by motivating factors; how both of these processes can be influenced by deliberate intervention through training, and through organisation and manipulation of incentives. Finally we shall review the influences which can be brought to bear through design of the workplace and its social and procedural environment, and by selection of the people who work in it.

8.2 PRINCIPLES OF INTERVENTION

Two models were presented at the beginning of this book;

1. the accident process as a dynamic sequence of events resulting from a deviation from (or loss of control of) some normal situation (Chapter 1, p14)

2. the human as a controller able to intervene in the system by detecting potential or actual deviations and correcting them, but also able to initiate those deviations (Chapters 2-7).

Figure 8.1 presents a broad synthesis of the two models.

The normal state of affairs is represented by the control loop immediately around normal operation. Some control functions are part of the hardware, but the individual also operates to maintain normal operation, largely through skill-based behaviour. Thereafter the individual acts as a detector and corrector of deviations (1), either by restoring the original system (at a skill-, rule- or knowledge-based level), or by more intrusive redesign of the whole system at the knowledge-based level to make it inherently safer, or less susceptible to deviations.

Two axioms of prevention can be based on this model:

1. Interventions should be as early as practicable in the accident sequence, where possible preventing deviations occurring or recovering them as soon as they happen, where it is safe so to do.

2. Prevention should aim at enhancing the ability and the opportunity for the system to detect and correct its own deviations. This role may be given to the hardware, but it is often a role in which individuals can exercise very well their controller function (2,3,4).

These axioms can be compared with the following classification of four prevention strategies (5,6,7), which are generally portrayed to be in descending order of desirability, given their equal practicability:

- elimination of danger
- - isolation of danger source
- - isolation (protection) of the individual
- - injury limitation.

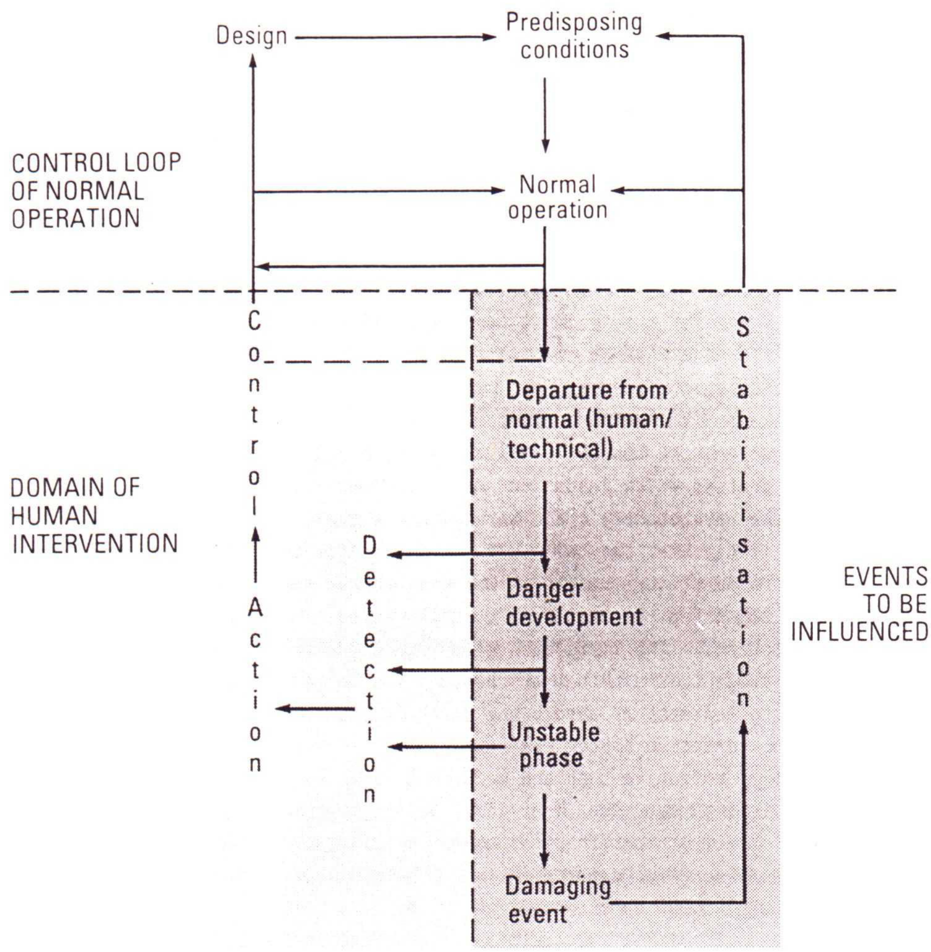

Figure 8.1. The individual as controller of the accident sequence

The earliest possible intervention in the harm process is to eliminate the source of danger so that deviations from normal operation cannot lead to harm even if they occur. Examples are substitution of 'safe', or at least safer raw materials (rock wool for asbestos, water-based for solvent based paints) or processes (pneumatic for electric drive on hand tools, low for high pressure operation in chemical plants). Such substitution often carries with it economic consequences. These substitutes are usually viewed negatively, because they involve replacement costs for the user, and retooling costs for the producer. With a rather more dynamic and long term view they frequently turn out to be positive; because the new product may have other advantages (fire-retardant PVC for mine conveyors also turned out to be much longer lasting than rubber), or because the first producer of the safer material can get into the market first, and become established before others are forced by legislation or public pressure to change. Where elimination is possible it may only solve part of the safety problem or diminish its seriousness. Deviations may still be possible and therefore need to be controlled.

Isolation of the danger source or of the individual is most often accomplished by placing barriers around either one or both. This gives too static a picture of prevention, as though hazards were wild animals which can be confined in cages, or approached while wearing a suit of armour. This analogy works to an extent for some hazards, such as noise or airborne contaminants (making a distinction between control at source (on the machine) and the use of personal protective equipment), or machinery dangers (distinguishing fixed guards for example for hot processes from the use of gloves or remote handling devices). However, the concept of physical barriers cannot handle the dynamic nature of the process which leads to many accidents or occupational diseases; for example, the way butchery trade workers wield their knives which makes it more or less likely that they will slip (deviate from the normal process) and cut the worker's hand; or the way in which a process control operator diagnoses and attempts to bring back under control an excursion in temperature in an exothermic reaction. The imposition of barriers can be seen as an intervention at the design stage to try either to prevent the danger escaping (the deviation occurring) or to redirect or absorb the energy when it does escape, and so stop it reaching the sensitive system elements - particularly people. If the barrier is not totally effective then the measure becomes one of injury limitation. Examples of this are, at the individual level, seat belts in a car, and at an organisational level limitation of exposure to radiation to a fixed extra dose per year. (See also 8 for a more detailed treatment of the 4 categories to take account of some of these criticisms).

To these concepts of elimination and of barriers we can add a series of other principles which can be derived from the model in Figure 8.1.

- increasing the predictability of the process so that deviations can be anticipated and planned for - for example, through better technical reliability, standardisation, or inherent controllability

- increasing the detectability of deviations, through such things as instrumentation, or training in hazard detection

- increasing the controllability of the process, so that deviations, once detected can be recovered - for example, influencing the system dynamics to avoid sudden failures

- increasing the confidence and competence of the operators to question the status of the system and to test out hypotheses about how it will develop in the future.

Some of the principles of prevention set out above are purely directed at the technical process (for example, elimination of hazardous materials, alteration of process dynamics, or installation of barriers). Others are directed solely at the people involved (such as training, or provision of protective clothing). Many, particularly the principles added from our model, are directed at a combination - the ability of people to control the process. Even where barriers are bolted onto the process the human element can play a role, by unbolting them again to gain access for a particular action, as in maintenance. Therefore all such prevention measures must take account of the effect they will have on human behaviour, and whether they will ultimately reduce accidents or occupational disease, or merely displace the harm to other people or to another time.

The focus of this book in general, and of this part in particular, is on the ways in which human behaviour can be influenced directly or indirectly to improve safety. Measures to increase the inherent safety of processes and systems are not discussed here, except in so far as they result in a change in the attitudes and beliefs which people hold about the safety and hence the acceptability of the technology. For such discussion the reader is referred to textbooks of technical safety (7,9,10,11).

8.3 PRINCIPLES OF BEHAVIOUR MODIFICATION

Human actions have been portrayed in our model as a reaction to, indeed as a dynamic interaction with the environment (physical, social and cultural). It follows that behaviour can be modified by directing attention to altering either the environment or the person. Such a dichotomy was labelled in the early days of occupational psychology as:

Fitting the Man to the Job (FMJ)	**v**	**Fitting the Job to the Man (FJM)**
Selection		design/layout
Training, experience		Organisational design
Motivation, supervision		Job/task/procedure design

It is a mistake to see these options as mutually exclusive alternatives. Any successful approach to prevention will combine elements from each in the attempt to arrive at a satisfactory system behaviour. In effect the activities in the right-hand column (FJM) can be seen as setting the constraints within which human variability will work, and those in the left-hand column (FMJ) as influencing the choice of behaviour which will occur within those constraints. The introduction of new technology (FJM) should always be preceded by consultation with those concerned, and accompanied by retraining (FMJ).

An important factor on which measures in the two columns can be assessed is their relative permanence. Given the variability and openness to influence of people, measures aimed primarily at them (FMJ) tend to have a shorter lifespan than design activities. It is true that organisations, jobs, and even equipment do not permanently stay the way they were designed, but the changes tend to be relatively slow. Even selection, which may appear to be a permanent 'design-type' activity, only sets broad limits to human behaviour which may change later through experience. FMJ modifications tend to require inherently more maintenance to keep them functioning adequately than do FJM ones. People need refresher training and supervision to ensure that they can and will want to continue to behave in the way which is desired. Hence, while an analysis of initial capital costs may often seem to tip the balance in favour of FMJ, an analysis of lifetime costs will often more than redress the balance in favour of design solutions (12). Most comprehensive solutions to safety problems involve a combined package of elements from both columns.

A factor which cuts across the FMJ v FJM dichotomy is that of internal v external control. Some influences on behaviour , such as specific design of equipment, staff selection, task allocation, and supervision are imposed upon the individual. The objective is to instil, in a more or less intrusive way, patterns of behaviour about which the individual has little choice. In other instances the approach is to change the person's capability or desire to control their own behaviour, in other words to improve internal control, through such actions as training, or motivation campaigns. The initial influence may come from outside the individual, but the aim is to achieve an internalisation of that behaviour, so that it requires a bare minimum of external support.

Choice is an important and complex concept in the discussion of prevention measures. Preceding chapters have indicated tasks which it is not reasonable to expect any individual to carry out safely, because task demands conflict or fall outside human capabilities. Examples are:

1. Combining rapid execution of routine tasks with detailed monitoring to look out for occasional signs of peripheral danger, for example, keeping an eye on an unreliable guard on a rivetting machine, which occasionally allows the machine to give an uncovenanted stroke while the finger is in the danger zone; this is incompatible with piece rate or quota production targets.

2. Maintenance of a high level of alertness for long periods of time during a monitoring or watch keeping task - for example, process controllers on highly reliable plants who have to intervene within a matter of minutes if something goes wrong.

3. 100% correct regular operation of a piece of equipment which does not correspond to population stereotypes of how it should operate - for example, driving a vehicle with steerable rear wheels in which the steering is connected up as though it was for the front wheels (such an arrangement means that the driver has to turn the steering wheel to the right to go to the left).

4. Consistent adoption of safe working methods which carry with them large real costs for the individual in terms of other motivations or objectives, such as a cut in piece rate earnings as a result of introduction of protective equipment which slows down production rate.

It is fruitless to seek solutions in terms of direct changes in human behaviour (influencing choice) within such design constraints. The most that can be expected in such circumstances is a minor and usually temporary improvement in safety at the cost of considerable increase in effort or loss in speed of working. Real long-term solutions must change those constraints and so create a task which is achievable and free of such conflicts. Those who persist in seeking motivational or training packages to get them out of such safety problems are at best deluding themselves with false hopes.

It is still common to see designers or managers blame the victims in the circumstances described above and to see no need for task redesign because they claim that the individual *could* have acted otherwise. This is an understandable but usually false attribution. Just because people sometimes or even usually act in the correct way is no proof that it is possible for them *always* to act correctly under those constraints. Indeed, where humans need to intervene to correct deviations of the system from normal, they *must* break with normal behaviour. It is during just such corrective actions that many accidents tend to happen (13). Managers and designers with such beliefs are, in effect, denying their own responsibility to take action and are shuffling that responsibility off onto the victim, who can often do nothing different within the constraints of the task and organisational design. They are in effect saying, as decision makers, that they are not prepared to accept the costs involved in the redesign of the tasks in return for a real improvement in safety. Discussion of the balance which should be struck between safety design costs and other safety measures is a value issue, which, while vitally important, is beyond the scope of this book. However, such a question of balance cannot even be posed while decision makers persist in a false picture of the problem, that workers could act much more safely if they chose. In this case, it is the behaviour and attitudes of the decision makers and not those of the potential victims which need to be modified.

One conclusion which must be drawn from this discussion is that it is extremely important to ask whose behaviour it is useful to try and modify. The answer can be just as frequently that of designers, supervisors, managers or safety experts as that of the person who eventually gets hurt.

8.4 STRUCTURE OF PART II

This brief discussion of general principles of prevention and of influencing behaviour has described a number of options for action. It should be clear from the discussion that the options are mutually dependent to a considerable extent. Design changes cannot be made without reviewing staff selection, instituting some training, and supervising the changeover period to provide feedback on the adequacy of the behaviour change. However, it would be too unwieldy to try to discuss all of the options in one go; therefore this part is divided up into separate chapters which consider in turn the topics listed:
1. Feedback, learning and training
2. Motivation
3. Selection
4. Design.

The subjects of learning and of motivation are particularly closely linked. No learning will usually take place without some motive having been present which the learning could satisfy. Since the two subjects are each large, an arbitrary split has to be made in order to make each a manageable topic for a chapter. The distinction we make is to consider changes in a person's capability under the heading of learning, and changes in the choice made between courses of action as motivation. Subjects such as 'risk compensation', the idea that people compensate for improvements in objective level of safety by taking more risks in order to produce a more or less constant level of risk-taking, sit squarely across the border between the two subjects, and will be dealt with as a bridge between them.

8.5 EVALUATION OF BEHAVIOUR CHANGE AND SAFETY

Implicit in any discussion of influencing behaviour in order to improve safety is the idea that the results must be evaluated. Did it work? Is the level of accidents or disease lower? Is the potential for future harm less?

These questions are amongst the most difficult posed in the field of health and safety. In many workplaces the level of accidents and disease is now comparatively low, or at least low enough that they can be called rare events in a statistical sense. Statistical evidence that there has been a change in accident rate in a group due to a particular prevention measure requires that a large enough absolute number of accidents occur so that the difference between the two periods has a chance of being statistically significant. A drop from 6 accidents to 4 might be purely due to chance. An ideal statistical evaluation of a particular prevention measure also requires that nothing but that measure changes over the comparison periods before and after its introduction. The first requirement demands a long comparison period to allow enough accidents to happen; the second demands a short period to limit other changes. All evaluation research is thus a compromise between the two criteria, or a search for alternative measures of effectiveness.

Research in this area is also beset by the phenomenon of regression to the mean. All variables such as accident rate are subject to fluctuation over time, and thus the chance is great that an extreme reading in one period (either very high or very low) will be followed by one which is nearer the mean, even when nothing is done to alter the situation. Researchers such as Adelstein (14) demonstrated this with accident records of workers; those labelled as accident-prone in one year were usually no worse than average in their accident rate the following year. Misunderstanding of regression to the mean can lead to erroneous attributions, as is shown in a study of flying instructors who fell into the trap of wrongly interpreting this phenomenon. They were taking part in an experiment to evaluate the effect of praise for good performance v blame and correction for bad performance on learning. Due to regression to the mean, a particularly bad performance on one flight was usually followed by a rather better one on the next, and similarly a particularly good performance by a rather worse one. The instructors therefore experienced the phenomenon that when they blamed and corrected particularly bad flying it was usually better the next time, while when they praised particularly good flying it was usually worse next time. They attributed the change to their own action, and considered the experiment proof that blame was better than praise as a motivator. (They incidently ignored the fact that the same result occurred without any action from them, since it did not fit with their expectations, see Chapter 6).

It is beyond the scope of this book to consider the ways in which the methodological problems of evaluation research can be overcome or by-passed. The reader is referred to methodological texts (15,16,17) for further information on this problem. It suffices here to say that evaluation of prevention measures must often rely on finding changes in intermediate criteria; for example, more wearing of protective clothing or reduction in traffic conflicts (near misses), rather than in the ultimate criterion - accidents or disease. These problems will surface again as we discuss some research results in the following chapters.

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CHAPTER 9

LEARNING FROM MISTAKES

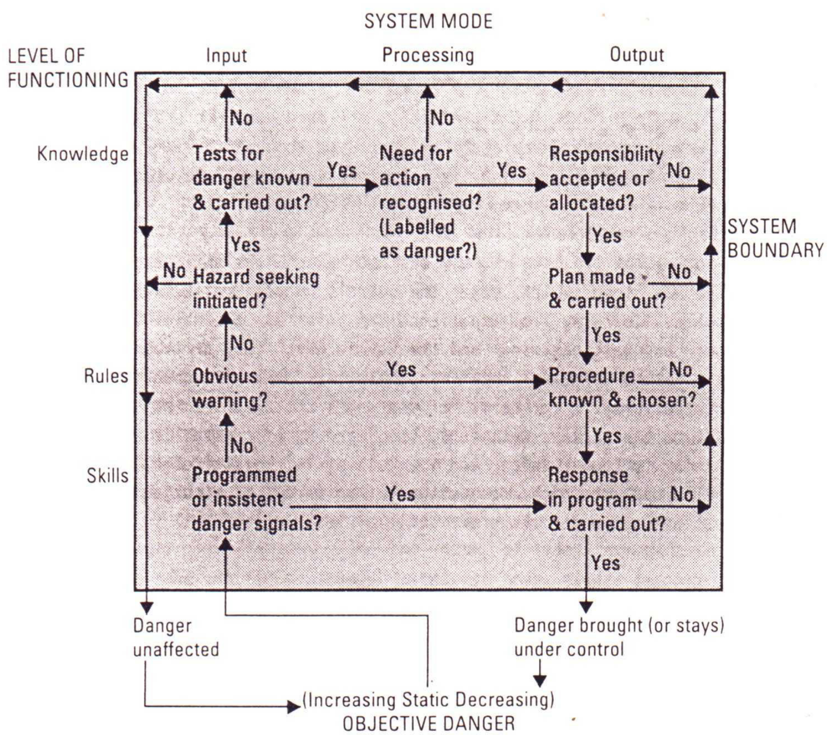

Figure 9.1. Behaviour in the face of danger model - learning from mistakes

9.1 INTRODUCTION

The model used to give structure to this book is dynamic at two levels, short- and long-term. In the short-term it is iterative. It represents a control loop which is superimposed on the dynamics of the total danger process (Figure 8.1). The individual intervenes, where possible, in those dynamics to control them and to restore the system to normal. Each of the 'no' answers which results in no control action being initiated means only that those dynamics carry on, and may finally result in harm. However, there is often still a chance to intervene at a later point and to work successfully through the 'yes' answers. The process may also be short-circuited at particular points and sections of it may be repeated. If the situation is not unambiguously classified as dangerous on a first analysis, it may still raise enough disquiet to send the person back to the hazard-seeking stage to check more thoroughly for symptoms. Similarly a first action may be unsuccessful and the person may return to choose another, or to get help from someone else who is better able to cope. The sight of the aftermath of an accident at an intersection may have a short-lived feedback effect by discouraging driving through an amber light. The first sight of a manager, inspector or policeman may result in the reflex response of donning protective clothing, fastening a seat belt, or obedience to safety rules, a behaviour which may be immediately abandoned as soon as they are out of sight. There are thus feedback loops built into behaviour at all levels to control it over the short- and medium-term.

What is not shown on the model, but what also plays an important role is a larger feedback loop which makes the overall model reflexive; namely the feedback called 'learning from experience'. This is the ability of people to examine their own past behaviour and the way in which they arrived at it, and to adjust their future behaviour and decision-making to take account of those past successes or failures. In terms of the model that means an adjustment of the values fed into the various decisions, the learning of new skills or routines to look out for or to combat danger and the falling into disuse of old skills which are not called upon or which do not appear to work. Such subjects are studied by social scientists under the broad title of learning theory.

We shall discuss these two levels of feedback under the two main headings 'feedback and monitoring' (short-term) and 'learning and training' (long-term). Finally in this chapter we shall look at the theory of risk compensation - which is based upon the feedback mechanism - and which has some relevant and disquieting predictions about the effectiveness of safety measures.

9.2 FEEDBACK AND MONITORING

9.2.1 Feedback in routine tasks

The importance of feedback and monitoring in the control of routine behaviour was described in Chapter 3. Feedback is a concept which has been familiar to engineers since the development of the theory of cybernetics and the use of the difference between a desired and measured state as the signal for activating control action by a machine. The concept came to have a major influence on the thinking of psychologists in the 1950s (1).

As a mechanism, feedback can work in either a negative or positive manner. Feedback works in a negative way to suppress information in the environment which is apparently not relevant to people. The most pervasive example of this is the phenomenon called 'habituation'. When a constant sensory stimulus, such as an unvarying sound is present the brain gradually ceases to respond to it; information about its presence is actively suppressed by the brain and the person habituates (ceases to be aware of it). If the noise stops suddenly this fact is immediately registered, and the person is alerted. A similar habituation occurs to any unchanging aspect of the environment. This ability to ignore what does not change leaves the limited processing capacity of the brain free to concentrate on what is changing, which by and large will be what is important, and what must be responded to. This can only create problems when a hazard warning increases very slowly, for example a smell of gas or smoke, or the sound of a machine which is gradually going out of adjustment. The rate of change of the warning may be so slow that it is treated by the habituation mechanism as a constant, and so is not registered until it is well above the theoretical threshold of detection. In contrast, someone coming into the room and smelling or hearing it can immediately identify that something is wrong.

This sensory habituation works by means of a feedback mechanism which actually suppresses the electrical activity of the brain. It is tempting to draw a parallel with the reported phenomenon of familiarity breeding contempt; the tendency for people to treat hazards with which they are familiar more lightly than those which are new to them. The Royal Society (2) in its report on risk assessment suggests that this arises because the hazards then contain no new information, and so are pushed out of consciousness. While the end result may be the same - that people ignore the hazard - the mechanism by which suppression occurs is different. In the case of familiar hazards it is a question of how the attention is allocated, and hence it is much more under conscious control than is sensory habituation.

The positive working of feedback to produce change in behaviour relies upon the detection of a discrepancy between the planned or expected situation and the actual one. Reason's theory (3,4) of the organisation and deployment of sequences of action, which was discussed in Chapter 3, gives a central role to the way in which attention is distributed over the various plans being prepared and carried out. It is vital that they are monitored at points where a person could branch by mistake into the wrong sequence, and that they are not monitored intrusively at times when this would only disturb the rhythm of the action.

Reason distinguishes between the monitoring of slips (lapses in the carrying out of plans) and of mistakes (cases where the wrong plans are chosen for the purpose), and provides evidence that the former are more likely than the latter to be picked up by the individual making them (5). Monitoring of the conduct of skill-based behaviour would thus appear to be more successful than that of behaviour at more conscious levels. Once a programmed sequence of actions is under way to check that it really is achieving the overall objective of reducing the danger, feedback may be a particular problem area. However, these are only relative statements. In absolute terms the vast majority of errors are picked up and corrected. Rasmussen (6) sums it up well in a chapter on the results of analysing the Licensee Event Reports stemming from US nuclear plants:

'The immediate impression one gets when reviewing a large number of case reports is that they are not reporting the errors that people commit, but the errors which are not corrected because they have an effect that is irreversible or not immediately apparent to the person himself'.

Many of the methods of improving on the quality of monitoring and feedback in such tasks involve making changes to the design of the system, and will be dealt with in Chapter 12. However, there are some changes which can be achieved by training. Teaching people how and why they make errors on this sort of task seems to have some promise, since it enables them to do their monitoring better and to look out for the problems. An example of this is teaching pilots about the effects of disorientation during instrument flying in cloud, or when flying upside down, and about the type of errors they are likely to make (5). People can be trained to make more systematic error checks, (for example, chemical process operators learning to check that instrument readings are corroborated by other information, 7) and this training improves their hazard detection. Training in 'creative mistrust' is also a feature of the defensive driving techniques taught to police drivers. Payne & Barmack (8) found qualified evidence that this training resulted in lower accident rates for truck drivers.

Reason & Embrey (5) also emphasise the value of forcing people to externalise their behaviour in situations where they are operating at the rule-based level - for example, in diagnosing faults. If people are forced to reason out loud two things become possible: first they must formulate their thoughts much more fully than they might otherwise in order to express them, and so can monitor the plans better themselves; secondly someone else can listen and monitor the process for errors or inconsistencies. Similar techniques of externalisation are used also in police driving training, and by the Institute of Advanced Motorists in the UK both to improve driving and to allow it to be assessed more readily by others. This idea was taken a step further by Embrey & Humphreys (9) who suggest eliciting these reasoning processes 'off-line' (when there is no emergency) and putting them into an expert system. This model could then be checked by the operator and used as an intelligent support during the crisis to monitor the adequacy of the reasoning carried out in the heat of the moment.

9.2.2 Isolation from feedback

Personality theory (10) suggests that some people are much less sensitive than others to feedback, and do not adjust their behaviour nearly so much in response to it. Eysenck calls such people extraverts, and suggests that they learn more slowly, and are less likely to alter their behaviour in response to social disapproval. If this is a basic personality trait which is not subject to significant modification, then the only thing which can be done to overcome such insensitivity is to enhance the amount and strength of feedback to such people. However, there is no clear evidence that such individual differences result in more accidents among extraverts (11).

If some people are less sensitive to feedback, so are some situations. When people work isolated in personal protective clothing (especially ear defenders or radiation suits) or in cabs of cranes, cars or other control cabins, not only is there physical isolation and attenuation of external signals, but also social isolation, which can lead to feelings of detachment from the rest of the system, and hence of invulnerability. Svenson (12) reports this in his review of driving safety. Adequate solutions to this problem lie more in the realms of design of communication systems than of learning.

9.2.3 Behaviour modification

One school of researchers in the field of health and safety has focussed specifically on the value of enhancing feedback about the results of behaviour as a stimulus to encourage safe behaviour. They emphasise particularly the value of positive feedback. The approach has come to be known in the literature as the behaviour modification school.

A typical study is that by Komaki et al. (13), who observed behaviour in a bakery over a period of time. They drew up a list of practices which, from accident records and experience, led to, and prevented accidents. A prerequisite for inclusion in the list was that the behaviour was readily observable. Based on this list they instituted a combined regime of instruction in response to bad practices and praise for good ones, both carried out by the supervisor. In addition, graphs of numbers of good and bad behaviours were made based on short unobtrusive observation periods, and posted in the work areas as feedback to employees. The percentage of safe practices rose from 70% to 96% in one shop, and from 78% to 99% in another, but fell back to the old figures when the feedback was stopped. When reinstituted and sustained the regime was accompanied by a drop in lost time accidents from 50 to 10 per million man hours over a five-year period. In a subsequent experiment (14,15) the researchers established that the feedback element based on good practice had a much greater effect than the instruction element in response to bad practice.

Similar studies in a range of industries have shown the effect of feedback and praise on a number of different behaviours: for example, increased wearing of safety goggles by shipyard workers with a drop in injuries from 11.8 to 4.3 per hundred employees (16), and an increase in wearing of hearing protectors with feedback of the effects of temporary threshold shift using audiometry (17, see also 18,19,20). A number of these studies also manipulated motivational factors such as praise or fear of blame, or provided information about the effectiveness of particular behaviour or protective equipment in combatting the danger (for example, that temporary threshold was less when using ear protection than without). It is therefore difficult to determine precisely how much of the effect is due simply to feedback of the results of behaviour making the actions more conscious and salient. However, it is likely that the combination is more effective than either feedback or motivation on their own. The results are consistent across studies and as a method of improving safety such an approach deserves wider application. It could be argued that the USA and Israel, where the vast majority of the research has been done, share a capitalist, achievement-oriented culture which would favour such a scheme working more than some European cultures; only further experimentation would settle this point.

In discussing behaviour modification studies an important new element has been introduced, namely that feedback there occurs through an external channel, and is not necessarily immediate. For example, results of the unobtrusive observations were only put up on the graphs in the workshops some hours after they occurred. The results also show behaviour change over a longer period than just a few minutes or hours. These studies therefore begin to shift along the scale from instantaneous feedback, which controls behaviour from minute to minute, towards more permanent changes which we shall deal with under the heading of learning. However, it is important to emphasise that this is a continuum. There is no distinction in principle between the mechanisms involved. Each piece of feedback provides information which either confirms that a given behaviour is adequate for given circumstances, and so makes it more likely that it will be used again when they next arise, or on the contrary shows that it is inappropriate and discourages its use. Learning based upon experience can be seen merely as adjustment to feedback which has consistently pointed in one direction.

9.3 LEARNING AND TRAINING

9.3.1 What needs to be learned

In describing in the first part of the book the way in which people respond to danger, we discussed such topics as mental models, expectations, action sequences and attitudes as playing a major role. They were largely portrayed there as things which existed, almost like software programs in a computer. In fact, the vast majority are learned. Babies may be born with instinctive reactions of fear and avoidance in relation to a small range of stimuli such as loud noises, sudden rapid movements, heights, and extremes of heat and smell. However, these crude reactions have to be shaped into more skilled escape and coping responses (21,22).

From the model (Figure 9.1) a list of areas can be identified in which learning must take place if a person is to respond successfully to hazards:

1. What are true warnings of the presence of danger?
2. When and where can danger exist? (signals to switch from skill-, or rule- to knowledge-based operation)
3. How can its presence be predicted detected or measured?
4. How does a hazard produce its harmful effect(s)?
5. How serious could the effect(s) be?
6. How can you tell whether the hazard is under control? (through your own action or that of others)
7. Who is responsible for taking action to remove or control the hazard?
8. What action must be taken to remove or control the hazard? (plans and practice)
9. What other advantages and disadvantages are there to the safe action?
10. When and how must action be monitored?
11. How can you tell whether the action is being successful?

Such a list can form the basis for the training appropriate to any hazard. In practice not all subjects will need to be taught to each person in the same depth, because the responsibilities of each will differ; but in principle everyone who comes in contact with the hazard will need to have some knowledge under every heading in order to have a coherent structure for their actions.

What will also differ is the level at which people are required to operate; skill-, rule- or knowledge-based. As a general rule it can be stated that a novice starts any task by operating at the knowledge-based level. Behaviour is fully interactive; each step must be planned, tried out, monitored and adjusted. As time goes by and experience is built up, these steps are built into larger routines or action sequences which form the skill-based level of operation. At the same time people learn when these skills are appropriate, and later how they can be strung together into larger sequences of behaviour. These form the rule-based behaviour which can be deployed when the appropriate signal is perceived (23,24). Thereafter much behaviour can be delegated to these less conscious levels, with only occasional monitoring and correction from the attention mechanisms. Particular actions which are important for safety must therefore be inserted into these sequences while they are still being carried out at the knowledge-based level, and then consistently practiced so that they become and remain a fixed part of those routines when they become sub-conscious. Trying to insert a new step into an already well-practiced action sequence is well-nigh impossible unless the sequence is first broken down and then rebuilt. This can be a lengthy and sometimes painful process for the individual who has become used to operating at a skill-based level.

9.3.2 How does learning occur? Learning theory

Given the vast number of human deaths that occur as a result of injury and disease through encounters with hazards, a surprising lack of attention has been paid by psychologists to theories and research which might help to explain how behaviour in relation to hazards is learned. A review of the literature on learning theory and developmental psychology reveals a vast amount of material on how people learn such things as language, norms for behaviour and how to solve problems, but almost nothing on those vital aspects which might be of direct help in individual survival in the face of danger. Part of the reason for such a lack of attention has been the general orientation of psychologists to an empirical tradition in which the laboratory experiment is conceived as the only acceptable scientific method. This adherence to experiment has precluded for ethical reasons the design of studies in which subjects would be faced with real danger.

Despite this lack of direct research attention to the ways in which individuals learn about danger, many attempts to change the way in which people behave in response to hazards in everyday life are based upon principles of learning which have been derived from the experimental tradition. Therefore it is relevant to look at the main types of theory which have been produced by learning theorists, in order to see how these approaches might help in our understanding of behaviour in response to danger. This will set the context for a consideration of lines of field research which have directly tackled the issue of learning about danger. Only one or two theories will be singled out. For a comprehensive review of learning theory and of its application readers are referred to psychology texts (25,26,27,28).

Two broad traditions in learning theory can be distinguished:

1. The behaviourists concentrated on the simple building blocks of behaviour and carried out much of their experimental work on animals, mainly rats, cats and monkeys (29,30,31). Their theories presented the concept of 'drive' or motivation as central, and saw learned behaviour as a continuing attempt to find ways to satisfy instinctive and learned drives. Within that tradition there were wide divergences over the exact status of different 'drives' and the way in which these were acquired and had their effect on learning. However, the majority of the research work was directed towards behaviour at what we have called the skill- based level. Dissatisfaction with the power of these theories to explain the more complex aspects of human learning led to a search for alternative approaches.

2. Cognitive theorists laid much greater emphasis on human learning and, in particular, on the learning of meaningful sequences of behaviour (rule-based operation) (32,33,34,35). They introduced the concepts of expectancy and cognitive maps (mental models), and stressed the role of social factors and the importance of attribution (Chapter 6) as an intervening variable in the process of learning. Within this tradition there has been a great fragmentation of theories

and approaches, some very mathematical, others purely qualitative. The cross-fertilisation with cybernetics and information science has also been of increasing importance.

Some psychologists concerned with the practical problems of education and training have tried to develop frameworks which link the two approaches and extract from them practical implications for the design of learning. Bloom (36) and Gagne (24) both developed hierarchies of learning which are built on the simple building blocks from behaviourist theory, but which elaborate them to consider how they are built up into skills, rules, and the ability to solve new problems. The model used in this book can be seen as part of this attempt to bind the two traditions together into a hierarchical structure.

A number of concepts from the varous theories can usefully be stressed:
- temporal association
- reward and reinforcement
- feedback and attribution.

Temporal association. Pavlov's famous experiments with dogs illustrate this principle. He found that, if he rang a bell at the same time as he put down food for the dogs to eat, they eventually came to salivate at the sound of the bell, even in the absence of food. The response generalised to an extent to other similar sounds, and gradually disappeared again if the bell was consistently rung without any food being present (extinction). Simple pairing of events in time and space caused them to become linked.

Such simple conditioning seems to occur in the development and treatment of some fears and phobias. People associate pain or fear with certain places or objects which may only have an incidental link with the actual cause of the pain; for example, associating the smell of disinfectants or hospitals with the pain of an illness or operation, or the sound of sirens with the fear of bombing raids. These are examples of conditioning building up fears. The opposite side of the coin is the use of conditioning to remove unwanted fears. A common therapy for phobias is to introduce the person gradually to the fear object first in attenuated form and then gradually more directly, all the time in combination with pleasant and soothing stimuli until the fear is extinguished.

Reward and reinforcement. Simple association plays only a marginal role in learning. The most important principle of the behaviourists was that most learning required the presence of a need or drive, which caused the person or animal to seek out ways of reducing the drive. Any behaviour which did so was reinforced, because the reduction of the drive (satisfaction of the need) acted as a reward. When the need arose again that behaviour was more likely to be exhibited. In animal experiments only a few drives were recognised - hunger, thirst, sex and avoidance of pain being the main ones. Other researchers admitted curiosity and social contact to the list, but the attempt was always made to limit the list as much as possible, and to explain all behaviour as far as possible based on these few (Occam's razor, or the principle of parsimony in scientific explanation). Skinner (29) claimed that all other objects and factors which come to operate as rewards and so as motives are themselves learned associations; thus people learn to look for affection because it is associated with either getting food or sex; similarly the motive for achievement is learned as a way of securing supplies of the basic needs. In his book Walden Two (37) Skinner describes a Utopia based upon the careful planning and control of such learning of secondary motives.

Other theorists have taken the basic concepts of drive and reinforcement and applied them as the 'motors' to explain how any learning took place. Their approach was simply to draw up lists of motivations and needs on the basis of empirical observation, without worrying particularly about whether they were innate or learned (38,39). The concept was turned on its head; if someone learned to do something there must be a need which they had, and which the learning satisfied. When we discuss motivation in Chapter 10 we shall take just such an empirical approach for the sake of simplicity. However, the question of whether, and if so, how motivation is learned remains a vital one particularly for educationalists and for those concerned with influencing whole groups or populations over long periods of time.

One of the topics which interested the behaviourists was how reinforcement could best be used to maximise learning. They were interested in two aspects of the learning; how fast the behaviour was acquired, and how resistant it was to extinction if the reward or punishment was removed (40). They found that continuous reward (given every time the behaviour was shown) was better for very rapid learning, but that the behaviour tended to extinguish just as rapidly if the reward was removed. If you get an immediate thrill of achievement, proof of skill and control from activities such as pot-holing or fast driving on narrow roads you may learn rapidly to indulge in them more and more. If through an accident or narrow escape to yourself or a close friend that reward ceases (or is replaced by anxiety) the behaviour is likely to stop almost instantly. Intermittent reward produced somewhat slower learning, but was much more resistant to extinction. The rationale might be that, because the reward did not always come in the learning phase, it might still come now, so it is worth carrying on in order to see.

An example of an intermittent reinforcement would be health checks at regular intervals, going to the dentist or to the occupational health service, who give feedback about the effects that sugar consumption or smoking is having on your health. Such fixed interval schedules have been shown to cause a characteristic 'scalloped' response curve in which the response rate is high immediately prior to reinforcement but drops to a low level just after. Transposing this to our health check example, one might expect to find an increase in behaviours designed to improve an individual's health such as better dietary behaviour, reducing alcohol or tobacco consumption or being particularly conscientious about dental care in the period immediately preceding the health check. Such behaviour would be aimed at increasing the likelihood of receiving positive reinforcement (a clean bill of health), and reducing the probability of negative reinforcement (being told that your health is not all that it should be and that you should change your behaviour in some way). If the outcome of the health check is positive reassurance then the special efforts are likely to diminish again until the next check is due. Only if it is negative would more permanent change of habits be likely.

If the interval between reinforcements is not fixed the effect on behaviour would be more spread out. An example of a variable interval schedule might be surprise visits by a factory inspector to premises. Such visits might be on average about once a year, but the management might have found from past experience that the interval since the last visit could be as little as six months but might be as long as eighteen months. Thus, they cannot afford to 'relax' their safety standards for too long and of course the longer the time since the last visit, the greater is the probability that they will be visited any day. Such a schedule, with its greater degree of unpredictability would be expected to keep management 'on their toes' in respect of managing workplace hazards satisfactorily, compared with visits which took place at regular intervals with very little variation about a mean value. Experimental evidence certainly suggests a more constant rate of responding for animals and people on such a reinforcement schedule.

Gambling in all its forms conforms to a version of a variable reinforcement schedule. This can be observed in any amusement arcade as people continue to put money into machines which occasionally reinforce their behaviour with pay-outs, but mostly do not. Yet individuals quite cheerfully empty their pockets until the machine, or rather those who own or rent it, takes all. The profitability of such machines rests on the very high resistance to extinction which goes with this form of reward.

Feedback and attribution. Behaviourist theory stresses the importance of reinforcement, the feedback that the behaviour achieved the desired result. This has long been recognised as a vital ingredient in good training (41). People who are being trained must receive feedback regarding whether their performance is getting better or not. Some of this will come from their own observation of their behaviour, and whether they are making errors or not. However, in some tasks the feedback is far from clear to a trainee, and has to be enhanced by artificial means. For example, Mason (42) took videos of trainees carrying out lifting tasks and showed these to them, as a way of letting them see how their posture and movements matched up with what they were trying to achieve. Simulators used in training pilots, drivers and process control operators can provide enhanced feedback of this sort during the early stages of training, which can then be gradually withdrawn until the trainees learn to do without it (43). In the simplest situations the trainer gives direct verbal feedback by indicating where mistakes were made and where performance was good.

Where behaviourist theory ceases to be helpful is in its silence over how feedback is perceived and understood. It assumes that the information is neutral and will be perceived by everyone in the same way. We have already seen in Chapters 5 and 6 that this in fact is not so. People take in information through a filter of their frames of reference and expectations, and attribute cause in terms of their mental models and hypotheses. Thus, what is an error to one trainee may appear to another simply as an acceptable variation in performance. The first will try harder to refine the behaviour; the second will carry on in the same way as before.

Internal and external attribution. Behaviour will also be influenced by the way in which individuals attribute a cause to any particular outcome of a task - be it error or success. It is possible to attribute such an outcome to any one of four factors (35), which carry with them different implications for future behaviour. Figure 9.2 shows the four factors. The column headed 'locus of control' indicates that the factor is either under the control of the individual (internal) or not (external). The 'stability' column indicates whether the factor can be changed (variable) or not (stable). Only if the outcome is attributed to 'effort' (or lack of it) is it likely that people will change their behaviour in the short term to try to influence the outcome. If they attribute an error to 'lack of ability' they may make efforts in a longer timescale to change their ability. Any other attribution will not lead to attempts to change personal behaviour, since the problem is not perceived to lie there.

Conditions under which people attribute outcomes to these four factors - for example, in a learning or testing situation - may be identified as follows:

Ability - when someone shows consistent performance at a task, especially where that does not seem to conform to an 'average' value.

Effort - when performance appears to vary either with incentive or with physiological signs of effort or with persistence.

Task - when someone performs much the same as everyone else, where difficulty the nature of the task suggests difficulty or when there has been recent failure.

Luck - when performance is random, the outcome (for example, seriousness of injury) was unimportant or where the chance nature of a task is apparent.

ATTRIBUTED FACTOR	STABILITY	LOCUS OF CONTROL
Ability	Stable	Internal
Effort	Variable	Internal
Task Difficulty	Stable	External
Luck	Variable	External

Figure 9.2. Perceived causes of success and failure
(source 35, Weiner et al. 1971)

While these are general tendencies in attribution there is also wide individual variation. Attribution to one or other of these factors will then affect future behaviour. If bad luck is put down as the cause then little attention will be paid to how the person behaved (how could it be relevant?), and so no learning from experience will take place. If another person attributes precisely the same outcome to lack of skill, they will try to modify their behaviour next time.

Individual differences in attribution to internal or external factors can themselves be learned (44). People may develop characteristic ways of attributing based on their experience over many years. Those who grow up in environments where they can exercise considerable choice and influence over what happens to them will tend to believe that they can influence more things which happen to them (attribute more things to internal causes) than those to whom things happen without their intervention. Such experiences are associated with certain types of school regimes (for example, emphasis on discovery learning v rote learning and fixed curricula), but above all they are associated with the economic status and environment of the family (how much money there is with which to buy or to do things, or how much freedom there is to explore). This has been suggested as the explanation for the marked difference between middle class and working class families in the way they respond to illness, the former regarding it as something over which they can exert control and which can be cured by rational scientific means, the latter being more fatalistic (external) and relying more on unscientific explanations and on faith in cures whether suggested by a doctor or by family and friends (45). If a person has had an adverse experience in which they seem to have been the object of arbitrary misfortune despite all their efforts they may sink into a state which has been called 'learned helplessness' (46,47), in which they become fatalistic and cease to try and influence anything which happens to them.

Attribution and frames of reference. Another factor which plays a part in learning is the tendency that people have to try to fit new information into the theories (frames of reference) they already have (48). Astronomers in the middle ages exhibited this trait. They remained faithful to their theory of an earth-centred universe, with the planets orbiting in perfect circular orbits, in the face of observational evidence of retrograde and eccentric movement. They simply added another epicycle to their model to explain each new discrepancy. Copernicus and Kepler found enormous opposition to their attempts to throw the whole theory out and replace it with a new and simpler one which explained all the facts, but without recourse to the sacred circular orbits.

Such conservatism (see also Chapter 5) means that there is a threshold which has to be got over before any learning at all takes place. A person takes some convincing that there is any need to change behaviour, because the feedback can still be forced into the old theory which supports the old way of coping. This means that small increments in information are often no good at producing change. Ross et al. (49) showed this clearly by presenting a series of (false) facts to individuals and getting them to draw conclusions from them and to express opinions based on them. Evidence was then sytematically presented to show each fact to be false and the study looked to see what happened to the opinions and conclusions. These were weakened, but not totally destroyed; they had taken on a life of their own independent of evidence, because they had become incorporated into a broader model or set of beliefs, which now provided the necessary support. In support of such consistent mental models people will also systematically, and often unconsciously modify their beliefs with hindsight, to make out to themselves that they expected all along the outcome which did indeed occur (50). This saves any dramatic need to accept that they were wrong and so must totally rethink their ideas.

In order to produce change in the frame of reference the new information has to challenge the current frame dramatically, or the training has to tackle directly the model which supports that frame. Ideological conversion and insight therapy try to do the latter in dramatic terms by providing a whole new ethic or framework in terms of which everything else must now be explained and reinterpreted. Accidents are normally a dramatic enough occurrence to provide this challenge to old frames of reference, provided that they occur either to the individual personally or to close aquaintances (51). However, if they happen to remote others they may not be sufficient to challenge the old beliefs. For example, Bucher (52), in her study of crashes at an airport in the USA, found that only after 3 accidents in quick succession was there a very general outcry and search for new explanations of why they were happening.

Green & Brown (53,54) suggest that people only learn from accidents that breach their expectations. This applies both at individual and societal levels. They single out the disasters of Aberfan (tip collapse), Summerland (leisure centre fire), Ronan Point (collapse of an apartment block), to which can be added Flixborough (unconfined vapour cloud explosion) Seveso (toxic escape) and Three Mile Island (partial reactor core melt), as examples of accidents which had profound impact on national and international lawmaking, and on design. Those were learning experiences par excellence, which all revealed shortcomings in the design or management of what had previously been considered to be types of technology which were understood and considered to be more or less under control. If there is nothing in an accident which challenges current beliefs, attribution tends to be to blame the people who should have been in control for doing their job badly (as at Chernobyl), or to point to unique or easily correctable failures in the system (55).

According to this view, accidents - particularly major ones - act as signals to people about the controllability of a technology, and about the size of the greatest accident which could credibly occur (56).

Conclusion. The factors discussed in this section provide some recommendations for the way in which training must be organised if it is to have an effect. Any planned training or experience must be built upon an understanding of the current levels of knowledge and expectations of those who will receive it, so that a decision can be made as to whether radical restructuring of their frame of reference is necessary (and if so whether the investment of time is worthwhile), or whether only adjustment and reinforcement of the current knowledge and approach is needed. The motivation for learning is a vital ingredient, since it will determine the type of reinforcement which can be used for successful performance (see also Chapter 10). Finally feedback about progress during learning must be carefully planned, so that the correct rules and skills are learned, and incorrect attributions are not made.

9.3.3 Sources of learning

There are two principal sources of learning, first-hand and second-hand experience. If a person has personal experience of a situation there is the opportunity for immediate feedback and, subject to the attribution biases which we have mentioned, subsequent behaviour will be shifted accordingly. However, there are a vast number of situations which individuals have not personally experienced and yet to which they can and do respond when they occur. Such responses will be based partly on generalisation from personal experience, but are also strongly influenced by what has been learned from others, through discussion, anecdote or formal education or training. In the next three sections we consider three sources in more detail: - personal experience - social modelling - formal training. As an introduction to the section on formal training we consider briefly what is known about learning about hazards by children.

9.3.4 Personal experience: accidents and near misses

It is not considered ethical to send people out to have accidents in order help them learn, although the time honoured method of teaching someone to swim by throwing them in the deep end comes close to this principle, and is consciously or unconsciously applied in many jobs and professions. It could be described as the provision of planned near-misses. Near misses are the common conversational currency of every bar, pub or coffee house. The 'wizard prang' of the Boys Own Paper and the four wheel skid on black ice expertly controlled to avoid a looming juggernaut have long been used to boast of the skill or daring of the storyteller. While such stories may suggest that the near miss, or seeing the results of someone else's accident are memorable events, there is little systematic study of whether that effect is turned into any lasting, or even temporary, change in behaviour. Everyone simply assumes that it must be good for people and must make them safer. Lagerlof (57) did describe the successful use of reports of near misses in the reduction of accidents in Swedish forestry. The reports were collected from individual forestry workers and then used as feedback material to groups of the same workers. It is likely that they served as legitimisation by the group that the threats were real ones and that action should be taken by individuals or the group to reduce hazards; 'I am not the only one this has happened to, so we should get something done'. Lewin (58) also reported a valuable increase in performance on a driving skill test as a result of getting trainees to record personal near accidents and then to go over them with the instructors

Many safety films are made on the basis that watching an accident happen to a character with whom the audience can identify will provide the viewer with enough of a near miss that they will learn from it. Experimental testing of such an assumption is almost non-existent. However, there is evidence from the study of the use of pictures and films which are full of blood and gore that great care has to be taken not to overdo the realism. This can so disturb people that they suppress all memories of the experience and so do not learn from it (59). However, it seems reasonable to assume that a well made film, which does not trigger off too much fear or revulsion may provide a mental image of the accident circumstances which can be triggered when the hazard arises and hence alert people to be cautious. Film is not the only medium which can do this. One study which used a role playing exercise to get people involved in, and identifying with the problems which arise in the aftermath of an accident or occupational disease did seem to have a dramatic effect on long- term wearing of the protective equipment which could prevent such occurrences (60).

A handful of studies have looked at the effect of simulated accidents (another form of near-miss) on subsequent behaviour. Rubinsky and Smith (61) made a simulator for an abrasive wheel which could spray water on the operator in the same way that a real disintegrating wheel would spray fragments. They reported better learning of the operating task with this method than with simple descriptions or demonstrations of how the accident could happen. However, simulation of the accident must be meaningful to the trainee if it is to have an effect. Simulators are widely used in the training of pilots and increasingly for the training of operators of process control plant and will usually include the simulation of accident sequences in order to train the staff in how to cope with them. The fault sequences and the accidents themselves can be made realistic, as the reports of trainees in aircraft simulators testify. The general conclusion from such work is that operators do learn what to do to diagnose and control the danger, but questions have been raised about what the simulator experience does to their estimates of the likelihood of the accidents. It may be that the fault sequences which are presented frequently during training are given an inflated probability rating, and so receive an unwarrentedly high priority in hypothesis testing when something goes wrong in real life (62). This would sometimes lead the operator into incorrect fault diagnosis.

Where accidents have happened it is possible to ask whether people do learn from them. Victims can be asked about their beliefs and assessments compared with matched control subjects who have had no acidents. Robaye et al. (63) carried out a study of approximately this design, although it is not clear whether their subjects had suffered the actual accidents which they were asked about, or had just suffered a large number of accidents. Their results showed that the high accident group rated accidents from the situations shown to them as more likely than did the low accident group (not surprisingly perhaps), but also as having less serious consequences. This was interpreted by the researchers as evidence that the high accident group had underestimated the consequences of the accidents and so had been less keen to avoid them; in other words they interpreted it as a factor which had caused this group to have a lot of accidents. It seems more plausible in view of other studies (64,65) to suggest that the experience of having an accident and of recovering from it (especially if it was a serious one) produces a re-evaluation of the seriousness. The sentiment is; 'it was not as bad as I thought it was going to be'. Whether that in turn feeds back into a more cavalier attitude towards having future accidents is unknown.

The value of personal experience of near misses or accidents is at present, therefore, a somewhat open question. It is an important, but remarkably neglected area of research in health and safety. The ability to learn from past experience, which is such a fundamental characteristic of human behaviour, does not seem to fare particularly well in the face of the experience of suffering or escaping from accidents. From the theoretical point of view the mechanisms which cope well with the assimilation and use of experience of frequent events will be inclined to be misled by uncommon ones. The very infrequency of accidents tends to provide feedback that makes people think of them as rare exceptions to normal events, from which there is little that can or should be learned. Near misses can also be interpreted as positive signs that everything is indeed under control. After all, nothing serious did go wrong in the end, so there is no reason to try harder next time, since we were skilled enough to get away with it. That picture deliberately takes the worst side of the foregoing discussion. Luckily other interpretations are possible, and there is some evidence that minor accidents and near misses do influence awareness of hazards, and that the use of simulation and case studies does have a positive effect on behaviour. The area urgently requires more systematic study.

At an organisational and political level the picture is also confused. As an example one merely has to take the differing interpretations placed in articles and scientific reports on the accident in the reactor at Three Mile Island. It has been used both as proof that the technology is safe (despite all the errors the radioactive release was extremely limited) and that it is unacceptably dangerous (look how close it got, and how fortuitous some of the recovery actions were).

Research into the value of accident investigation systems in companies does seem to show dividends. Low accident companies do tend to have good accident and inspection analysis systems (16,66,67,68) and introduction of such systems can produce significant (up to fifty percent) reduction in accident frequency and/or severity figures (69,70,71). As we noted in the last section, major disasters do produce dramatic changes in design and in laws. On the other hand some have argued that such dramatic responses to specific disasters are uncalled for, since they tend to lock the stable door after the horse has bolted. They prevent the last disaster not the next (72), which is almost by definition very different in nature and causes. Dramatic accidents can thus be signals which direct attention away from new dangers and focus it too much on the past. It is the very dramatic nature of the outcome which galvanises the system into action by exceeding the threshold of inertia. Without that dramatic aspect no lesson may be learned. Indeed, many inquiries into disasters reveal that there were precursors from which lessons could have been learned, but they were not serious enough, or not noticed by the right people. For example, an accident with a DC-10 cargo door occurred some time before the crash at Ermenonville which killed all those on board; but the plane in the first incident was landed safely and, perhaps because of the lack of serious consequences, no satisfactory redesign measures were taken. The value of accidents and near misses as feedback at the organisational or national level can be seen from this brief discussion to be not without its problems. Much more research is needed to establish how such feedback loops could best be organised to achieve measured and effective modifications in system behaviour, which neither overreact nor remain blinkered.

9.3.5 Social modelling

All children from an early age identify with and mimic the behaviour of their elders, usually a parent or sibling more than anyone else; thus, a son tries out father's shoes, wants to help in all his jobs, tries out his swear words (and according to Freud's formulation of the Oedipus complex also covets his father's wife).

Copying behaviour occurs not only in childhood. It is a standard and important way of learning. The few studies of the learning of safety-related behaviour in schools and colleges show that the behaviour of the teacher, in using safe working methods and protective clothing, is the most important factor in accounting for differences in behaviour between pupils (73,74). In pedestrian behaviour, such as crossing the road, the behaviour of others is a very powerful stimulus to action, particularly to children who will often simply follow an adult across the road without making any independent check of whether it is safe (75).

Group norms are powerful controllers of behaviour (see Chapter 10). People rely heavily on the things they learn from their friends, neighbours and colleagues to determine whether they believe something is a hazard (51), and trust such people far more than the media or abstract information sources when it comes to such things as taking precautions against or evacuating before natural disasters (76).

The problem with second-hand experience as a source of learning is that it may not be appropriate. It is usually taken over only partially from its source, since nobody can convey the full detail of their experience of any event to another. Hence it lacks the richness of personal experience and may turn out not to be as appropriate as expected for the circumstances in question. This difference accounts for some of the gap between people's knowledge and attitudes about hazards (often culled from friends or from books and the media) and their behaviour when actually faced with the hazard (77).

9.3.6 Development of hazard perception and safe behaviour in young people

Children between one and about six years of age are far more vulnerable to accidents than at other times of life. In the mid to late teens the accident frequency graph rises again for certain hazards, especially road accidents among young males. These features of the graph of accidental deaths have been demonstrated in countless studies, in many different countries (see for example, 78). Yet there has been remarkably little study of the reasons for the peaks, particularly for the high accident rate of young people at the age when they enter work (79). Simple lack of experience of the hazards to which they are exposed on going to work in a factory or in starting to drive a car or motorcycle account for some of the peak, but not all (80,81). Suchman & Scherzer said in 1960 (82) that we knew very little about how children (or indeed adults) learned to behave in actual danger situations. That is still unfortunately largely true today.

Studies of child pedestrian and home accidents (83,84,85,86) have thrown some light on the early learning related to hazards. Piaget's theory of four developmental stages in child development (87) long held sway in this field, although not adequately tested in the realm of accidents. The stages he identified were:

- sensory-motor (0-2 years)
- pre-operational (2-7 years)
- concrete operations (7-11 years)
- formal operations (11+ years).

These represent stages in the mastery first of concrete skills and then of more abstract ones. The high accident rate in the pre-operational stage may be ascribed to the occurrence of mastery of mobility, and hence greatly increased exposure to hazards, before mastery of concepts of danger, and learning of skill in avoiding it. However, it has been suggested that the Piagetian model is inadequate as a basis for understanding children's behaviour in respect of danger and that while it is necessary to recognise the limited verbal skills - for example, of a 4-year old - we should not underestimate their cognitive abilities (88).

Rothengatter (85) emphasises the need to avoid sweeping generalisations over the capabilities of children to avoid danger, and rather to concentrate on detailed task analysis of the behaviour to be learned. He showed that theoretical learning about hazards had very little effect on behaviour. Only practice of the specific skills to avoid danger had a significant and long-lasting effect, and then only patchily, because children's behaviour was inherently more variable than adults. Children in a number of studies have been shown to possess a general belief in safety and even a knowledge of the rules they should follow (such as the procedure for crossing the road), but then to reveal a gap in applying this knowledge to reality. They sometimes believe that the rule acts as a sort of talisman which will keep them safe in all circumstances. For example, it has been shown that children would mechanically perform the actions of looking right and left at the kerb, and then would sometimes cross no matter what the traffic situation, as though the act of looking would stop the traffic (89,90). Despite Rothengatter's strictures about global judgments of capabilities some patterns do seem to emerge. In the very early years control of body movements is a major problem, and young babies, despite showing aversion to heights, are often still too uncoordinated to avoid falling from them (22). Perceptual skills also develop only slowly; peripheral vision and ability to localise sounds are still improving even up to the age of 22 (91). The ability to spot hazards also develops through the years up to the teens, certainly in numbers of hazards spotted. Thereafter it may change in nature, with more abstract hazards being noticed, although the number of hazards detected does not seem to increase further (86,92,93).

The explanation for this last point may lie in the developments going on in powers of reasoning. Up to the age of six the road environment is too complex for the child to take in and to process unaided (83). Hazard perception is purely structural in form; that is to say items in the situation are labelled as dangerous per se. In contrast, adults are also able to reason in functional terms; something is dangerous if used in a particular way (see also Chapter 4). This causal form of reasoning only develops clearly from about the age of seven onwards, and complex, abstract reasoning is not much apparent before 15 (92,94,95). The result is that young children tend to see things far more in black and white, and are far more trusting - if I am with mummy everything is all right (86,96). Their action sequences or programs for carrying out safety rules are also in a far cruder form, and are either carried out fully or not at all, rather than being adapted to meet circumstances as they are in adults. As a result, compared with adults, children tend to anticipate behaviour of traffic or other pedestrians less, and although they respond faster, the overall result can be to leave less of a safety margin.

While there is insufficient space here to develop fully recent ideas about the way in which children learn about danger, interested readers are referred to work by Valsiner (97).

The value of giving this sketch is to suggest some lines of research which might throw light on the peak of accidents occurring in the late teens, and the problem of accidents to young workers (98). In this age-group there may still be an inadequacy in abstract reasoning about hazards, and a shortfall in integrated rule-based behaviour to cope with them. Such shortcomings may be susceptible to specific training in addition to that needed to provide knowledge about the hazards which are present at work. A final area of potential study is the emotive element, the value of risk itself and of showing off to friends, and the symbolic value, especially to the young male of having and driving his own transport, of defying rules, and of projecting a macho image (99).

9.3.7 Formal training in safety

What has been said in this chapter so far has been concerned largely with learning by experience, the process of unorganised learning. We turn now to attempts which have been made through organised training courses to improve on performance in the face of danger. All reviews of safety training remark on how few studies have evaluated the effect of training on either accident occurrence, or critical behaviour towards health or safety hazards (100,101,102,103,104, 105). Despite this shortcoming, training is advocated as a means of prevention in all safety manuals, and safety legislation increasingly demands the appointment and training of competent persons to carry out particular tasks sensitive to danger (105). It is as though training in safety were self-evidently a good thing.

The literature on the effect of work experience on accident rate would appear to support this general belief. Ever since the early studies of the Industrial Fatigue Research Board (106) there has been ample evidence that older and more experienced people have a lower accident rate than matched groups of the young and inexperienced. Experience comes at different levels (11) - number of repetitions of a task, the length of time a person has been working on the task at any given moment and more general experience of the industrial environment - all of which can be linked to a lower accident rate. It is surprising that studies of formal training programmes do not always show such a clear and positive picture. There are even some studies which show that trained groups had more accidents than matched untrained groups; Raymond & Tatum (107) showed this for motor-cyclists, and Rotta & Gani (108) found that workers who had been through an apprentice school had more accidents in the next two years of work than a matched group who had not gone through the school (though in the following five years the position was reversed). It is not clear whether such results come from poor training, whether the matching of the two groups studied was not sufficient, or whether training was not capable of having an effect in those cases.

The issue of the matching of groups in such evaluation studies is not a simple one. For example, Jonah & Dawson (104) compared two groups of motorcyclists, one of which volunteered for training, the other of which received none. They found that the former did appear to have less accidents overall than the latter. However, when they controlled for distance travelled and for drinking habits, the difference in accident rate disappeared, although there was still a lower rate of traffic violations in the trained group. The number of possible explanations for such findings is unfortunately large. The training could have resulted in some of the trained group changing their drinking habits and/or driving less. Shaoul (109) certainly found the latter happening with his study population. People who had received training drove less mileage, particularly in hazardous situations. Alternatively, seeking training may simply be part of a general approach to a hazardous task which also includes taking more care and obeying the rules better; in other words it may be that the trained group was already safer before going on the course, and that attendance was not itself the cause of the better driving, but a concomitant effect of some deeper common cause.

The study of bus drivers carried out by Shaw & Sichel (110) illustrates another facet of this problem of evaluation. They found that institution of a training course improved the overall accident rate of the group of drivers, and that good performance on the course and on the test at the end of it was generally negatively correlated with later accident rate. However, within the group there was a small sub-group who did particularly well on the training and test, but then went on to have a very high accident rate. High driving skill was, in their case combined with personality factors which led them to drive aggressively, and to exceed those (admittedly high) limits of skill. These examples caution against over-enthusiasm about training as a solution to accident problems. Its effectiveness is not easy to evaluate, and some of its effects may be at best indirect. It also cannot influence all factors related to the choice of behaviour in the face of danger.

Having registered some caveats we will next consider the more specific studies which have produced change in particular aspects of behaviour in response to danger. In doing so we shall use the categories of our model as headings.

Warnings and hazard seeking. The skills of searching for and recognition of hazard warnings can be improved. Research with miners (111,112,113) showed that failure to detect hazards, particularly potential rock falls was an important factor in mining accidents, and the ability to do so was not present in many miners, particularly novices. Training in formal search strategies in the laboratory using slides of actual mining situations improved this ability, but only for groups given active practice in the skill and not for those who were just told what to look for without any chance to try it out for themselves.

Studies in the process industries have shown that it is necessary and possible to train operators to be both more prepared to undertake, and more systematic in searches for signs that something is wrong with the process (7,114,115,116,117,118). The training can make operators more constructively suspicious of the information coming from their instruments and so more likely to check its accuracy by reference to other information before taking action. This is similar to training in defensive driving (8) which encourages people to think ahead about possible hazards which may arise because of the behaviour of others. The process industry studies also included training in the way to approach diagnosis of faults. They concentrated on building up the operators' mental models of both the normal process and possible fault sequences. They also taught operators to search systematically for information to test their hypotheses. Hazard detection in such processes is a matter of problem solving, and the extensive literature on the subject (119,120) has shown that people can be taught the heuristics to improve this skill so that learning is faster and more resistant to decay when not used for a time. People become better at recognising patterns of symptoms rather than concentrating on single symptoms, and they learn how to break down large problems into smaller, manageable chunks. However, again it must be stressed that practice does not guarantee perfection; all operators still show occasional lapses where they make quite simple errors in carrying out the heuristics they have learned (118, see also Chapter 3).

Learning of the causal link between hazard and harm is particularly important for long-term hazards such as noise, certain chemicals and the effects of bad posture on muscle and joint injury (42). If this link is not specifically dealt with during training, people may learn precisely the opposite to what is desired, namely that presence of the noise or chemical does not lead to any apparent effect and therefore there can be no danger. The training in one study of styrene workers (102) concentrated on explaining why particular work practices gave rise to danger, and then on giving feedback in the form of supervision to reinforce the correct behaviour. A forty to fifty percent reduction in dangerous behaviour was reported as a result. The use of audiometry to demonstrate the link between noise exposure and temporary threshold shift can also be seen as a training device to bring home the reality of the effect of noise (17,121). It stresses the short-term effects of noise exposure on hearing and provides an analogy with what will occur in the long term. Lagerlof's use of information on near-misses as material to feed back to forestry workers (57) may also have resulted in group learning of what factors could lead to injuries (see also 122).

Labelling as dangerous. A study of air traffic controllers looked at their behaviour on a simulator in which conflicts between aircraft could be programmed (123). It found that the controllers gradually modified their criteria for deciding when to initiate action to reroute one or other aircraft; they became more cautious over the training period, recognising sooner the need for action as they became used to the speed with which events built up.

In Chapter 5 we described the factors which seem to influence assessments of the degree of danger in a situation. The two key concepts were controllability and seriousness. No training studies seem to have set out directly to change beliefs about controllability, nor would this be simple to do. As we suggested in that chapter a delicate balance has to be struck between indications that a person is not in control and must change their behaviour in order to regain control, and the extreme case where they believe that the danger cannot be controlled. The defensive driving training mentioned above tackles this difficult balance by forcing people to think actively about how the situation might go out of control and how they would respond to that.

Pirani & Reynolds (60) compared different methods of encouraging the wearing of protective equipment and found role playing the best. The workers played through situations concerned with compensation claims for occupational disease which stressed the extent of the consequences of the disease (not just physical but social) and the problems caused in a claim if protective equipment had not been worn. This combination of demonstration of the seriousness of a problem with knowledge about how to control it, and about the efficacy of control measures worked well. A number of studies of health-related behaviour have shown this in relation to such measures as attendance at dental and medical check-ups, use of protective equipment and of safety procedures (124,125). McKenna (126,127) found changes in beliefs about the potential seriousness of injuries among people who had received first aid training. This was coupled with a reduction in the number of accidents which happened to them in the subsequent six months. He explained such changes in terms of the greater feeling of control which knowledge of first aid gave people, and which allowed them to accept the seriousness of the problem of injuries without either panicking, or suppressing all thoughts of the subject (see also Chapter 10 on motivation).

As well as trying to influence beliefs about controllability and seriousness, attempts have been made to modify through training the way in which people arrive at judgments of the probability of hazardous events (128,129,130). The biases of overconfidence and of availability (see Chapter 5) would appear to be modifiable to a certain extent, particularly through training in the statistical theory which lies behind the judgment of probability. Teaching people to structure problems in systematic ways also has some effect. It has also been found valuable to get people to be deliberately divergent in their thinking; to take time to think about other things which could happen in the situation apart from the obvious, or what they would like to happen. In all these cases people are being taught to distrust their first gut reaction to a question and to examine it for the traps which would lead them astray. When they do this they can compensate for decision biases to an extent, but still not completely. Knowing that the bias exists is not enough; they must also know how and why it exists, and how to combat it; otherwise the compensation is generally not great enough.

Allocation of responsibility. Very little study has been made of the effect of training on this area of behaviour in the face of danger. McKenna (126), in his study of the effects of a short (four hour) emergency first aid training course found that a major effect of the training was on feelings of responsibility. The trainees became more inclined to acknowledge their own responsibility for (and control over) injury prevention. Pipes & Walters (131) report an increase in personal attribution of responsibility among drivers who had had alcohol related accidents after they had received training which specifically aimed at giving them insight into the causes and effects of drinking. Reporting and group discussion of near accidents and of safety problems among groups of workers also seems to have the effect of increasing their feelings of responsibility for prevention, and their participation in safety programmes (57,132,133).

Planning and execution of actions. This is in one sense the most obvious area of training, and the bulk of the general training literature (27) shows the value of training under this heading. It concerns the establishment of the smooth, automatic sequences of action which characterise skill-based behaviour. Some of the studies reported under the hazard seeking section above overlap with this section, namely those concerned with training people in problem solving. The extensive literature on first aid training and its effect on the ability to carry out life saving treatment in emergency is typical of the work done in this area (134,135,136). This research and the comparable literature on inspection training (137), manual handling (42) and process control (43,114) all point to the importance of active feedback and practice in stamping the learning firmly into the brain.

Research in health education (125,138) has shown that knowing what to do to control a hazard, being reminded of it, and being convinced that it will be effective are more important than the arousal of fear in getting people to do something to protect their health.

Finally training which aimed to give insight into the decision-making process and the way it could be distorted by a number of personal attitudes and biases was found to lead to better judgment in emergency situations in trainee military pilots (139). The researchers had traced attitudes such as fatalism, impulsivity, dare devil beliefs, feelings of invulnerability and of opposition to rules and authority as factors in poor decisions leading to aircraft crashes. Training material was then devised to illustrate these factors and to serve as a basis for discussion during the courses.

Discussion. As the above-mentioned studies reveal there is considerable evidence to show that training can have positive effects on behaviour and result in reduction in accidents. What little work there is looking at the best methods of training in this area seems to suggest that active, participative methods with plenty of feedback are particularly needed to get the message over. However, evidence available from well-conducted and adequately controlled evaluative studies is still not enough to bear the weight of training which is now done in the name of safety. Far more needs to be done to analyse precisely what aspects of behaviour require to be modified in any given situation to improve health and safety, and far more to discover how best those changes can be brought about with lasting effect. Figure 9.3 illustrates the scope of such training for one particular problem, (the selection and use of respiratory protection). It contains a list of questions to which people must be taught the answer, arranged according to the sections of our model. The needs in relation to selection and purchase (S), maintenance and storage (M), and use (U) are given. These tasks may be spread over a number of different people and hence the figure gives a picture of the total training programme for a company rather than that for one individual. In addition the whole programme requires to be supervised and monitored by people who have an overall grasp of all aspects. The depth of training in relation to some questions will differ between selectors, users and supervisors.

A similar table could be drawn up indicating the training needs in relation to any hazard or preventive measure. The choice of appropriate means to achieve the objectives can then be made on the basis of the type of skill or knowledge involved.

This section has stressed the need for careful and thorough task analysis as the basis for the design of good training. It must be clear what the overall objectives of any task are, and how they can be broken down into specific sub-tasks which will achieve the overall goal. Training must then be specifically directed to those defined objectives if it is to have a good chance of succeeding (83,85,141,142,143). But these are, to an extent, counsels of perfection when seen against the realities of what is actually done in practice. It is perhaps salutary to end with the results of a study by Heath (144) into the safety training which had been received by the victims of some 1300 accidents. The results are shown in Figure 9.4.

While the victims may be biased towards claiming that they had received no training, and towards failing to label a short explanation as training, the figures are nevertheless a stark reminder of how far there is still to go to ensure that even some sort of training, let alone well designed training, is given to those who need it. As the example of the training programme for ppe (Figure 9.3) indicates, the investment of both time and money required to organise and to provide adequate training is great. Sadly there is often only lip service paid to this investment. As a result training may get a bad name as a preventive measure, because too much is expected from poorly conceived and executed programmes.

WARNINGS & HAZARD SEEKING

When and where can the hazard(s) exist which require the use of personal protective equipment (ppe)? (S, U)

How can the hazard and exposure to it be measured or estimated? (S)

How do you tell when the hazard is present (is it naturally obvious or must warnings be used)? (U)

What warning signals are used, and are they warnings that the danger is present or that it may be present? (U)

Can the warnings be faulty or inadequate (either false alarms or failure to warn), and how do you tell if they are? (U)

How do you tell if the ppe being used is (still) giving adequate protection? (U,M)

LABELLING AS DANGEROUS

What does the hazard do to you if you do not use ppe, and how does it do it? (S,U,M)

How can you tell when the hazard is serious enough to wear the ppe, and what factors make it so (e.g. concentration, time, work rate, temperature)? (S,U)

What are the norms for exposure to the specific hazards and are they applicable to the group under consideration? (S)

How do you calculate whether the given population is in danger or not? (S)

RESPONSIBILITY FOR ACTION

Who is responsible for providing (maintaining) the warnings? (U,M)

Who is responsible for selecting, ordering, checking, testing, cleaning, repairing and replacing the ppe? (S,U,M)

Who is responsible for ensuring that ppe is worn when necessary? (U)

Who is responsible for solving any problems which arise? (S,U,M)

PLANS & ACTIONS

Which type and make of ppe will protect against what hazards both in theory and in the practical working conditions under consideration? (S,U,M)

When, how and how fast does the ppe deteriorate? (S,U,M)

What foreseeable factors can reduce or destroy the protective properties? (S,U,M)

What factors affect the fit of the ppe? (S,U,M)

How do you fit, test and adjust the ppe? (S,U,M)

Incorporation of the fitting, adjustment into the job routines. (U)

How often do you need to practice the fitting, use etc? (U)

What factors discourage the use of ppe and how can they be overcome? (S,U,M)

Figure 9.3. Training needs: respiratory protection (source 140, Hale and Else 1984)

WARNINGS & HAZARD SEEKING

When and where can the hazard(s) exist which require the use of personal protective equipment (ppe)? (S, U)

How can the hazard and exposure to it be measured or estimated? (S)

How do you tell when the hazard is present (is it naturally obvious or must warnings be used)? (U)

What warning signals are used, and are they warnings that the danger is present or that it may be present? (U)

Can the warnings be faulty or inadequate (either false alarms or failure to warn), and how do you tell if they are? (U)

How do you tell if the ppe being used is (still) giving adequate protection? (U,M)

LABELLING AS DANGEROUS

What does the hazard do to you if you do not use ppe, and how does it do it? (S,U,M)

How can you tell when the hazard is serious enough to wear the ppe, and what factors make it so (e.g. concentration, time, work rate, temperature)? (S,U)

What are the norms for exposure to the specific hazards and are they applicable to the group under consideration? (S)

How do you calculate whether the given population is in danger or not? (S)

RESPONSIBILITY FOR ACTION

Who is responsible for providing (maintaining) the warnings? (U,M)

Who is responsible for selecting, ordering, checking, testing, cleaning, repairing and replacing the ppe? (S,U,M)

Who is responsible for ensuring that ppe is worn when necessary? (U)

Who is responsible for solving any problems which arise? (S,U,M)

PLANS & ACTIONS

Which type and make of ppe will protect against what hazards both in theory and in the practical working conditions under consideration? (S,U,M)

When, how and how fast does the ppe deteriorate? (S,U,M)

What foreseeable factors can reduce or destroy the protective properties? (S,U,M)

What factors affect the fit of the ppe? (S,U,M)

How do you fit, test and adjust the ppe? (S,U,M)

Incorporation of the fitting, adjustment into the job routines. (U)

How often do you need to practice the fitting, use etc? (U)

What factors discourage the use of ppe and how can they be overcome? (S,U,M)

Figure 9.4. Percentage of injured workers who had received training in the specified aspects of the tasks on which they were injured (source 144, Heath 1983)

9.4 RISK COMPENSATION

9.4.1 Introduction

In this chapter we have so far concentrated largely on the positive side of feedback and learning. We have portrayed it as the way in which behaviour is adapted to conform better to the real danger which is present. Here and there comments have been made which indicate that there is another side to the coin, and that learning can result in the acquisition and preservation of unsafe behaviour. It is to this negative side that we turn finally in this chapter.

Most accident risks are very small per unit of time, or per number of occasions when an individual carries out a particular task or action. People may use a sharp knife thousands of times in a particular way before they cut themselves and only then do they get feedback that it is not the safest way. Someone may sharpen a tool on an abrasive wheel many hundreds of times without using the protective screen or goggles before getting a splinter of metal or dust in the eye. Translating this into motivational terms, a person may carry out a piece of behaviour many times and receive feedback that it is successful before anything goes wrong and any negative feedback is produced. The successful, but unsafe behaviour thus becomes highly learned and firmly implanted, and thus resistant to unlearning. Repeated exposure to danger and even to injury can result in reduced rather than increased fear as people learn that they survive the danger quite adequately and that it is not as bad as they first thought (145).

Many of the problems of designing adequate training in health and safety are connected with ways of providing short-term substitutes for the negative feedback of an accident which will help to counter the positive feedback of successful use of unsafe behaviour. An example is the stress which can be laid on the short-term effects of shortness of breath and bad breath as results of smoking. These may be more meaningful as factors in a decision to give up smoking than the threat of cancer which may not occur for twenty years. In earlier chapters of this book we have discussed many of these aspects, and the following chapter on motivation will return to the issue. The general principle that feedback can reinforce unsafe behaviour needs no further proof here. However, we want to turn to a specific application of that general principle which has made more specific predictions, namely 'risk compensation' or 'risk homeostasis' theory.

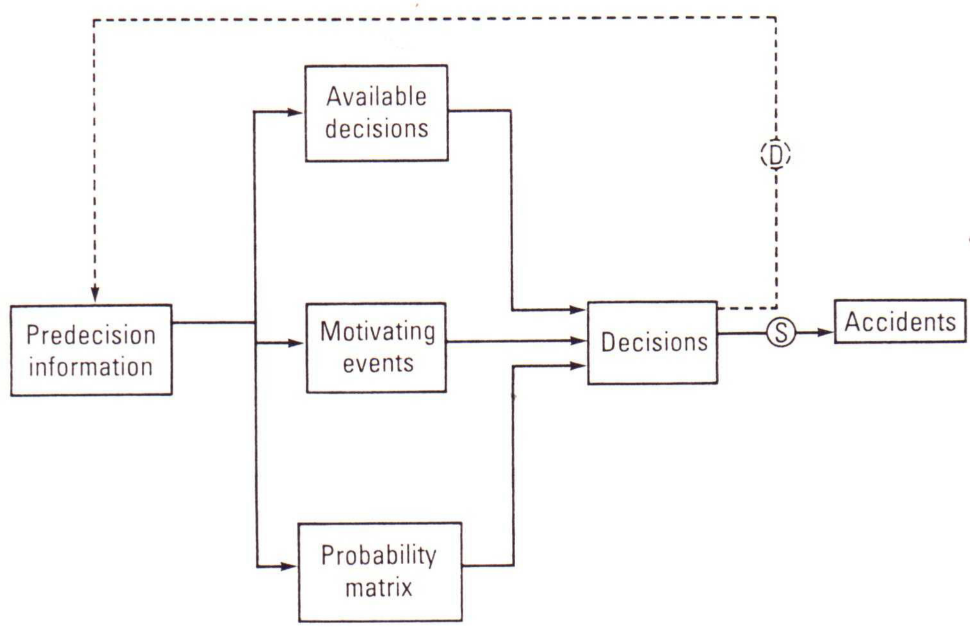

Figure 9.5. Hazardous activity as a closed-loop process (source 146, Cownie & Calderwood 1966)

9.4.2 Risk compensation or homeostasis theory

The origins of the theory can be traced to early ideas of cybernetics (146) and of self regulating systems which seek to maintain optimum levels of stimulation (147). More recently it has been most strongly advocated by Wilde (148,149). It has usually been elaborated in the context of road safety, but its protagonists claim that it has similar implications for occupational safety. Cownie and Calderwood (146) express the theory in terms of the model in Figure 9.5. The symbol 'S' on the link between decisions and accidents means that the relationship is stochastic - there is a probabilistic relationship between the two. The symbol 'D' on the feedback loop indicates that it occurs with a time delay.

The theory runs that people have a certain desired or acceptable level of risk (probability of accident of a given type) which functions within the motivation block. If the perceived level is above or below this target level, they adjust their behaviour to compensate and bring it back to the desired level. If, as a result of feedback, they learn that the situation is safer than they thought or they perceive that changes have been introduced to make it safer, this is registered in the probability matrix, and, if this new level is below the target, behaviour is adjusted to compensate and to bring risk-taking back up to the desired level. Where the task has been made safer, unsafe behaviour will be less often punished by a near miss or accident, and so will become more likely to occur. The end result claimed is that, in the long-term, there is no improvement in safety level from the introduction of many safety-design measures aimed to reduce risk.

The theory thus predicts an increase in speed on roads if dangerous corners or other black spots are eliminated, or if drivers wear seat belts and so feel safer; this in turn should lead to an increase in accidents per unit of time until they are back to previous levels. Because the effect is postulated to work on the measurement of accidents per unit time, and because the increase in speed may mean that a person spends less time driving the same number of miles, there can still be an overall reduction in accidents per mile driven. However, the reduction will not be as much as expected without the effect of feedback. In addition the theory asserts that accident blackspots are merely points which have attracted accidents to themselves and that removal of blackspots will simply spread the accidents out; in other words accidents will migrate from the old black spot to surrounding areas, because people now approach at a faster speed and/or with less attention to danger. In terms of occupational health and safety the theory would predict less wearing of hearing protectors if the noise level is reduced towards the exposure limit, or less care by workers if machines are enclosed and comprehensively guarded.

The protagonists of the theory go on to assert that the only effective long-term measures which would overcome the compensation are ones which would influence directly the values given to safe and unsafe behaviour and what is an acceptable or desired level of risk - such things as supervision, enforcement, incentives and education (146,148,150).

The tenor of the theory tends to be pessimistic about the value of much current accident prevention effort. As such it provides an open invitation to those who do not want to spend money on prevention to justify their standpoint on the grounds of the futility of engineered safety measures. When combined with the conclusions which can be drawn about the dubious and short-term value of many attempts to influence motivation directly (see Chapter 10) the theory can lead to an overall deep cynicism about the preventability of accidents and diseases. It is therefore important to examine closely the evidence which can be brought to bear to support the theory.

The early papers on the theory quoted evidence from studies of industrial absence (151) which showed that the overall level of absence in a steel plant remained constant over time, but that the category in which it was recorded (sickness, accident, unsanctioned) varied according to the pressures exerted by management against any particular category (for example, safety campaigns or checks on sick notes). Most of the later evidence has concerned road safety and has either attempted to compare 'risk taking' over different situations or has compared accident rates before and after the introduction of technical or design solutions. No specifically occupational studies of the theory appear to have been carried out.

9.4.3 Predictions from the theory

Before examining the evidence it is important to be clear what the theory is claiming in detail. Unfortunately its proponents are not always entirely clear or consistent about its formulation; for example Wilde (152,153,154) has changed the emphasis of his formulation from suggesting a fairly conscious compensation at the level of individual risk-taking to suggesting a largely unconscious compensation at the level of groups or society. Subsequently (147) he has argued himself into a position which renders the theory virtually unfalsifiable by claiming that the accidents removed from blackspots will spread themselves out in both space and time over all relevant groups in the traffic system, and that the compensation process can take as much as a year and a half (see also 155,156,157,158 for detailed critique).

Despite these shortcomings it is possible to formulate three points about which compensation theory makes claims:

1. That there is a desired or acceptable level of risk which people will either strive to remain below or to maintain.
2. That compensation will occur by seeking out other gains at the expense of the increased margin of safety introduced by the preventive measure. The gain most frequently studied is in speed of driving.
3. The mechanism proposed for the compensation is either a (semi-) conscious process of trading off gains and losses, or a (largely) unconscious adjustment in response to regular feedback.

The formulation can be critically examined on two grounds.

1. Different researchers formulate the target level of risk differently. For Cownie & Calderwood (146) it was a level of probability not to be exceeded. For Wilde in 1976 (152) it was a level of personal risk not to be exceeded, in 1985 (154) a level of accidents per unit of time to be actively maintained. For Naatanen & Summala (159) it was a subjective risk level of zero, which could be an objective level above zero. For Taylor (150) it was a level of control to be maintained, where a small loss of control was seen as pleasant and positively rewarding, a larger loss as increasingly negative.

The work of Green and Brown reviewed in Chapter 5 showed that it is not really possible to talk of an absolute level of risk which is acceptable. People would always like the level to be lower than it is currently if it is measured in terms of probability. On the other hand it is meaningful to talk about an acceptable level of control, where a small loss of, or challenge to, control in cases where people believe they are personally in control of the hazard, is seen as exciting and positive (see also Chapter 10). However, even here, it is not meaningful to talk in terms of level of risk or even of control in isolation from the gains, or other losses that accrue from any given choice (160). It is only meaningful to talk about a new balance of losses and gains being struck after a preventive measure has been introduced, rather than an active seeking after a particular desired level. This means that it is unlikely, a priori, that the level of accidents would return to exactly the same point as before the design change.

2. If compensation is to take place there must be some detectable change in the situation facing the individual or group which is being expected to compensate. The detection must either be through direct or delayed feedback. In the first case there must be a clear change in the look or feel of the car or road which either alerts conscious processes of modification of behaviour, or largely automatic adjustments. In the second case there must be a noticeable change in the accident rate on an activity which triggers general lessening of the care taken on it.

It would therefore be expected that obvious changes in safety such as seat belts would have greater and faster effect on producing compensation than invisible changes such as strengthened passenger compartments or collapsing steering columns. Changes which produced only small changes in risk would be expected to go unnoticed, because subjective scales of risk have been shown to be much more compressed than objective ones (161). Also, given the biases and inaccuracies in assessment of probability which we discussed in Chapter 5, the accuracy and effectiveness of the feedback loop via changes in accident rate can be seriously questioned.

9.4.4 Research evidence

The earliest field study in this area was by Taylor (162) who measured stress levels of drivers on a standard drive around public roads and compared it with their speed. When the stress level during the drive was plotted against the distance travelled per minute it came out at a remarkably constant figure. Taylor interpreted this as evidence that the drivers were regulating their speed to maintain a constant mental load or stress level. He then correlated speed over the various sections of the road with the number of accidents on each section as recorded in police reports and found it to be inversely proportional. When the two parts of the study were combined it appeared that drivers were adjusting their speed so as to maintain a constant accident risk over time, using the mental load as the means of control. Compensation was not perfect; it was not sufficient where there was a rapid change in the number of hazards over a short stretch of road.

Studies in the laboratory on simulators (163,164) seemed to show a similar constant level of risk-taking independent of the probability or size of the penalty. In neither case could this be a physical injury because of the ethics of experimentation, and these studies must therefore be somewhat suspect.

Subsequent studies of real changes in road or car layout and design gave mixed evidence. Some showed no compensation; for example, a change from cross-ply to radial tyres in terms of increase in speed (165), and seat belt use in terms of headway to the car in front (166). Others showed partial compensation, but not enough completely to wipe out the gain from the safety; for example, migration of accidents following introduction of pedestrian road crossings or treatment of black spots (167,168), relayout of intersections (169), studded tyres and speed (170), and changes in weather conditions (171). Some studies showed complete compensation over a period; for example, changes to road width and layout on corners (172). The preponderance of cases where compensation is incomplete is perhaps not surprising in view of the general finding reported in Chapter 5 that people do not adjust their decision processes sufficiently to accommodate new information which they have received.

9.4.5 Conclusion

The debate on the theory continues, because most of the studies cited can be criticised on methodological grounds by one side or the other, and the results are often open to interpretations compatible with either viewpoint (173,174). The evidence from the research is therefore far from conclusive. Most studies have only used rather crude measures to assess whether compensation does occur - for example, only counting numbers of accidents without taking account of their severity or only assessing whether there was increase in speed without adequately checking if this did actually result in restoration of the accident figure to its previous level. No study has been adequate to test the hypothesis that compensation occurs at a group or societal level, namely that gains in safety for one individual or group are compensated for by losses for another. Peltzman (175) showed that such a transfer can occur between drivers and pedestrians in some cases, but did not study enough different groups to assess whether the losses and gains balanced perfectly.

Despite these methodological shortcomings it seems reasonable to reject the theory in its most extreme form (176) which claims that there will be perfect compensation at the individual level. There is ample evidence that some lasting gains in individual safety occur through preventive measures (171). The large decrease in overall fatalities per worker in most industries over the course of the last century is witness to that fact in relation to industrial safety.

However, it is also clear that compensation does take place in a range of situations, and that people do trade off some of the potential gain in safety for gains in other factors which are important to them, such as speed (177). Migration of accidents from blackspots removed by design treatments has been shown to occur in the road system, but not to the extent that it wipes out all the gains from the treatment (although it may make the cost-effectiveness of some of them more questionable). The major questions to be answered are:

1. in what circumstances does compensation occur? (for example, are work settings less prone than driving to compensation effects?)
2. how can it be minimised in the face of positive preventive measures (and maximised in the case of deterioration in conditions, or the occurrence of an accident?)

This is a case of manipulating the feedback mechanisms which we have described in this chapter. Such an approach leads to the following conclusions:

1. Both proponents and opponents of the theory are agreed that no compensatory increase in unsafe behaviour will occur when the old level was above what was 'acceptable', however that is defined.

2. Where there is no particular gain to be had from adjusting behaviour to be more dangerous there is unlikely to be any compensation. Therefore, safety measures must address this motivational aspect. This is another point of agreement between both sides in this debate. Where individuals can for example discard uncomfortable, cumbersome or restrictive personal protective equipment and still achieve the same level of protection because engineered safety measures have been introduced it is natural that they will be tempted to do so; it could be argued that, even if they do, there has been a worthwhile gain in job satisfaction and equity (140). The expectations from such a programme should therefore not be too high in terms of total gain in protection, although they can be made greater if as a result of the control at source the ppe which has to be worn is less onerous.

3. If the safety measure removes the possibility of risk taking no compensation is possible. This should therefore be the ultimate ideal. If that is impossible, compensatory changes in behaviour should be made as difficult as possible.

4. Safety measures should aim never to reduce the subjective level of danger more than the objective level. Safety measures which are highly visible but largely ineffective should be treated with great suspicion; examples are machine guards which are flimsy or unreliable, ppe which has been badly chosen in relation to the purpose (dust masks used in solvent fumes).

5. Efforts should be made to avoid unexpected and rapid increases in the level of hazard, since the compensation mechanism cannot work rapidly enough. This reinforces the need for

warnings especially where a simple action (for example, lifting a cover off a machine part) directly exposes dangers.

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CHAPTER 10

MOTIVATION AND SAFETY

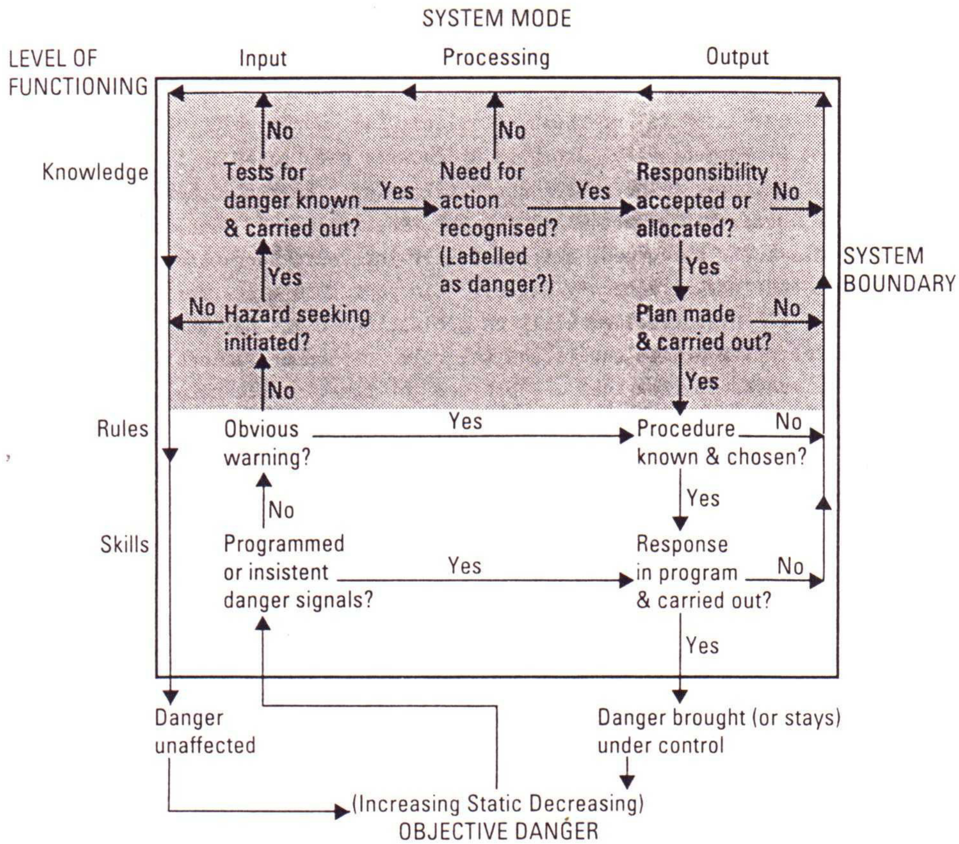

Figure 10.1. Behaviour in the face of danger model - motivation & safety

10.1 INTRODUCTION

The last chapter ended with discussion of a theory which concluded that changes in attitudes and motivation were the only means of producing a lasting change in the number of accidents occurring. While we rejected the extreme form of the theory, and showed that other forms of accident prevention were still possible and valuable, we concluded that there was enough evidence for the theory in a somewhat weaker form to make it imperative that any prevention campaign take full account of motivation as a factor.

What we mean by motivation is the whole subject of what drives behaviour. What are the goals that people are trying to achieve? What are the factors which guide the decisions and choices between the various courses of action open to an individual at any given moment? The first part of the book considered what those various courses of action consist of. We identified a number of choices which are important for safety; the choice of whether to inspect or to look out for hazards, the decision as to whether a safety problem exists and needs to be tackled, the choice of what to do and who should do it, and, at a routine task level the choice between competing action sequences. In Part 1 we concentrated on the cognitive aspects of those decisions; the way in which information was collected and processed; the judgments which were made based on it; and the way actions were monitored. The whole activity may have seemed rather dry, logical and lifeless, because the emotional side of the decisions was hardly touched upon. Words such as greed, altruism, self-interest, carelessness, ambition, achievement, and fear were hardly used. In part this was a deliberate choice to counteract the historical emphasis on motivation which has dominated, and in our view marred attempts to understand the role of human factors in health and safety. We wanted to show that a great deal of the mismatch between people and the situations and tasks they work in could be understood in terms of a mismatch in abilities and expectations, and that choosing to act dangerously while knowing the consequences is a comparatively small part of the problem.

The other reason for leaving a consideration of motivation until now is that its influence pervades the model we have used. All activities at the knowledge-based level are concerned with either conscious or unconscious choices and decisions. Therefore what we have to say in this chapter is relevant to many of the preceeding chapters, and makes more sense once they have been read. In particular we shall hark back to Chapter 5 where we discussed the factors of choice, control, foreseeability and severity as factors determining whether people feel there is a need to act to bring danger under control. We shall also refer to Chapter 7, where the idea of different action thresholds was introduced, to explain why more evidence and pressure is necessary to secure some actions rather than others. Finally we shall refer back to Chapter 9 where we indicated that all learning required the presence and satisfaction of drives or motives.

The topics of this chapter will be questions such as:
Do piecework payment systems discourage people from carrying out safety checks?
Can safety films full of blood and gore assist in getting people to wear safety goggles?
Why do experienced craftsmen resist suggestions from inspectors or safety experts to change their work methods?
What role can safety laws and their enforcement play in reducing accidents and occupational diseases?
Why do operators defeat or render inoperative safety mechanisms on machinery?

These sorts of questions have echoed down the years through the reports of labour inspectors, the speeches of company chairmen and the writings of scientists. It is a sweeping but useful generalisation to state that the predominant tone of these questions has been one of pique and uncomprehending irritation. How could people act in a way that they must have known to be dangerous?

So strong has been this tone that theories of unconscious motivation - the idea that people really must unconsciously have wanted to get hurt in order to do such crazy things - have held quite strong sway in some quarters (1,2). The work of Hill & Trist (3,4) and others (5) is quoted in support of this view. They showed that the patterns of accident absence correlated highly with other measures of absence and morale, and suggested that people who were dissatisfied with their work unconsciously had minor accidents in order to legitimise being absent from it. It seems much more reasonable to assume that the findings arise simply because dissatisfied people use the opportunity of such accidents as do happen in order to take (more) time off than those who are satisfied with their work. It is also plausible to suggest, as does Baldamus (6,7), that dissatisfaction leads to lack of job interest and attention, and so to a greater tendency to be caught out by hazards. No positive motivation to take risks or to get injured is needed to explain the findings of these studies.

Even where people have not gone so far as to suggest such unconscious motivation they have frequently taken the rather simplistic view that such unsafe actions prove that people are like irresponsible, lazy and rather greedy children who are unable to choose rationally for their own long-term good, and need to be beaten with sticks or cajoled with carrots into looking after themselves. Out of this paternalistic view of safety motivation come the requests to psychologists to help companies increase the safety consciousness of their employees, and the quotations such as the following, given in written evidence to the Robens Committee in the UK when it was considering reform of its health and safety legislation:

> 'This state of mind (a safe attitude) has to do with leadership, moral discipline, the will to work safely, motivation and working climate'.
> (8, The Soap, Candle & Edible Fat Trades Employers' Federation, Evidence to the Robens Committee P132).

Such a formulation of the problem is only a small part of the story of motivation. The theories of motivation on which it is based are those of F.W. Taylor (9) and his contemporaries in the 'scientific management' movement which stressed the power of money as the one great incentive of relevance to the worker. Their theory claimed that workers only wanted to make as much as possible for as little effort as possible, and that they were neither interested in, nor capable of planning and decision-making. Later experiments and theories of motivation showed the narrowness of that view, and the importance of other factors such as social group norms, challenge and achievement. More modern theories also stress the variety of factors which motivate, and the individual differences between people in the priorities they adopt between the factors. This has underlined the fact that the choice of behaviour in any situation may differ between individuals because of such varying priorities; hence there is not necessarily any one right decision. A position of moral outrage that someone did not do what you personally would have done in their place may be comforting for you, but, of itself, gets the discussion of how to discourage further such acts little farther forward. Analysis must go much deeper to identify the particular factors relevant to that individual or group in influencing a particular phase of the decision-making set out in our model.

In this chapter we shall first put forward a more recent formulation of the issue of motivation, and discuss the major factors which are relevant to it. This will lead to a discussion of the differences found in attitudes towards safety and to the use of safety measures. We shall then consider the major groups of motives which have been shown to be relevant to health and safety decisions, and the importance of the ideas of conflict and balance between motives. Finally we consider the evidence from studies which have looked at the effect of attempts to influence motivation in order to promote safe behaviour.

10.2 THEORIES OF MOTIVATION

There have probably been more words written by social scientists about motivation than about many other topics in psychology, and there have been a correspondingly large number of theories which have succeeded each other over the last century. To a non-psychologist the theories seem confusing, since it is often not clear whether they are making conflicting, or merely parallel predictions. This book is not the place to try to explain or to clarify those differences. For that, the reader is referred to other sources (10,11,12). Many of the differences are ones of emphasis arising out of the different fields in which the research was done (in business organisations, during education, among the mentally disturbed etc); other differences arise at the level of explanation being attempted (detailed explanation of individual actions or general predictions of behaviour of populations) or in the type of model being used (systems model, medical pathology, behaviourist). In this book we have chosen one particular approach, which is often labelled expectancy theory. We shall then try to fit the main conclusions from other theories into that framework. The choice is made largely because the theory fits well with the model which we have used in this book, and because a number of specific research studies in the field of health and safety have used it as a framework. Within the general expectancy theory approach we shall combine two specific models, that of Lawler, Porter & Hackman (12) and that of Fishbein & Ajzen (13). The combined model is shown in Figure 10.2.

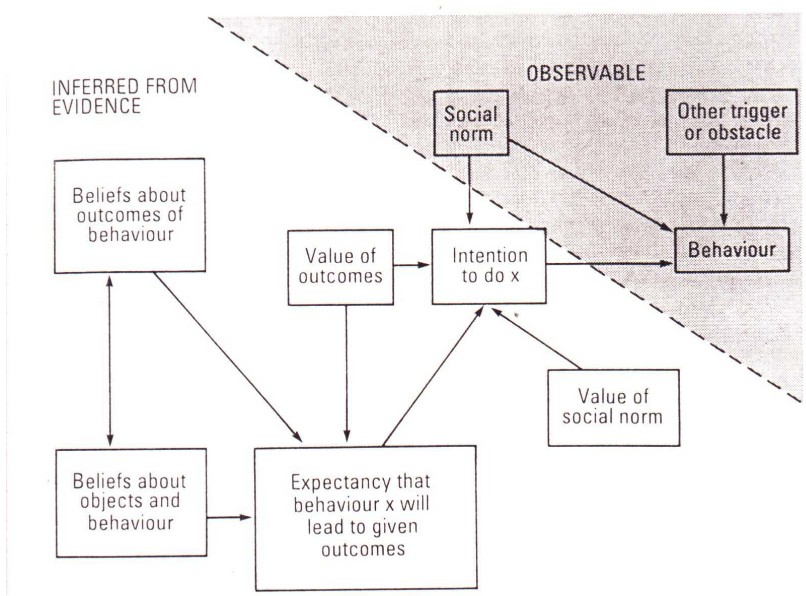

Figure 10.2. Motivation, attitude and behaviour

The beliefs which we discussed in the first part of the book feed in at the left hand side of the diagram (beliefs). These may be beliefs about whether a particular process is under control, whether a respirator will keep dust particles out, how serious it is to lose the top of a finger, or what has to be done to shut down a machine or plant in an emergency. The discussion in Chapter 5 on the way in which judgments about probability are made feeds into the expectancy that any given behaviour X will lead to particular outcomes. Here also feeds in the information about actions and outcomes contained in the various stored programmes of action sequences which we discussed in Chapter 3. The values of outcomes are the positive or negative values attached to the results of given behaviour; how unpleasant is the embarrassment of making a mistake in front of your boss, how pleasant pulling off a difficult task against the odds, how positive earning an extra few hours overtime pay, how negative the feelings of fatigue from doing the overtime etc.

The crucial aspect of this theory is that the values of given outcomes are only brought into the equation if the person believes that the behaviour will have a reasonable chance of resulting in them - thus, if I do not believe I can control whether I have an accident working on a particular process, it will be no good trying to influence my behaviour by telling me that the injuries I can get are serious.

The expectancies multiplied by the values of different outcomes are then summed across each behaviour, and a basis is formed for choosing between the behaviours. However, this only leads to an intention to behave in a particular way. This intention can be changed by social pressures; I may intend to drive off in my car without wearing my seatbelt, but I am giving a lift to a friend who will not give me a moment's peace if I do not wear it, so I hastily buckle it on. Again this effect will be mediated by the value which the individual gives to the social norm; do you care for the good opinion of that friend, or would you only reverse your intention if you saw a police car in your mirror as you drew away? In fact the process of forming intentions may result in two different courses of behaviour being nearly equally attractive, and then small triggers or obstacles in the situation may result in one or the other finally capturing control and determining what is done. This last point is analogous to the processes of control of routine behaviour described in Chapter 3, where we emphasised the role of external circumstances in triggering available action sequences.

The end result of a chain of events of this sort has ample chance to differ from what one might expect if one looks only at the beliefs and attitudes which are fed in at the left hand side. This difference between beliefs, attitudes and behaviour has been a constant headache for the social scientist and those who try to predict behaviour through the use of opinion polls and attitude surveys (14). Even the most thorough survey which identifies all of the relevant outcomes, values and expectancies cannot expect to produce anywhere near a perfect prediction of behaviour.

This point can be illustrated from the literature on safety measures. For example, Guttinger (15) in a study of welders found only a correlation of .69 between the workers' expressed intention in relation to use of protective equipment and following of safety rules and their own reported behaviour. This gives an idea of the effect of the situational factors. Reported behaviour was more correlated with social norms (.44) than with individual attitude (.28), but both correlations are relatively low. Several studies of protective equipment have shown that both users and non-users think it is a good thing, and even that users rate the negative aspects of the protection higher than non-users (probably because they have more experience of them); what distinguishes the two groups is habit, and sometimes general attitudes to rules or coercion to obey them (16,17,18,19).

Analyses of studies aimed at changing behaviour also often reveal only partial and sometimes unexpected changes in the attitudes which go with the behaviour.

For example, Sheppard's study of the British anti-drink and driving campaign in 1967 (20) found that there was a drop in drunk driving, but that this was not due to any drop in drinking, nor any change in the tolerance of drinking and driving or its results (value), nor in beliefs about how much alcohol people could individually take and still drive (all targets of the campaign). The result was simply due to refraining from driving after drinking probably because of a fear of getting caught while the campaign was on and police action was high. With no change in the underlying attitudes and beliefs it is hardly surprising that the effect of the campaign was short-lived.

This incomplete association between beliefs, attitudes and motivation makes the analysis of problems in this area difficult, and the evaluation of changes in behaviour from motivation campaigns particularly problematic, since the amount of change which can be expected from influencing any one outcome value is probably small. The important effect of social pressure also means that quite opposite behaviour can be expected in situations where people are under observation or in a group compared with when they are on their own. The effects of the clash between very strong personal convictions and high social pressure can be seen in very sudden and dramatic reversals in behaviour which are typified by religious conversions; a person may resist pressure very long and stubbornly, but evidence suggests that, if conversion does occur it is the more complete and sudden the stronger the original opposition was (21).

10.3 VALUES, MOTIVES AND BALANCE

10.3.1 Theories of motivation

Within this framework of expectancies and values and of the influence of social norms we have already dealt, in Chapter 5, with the values which are directly relevant to assessment of danger. We noted there that decisions about whether to act or not against the danger were not only influenced by factors related to the negative aspects of harm. The advantages to be gained from the action or activity are also crucial. At that point we did not go into those other factors or values which are weighed in the balance. That is the subject of many of the motivation theories which have been put forward. Unfortunately, each theory has produced a different list of what those values are. The lists vary greatly in length, from as few as one to as many as 14,000 factors (12). The reason for such diversity lies in the approach and time perspective adopted by different theorists. Some simply observe the behaviour that people exhibit and the consistencies in the goals which they seem to pursue, and thus end up with a long list of rather detailed needs or motives. Others take a developmental or learning approach and try to explain how this great diversity of short-term goals can be traced back to one or a few deeper lying needs; for example, they try to look beyond the immediate pursuit of money and to explain it as a learned way of gaining food and drink to survive and of acquiring possessions to impress others. The most reductionist of the psychological theorists were the behaviourists such as Skinner who were willing to accept only the need for food, drink, affection, sex and freedom from pain as truly basic motives, with perhaps the addition of curiosity (though some of the purists argued that even this could be explained in terms of exploration to find further sources of the first five). All other things which people tried to achieve were thought by the behaviourists to be merely learned secondary motives which could be explained in terms of early experience of trying to satisfy the basic needs. For example, they might trace the pursuit of qualifications and promotion to learned ways of gaining attention and affection from parents. Some biologists go even further and reduce all motives to one, the survival of the species, and succeed in explaining even such altruistic behaviour as sacrificing one's life to save one's children or relatives in terms of the advantage that gives to the survival of the gene pool. In this view adult animals (including humans) are simply a means used by the genes to secure their survival and multiplication.

In this reductionist vein, we indicated in Chapter 5 the considerable evidence to suggest that the need to explore and to control the environment around one should be added to the list of fundamental motives. A developmental approach to motivation is essential to the study of psychology, and to any attempt to influence learning in the early years of life. We suggested in Chapter 9 that too little is known about how and why children learn to behave in the face of danger. However, the approach becomes too cumbersome when talking about adult behaviour. There is often no point, when we are trying to change adult behaviour, in tracing every value which seems to be relevant in coming to a decision back to its origins in basic bodily and mental needs. It may be true that a child originally learned to play in dangerous places because it thereby got attention and perhaps even praise for skill in not getting hurt; the remaining tendency to enjoy hazardous situations in adulthood may be largely independent of any praise or attention getting as a reward to make it persist. It is often better to plan purely in terms of later learned motives such as setting a good example to others, or protecting family and dependents from the consequences of injury.

The pragmatic need to describe and explain the behaviour of adults, particularly in a work setting, led theorists to seek ways of grouping the multitude of different specific goals into clusters which had developmental validity, but were not too great in number.

The theory of Maslow (22,23) is typical of such attempts to group motives. He put forward a hierarchy of 5 types of need in descending order of priority:

1. Existence needs; food, drink, air, sex.
2. Security needs; shelter, secure sources of the existence needs, freedom from fear, need for structure in life.
3. Social needs; affection, belonging to a group.
4. Esteem needs; need to be valued by self and others, competence, independence, recognition.
5. Self-actualisation needs; self-fulfilment, achievement.

Unfortunately Maslow sometimes described the second level needs as 'safety' needs. This is a confusing use of the word, because imminent threats to life and limb fit more neatly under existence needs, and the meaning of the level two needs is far broader than just threats to health and safety in the sense that we use them in this book.

Maslow postulated that the most basic level of need which is not yet satisfied is the one which controls behaviour at any moment in time. Hence, people will not be very concerned with pursuing needs for esteem if they are threatened with the loss of their job, and so of their security. The concept of the hierarchy as set out here has not received very great empirical support (24). While there is evidence that the first two levels do need to be satisfied in most people before much concern is shown with the remaining levels, there does not appear to be any very clear progression among those supposedly higher levels.

The influential theory of Herzberg (25) postulates only two levels or types of motivation. He contrasted wages, working conditions, interpersonal relations and supervisory behaviour (Maslow's first three levels) which (unfortunately for clarity in a book about health and safety) he called 'hygiene' factors, with recognition, achievement, responsibility and advancement (Maslow's top two levels) which he called 'motivators'. Again this conceptually simple theory did not receive unequivocal empirical support (12), and seems to be an oversimplification. Even the postulation of a hierarchy between the survival and security needs on the one hand and the remaining levels on the other suggests that people should always be averse to any dangerous behaviour unless they are faced with the choice of that as the only way of satisfying pressing needs for survival. The great body of evidence presented in Chapter 5 shows that such a postulation is clearly not true in many situations.

10.3.2 Motivation and decision

Even if the concept of a universal hierarchy of needs must be rejected, the idea of grouping motivating factors into clusters for convenience of discussion and to guide attempts to change behaviour is still attractive. Individuals also appear to operate with reasonably stable priorities. Discovering which factors are more basic for any given person or group is therefore an essential step in trying to influence them. The priority will in great part be determined by experiences in early life, and what is learned from parents and peers. There will also be cultural variations depending upon the customs and conditions applying to a particular group of people; for example, for many people human life (and the expectancy that events may lead to its loss) will be valued differently in a Third World country with high malnutrition and a precarious agriculture than in an industrialised country with an extensive welfare system, and health or education will be valued differently in different social classes.

The temptation among many people, including many scientists and managers, is to assume that the priorities and values which they personally hold are universal, and that decisions and policy can be made simply by projecting their own values onto a given situation. Such an assumption is dangerous in all cases, and the more so the greater the difference in background and experience of the policy maker and the person in the practical situation. In particular, people who are experts in a particular field will often give far greater value to factors relevant to their specialist knowledge than will lay people. For example, doctors weigh medically relevant issues (effects on short- and long-term health, or prognosis for recovery) far more heavily than the social consequences of a course of action (embarrassment from visible signs of treatment such as hair loss from radiation therapy, or inconvenience), and tend to dismiss the latter as irrational (26).

When a decision has to be made at a particular time the various motivating factors will be weighed according to some priority. This process can be envisaged as the aggregation of the various values which will be produced by any given outcome, multiplied by the expectancy that the person has that a particular course of action will result in each of those outcomes (Figure 10.2). Different courses of action can then be compared according to the different patterns of pros and cons which come out of that calculation.

Economists use just such a model for trying to explain human market behaviour, and for setting up techniques for making logically consistent and economically rational decisions. In doing so they attempt to reduce all motivating factors to one scale of value. In their case this scale is a scale of utility, which is usually linked to the subjective value of money. Much of the complexity and uncertainty of economics as a subject arises from the assumptions which have to be made in reducing such subjective factors as freedom from fear, job security and life itself, to this utility scale.

Economists also postulate that the only rational behaviour is one which maximises the gain to be had at a given moment by the individual. But there are ample experimental studies to show that this is not the strategy used by ordinary people, even in decisions where only money is at stake (27). People will often use other decision criteria, such as accepting the first alternative which satisfies certain minimum criteria, without attempting to maximise gains ('satisficing'). People are not concerned to squeeze the last drop of advantage out of a situation, but merely to accept an outcome which is good enough. In situations of uncertainty (see Chapter 5) people are also inclined to use a 'minimax' strategy; minimising the maximum loss they can possibly suffer, even if this means foregoing the chance of a large gain. This is the strategy of playing safe; I am not willing to take even a tiny chance of getting killed, even though I can earn a huge amount by taking the risk, if I can still come out ahead by choosing another course of action which has no chance of death attached.

These 'sub-optimal' strategies (at least in the eyes of the economist) are ways of coping with conflict between factors which make the individual both attracted to and repelled by a given course of action. Such 'approach-avoidance' conflicts (28) are common in health and safety; the gloves which are uncomfortable and slow down the work, but prevent cuts to the hand; the extra safety device on a process which is going to put a manager over budget on the job, but will make a death (and the consequent damage to the managers reputation and career) much less likely. In such cases it seems likely that people use crude cut-off values; if the chance of an injury or death is greater than a certain subjective value, no amount of gain is worthwhile. Only below that limit is there a more direct trade-off of potential losses and gains.

Since decisions are made at a particular point in time, while the advantages and disadvantages of the chosen action will only accrue over a period of time, there must be some mechanism for taking into account the time scale of payoffs (discounting in the economists' terms). We saw in Chapter 5 that long-term effects are usually undervalued if they are negative; the assumption being that there is enough time for them to be avoided later by changing behaviour (I can always give up smoking - tomorrow). In contrast, long-term positive effects may be overvalued on the assumption that events can be steered later so as to maximise the chance of them materialising. They and immediate payoffs thus get weighted more heavily than the long-term disadvantages, because there is less uncertainty that they will actually happen. This technique also results in a simplification of the decision to be taken, since some factors can be left totally out of account now to be returned to later.

In the next section we shall look at the range of factors which have been identified as being relevant to decisions about safety. The list which we use is inevitably arbitrary, given what we have said above. The specific goals and motivating factors which can compete with or reinforce safe behaviour will be as varied as the situations which can arise. We can only hope to provide a range of examples and some sort of checklist of clusters of factors which can serve as an aid to the analysis of any specific situation. We have chosen not to use categories such as Maslow's as headings because they lie too far from the practical consideration of what can be altered in a situation. For example, money and payment systems, which clearly interact with safety, can have an influence on survival and security (how much money is earned), social needs (whether bonus schemes are individual or group), esteem and achievement (by providing the means to buy goods which bring with their possession the tangible signs of success, and the respect of other people). We have therefore chosen a compromise list which is a step nearer to factors which can be manipulated, but which can still be linked to the more basic needs.

10.4 MOTIVATION AND SAFETY

10.4.1 Fear and horror or danger and excitement?

We deal first with the motivation which is most directly associated in many people's minds with health and safety; the generation of fear to prod people into taking action. This is an approach to the prevention of accidents and the promotion of health which has been widely attempted and also widely criticised (29,30). It has made use of pictures, films, or descriptions of the horrors of the particular accident or type of illness. Examples are close up film of an eye operation to remove a metal splinter as the visual background to the message that eye protection is vital; pictures of tumourous lungs and the tars that they contain shown as part of an anti-smoking campaign; close-up photographs of broken skulls and lacerated faces to promote the use of head protection; and the detailed second by second description of how and in what order bones, body and internal organs are broken, burst and mangled during a car accident if a seat-belt is not worn.

The (usually implicit) hypothesis which is put forward to justify the use of these horror pictures in promoting action is that the gruesome details will grab attention in such a way that the reality and seriousness of the danger cannot be ignored; that the fear which is generated will motivate the audience to seek ways of preventing those horrific results or to carry out preventive measures which are already known.

We discussed in Chapter 5 the factors which were important in persuading people that they needed to act to control danger. One of the four factors mentioned was the seriousness, vividness or dreadfulness of the outcome of an accident or disease. It would therefore seem, a priori, that attempts to manipulate such a factor should produce some worthwhile change in behaviour. However, it must immediately be remembered that this factor came out fairly consistently as a secondary one to the controllability of the hazard in the studies reviewed, except in a minority of individuals where it swamped their whole conception of danger (31). Nevertheless, the use of fear as a motivator seems worth careful study, since it has been shown in many experiments with laboratory animals to be a powerful force for the learning of skills, and it appears among the factors at level two of Maslow's hierarchy, suggesting that it should have a fundamental effect. This section will therefore explore the research on the use and effectiveness of fear as a means of geting people to act safely. The discussion will revolve largely around the apparent paradox that, despite the fact that fear is a strong motivator the behavioural results of its use in health and safety are disappointingly small.

The nature of fear. Since the beginnings of psychology as a science the nature of fear has been the subject of competing theories. In 1890 William James put forward (32) a controversial theory that the body first responded physiologically to a threatening stimulus by either fighting or running away, and that the brain responded by labelling those preparations as fear. He encapsulated the theory in the phrase; 'we are afraid because we run away'; which was the opposite of the then accepted idea that people ran away because they were afraid. While James's theory is not accepted now in quite the way he formulated it, it does emphasise a division between physiological and mental processes of fear which is a central feature of modern theories. Reviews of research on fear (33,34,35) point out the difficulty of measuring and researching it. There are a number of possible indicators of fear, ranging from physiological indicators of hormone levels in blood (or more usually urine), through sweating, skin resistance, electrical activity in brain or muscles, to verbal reports of feelings of fear or anxiety. Unfortunately these indicators are frequently not highly intercorrelated. For example, a study of trainee parachutists (36) found that physiological indicators indicated a steady increase in fear during the period before a jump, while expressed fear was very high on the morning of a jump, declined during the active preparation period and only increased again during the flight and actual jump. The uncoupling of physiological and verbal indicators is much more marked among veterans of a particular activity than among novices who are meeting it for the first time.

A study by Schachter & Singer (37) illustrates another aspect of this distinction. They injected the hormones which are characteristic of the state of fight or flight directly into people's veins and found that, in neutral surroundings their subjects reported only feelings of arousal and anticipation. However, if they were in the presence of others who were showing clear behavioural signs of fear, the subjects also reported feelings of fear. Alternatively if those around them were behaving as though excited and happy, the reported feelings were ones of pleasure and excitement. In other words social factors conditioned whether physiological responses were labelled as positive or negative (38). This is a further example of the mediating role of attribution in behaviour, which we discussed in Chapters 6 and 8. This close link between fear and excitement is also discussed by Allen (39) who points to the fascination that horror movies, fairground rides such as the Wall of Death and Big Dipper, and dangerous sports such as caving and motor racing and disasters have for people. They will pay good money to be frightened. He attributes this partly to the positive value of arousal, partly to the social bonding which shared fear produces, and partly to the reinforcement that surviving the experience gives to the belief that the situation was really under control all the time, even though it appeared not to be. The personality factors of arousal seeking, extraversion and sensation seeking have been linked (40,41) with a tendency to get involved in incidents, although the experimental support lies rather more in the area of use of drugs and in traffic violations than in accident experience.

The social effects of dangerous situations are ones frequently reported in studies of those who have been in combat together, or who have lived through air raids, or civil disasters such as floods. These events are often remembered with a great degree of nostalgia for the comradeship and unity of purpose which they created. The testing of control which occurs in dangerous situations provides the link with the controllability factor discussed in Chapter 5, and with the idea that a subjective feeling of control only remains real if a person at least occasionally experiences situations in which they can test where the limits of that control lie. This sense of testing of control also has much in common with the risk-taking of entrepreneurs with investments and speculative ventures, a subject which has been much studied in the context of achievement motivation (42,43). The importance of the element of subjective loss of control in fear is also seen by a series of experiments linking fear, pain threshold and control (44,45,46,47,48). These experiments used mild electric shocks, loud noise or other noxious stimulus as punishments in studies. For some subjects the noxious stimulus was described as being under the control of the subject, for others as beyond their control. The subjects were then allowed to set experimentally (by trying out the stimuli at varying strength) the level of shock etc. that they found the maximum tolerable. Those who believed the shocks to be controllable set this level higher than those who believed that the stimulus level was random. Other studies found that patients in surgical operations who expected post-operative pain reported experiencing subjectively less than those who did not expect it, and that certainty that pain would occur sometimes reduced fear compared with situations in which there was uncertainty (49,50). The existence of fear at a subjective level therefore seems to result in a search for ways of restoring subjective control and so reducing the fear. Festinger (51) called this process the reduction of 'cognitive dissonance'; the removal of a state in which there is a conflict between what a person would like to believe or to happen, and the state they believe themselves to be in. At the physiological level there are also mechanisms to keep the effects of fear and stress under control through fight or flight. Studies of stress (49,52) show that the physiological changes which go with the preparation of the body for fight or flight release into the blood stream hormones and other chemicals which are particularly aimed at stimulating the efficiency of physical activity. If no physical action follows, the chemicals remain in the bloodstream. Where the source of the stress or anxiety is also not removed and the situation is not seen as returning within control, the body will be subject to high levels of these chemicals over long periods. In the short term this is exhausting, because metabolic changes result in faster utilisation of food reserves and more rapid functioning of other body systems, such as the heart. In the longer term (days and months) the existence of significant levels of anxiety result in long term changes in the circulatory and digestive systems leading to ulcers, heart disease etc. The physiological manifestations of fear and stress are thus harmful if they remain present for too long, and are not removed by an active behaviour to remove the fear object or to run away from it.

At both the physiological and cognitive level there seem therefore to exist powerful mechanisms to avoid or to reduce strong levels of fear just because those levels are so bad for the bodily and mental functioning if they go on for long. On the other hand, if the stimuli which are aimed at producing the fear are comparatively mild and short-lived they risk producing only arousal, which may well be experienced as positive and stimulating.

At the behavioural level people can protect themselves from fear in several ways. In the short-term people can avoid the nasty information by turning the other way; in the longer term they can learn defence mechanisms to convince themselves that it is under control. This process can be illustrated by taking an example, the use of unpleasant information about the results of smoking to reduce or stop smoking. The 'logical' structure of what people are trying to achieve in the minds of smokers with this material runs as follows:

1. I am a smoker;
2. the results of smoking are as depicted in the information material and pictures;
3. this is very unpleasant; therefore
4. I will attempt to give up smoking.

In a series of informal experiments during courses on safety and motivation we have asked smokers and ex-smokers to talk about their experience in trying successfully or not to give up the habit, and about their response to such propaganda. Most report that they found the information unpleasant and disturbing, and that there was at least a period of feeling that something had to be done. Some did try (and some succeeded) in giving up, showing that the 'logical' sequence can be the one which is followed. Those who did not try, or who tried and failed, always reported coping with the unpleasant information either by suppressing all thought of the subject, or by modifying one or more of the statements in the sequence.

1. can be modified to: 'I am not really a heavy smoker; I only smoke a pipe, or cigar; I do not inhale (or another variation on the theme) and therefore there is no need to give up';
2. can become: 'I do not believe the information; the problems are always exaggerated; I have been doing it for 30 years and have no problems; my grandfather smoked like a chimney and lived to 96; I have tough lungs; etc';
3. can become: 'you have to die of something; the pleasure outweighs the risk; if I did not smoke I would die from the stress far sooner; etc';
4. may be put off with: 'I have tried and always failed; I'll do it when the exams/board meeting/this crisis/Christmas are/is over; there is no point while I share an office with a heavy smoker; I am still young; etc'.

Readers who do or did smoke may amuse themselves by adding their own and their friends' excuses to the list (and who knows, the very exercise may convince a few that these really are only rationalisations, and it is about time that they treated them as such and got on with giving up). What all the rationalisations have in common is that they enable people to live with information about the nasty effects of an action without the belief that it will also affect them personally. In other words the illusion of control can be maintained, and the horror dismissed. The problem is that many of these rationalisations are highly plausible, and very difficult to disprove. The dividing line between real control and illusions of control is very fine. In the case of chronic hazards such as smoking there is a very long latency period in which all personal evidence seems to reinforce the beliefs that there is no problem, and strong contrary evidence can only come from outside in the form of the painful deaths of friends or relations. In the case of acute, but rare events the proof of control or lack of it will also be long in coming.

With all these techniques for reducing fear and learning to live with unpleasant information the room for manoeuvre for the use of such stimuli to promote behaviour change would therefore, on theoretical grounds alone, appear to be limited. We turn now to the evidence of field studies to see how far this is true.

Experimental studies. The research literature on health education and the use of fear and other unpleasant information is extensive (53,54,55,56,57,58,59,60, 61). Much work has concentrated on the effectiveness of different levels of fear arousal, and has shown broadly that very unpleasant material aimed at producing high levels of fear often has an effect on attitudes, but is very variable in its effect on behaviour. Those for whom the message is least relevant (for example, non-smokers in the case of anti-smoking propaganda) are often the ones whose attitudes are most affected (in this case strengthened) by strong appeals to fear. The greater the unpleasantness the simpler the message had to be to register, and in some experiments the memory of the message was totally wiped out by the experience of revulsion from the horror. In one smoking experiment high fear levels even resulted in an increase in smoking in heavy smokers after the film. The explanation offered was that the response which these people had learned to use to cope with high anxiety was to light a cigarette. Rogers & Mewborn (58) showed that high fear arousal was only an effective weapon in the armoury of change methods where the people believed that they had it in their own hands to change their behaviour, that the recommended action was not aversive for any reason and would be highly effective in removing the danger, and where the people's self-esteem was high. Otherwise much milder levels of fear arousal were far more effective.

Other studies showed that fear arousal was very ineffective compared with simple instructions about how to go about the healthier behaviour. This was especially so where the recommended 'health action' was to carry out, or to go for a check-up which would indicate whether any serious problems were present (for example, chest x-ray, dental check-up or mammary or testicular self examination for signs of cancer). Here, even comparatively low levels of horror propaganda had a discouraging effect on the behaviour.

Propaganda aimed at arousing fear seems, therefore, to have two related effects; first leading to a reappraisal of the situation, which may lead to a rational change in behaviour; second leading to emotional flooding and a desire to escape from the fear source either by running away, rationalising, suppressing or attacking it. In addition the emotional effect inhibits the rational one, while the belief that one is not susceptible to, or can cope with the threat inhibits the emotional response. Hence horrific propaganda produces more reappraisal in those who believe themselves not susceptible, while the highly susceptible are more open to informative and reassuring messages. People who have personalities susceptible to anxiety are subject to earlier flooding and so respond better to low or to no fear. The time scale over which action to remove the threat can be taken is also important. If immediate action is possible the flooding has no time to develop. Thus, Piccolino (55) found that more horrific posters of the effects of falls from stairs worked well if placed immediately by the stairs, since those seeing them (in this case airline passengers) could immediately grab a handrail and so reestablish control.

Conclusion. From these studies it can be concluded that the use of information and pictures about the seriousness of the consequences of a hazard can be effective provided that people already know, and can put into effect at once, effective ways of reducing the risk. If they have to go and seek out those ways of coping, the level of horror used must be much lower, otherwise the rationalising defence mechanisms will take over and the fear will be suppressed in ways which will not lead to an increase in health or safety. In any event the effect of the fear and horror cannot be expected to last long. Pirani & Reynolds (62) demonstrated this with their study of horror posters in which the initial gain in wearing of protective equipment of 18% at the end of two weeks had regressed to an overall loss of 2% after 4 months compared with the period before the posters were put up.

Fear can therefore be expected to have its best effect in situations where a once for all decision can remove the fear and restore control. It can help someone to learn a safe routine of behaviour, but cannot be expected to sustain that behaviour if it does not become routine. Somewhat paradoxically it is likely that horrific images will be more effective in keeping the converted (those who have acquired the safe routine) from lapsing than in converting the sinners in the first place.

10.4.2 Control and self image

We turn now to the motives which may come into conflict with the desire to work safely, or to adopt safety measures. The first of these factors links closely with the major factor which was identified in Chapter 5 as influencing assessments of action need; is the situation under control? We said in that chapter that beliefs in control were so important that, just as with fear, people were highly motivated to cope with any situation which threatened those beliefs. If this is possible by reasserting control by a positive action over a reasonably short period of time this will be likely to occur. If not, the belief would still be likely to be restored, but by establishing an illusion of control. The strength of this motive means also that there is strong resistance to accepting that one is not in control of a situation. We quoted instances in Chapter 5 where people believed themselves to be far more competent and in control of tasks than was objectively the case. For example, the vast majority of drivers believe themselves to be better than average.

Attempts by outsiders to change behaviour that has been practiced over a number of years are direct attacks on this belief in control. They imply that the person did not know how to cope previously and so must change now. This is particularly hard to take when the comment comes from someone who has not had long experience in doing the same job, as is typically the case with a safety adviser, labour inspector or doctor. One way of avoiding this head-on clash over sovereignty and competence is to hang the request for change onto a change in the task, equipment or circumstances of the job. This diverts the implied criticism of the individual's competence to control a familiar task into an acceptable statement that there is a need to learn new ways to cope with new circumstances. A related problem arises in some jobs which are relatively simple in terms of skill, but whose incumbents can gain a certain distinction among their fellows and among new beginners by the nonchalant way in which they can take short cuts. Here risk-taking becomes a way of demonstrating competence; the steel-erector shows his skill by strolling across a narrow beam with no harness, or the hod-carrier by climbing the ladder while rolling a cigarette. Many of the short cuts may not in fact present dangers to those who are really competent, but they may inspire those less so to copy the behaviour with disastrous results. The counterattack is to conduct campaigns to link competence and safe behaviour together in people's minds, so that the latter becomes a proof of the former. Some success has been registered in, for example the oil industry in promoting safety gear such as hard hats, boots and safety harnesses as symbols of the professionals. The change in image (and styling) of motorcycle helmets is a striking example of the same approach in transport;

the hero of the '30s roaring through the countryside on his 1000cc machine with the wind blowing in his hair has been replaced by the knight in shining leathers and sinister helmet who features in the television series of the '80s. The helmet has become a symbol of masculinity (another sort of competence).

These are examples of 'self-image'. Each of us has a mental picture of what sort of person we are; for most of us somewhat idealised, with the worst warts removed, and the best features highlighted. If someone or some event sharply contradicts that image we feel resentful and wounded, and try to defend ourselves, either by attacking the outsider, or by withdrawing into our shell. We also have mental images of others, to which we attach labels. These stereotypes enable anyone to describe the quintessential salesman, mother-in-law, judge, German, Scotsman, nobleman, librarian, rugger-player or peace campaigner. These images are used to help make judgments about joining groups, taking jobs, starting activities or copying behaviour. They are examples of the frames of reference which we discussed in Chapter 5. Pirani & Reynolds (62) explored the image which the wearer of personal protective equipment (ppe) produced among the employees and managers of a number of small factories in the north of England. They asked their subjects to choose from a long list of pairs of adjectives the description which best fitted people shown in photos, some wearing ppe, others not. The employees' list for the ppe wearer contained: good, reliable, responsible, elderly, conscientious plodder, out of touch, isolated, fastidious and compulsive. The managers' list contained: reliable, slow, gives little trouble, can leave safely alone, makes trivial complaints. Neither list is exactly sympathetic, and it is not surprising that such people did not want to wear the protective clothing. The need to build a more positive image is clear. Protective equipment which people find makes them unattractive (for example, goggles for women, hairnets for men) will never be easy to sell.

10.4.3 Effort, trouble and convenience

In all studies of personal protective equipment and machinery guarding these factors come up as major determinants of wearing and use. Laner (63) found easy availability, comfort, price and appearance to be prime factors in determining the wearing of safety boots in steel works. Cheradame (64) reported them again in relation to protective equipment use, and commented on how specific they are to specific use conditions. Fhaner & Hane (65) found that attitudes to comfort and convenience together with attitudes to effectiveness accounted for 50% of the variance between users and non-users of seat belts. Hale & Else (66) stressed the importance of the fit and comfort of all protective clothing for the wearer. Booth (67) laid great emphasis on the responsibility of the designer to make the defeating of machine guards as difficult and time-consuming as possible, and the means of refixing the guards after maintainance as easy as possible (68).

In another sphere, road traffic researchers point to the gross overestimates that people make of the time saved by driving at high speeds or of using motorways, and of that lost in traffic jams (69,70,71). These estimates work their way through into the choice of the speed to travel, the effort made to overtake, and so on. This generally results in people increasing the risk, in the erroneous belief that they also are greatly increasing the benefit and convenience of such behaviour. This error needs to be demonstrated as graphically as possible.

The obvious solution to the problems of comfort and convenience lies in the detailed design of the safety measures and equipment, and the way in which people are allowed to participate in and choose what suits them best within the limits of what will protect them adequately. The fit and tailoring of industrial clothing is only belatedly catching up with that of everyday clothing, and only then in industrialised countries. The manufacturers are still largely catering for western clientele, and the very different anthropometry of the Asian, African, South American and Polynesian peoples is frequently not allowed for in sizes, fit and comfort (72).

10.4.4 Job interest

Job interest is a motivator which has received considerable study in the decades since Herzberg (25) propounded his theory. He advocated the introduction of challenge, variety and responsibility as ways of increasing interest and so getting better performance out of people. Very few of the studies on job enrichment which tried to put his theory into practice quoted figures on accidents (73,74), and most of the changes implemented were so far reaching that it is difficult to pin down what aspect produced what result. However, there was a clear indication that absence rates, including those from accidents went down as a result of such changes. Apart from any improvements in safety through better ergonomic design of plants which sometimes accompanied the introduction of job enrichment, the reduction in absence could result from people taking less absence from similar accidents, a suggestion we made earlier in reverse to explain why poor morale led to increases in accident absence in the studies of Hill & Trist (3,4). In other words the hypothesis is that job interest prevents or reduces withdrawal from work. Baldamus (6,7) put forward a related theory to suggest that alienation from work and 'anomie' (being distanced from social norms) were important underlying factors in accidents. His theory suggested that people who were not keen on their work would be less attentive, less willing to follow rules, including safety rules, and so were more likely to get injured. The practical support for both theories falls far short of acceptable, largely because neither author investigated the process by which the morale or anomie could manifest itself in accidents.

Saari (75,76) sounded a warning note about the wholesale advocacy of job interest as a way of reducing accidents. He pointed out that job enrichment and job rotation would lead to more complexity of jobs, and to a dilution of experience of workers. His analysis of a range of jobs showed a positive correlation between job variety and accident rate.

The case of the interaction of job interest and safety must be regarded as not proven, and subject to many other factors which will be affected by the detailed changes introduced to further job interest.

10.4.5 Danger money, piecework and safety incentives

Danger money and piecework. These factors have been seen for many years by some sociologists, government inspectors and political scientists as major factors in the genesis of accidents (8,77,78,79). The argument runs that workers are employed to produce as much output as possible. If their wages are dependent upon that output, or if they are paid extra money to carry on working in particularly dangerous or dirty conditions an inevitable result is that safety precautions which get in the way of that earning capacity will be defeated or ignored.

Danger money as a deliberate policy and as an alternative to spending money on improvements in working conditions is now universally condemned as immoral, although there are numerous ways in which its practice can go on in disguise. If higher wages are paid for dangerous jobs than for safer ones this can be explained simply in terms of the difficulty of attracting people to take the job on. Other euphemisms such as 'dirt money', 'unsocial conditions bonus' and 'inconvenience money' can also hide what is in fact a direct subsidy for accepting dangerous work and not demanding improvements. Such practices are akin to the employment of migrant or immigrant workers on particularly dangerous jobs. This may not explicitly be done because they will not complain and are not unionised, but the result is still the same; unsafe working conditions are accepted because they are the only ones which offer employment and a wage. During times of high unemployment there are always complaints from employee and trade union organisations of these sorts of practices increasing, but there is no record of successful empirical attempts in the research literature either to prove or disprove their existence or their effect on accident rates.

Whenever an adverse effect of piecework on accidents is claimed, the counter-argument from its supporters is that it is the task of supervision to ensure that safety rules and measures are treated as the baseline below which no behaviour falls. Hence, they claim, piecework is not inherently unsafe if supervision is good. It is suggested that the problem is a purely technical one of devising a payment to reward safe, and not unsafe behaviour. Considering the importance of this debate there has been surprisingly little adequate research to settle the arguments. We can say, logically, that those who advocate the value of safety incentive schemes cannot then deny the possibility that the same economic and acquisitive motives can theoretically lead to the reward of unsafe behaviour if the system of work is set up in that way. What is at stake is whether research has demonstrated that safer or unsafer behaviour actually does result.

A few studies in Sweden (80,81), Alberta (82), and Britain (83,84,85,86) have attempted to investigate this problem. The Swedish studies in the forestry industry looked at the effect of a changeover from a piecework system to one largely based on a flat rate merit payment, with the addition of a small productivity element over the whole group working in one region of the country. They showed a 29% drop in the frequency rate, and one of 32% in the severity rate of accidents, a change which was greater than the drop in productivity; that is, the accident rate per output also dropped, although not so much. The workers commented that they had more time to listen to safety advice, and were no longer forced to use unsafe methods. In the Swedish mining industry the frequency rate after a similar change did not drop, but there was a dramatic change in the pattern of accidents; severe accidents dropped 95% and medium ones 70%, while slight accidents rose 45%. Workers had leisure to take time off for more minor incidents, which is arguably either a good or a bad thing, depending on whether or not they were previously starting back to work too early. There was no change in productivity in that industry, but again comments were made that unsafe methods did not have to be used under the flat rate system.

Wrench (83) quotes considerable anecdotal evidence from reports of government inspectors, accident investigations and literature from the technical and trade union press of instances of unsafe practices and accidents caused by haste, and piecework systems. He also quotes a simulator study

(87) in which greater risk taking (though not in relation to physical injury for ethical reasons) took place under piecework conditions. In this and later studies Wrench and his collaborator favour the time series analysis method pioneered by Baldamus (6). This looks at accident trends over the week and relates them to pay day. A rising trend towards pay day under a piecework regime is interpreted as evidence that haste and the rush to make sure that enough is earned that week are major factors in accident causation. Unfortunately this reasoning is open to objection based on observation in factories, which shows that workers may also respond to a piecework system by working flat out at the start of the week, and slowing down towards pay day, perhaps with an end spurt. Wrench & Lee's results do show some evidence of a rising trend through the week, but this could also be interpreted in other ways, including being evidence of fatigue. Wrench did show a consistent underreporting of minor injuries because of the cost to the worker of leaving the workplace to go and get treatment.

Other studies in this area, which looked not directly at accidents but at behaviour within organisations under piecework regimes (78,88,89), did show systematic evidence of violation of production rules leading to the defeat of machinery guards in order to increase output, of implicit understandings between workers and supervisors to turn a blind eye to unsafe practices, and of beliefs among workers and managers that adherence to all safety rules would considerably reduce production, and consequent obedience only to those rules which did not cost time.

The evidence, despite its scrappy nature, is reasonably conclusive that the potential for the effect of piecework and other payment systems on accident rate is there, and that movement away from piecework to flat rate systems can reduce severity rates, and sometimes frequency rates.

Safety incentives. The evidence on the impact of safety incentives on safety is less conclusive. Many companies operate safety incentive schemes of one sort or another. These range from competitions between departments or factories for an award which then hangs in the manager's office or the factory reception area, to elaborate schemes in which carefully worked out safety objectives are monitored using statistics, inspection and auditing to check whether they are met, and are rewarded with increasing prizes or credits which can be cashed in for consumer goods, holidays or sometimes cash. The evaluations made have usually not been reported in the scientific literature, but appear in the trade and professional press (90,91,92,93,94). The result is that the claims are usually not backed up by detailed analysis or argument. This is a great pity, because the overall results reported from the major schemes are impressive;

1. Halving of reported accident rate in one year (91) in a scheme in which supervisors' salary/bonus had an element reflecting accident performance of their group; cost over 1 year $100,000, saving from accidents prevented $228,000.

2. 81% reduction in works injury accidents and 50% reduction in driving accidents over ten years (90) in a scheme with awards in the form of points exchangeable for goods for keeping below monthly and quarterly targets of accidents, and for specific achievements - for example, passing safety related exams and tests.

3. Reduction in disabling injuries over ten years from 114 to 3 per year (92) in a similar scheme in which vouchers for goods were awarded for meeting specific targets related to time free of disabling injury and other specific criteria.

4. Halving of accidents over 5 years in a mining company (93) in a scheme using trading stamps, at a cost far less than that recouped from savings in not having the accidents.

5. Reduction in reported accidents from 116 to an average of 10 per year in an Australian company using gifts linked to group accident rates (94).

The authors usually do not claim that all of the effect comes directly from the incentive scheme, since many design and work procedure changes have usually taken place over the same period. The all-embracing programmes also usually aim to include managers and supervisors, and to reward not only safety performance but also: safety suggestions, completion of safety improvements and regular maintenance programmes. Hence it is very difficult to disentangle the incentive effects from those of other activities. The programmes are designed to create a complete safety climate, and so could be given the indirect credit for many improvements which happen during their currency. The improvements are still far too impressive to dismiss lightly. It is striking that the schemes which are reported as successful are the ones which have specific and attainable targets linked with individual and group behaviour, with carefully thought out and significant prizes which keep interest alive, and always give a target to aim for even if a first one is missed. The schemes all involve elaborate target-setting and monitoring. No successful schemes which are based only on simple inter-departmental or inter-factory competitions for purely symbolic awards are reported in the literature. Recognition by one's peers and superiors of achievement is an important motivator, but actual tangible reward in the form of goods would be expected to be more universally applicable and valuable. Critics of safety incentive schemes point to anecdotal evidence of people brought in in wheelchairs to avoid being registered as sick and spoiling the department's record, of people coming back to work too soon, and of accidents being covered up. These are obviously theoretical possibilities and any scheme which is implemented would need to guard against those effects by making sure that there was some independent monitoring of the scheme to minimise the bad sides of it.

Conclusions about this area must remain somewhat tentative. However, what is striking about discussion of the subject is the passion which it generates on both sides, and the extremes of language, bordering on moral fervour and indignation, which it produces (92,95). Those against the schemes stop little short of accusations of bribery, and of buying safe behaviour which should be considered a part of the normal employment contract, while proponents talk of the political dogmatism and utopianism of their opponents. The heat of the discussion comes perhaps more from reactions to the model of human behaviour which is seen to lie behind the idea of safety incentives than from the content itself. It is strongly tinted by Taylorism; at best paternalistic, at worst manipulative. The objection is more to how the behaviour is being influenced than to the fact that it can be influenced. It would be a foolish person who would deny the potential for the manipulation of behaviour either for or against safety through the payment and reward system of an organisation. Some of the manipulative sting can be taken out of incentive schemes if those who will be subject to them also take part in setting the targets and deciding on the rewards. Such principles of participation can also be applied to the devising of payment and incentive systems in other areas. Those interested in studying the theoretical and practical issues behind the establishment and running of payment systems in general are referred to general texts on the subject (96,97,98) while definitive evaluations of payment schemes aimed directly at safety are awaited.

Petersen (96) tries to encapsulate the important issues in this area in a series of six questions which will determine the response to incentives:

1. Will my efforts bring results, or will factors beyond my control play a large part in outcomes?
2. Will the safety goal be rewarded?
3. Even if the safety goal is rewarded, will alternative goals be rewarded more?
4. Will other people be rewarded for my efforts?
5. Are the performance measures used by management valid?
6. Would I achieve better results in another area?

To this list might be added the question:

7. Is it clear what the safety goals are?

10.4.6 Social factors

The model of motivation which we presented earlier in this chapter specifically singles out social norms and people's attitude to them as vital factors in the decisions about behaviour. In earlier chapters of this book the influence of the social and family group have been mentioned on numerous occasions. People are social animals who acquire many of their ideas and attitudes from those around them in order to supplement their own experience, and who use shared attitudes and beliefs as a way of defining themselves and their place within the interlocking groups which make up society. There is a tendency to agree with what is said by friends and colleagues as a way of strengthening one's ties to the group. This tendency is particularly strong when non-members of the group are present, and if they attack what the group believes in. The group then erects a barrier round itself to keep those alien views out. The more the alien views threaten the existing structure and function of the group the higher the barrier. In contrast, once a new idea has succeeded in getting over that barrier, the same mechanisms of group solidarity will protect and propagate it and guard it from being changed in its turn.

Norms, morale and communication. Groups are thus features which promote conservatism in any organisation or society. If their norms favour safe behaviour they are a good thing for health and safety, if the opposite then they are a major barrier to its propagation. A number of attempts have been made to link high group morale and satisfaction with good safety record, and bad industrial relations and communications with high accident rate (99,100,101,102, 103,104). Nearly all the studies also report differences in management commitment, training schemes and working conditions between the groups or factories with good or poor morale and communications. It is thus difficult to establish which factor is cause and which effect.

Attitudes and norms play a central role in the way in which a group operates. Any group is constantly in dialogue over its norms and functioning. In addition, most individuals belong to more than one group, and so are constantly subject to several norms which may push them in different directions, and lead to different behaviour in each group. We may see a very different side of our work colleagues if we meet them among friends or in their family. Group members bring new ideas and information from one group into another and test how they are received. If accepted, the ideas will be strengthened; if rejected, the views may be modified or suppressed, at least while the person is in that group. In the phase in which a new member is being tested out for full acceptance by the group this dialogue will be most intense. The more that the group operates together from choice, the stronger this tendency will be. Thus, informal groups will often be stronger than the formal groups set up by an organisation for work purposes. Also the more central the attitudes and beliefs are to the purpose of the group, the greater the pressure will be to conform. Thus, differences of view over fundamental direction and priority will split a management board, differences over meeting venues can cause conflict within a social club, and differences over the approach to exposure standards may divide a professional hygiene group. All these activities are aimed at the continued existence of the group, and will be played out in parallel with those aimed at furthering its direct objectives.

Health and safety are only the basis for the central objectives of a relatively few groups such as safety committees and professional health and safety groups. In most cases health and safety issues are peripheral, and therefore tend to be seen by the group as negotiable. The study of construction site supervisors discussed in Chapter 6 (105) is a classic example of the way in which safety is used as one of the bargaining counters in regulating the social groups on construction sites. The supervisors felt that they did not have the power to impose obedience to safety rules onto the contractors working on site, since they were open to retaliatory pressure from them over deadlines. They were caught in the argument; you can have it safe or on time. Therefore they had to negotiate safety as part of the informal group process, and again found themselves in a weak position as a semi-outsider to the group of contractors, because they always appeared to be put in the position of telling the contractors that they were not working competently; they were attacking a value central to the contractor (106).

Groups as a source of information. Social groups are a major source of information about hazards and precautions. This has been shown in studies of insurance buying (107), hazard perception (108) and its effect on the use of protective equipment (109,110), and natural hazards and precautions against them (111). Laner (63) not only demonstrated the power of social norms in encouraging people to wear safety boots, but also showed another side of the problem; both wearers and non-wearers of boots believed firmly that they belonged to the majority in the works. Both groups tried to bring to their side in the argument the support of a powerful, numerous group in order to bolster what they believed. There is evidence (112,113) that the views of the social group tend to be more important determinants of health behaviour among those from the working, than the professional classes. The latter are somewhat more inclined to take a scientific approach to decisions about safety precautions than the former, who will be more likely to turn first to advice and remedies from family and friends, rather than analysing the problem in a systematic way.

Clark & Prolisko (114) found that a population of young drivers with accidents was markedly less open to social influence and less concerned for social rules than a matched accident-free group. This underlines the effect of individual differences in the importance accorded to social groups and social norms as motivators.

Groups and change. The power of social groups makes them a central focus when trying to achieve change. Studies have shown the value of directed group discussion in changing the attitude towards and acceptance of safety measures. A series of studies in Sweden in a number of industries concentrated on the collection of information about hazards, incidents and near-accidents either from inspections and accident investigations or directly from workers. The analyses of these were then fed back to the workers in groups to form the basis for discussion (115,116,117,118,119,120). The results reported showed worthwhile gains in safety performance, though not in all factories, and not always sustained over a long period once the experimenters had ceased to push the scheme actively. Iacono (121) also reports useful attitude change from the use of discussions groups lead by a psychologist in altering attitudes towards protective clothing. The study of Pirani & Reynolds (62) went rather further and used role playing exercises in groups to try to alter attitudes in the same area. They found this to be the most successful of the techniques that they tried.

In all these studies the common feature is the involvement of the group itself in the process of analysing and thinking about solutions to a safety problem. The solution is not imposed from outside, but is generated under guidance from within. Group commitment to a solution and to an eventual change in behaviour is thereby secured from the beginning.

Supervision and groups. Another way in which the barriers around groups have been successfully overcome or avoided is through use of opinion leaders (sometimes, but by no means always supervisors) to bring ideas into the group, and to act as an ambassador (or fifth columnist). The success of this method depends crucially on the choice of the opinion leader. If the group does not see their supervisor in that light an attempt to use that person will fail. Pirani & Reynolds (62) report limited and short term success in using this approach in promoting the wearing of protective equipment but the gains had dissipated within four months. However, other evidence (110,122,123) demonstrates the vital role that an example set by the supervisor or teacher has on the use of safety precautions by workers and students. This is echoed by a number of the organisational studies which show a clear link between the safety attitudes of supervisors and the safety performance of the sections or departments under them (102,124,125). Butler & Jones (126), admittedly using a military situation, found that the role of the supervisor was far more crucial in situations where hazards are low than where they are high; in the latter circumstances the need for close cooperation and attention to danger is obvious enough not to need a driving force from supervision to keep it going.

10.4.7 Conclusions

The range of evidence on what are important factors in supporting or conflicting with safe behaviour is both broad and fragmented. The framework we have tried to fit it into identifies only major headings, and gives specific examples of conflicting and supporting motives. The message which we wish to draw from this review is that, while there are some universal categories of motivation which can be described, the interactions which they have with health and safety are usually highly situation-specific. Group pressure may work for safety in one situation, against in another; incentive and payment systems can be used to further safe behaviour and can conflict with it; job interest may promote positive morale and attitudes to safety rules, but may also introduce greater complexity and a wider range of hazards to be learned. Each situation therefore has to be analysed on its merits: what behaviour is rewarded by what means, and how will that influence health and safety? As we said in discussing risk compensation theory in Chapter 9, design solutions which improve safety will also promote attempts to defeat them if they threaten other valued outcomes, or if the safety can be traded off against more valuable gains in other directions.

Attempts to produce change in behaviour by manipulating these gains and losses must therefore promote a number of aspects:

1. increasing expected benefits from safe behaviour;
2. decreasing expected benefits from unsafe behaviour;
3. decreasing expected costs from safe behaviour;
4. increasing expected costs from unsafe behaviour.

Such attempts must also consider ways in which the altered balance between costs and benefits may lead people to try and modify, rationalise or defeat the new measures, so that these avenues can be blocked. Finally the means of introducing the changes must be considered, so that attempts to defeat the safety measures are not provoked unnecessarily. A final example may serve to illustrate this last point. Robertson (127) reported that in almost sixty percent of the cars he studied in which there was an interlock between seat belt fastening and the ignition key the system had been defeated. This still resulted in a better percentage of belt wearing than where a flashing light rather than the interlock warned of non-use. However, it shows two things; first that imposition of a solution from outside produced massive resistance in those concerned, and enough resentment to disconnect the system; second that defeat of the system was too easy for the design to be considered effective.

In the course of discussing the various motivating factors we have also presented the results of many studies which have used motivational changes to try to alter behaviour. In the final section of the chapter we shall group a number of other studies under the heading of the medium or method they attempted to use, rather than the specific motivating factor on which they focussed.

10.5 MOTIVATIONAL CHANGE

10.5.1 Posters, films and informational campaigns

A number of the studies reviewed under the heading of 'fear' earlier in this chapter used posters or films to get over the message about the seriousness of the danger which people were facing. Hazard warnings discussed in Chapter 4 also bear many similarities to posters. Information campaigns are hard to distinguish from other means of learning and training discussed in Chapter 9. The information given in those other ways contains elements which, besides trying to alter beliefs and knowledge and to alert people to the need for action, also attempt to motivate and encourage people to act in the particular way recommended.

The relative importance of information and motivation can be seen in the study of Pirani & Reynolds (62). General informational posters about protective equipment reminding people what to use, and of the need to use it resulted in a 51% increase in wearing two weeks after the start of the campaign, which fell back to an 11% increase after 4 months. General films produced 40% and 11% increases over the same periods, and posters with a specific fear content only 18% increase after 2 weeks and a decrease of 2% on the pre-campaign figure after 4 months. The work of Levanthal et al. (53) also showed the superiority of information about what to do to combat the health problem over messages designed to arouse fear which did not have the specific information content.

The general effectiveness of poster and other media campaigns is very patchy. Sell (30) reviews a wide range of studies covering both occupational and road safety, while Singh (128) reviews purely road safety campaigns. The general consensus is that campaigns do produce change in a number of cases; for example, out of thirty reports on road safety studies seven showed some behaviour change and six others a reduction in accident rates, though in four cases this was in campaigns where there were also physical changes to the road layout and/or changes in enforcement practice. The campaigns with specific messages and targetted behaviour seemed to come out best (129,130,131,132,133), and could in some cases result in gains which were still of the order of fifteen to twenty percent in the desired direction even after six months (134). However, in the majority of cases the effect was short lived, with behaviour, where it was measured for that long in a study, back to the baseline level after four to six months if there was no attempt to reinforce the effect of the posters with some other changes or renewed motivational campaigns. Whittington & Wilson (135) report a typical study which used television campaigns to attack the specific problem of chip pan fires. There was a short-term drop of 30% in fire brigade calls to chip pan fires, and a 40% drop in those that were not under control when the brigade arrived. The figure was back to the pre-campaign level after six months.

Other means of presenting information have been studied: safety signs attached to products (136); literature accompanying insurance documents (137); personal letters pointing out specific contraventions of traffic rules (138,139); and audiograms (111,140). Again there are worthwhile immediate increases in the relevant safe behaviour. These studies also indicate the importance of the style and comprehensibility of the message (111,132), its positioning so that it is seen easily, and its content. Dickson's study (137) shows that the information in the pictures and descriptions of losses from fire and theft which he used seemed to serve as a substitute for personal experience of an actual loss; they brought the amount of money that individuals who had not suffered a loss were prepared to spend on insurance up to the level of those who had suffered a loss. In other words they made the idea of loss real to people. A number of these studies are very closely similar to the studies of feedback of information about compliance with safety rules, which were discussed in Chapter 9 (141).

Hale (29) sums up the prerequisites of a successful poster campaign as follows:

- clear objectives leading to a clear message
- exposure in a visible spot relevant to the action required
- design to grab attention
- a simple comprehensible message
- a believable message from a reputable source
- a clear motivation to comply.

With all of this the effect can be significant over a short period, up to a number of weeks. To convert this into a longer term change requires either concerted and continuous reinforcement through feedback of results and reinforcement by supervisors or the sort of incentive schemes discussed in the previous section.

10.5.2 Laws, rules and disciplinary measures

Considerable controversy surrounds the subject of passing laws to legislate for safe behaviour. The principle has been accepted (if at first somewhat reluctantly) in the sphere of industrial and public health and safety for well over a century. The use of laws to impose the wearing of protective equipment in voluntary activities (helmets on motorcycles, seat belts in cars) has been much later in coming, and has sometimes provoked bitter libertarian opposition as an invasion of individual freedom. Opposition of that sort, for example, headed by a small number of Members of Parliament delayed passage of seat belt legislation in the UK for several years.

Industrial companies were quick to translate the occupational safety laws of the early nineteenth century into sometimes draconian company safety rules, with instant dismissal the penalty for many contraventions. However, the simple passage of a law or rule is not enough to achieve obedience. The discussion of the effects of piecework and reward systems (10.4.5 above) showed that the breach of many safety rules is winked at if they conflict with other priorities such as production. The fact that a 'work-to-rule' has become a synonym for a paralysing industrial action almost as disruptive as a strike is an indictment of the state of the safety rules in many large national organisations; many of them cannot be complied with if the expected efficiency, deadlines or productivity are to be achieved. As such they are worse than useless, because they bring the whole system of rules into disrepute. This book is not the place to embark on a discussion of the status of safety laws and their enforcement (8,79,142,143,144,145,146,147), but two purposes of rules and laws can be distinguished; as a statement of what should be done in a given situation (information or advice function) and/or as a measuring rod against which behaviour is compared and any contravention of which, if discovered, is punished.

It is not possible in practice to distinguish the effects of the rule or law itself and of enforcement or disciplinary action. The evidence on the effectiveness of the combination is mixed (148). There have been some dramatic successes where there are clear discontinuities in the curve of accidents and disease following the introduction of laws, regulations or rules; The Power Press Regulations (149) in the UK is an example, as are the regulations governing lead and some other occupational diseases such as TNT poisoning in the earlier years of the century, on the basis of the figures of reported cases in the Annual Reports of the Chief Inspector of Factories.

Perhaps the most widely studied example of legislation is that in many countries in the world making the wearing of seat belts compulsory. Reviews of the evidence from a number of countries (19,150,151,152) suggest that, over a short to medium term the passage of laws is extremely effective. Rates of wearing before legislation typically lie below 30%, often as low as 15%. After legislation they go up to 80-95%, while measures some years after introduction show rates still around 50-60% even without a very sharp enforcement campaign. The experience of Switzerland provides the most ideal 'experimental' situation because a law was passed in Jan 1976, repealed in Sept 1977 and reintroduced in 1981; the percentage of usage was 30% before the first introduction, 75% in the first period of the law, dropped to 40% during the period of repeal and rose again to about 80% on reintroduction. The effect of increased wearing on accidents is much less clear cut over the long-term, with some evidence that risk compensation takes place and that accident rates return to pre-legislation figures (152). Wearing reflects the relative perceived danger of the roads, with far more people wearing the belts on motorways. Figures quoted for the effectiveness of the laws in terms of reduced injuries and costs range from about 15-75% reduction in deaths and about the same range of reduction in injuries.

A study of enforcement of speed limits in a built up area using radar traps and police motor patrols showed a significant reduction in speeds and a reduction in injuries of 25% on the stretch of road concerned during the year it was in operation (153). This did not justify the cost using standard methods of costing death and injury treatment. However, there was an accompanying reduction in injuries on surrounding roads of 7.5%, and, if this is attributed to the same action, the costs were justified.

Barmack & Payne (154) reported dramatic effects on traffic accidents of a campaign of severe disciplinary action against airmen found violating traffic laws (especially drunken driving). Discipline included loss of rank, referral to a psychiatrist or even dishonourable discharge. The effect while the measures were in force was dramatic, but unfortunately no follow-up was possible when they were relaxed. Studies of much milder disciplinary action, for example, the sending of warning letters after traffic violations generally show much smaller, but still often significant effects on further offending, which fades after a few months (155). Lewin's study (155) included a personal interview with recidivists who offended again in the first period, and that showed a further 40-50% reduction in reviolation.

When the effect of disciplinary action in factories is considered the picture is very much less positive. Most studies show only a moderate increase in compliance (for example, Pirani & Reynolds, 62, found 39%) which rapidly declines to zero once the disciplinary action is stopped (110,156).

The problem with all disciplinary and sanction schemes is to make the chance of apprehension high enough to influence behaviour. If this chance is low it is something which people can ignore in the same way as they can ignore the low chance of an accident occurring as a result of the same piece of behaviour (157). For this reason a number of authors argue that this application of feedback mechanisms must aim at frequency and appropriateness of information rather than necessarily going for great severity when a breach is detected. The negative effects of withdrawal of disciplinary action (compliance may drop below pre-campaign figures) also acts as a warning that, once begun the disciplinary action must not be abruptly discontinued.

The latter point can be given a more theoretical underpinning by referring to a series of experiments in the attitude change literature on 'induced compliance' (51,158,159,160). These studies, which were not specifically related to safety, found that getting people to advocate a position with which they disagreed during a debate or role playing, produced quite significant attitude change towards that position. Part of the reason was put down to further familiarity with the position, and being forced to consider its good points. However, when it was further found that the less the inducement to advocate the position the more the attitude changed, further explanation was necessary. An explanation from an attributional approach (see Chapter 6) is that the people who were subjects in the experiment saw themselves advocating a view, and often advocating it well, and could only fully explain their behaviour in terms of partly believing in the position. If they were given money to do it, or were promised some other reward there was another perfectly good explanation for the behaviour (they were just doing it for the money), and hence had no need to adjust their attitudes. If we extrapolate this finding to the use of safety measures, we would expect that people who are strongly disciplined for not following safety rules which they do not find congenial will have a perfectly good explanation of their behaviour; they do it because they are forced. If that force is discontinued there is no reason to continue the behaviour. If on the other hand much less compulsion is used there will be a gradual change of attitude and habits, and final removal of the discipline will still leave good reasons behind to continue the behaviour. The same reasoning will apply to positive incentives. This may be an attractive theoretical explanation for the observed effects, but it has not been tested specifically on safety related behaviour.

10.6 CONCLUSION

A continuing theme throughout this chapter has been the insistence that most motivational measures are ones which have a temporary effect. Only if motivation is combined with new facts or teaching of new skills will it be turned into the more permanent gain which we have called learning. Otherwise the effects of motivation which is removed gradually fade away. Typically the effects have gone within a period of about six months. Within that picture some motives are more effective than others. Broadly speaking the more basic motivations are usually too powerful to be used very effectively. If fears and anxieties are really aroused, or people become convinced that the situation around them is really out of control they will react strongly and rapidly. But if attempts are made to prolong the use of these motives the pressure to reduce the fear becomes so great that rationalisations will set in and illusions of control will be instituted. These illusions are difficult to dislodge without use of excessive horror or drama. In much the same way disciplinary action is frequently too big a hammer to crack the particular nut of unsafe behaviour.

The more successful use of motivation is often therefore to use the rather less extreme motivators of praise, feedback of results or challenge. This can often be done through manipulation of work procedures or of organisational factors, or through social groups. However, even here the efforts at motivation must be continuous if the familiar fall-off in effect is not to appear. The motivation option is therefore not a simple one to use. It may require comparatively low initial costs compared with design changes, but its continuing costs are high if a high level of performance is to be sustained.

As a final summary of many of these points we include a table of results from the study by Pirani & Reynolds (62) from which we have quoted on several occasions. They compared various methods of inducing the wearing of protective clothing against four different hazards (to head, hands, eyes and feet) in small to medium sized companies in the north of England. They measured wearing for four weeks prior to the particular treatment (A), and then again two weeks afterwards (B) and four months after (C). While the different factories were not fully comparable, and the research design could not be adequately randomised, the results give an interesting comparative picture of the short- and long-term advantages of each scheme, out of which role playing comes a dramatic first. The results reported in the paper are presented in terms of the numbers of people 'always', 'most of the time', 'occasionally' and 'never' wearing the protective gear. For the purpose of Figure 10.3 and for the figures we have quoted in the text throughout this chapter we have converted these numbers into a single score by giving a value of '3' to 'always', '2' to 'most of the time', '1' to 'occasionally' and '0' to 'never'.

HAZARD TO	GENERAL SAFETY POSTERS			APPROPRIATE FILMS			FEAR POSTERS			DISCUSSION + OPINION LEADERS			ROLE PLAYING			DISCIPLINARY MEASURES			TOTALS % change from baseline		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Head	116	189	143	132	237	153	98	136	100	164	184	162	145	253	240	184	263	166	839	1262	964
																				50%	15%
Hands	193	253	195	184	241	202	193	213	202	165	167	157	156	255	249	190	277	151	1081	1406	1156
																				30%	7%
Eyes	132	227	153	126	183	143	138	203	140	121	155	139	128	240	243	191	256	185	836	1264	1003
																				51%	20%
Feet	146	216	158	186	221	199	231	227	207	195	198	198	168	272	272	185	243	194	1111	1377	1228
																				24%	11%
Total	587	885	649	628	882	697	660	779	649	645	704	656	597	1020	1004	750	1039	696	3867	5309	4351
% change from baseline		51	11		40	11		18	−2		9	2		71	68		39	−7		37	12.5

Figure 10.3. Effect of different motivational schemes (source 62, Pirani & Reynolds 1976)

Finally, it must be emphasised that methods of producing change must fit the culture of the organisation in which they take place. Corthouts (161) demonstrated this in a study of two alternative methods of instituting change - group discussion and the issue of safety rules - in two mines, one with an authoritative management, the other a participative one. The better change was the one most fitted to the existing style and expectations, group discussion in the participative mine, and the safety rules in the authoritative one.

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CHAPTER 11

INDIVIDUAL DIFFERENCES AND SELECTION

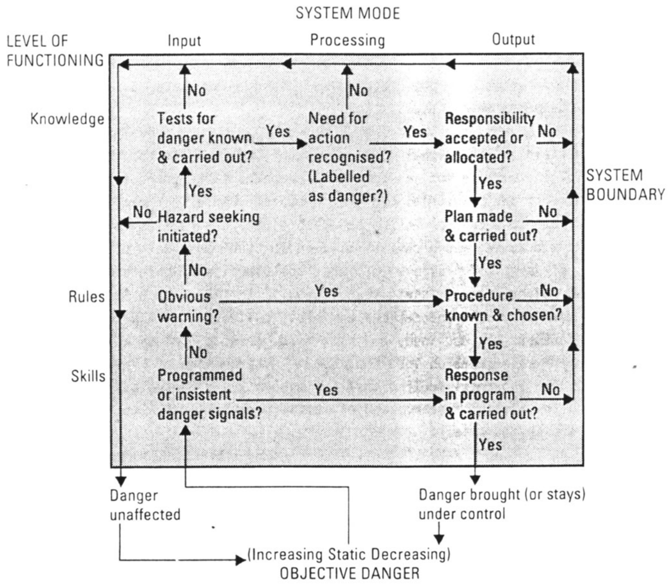

Figure 11.1. Behaviour in the face of danger model - individual differences

11.1 INTRODUCTION

The emphasis throughout this book so far has been upon a systems approach in which we have stressed common features in the way in which all individuals approach the control of danger. From time to time comments have been made about individual differences in ability, knowledge and experience, frames of reference and the emphasis given to different motivational factors, but we have laid very little stress on them. This was a conscious choice, as we described in Chapter 2, to emphasise the difference in our approach from the earlier accident proneness model which had been dominant for too long in accident research. This dominance is to be seen in the structure of the three major reviews of the psychological literature which appeared around 1970 (1,2,3). Each of these devoted a large proportion of their space to a review of the literature on accident proneness and on the specific physiological, psychological and demographic factors which researchers had tried to relate to accident liability. Surry's review (2) departs most from that structure in giving far more space to an explanation of the underlying mechanisms leading to errors and accidents. The fact that this book devotes less than ten percent of its space to the topic of individual differences is a measure of how the field has changed since then. Nevertheless it would be inappropriate to ignore individual differences in the factors we have discussed, or the group and cultural differences which go with them.

The whole field of individual differences and accident proneness was highly controversial and emotive for a period of perhaps fifty years from the end of the early work of the Industrial Fatigue Research Board in the mid 1920s (4) - which established the concept in the research literature. The early period of optimism and blossoming research was followed in the post-war period by the appearance of critical reviews of and sometimes virulent attacks on that research and on the concept itself (5,6,7,8,9). In 1971 Shaw & Sichel produced a spirited defence of the theoretical and practical value of the concept (10). Since then interest has declined, and with a few notable exceptions (11) there has been very little research into the issue. The decline of interest has been accompanied by a general feeling that the subject is a backwater of health and safety which is hard to research and of little practical value to those wishing to improve health and safety.

There appears to have been a parallel decline in the amount of attention paid to selection in general as a tool in personnel management. This may be partly because of the general climate of full employment which existed in the economic boom of the 1960s and 1970s, which limited the scope to select on anything other than the 'vital capacity' test (can the applicant breathe and work?). Indeed, interest has, in the depression of the 1980s revived somewhat (12). However, another factor in the decline was the increasing pressure against any discriminatory workpractices which did not give people equal access to jobs regardless of sex, race, religion and sexual preference. Such antidiscrimination laws and policies made difficult the use, for example, of selection tests with different norms for males and females, and tests which could not demonstrate their 'culturefairness'. At the same time legislation such as that governing hours of work and employment of women came under critical discussion on grounds of discrimination (13,14). Even such time-honoured practices as pre-employment medical examinations, used to select or to redeploy workers employed on jobs with specific hazards, have come under increasing attack, especially from employee organisations and those who speak for them (15). They are attacked as violations of the individual's freedom to choose work, and as illegitimate procedures to justify and perpetuate insufficient attempts to make the jobs safe enough so that all workers can undertake them safely.

Despite these attacks, selection still remains a potential weapon in the armoury of accident and disease prevention, and one which is used quite routinely in a number of instances:

1. Pre-employment medical examinations, despite the comments made above, are still widely used as screening devices to avoid exposing people with particular physical characteristics and health records to conditions to which they are likely to be abnormally susceptible (eczema and work with solvents or some metals, asthma and work in dust).

2. Periodical medical examinations are used to identify those who have proved more susceptible than expected to such substances as lead, and to identify when people in certain occupations are no longer able to carry on safely with their jobs (such as airline pilots or train drivers).

3. Accident records of individual motorists are used by insurance companies to refuse or to increase the cost of insurance cover; group accident statistics are used to fix higher premiums for some drivers according to age, occupation and personal circumstances.

4. Legislation in most industrialised countries forbids young persons, pregnant women, those of child-bearing age, and often all women from working in defined occupations, tasks or working conditions.

5. Legislation in an increasing number of cases specifies the appointment of competent persons to carry out tasks of particular relevance to safety (16).

6. Specific groups of workers, such as immigrants or guest workers (17,18) or young people (19,20) are frequently singled out for particular study as 'problem groups' in order to determine whether special prevention policies need to be developed for them.

In this chapter we shall review briefly the evidence and scope for selection as a prevention device, and suggest ways in which this scope can be maximised.

11.2 SELECTION, TRAINING AND EXPERIENCE

Selection is always logically the other side of the coin to training. If it is reasonable to say that the safety performance of an individual can be improved by training, the option always exists for a company to go and select from the market place an individual whose performance is already high due to innate ability or prior learning. Three types of selection tests or criteria can be distinguished:

1 Selection for innate or early acquired ability or characteristics which can no longer be influenced by training or other means. Intelligence, physical dimensions, sensory functions and perhap some personality factors are typical of this group.

2. Selection on the basis of ability to acquire new skills or behaviour. Dexterity, some personality characteristics and the link between youth and flexibility of skill are typical of this group.

3. Selection for already acquired skills and knowledge. Driving tests, college examinations and trade tests are typical here.

In practice it is not always easy to say whether a particular test measures only one or a mixture of the three types of factor; for example, written examinations at the end of school or college courses measure both acquired knowledge, and the partially acquired and partially innate intelligence and ability to express oneself verbally within a limited time period.

Tests of acquired skill. The third category of test mentioned above can be dealt with comparatively rapidly. We discussed in detail the role of learning and training in health and safety in Chapter 9. Experience was shown there to be a major factor in determining accident rate on a particular job. Tests based upon the acquired skills and knowledge can be seen merely as the way in which we confirm that the appropriate learning has taken place. Indeed we laid great emphasis there on the need to evaluate training as a contribution to accident and disease prevention, and hence to develop tests which will measure the qualities we are trying to develop by it. Hence, all the factors which we discussed in Chapter 9 can be the subject of testing, and in principle also of selection. The same problems of design and use of tests arises for this group of factors as for the other two. Therefore the general methodological points we make below apply to this type of test also.

Suprisingly little evaluation of such knowledge and skill based selection tests has been done in the safety field. What there is is mainly concerned with safety in driving, and the use of driving tests. Evaluation is not easy, since those who fail the test will not be allowed to drive and so it is never possible to know if they could have done so safely. It is theoretically only possible to compare those who passed first time with those who passed after a number of attempts, and the study population is therefore truncated. Only with tests such as the Advanced Motorists' Test in the UK, which is voluntary and does not result in any driving ban if the person fails, is it possible to do a full experiment. In one study of that test those who passed were found to have 25% fewer accidents per mile driven, less serious accidents and fewer traffic offences than those who took the test and failed (21).

Tests of ability and personality. In the rest of this chapter we shall concentrate on the first two types of selection, those aimed at detecting fixed or slowly changing characteristics of individuals which may be related to liability to suffer accidents or occupational disease. We shall further limit ourselves by not dealing with the use of medical examinations to detect susceptibility to occupational disease; such discussion belongs more appropriately within textbooks of occupational medicine (22,23). However, we shall refer to some tests frequently used in medical examinations, but intended to assess skills, abilities or charateristics relevant to accidents. The discussion is grouped under two broad headings: first whether it is possible to identify reasonably stable individual differences in accident rate which might be the subject of selection tests; second whether selection tests have been, or could be found to predict these individual differences and so to reduce the rate of accidents. A further section looks at the specific factors which have been studied.

11.3 INDIVIDUAL DIFFERENCES IN ACCIDENT LIABILITY

The question which sparked off the long research tradition called accident proneness was:

> 'are there stable differences between individuals in accident liability which contribute significantly to the toll of accidents and which offer the potential for selection to eliminate susceptible individuals from dangerous jobs?'

We do not propose to discuss in detail the history of research on this question, which is already widely covered in references mentioned in the introduction to this chapter (6,7,9,10). We shall confine ourselves to setting out the major features of the work, and so describing the requirements of a research study which sets out to answer the question.

Anyone who begins a study by looking at the sort of accident statistics which are typically collected by companies will be faced with the self-evident fact that some members of the work force have had more accidents than others in any given period. This is hardly surprising; indeed we should be amazed to find any different pattern (24). Two questions should immediately arise:

1. is it the same people as in the previous period?
2. is it just that those in more hazardous jobs have had more accidents?

Only if the answer to 1 is 'yes' and to 2 is 'no' have the statistics said anything interesting about individual differences. The problem is that the research planning and care in analysis needed to find out whether the answers are 'yes' or 'no' are considerable. The first question merely requires the calculation of correlation coefficients between periods for which the accident data are available provided of course that the people in the study have not changed jobs in the meantime). The second question presents the more fundamental difficulty because of the need to control the factor of risk exposure in the research.

11.3.1 Accident liability and hazard exposure

The only interesting question from the point of view of selection as a preventive device is whether individuals exposed to the same hazard for the same length of time have different accident liabilities. If the hazards to which people are exposed are different, the comparison only allows a decision to be made as to which hazard requires design attention first; if the exposure time is different it leads to recommendations as to how the exposure of that group in particular can be cut down. For example, studies of road accidents to young children (25) have found that accident rates for those from about eight years old upwards was purely a reflection of the amount of exposure to roads - that is, differences in age per se played little part. Below eight years of age the accident liability for a given exposure was higher than for older children. This suggests the desirability of special prevention measures such as close supervision for those younger than eight, while for those over eight, measures should concentrate on general means of reducing exposure to traffic or of improving the training of the whole population. Several other studies of childhood accidents have also shown that it is the more active, daring, explorative and extravert children who get injured more in their early years, because they expose themselves to more hazards (26).

Controlling for exposure to risk is a difficult problem in accident research. Many researchers have claimed to have done so, but not all that many claims stand up to close scrutiny. Some researchers are satisfied with the selection of a group of people who all work in one factory department or have the same job title. Extensive field studies (27) have demonstrated very clearly that there are large and consistent differences in the exposure to different types of hazards between individuals with the same job title. The report quotes the example of an experienced worker who had a high number of minor accidents compared with her fellow lathe operators. This was because she was always given the awkward jobs simply because she was such a good worker. This is not an isolated example, but represents a normal strategy among supervisors to allocate tasks, not randomly, but according to their assessment of their workers' abilities and preferences.

Matching of risk must therefore go further and examine the detail of the tasks done and the time spent on them. The studies of Hakkinen (28), Cresswell & Froggatt (29) and Shaw & Sichel (10) on bus drivers all illustrate the lengths to which this must go. They made sure that drivers were genuinely randomly allocated to different routes over periods of the day, week and year so as to randomise the effect of differences of traffic density and weather and road conditions on the accident rate and let any individual differences which were present appear unequivocally. In the industrial sphere the work of the Industrial Fatigue Research Board (4,30) and later the Industrial Health Research Board (31,32), stressed this problem, although descriptions as to how it was done are limited. Boyle (11) had great success in solving this problem. He found two locations where risk exposure was equal for all of individuals in a group. In one department there was a large pool of women doing identical work for most of the time, plus job rotation through a series of other tasks, so that, over time, all were exposed for an equal time to all tasks. In another department there was a very stable work force, and the jobs done had not changed over a number of years; the jobs were allocated each morning to the workers by placing all the job numbers in a bag and drawing out one for each person - a truly random job allocation which ensured randomisation of exposure for the whole of the period that the group had worked there.

11.3.2 Research results

It is striking that all the studies which looked at stable work groups exposed over long periods to equal hazards showed clear signs of individual differences in accident liability. In several cases (10,11,28,33) there were also high correlations between individual accident rates occurring in two periods of time (individuals showed consistent accident rates). The rates from Hakkinen's study which looked at a population of 66 drivers over 20 years were: 0.2 - 0.35 correlation over successive periods of 1 year, 0.6 - 0.7 over successive 4-year periods, and an average of 0.56 over the original 8-year study period and a follow-up period averaging 9 years. As Hakkinen (33) remarks, this is an impressive picture of stability over a long period.

Having said that many of the better studies did produce clear evidence of stable differences in liability, it must be said that other good studies failed to find such clear-cut evidence. Adelstein's study of railway shunters (7) and Cresswell & Froggatt's study of bus drivers (29) showed only low correlations between periods of time, and both concluded that proneness was only a temporary phenomenon.

It must also be remembered that the researchers had to go to extraordinary lengths to control not only for hazard exposure, but also for experience before the stable individual differences were clearly discernable and provable. This gives some indication of the relatively low priority of such individual differences against the background of the general mismatch between humans and the tasks that they were being asked to work on.

We have deliberately cited only a few of the studies from the history of research into accident proneness. The research techniques used in much of the remaining work have been subject to such criticism that little reliance can be placed upon their findings. However, enough studies do stand up to methodological criticism to conclude that stable differences in liability do exist between individuals, and can be proved. The evidence is stronger for driving tasks than it is for industrial tasks, probably because there is far more freedom allowed to individuals in the way that they drive than in the way that they do most of the industrial jobs which have been studied. Driving is also a far more complex and uncertain task, with a higher overall risk of accidents than most industrial jobs. Therefore individual differences have a greater chance to show themselves on the road than in the factory.

However, although it has been shown that it is possible to find stable differences between individuals in accident liability in specific tasks, we still need to know why this is so. The studies which have looked to see whether differences in liability carry over from one type of accident to another, one task to another, or one environment to another have tended to show very low correlations (3). This suggests that the reasons for differences in liability must be sought in a mismatch between an individual and the specific set of task requirements of a given job. In other words accident proneness is not usually some universal failure to cope with all types of danger, but a task specific problem.

11.3.3 From problem to prevention

Without further study of the specific factors which are causing the differences in a particular situation there are still some practical conclusions which can be drawn for prevention purposes. It may be worth setting up general monitoring systems to detect as early as possible individuals having more than their fair share of accidents on any given job, with a view to finding out why, and either removing them from the job or remedying the mismatch through redesign of the job, or by counselling or training of the individuals. Just such a scheme, based on experience particularly with transport and bus companies, was recommended as early as 1932 by Viteles (34). A similar, but more elaborate scheme was worked out by Shaw & Sichel (10) in the bus company which they studied, and was presented in the form of an accident graph for each worker. An example of such a graph is shown in Figure 11.2. The graph shows the interval between accidents on a logarithmic scale plotted for each successive accident. The graph can be used in the same way as a quality control graph for quality assurance. The average time interval for the whole group (the solid line at approximately 1.85), and 95% confidence limits (the dashed lines) can be plotted on the graph. If the trend line for an individual approaches or falls below the lower bound indicating frequent accidents, action can be taken to investigate why this is happening, and what can be done.

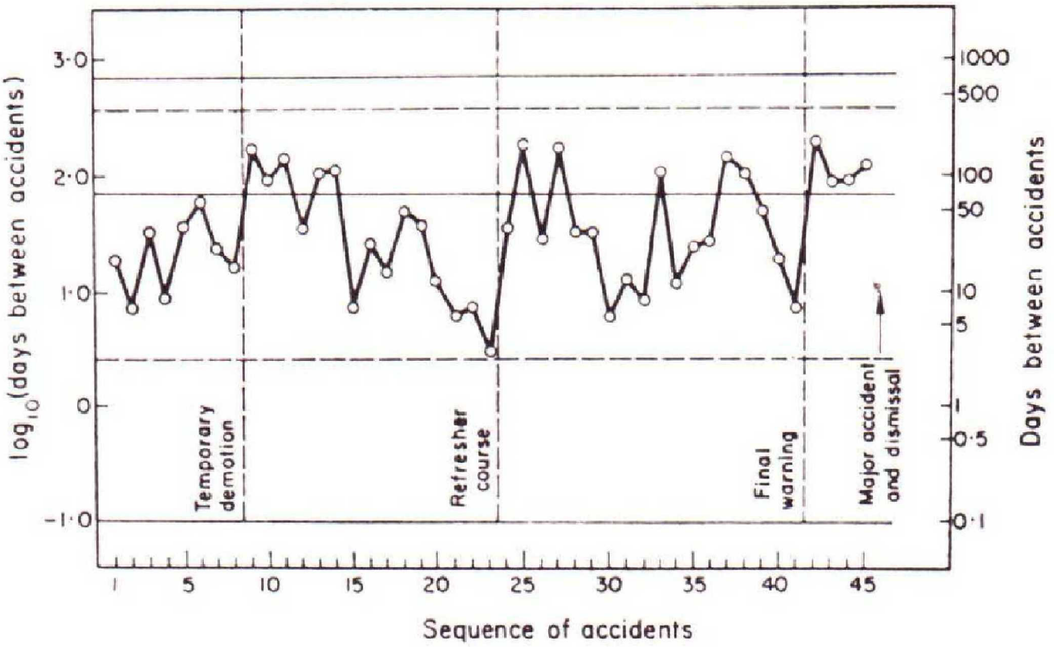

Figure 11.2. Example of an accident control graph (source 10, Shaw & Sichel 1971)

In order to proceed further with the use of selection it is necessary to find out why relevant individual differences exist. This is the subject of the next section.

11.4 EXPLAINING ACCIDENT PRONENESS

What we have said so far establishes accident proneness only as a statistical phenomenon. It is a convenient label given to the observation that different people have different accident liabilities in the same situation. It is not an explanation as to why this happens, and provides no clues as to how to recognise those people before they have any accidents. At the end of the 1920s the Industrial Health Research Board began studies to try and take the discussion further (31,32). In other research institutions and countries there was a similar research effort which produced an enormous range of reports. Many of the studies were very poorly designed and failed to make the necessary careful arrangements for the control of risk which we outlined in the last section.

11.4.1 Accident proneness and accident classification

Many of the studies considered only a few factors as possible explanations of the differences in liability to a whole range of accidents and were thereby guilty of treating accidents as a homogeneous class of events which should have only a few underlying causes. To take a medical analogy, such theorists were at the stage of sophistication of the barber surgeons when they believed that all disease was due to an imbalance of four humours in the body. Such medical theories gave rise to the simple classification of patients into choleric, melancholic, sanguine and

phlegmatic depending which humour was in excess. Treatments were prescribed on that classification, for example, bloodletting with leeches to drain off excess or bad blood. Medicine progressed by recognising that there were, in fact, many hundreds of different diseases with specific pathologies and causes. It is true that, as well as the specific disease factors like bacteria and viruses, there were many common environmental factors such as poor sewage disposal, and life style factors, such as diet and smoking which increase the likelihood of many diseases. Hence, some general preventive measures such as improved housing and waste disposal had dramatic effects on a range of diseases. However, these common features could only be exploited once medicine had recognised the complexity of disease causation and the reason why there was overlap in the aetiology of a number of diseases. Similarly, individual susceptibilities to particular diseases could only be fully understood when these underlying mechanisms were appreciated.
The model used in this book provides one possible basis for a classification system which could perform a similar service for accidents and exposure to occupational disease. Accidents can in principle be classified according to the point in the model at which control over the hazard is lost, and the individual characteristics of the individuals who lost that control can then be examined to see whether patterns emerge which have value for prevention purposes, or for advancing theory.

As was shown in Chapter 3, the circumstances surrounding errors and accidents on routine tasks where people are operating at the skill- or rule-based level cannot be expected to be the same as those where they are acting at a knowledge-based level. Similarly, one would expect to find different individual factors operating in accidents where people failed to detect the danger from accidents as opposed to those where they overestimated their control over a hazard of which they were perfectly well aware. The main stumbling block to research using such a subdivision into different accident types is that no industrial accident recording and registration system collects data using such a model as its basis. Hence the vast majority of accident investigation data does not contain the information necessary to undertake such an analysis. The change to accident reporting and recording systems would have to be fundamental. This issue is discussed further in Chapter 13.

Apart from failing to ask questions about most of the factors covered in this book, almost all current accident data collection systems are injury recording systems which collect data only about selected individual characteristics of the victim. As has been pointed out many times in critiques of accident proneness research (3), a significant proportion of accidents is not caused by the victim's behaviour, but by someone else's. Eisner (35) quotes two reports which classify causes or preventive measures for accidents under headings which allow some judgment to be made of where the responsibility (or locus of control) lay for the accident. In only 27% of cases in one report (factory accidents) and in about 40% in the other (mining accidents) was the accident considered to be under the control of the worker. And even then it is not clear that the control always lay with the workers who got injured rather than with their fellows. In the other cases the control was allocated partly or wholely to management. Despite this evidence, personal data about people other than the victim very rarely get into any existing accident recording system. This means that all analyses of accidents from existing reporting systems will be cluttered with much irrelevant data about people who had no control over their accidents. Any personal characteristics related to causing or failing to control the accident will become swamped in this statistical 'noise'. It is as though people were to seek common personal factors among all the victims of air crashes (passengers and crew). The only one which would emerge is that they were all present at the time of the accident. Only if pilots are separated out as a sub-group can research hope to detect individual factors of relevance to causation.

11.4.2 Theoretical and practical considerations

Because of these shortcomings in data and in the design of research studies expectations of results from studies of accident proneness were often unrealistic. Some researchers seemed to expect that they would easily achieve high correlations between accident rate and a couple of simple selection tests and were surprised when the correlations typically came out in the order of 0.2 or lower. Cobb (5) showed that the highest correlation which could be expected between accident rate and test result in the vast majority of the research done on accident proneness was between 0.3 and 0.5 because of the inadequacies of the research design and of control of other causal factors (see also 36). This implies two things:

1. that the studies which did achieve correlations approaching these figures were in fact not doing badly, and that their results should not be too glibly dismissed,

2. that the contribution of selection tests to accident prevention can only be expected to be very limited in practice.

The second point stems from the simple mechanics of the use of selection tests. Figure 11.3 shows a general picture of the problem.

A selection test attempts to predict the practical measure of accident liability. The ideal is a correlation of 1.0 between test measure and accident liability (graph A). In this case a decision can be made to draw a cut off at a given accident liability, which will correspond to a given test score. Where the correlation between test measure and accident liability is low the plot of test scores and accident liability will resemble graph B. In order to achieve the same cut off of accident liability it will be necessary to use a much more stringent test score cut off, and most of the population will be excluded from the job. In general personnel selection, no single test or test battery which produces a correlation of less than about 0.8 is considered viable for practical use, because the applicant pool will not be large enough to sustain the high percentage who will be rejected. Only in exceptionally popular jobs, or in an economy with high unemployment can tests with lower predictive values be used successfully, and then only at the cost of testing very large applicant populations. Selection in these circumstances is an expensive accident prevention measure, only justified if the cost of the accidents and of other prevention measures are also high.

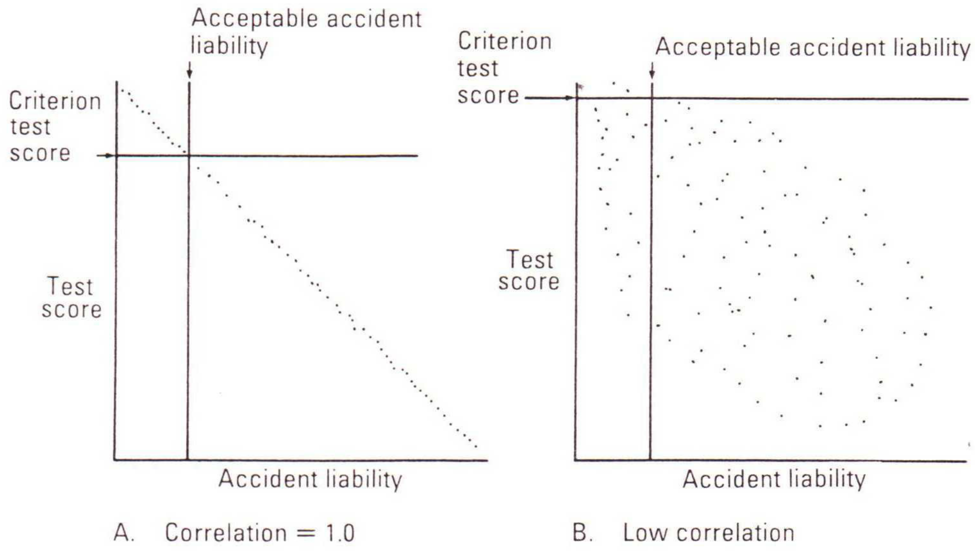

Figure 11.3. Test cut-offs to achieve significant improvement in accident rates

This conclusion represents a parting of ways between two groups of people potentially interested in accident proneness, practitioners and researchers. Practitioners who are interested in selection for prevention purposes have to impose strict demands on the correlation between test measure and accident liability. Only if these are met is there any point in pursuing testing. As we shall see below, the number of instances where this is found are very limited, and hence the whole concept of accident proneness among practitioners of safety has fallen into disrepute and disuse. On the other hand researchers trying to unravel the theoretical aspects of accident causation are interested in low correlations provided that they are statistically significant. It is inadequate accident models and the difficulty of the research on individual differences which have discouraged such researchers from pursuing the potential theoretical insights.

In summary, the only research studies which could have been expected to produce any clear results in terms of reasonably high correlations between test of individual differences and accident liability (enough to interest at least the researchers, if not the preventionists) are ones which fulfil the following criteria:

1. adequate control of other relevant factors, notably hazard exposure and experience
2. study of a job or task with a fairly narrow range of accident types associated with it
3. use only of accidents where the victim was clearly in a position to have controlled/prevented the accident
4. use of a large enough battery of tests to ensure that all significant individual factors were covered.

A practical problem arises with the fourth criterion. While selection tests can be devised for a wide range of individual abilities, achievements and inclinations, performance on some of them is particularly affected by practice and by motivation. The practice element can be taken account of by ensuring that those taking the test have adequate opportunity to practice on similar tests. The motivational element is much harder to deal with because test takers can often work out what answer to give in order to create a particular impression. Since nobody would normally wish to project an image of being accident prone the incentive to falsify results on such tests may be considerable. Inclusion of tests to measure such traits in a selection battery thus presents particular problems of how to minimise the opportunity to fake the results, and how to find more objective measures of these factors.

Very few of the studies which have been undertaken meet all of these criteria. Studies which do stand up well to them include:

- Newbold (4) on workers in a wide range of manufacturing industries
- Farmer & Chambers (31,32) on dockyard apprentices and bus drivers in London (despite their grossly over-optimistic conclusions)
- Lahy & Korngold (37) on bus and tram drivers in Paris
- Cobb (38) on car drivers in Connecticut
- Adelstein (7) on railway shunters in South Africa
- MacFarland & Moseley (39) on US truck drivers
- Hakkinen (28,33) on Helsinki bus drivers
- Hagbergh (40) on Swedish steel workers
- Coppin (41) on California drivers
- Shaw & Sichel (10) on South African bus drivers
- Boyle (11) on workers in the food & engineering industries.

This brief review of the methodological difficulties of research in this area does not exhaust its problems. The reader is referred to earlier mentioned reviews of the subject for further insights and discussion (10,11). In view of these problems, and in order to keep the rest of this chapter within bounds we shall confine ourselves to a brief discussion of the range of factors studied, and the main findings which emerge, despite the methodological difficulties. We also link each of the factors to the model which forms the framework for the book, in order to suggest hypotheses which could be further tested with studies using a better classification of accident types as the basis.

11.5 FACTORS STUDIED

The range of possible measurements which can be made of human abilities, performance, attitudes, motivation and personality is huge. A text such as Buros (42) which contains a critical review of the majority of tests which have been used and to some degree validated in the psychological literature runs to 2000 pages with more than that number of tests. These include tests of psycho-physical performance (reaction time, attention, dexterity), through psychological (intelligence, verbal aptitude), personality (extraversion, aggression, anxiety) and physical factors (health, anthropometry) to interests and life style.

It is important to distinguish between descriptive and explanatory factors. Some individual factors relate more closely than others to the direct causal mechanism of accidents. For example, differences in how people distribute their attention over information sources in a task can be directly linked to failures to detect hazards; differences in anxiety could be plausibly linked to the weight given to danger as opposed to other factors in deciding on the need for caution, and also to the frequency and care with which action sequences are monitored. However, demographic variables such as sex, age, ethnic origin, and social class are more remote from the accident sequence. It is always necessary to ask why such variables show an association with accidents (or indeed with any other measure of performance). The reason must be sought in other explanatory variables which are correlated with the demographic ones; for example, the correlation of age with experience and maturity, the correlation of sex with job allocation, strength and perhaps risk taking, and the correlation of ethnic origin with job allocation and ability to understand the prevailing language.

Identifying demographic variables which correlate with accident rate can, on the face of it, offer opportunities to select directly on this basis. This has certainly been done with regard to age and sex, and has been enshrined in legislation through prohibition of the employment of women and young persons on certain jobs. Increasingly this approach comes up against opposition from the viewpoint of unfair discrimination, particularly against those who - whatever their age or sex - are perfectly capable of carrying out the particular task safely. The pressure is to test the characteristic which is linked directly to accident liability rather than to rely on perhaps more convenient but, in explanatory terms more remote demographic factors. The study of demographic factors is therefore of value only as a guide to further research, and in providing clues to underlying variables.

In the following sections we shall first consider demographic variables, then physical and psychophysical and finally psychological factors.

11.5.1 Demographic variables

Sex. Despite the slow changes being brought about by anti-discrimination and equal opportunity legislation there are still comparatively few jobs where men and women do precisely the same work and are thus exposed to the same hazards. The evidence on the effect of gender on accident liability is therefore difficult to assess. Many psychological tests, such as tests of mechanical and verbal ability, provide different norms for the two sexes but it is almost impossible to establish whether differences in performance on such tests are due to innate sex differences or simply to differences in experience culturally imposed from an early age by parents and society, and which result, for example, in marked differences in the numbers of boys and girls studying technical and engineering subjects in the schools of many countries. The effect of this difference in general experience might be expected to show itself in accidents involving problemsolving in those particular areas.

There are clearly differences in physical dimensions and strength between the sexes, men being on average larger and stronger, while women appear to be more resistant to fatigue and better able to sustain effort. Against this last point Vernon (43) found as early as 1926 that womens' accident rate went up more than mens' when hours of work were increased, but he suggested that this might be because they also had to perform more additional household tasks outside work, and so had a much higher overall load.

Where controlled studies of the sexes have been possible (44,45 - both studies of drivers) the results consistently show women having fewer serious accidents, though sometimes more minor ones. This may be related to a tendency for women to take fewer risks (46); that is either to look out for hazards more assiduously or to take action to control them at a lower risk level. Research comparing men and women on these two aspects of the model might pay dividends in clarifying this question. However, it would not indicate whether any differences found were inherent, or simply culturally determined by the value attached to the male as risk-taker.

Specific studies of the link between accidents and menstruation (47,48) have shown sharp changes in accident rates, with peaks just before menstruation and again early in the cycle.

Age. Peaks in accidents have usually been reported in very young children under two years of age, in boys around the age of eight (road accidents), among those in their late teens (again more so with males than females), sometimes lasting through until the mid twenties, and in older workers around the age of retirement (particularly on heavier or paced tasks, 3).

Children's accidents. The peaks in accident rates among young children were discussed briefly in Chapter 9, and seem generally to reflect a mismatch between the stage of development of the physical, sensory and reasoning abilities and the difficulty and demands of the task (for example, crossing the road, or avoiding hazards in the home).

Young workers. In a review of the literature on young person's (aged up to 24 years) accidents at work carried out in 1986 (20) which considered the research from a number of countries, remarkably little well-controlled research was found which threw light on the peak in the teens and early twenties. This is surprising considering the amount of attention given in international conventions and national legislation to young persons as a vulnerable group. Analysis of the small amount of available statistics which had taken at least some account of exposure to danger revealed that the accident peak was only present for accidents leading to temporary disabilities, and not for those causing permanent disability or death. Deaths tended to show an increasing trend with age, being particularly high in the oldest groups. The peak in temporary disabilities was also found at different ages in different industries and occupational groups, and was different for the two sexes. Anecdotal evidence indicates that a part of this difference is due to differences between the jobs that young and older people do, even in the same industry and occupational group (49).

The few controlled studies which have been undertaken indicate that lack of experience is a major factor in the accident peak, but that other factors probably play a role. Indeed, where experience has been controlled for, there is sometimes a reverse trend, with older workers with little experience showing a consistently higher accident rate than younger ones with the same experience.

The review (20) concluded by summarising other variables which might be expected to be different between young and older workers:

1. Physical and sensory development relevant to hazard detection and to resistance to overstrain of muscles and joints.

2. Development of hazard detection strategies (see Chapters 4, 9) and cognitive reasoning relevant to decisions about action.

3. Personality development and maturity related to attitudes to rules, and the value placed upon security versus creation of an impression on peers, relevant to motivation to choose safe action (50).

4. Flexibility and adaptability to new technologies and work methods, relevant to the speed with which young persons can replace old action plans and routines with new ones in response to changed working conditions, mistakes and near-misses.

These factors suggest that there could be age-related differences at practically every stage in the model used in this book; some being positive, others negative influences on safety. In order to plan prevention measures further there is an urgent need for good controlled research which studies the accidents of young and older workers who have the same experience on identical jobs, in order to demonstrate conclusively that such differences do exist and to determine at what stage in the model the most crucial differences influence accident liability. Studies of hazard detection and perception of young compared with older workers also offer good potential for significant results.

Older workers. The peaks in older workers' (aged 45 years or above) accident rates can be attributed partly to the accumulated strain on joints and muscles, which render these workers more vulnerable, reduced resistance to illness and injury (for example brittler bones), and gradually decreasing sensory, memory and concentration ability, which may make them more likely to lose their place in routine activities if interrupted. These features may be partly counteracted by greater experience, but this too has its negative side, since it may lead people to resist change, and to resort to rule-based behaviour when a knowledge-based analysis would be more appropriate. Again further progress in prevention is dependent upon detailed studies of the accident process among older workers, in order to see if there is either a gradual or sudden change in the type of accident which occurs on a given job. The results of such research would have consequences for the employment of older workers on safety-sensitive jobs, where up to now decisions on forced early retirement are made almost exclusively on physical health grounds.

Experience and qualifications. Experience was dealt with extensively in Chapter 9. It was one of the earliest factors to be shown to have an effect on accident liability (4). It is a composite variable, made up of a number of factors, shown below:

1. Knowledge gained from formal courses during education and working life, and often measured by qualifications and certificates. Such courses may or may not result in lower accident rates, depending upon the quality of the training, and the care with which transfer from the classroom to the workplace is handled.

2. Direct experience of specific work tasks and environment in which accidents may occur. Such experience usually results in a lowering of accident liability, but may also produce a change in the type of accident which occurs. Experience increases the tendency to work at either a skill- or a rule-based level and not at a knowledge-based level, even where that would be appropriate. That can result in more 'strong-but-wrong' errors (see Chapter 3).

3. More general experience, gained perhaps in other establishments, of the type of work being done, which may carry over either positively or negatively to the current situation depending on whether different conventions, procedures or machines are used.

4. General experience of industry which broadens the general ability to cope with unusual situations and to anticipate what might happen in new situations.

Powell et al. (27) showed the paramount importance of the sort of experience identified under 2 above. Almost all studies (3) show an effect of this sort of experience over the first few months working in a given section or factory. In some studies the graph continues to show a downward trend even after several years (20), although this may be partly because shop floor workers are moved around within a company more during their first few years than later, and partly because the population working on any one job tends to become truncated with time, as those who do not find the work congenial (including not finding it safe enough for them) tend to move to other jobs. Therefore, those left tend to become a self-selected safe group. This process is analogous to the 'healthy worker effect' in relation to occupational disease.

Experience will affect all stages of our model; knowing when and how to look for danger, having more routine action sequences ready to cope with it automatically, knowing how to tackle it, and who should do so, and being practiced in doing so. The negative effects of experience will be in lower responsiveness to new or changed circumstances, the tendency to overconfidence in one's own ability to predict and control a situation and to discount very low probability events. These predictions need to be tested out on studies of actual accident processes from experienced and inexperienced workers. A question of both theoretical and practical consequence is whether experience on one task or machine can totally wipe out incompatible earlier action programmes learned on similar equipment. For example, how much experience of driving on the left hand side of the road guarantees that a driver will not revert unconsciously on some particular occasion to driving on the right; how long must a conversion course from one process panel, microcomputer program, lathe or other piece of equipment to a different model last to minimise errors.

Social class and ethnic group. The direct effect of social class on health and safety is very difficult to study, since occupation plays the major role in defining which social class people are considered to belong to; equality of hazard exposure at work between members of different classes is therefore hardly possible. Major differences in mortality between the different classes continue to exist because of these differences in risk exposure (51). Difference in attitudes towards causes of disease and accidents, and the influence of social group in choice of preventive action has been demonstrated (52), with the higher social classes taking a more 'scientific-rational' view and being less influenced by social norms.

Studies of different ethnic groups have usually been carried out in the context of immigrant or guest-worker labour. Where national statistics of accident rates are published separately for foreign and indigenous workers (see for example, 53) the rates are almost always higher for the foreign group. Lee & Wrench (17) confirmed this observation in a study of accidents to immigrant and native British workers in a range of engineering companies. However, when they looked further at the jobs done by the two groups they found that the immigrants were disproportionately employed in the more dangerous tasks, and that when workers on the same job were compared the difference in accident rate seemed to disappear. On the basis of this evidence it is most likely that immigrant workers are exposed to more danger through working in more hazardous industries, and in smaller firms with little or no controls over working conditions and that this accounts for most of the apparent peaks in accidents. Other possible factors are: differences in the trade-off between danger and other criteria such as earnings, brought about by different cultural expectations, and the generally more perilous financial status of immigrant workers; greater problems understanding training and instructions, particularly written ones, because of language difficulties; different physical dimensions allowing easier access to danger points (slimmer wrists of Asians, greater height and reach of some of African origin); and less protection from protective clothing (face masks, ear defenders, goggles) designed for Caucasian anthropometry (54,55).

Better controlled studies of immigrants and indigenous workers doing identical jobs are required to establish clearly the importance of the problem, and the relative contribution of the different possible factors to it.

11.5.2 Physical and physiological factors

Health. A number of researchers, usually those from a medical background, have studied the relationship between accidents and other signs and symptoms of ill-health. The rationale for such studies is either to find a direct causal link between the ill-health and accidents - for example, accidents precipitated by strokes or heart attacks - or to establish a general syndrome, that poor health and accidents are both the result of some other underlying factor, such as stress. The research reviewed by Hale & Hale (3) indicated that there were frequently slight negative correlations between the presence of chronic disease or symptoms such as high blood pressure and accidents, indicating that compensation for the presence of the disease might be taking place, either through extra care or through movement to less hazardous work.

Studies comparing absence from sickness and from accidents (56,57) tend to show that the two are positively correlated, although in other studies (58) the total absence in a factory remained the same, but shifted from one type to another as management shifted its emphasis from trying to control accidents, to clamp-downs on uncertificated absence, to checks on sickness absence. Results from both sets of studies suggest that what is important is the tendency to take time off, probably related to morale, job satisfaction and social norms, rather than any underlying relationship between tendency to sickness and to have accidents.

It is clear that sudden illness could precipitate an accident, and examples in the literature of air and rail transport are known. Medical screening is used to detect such incipient problems and to retire people from such sensitive jobs. General ill-health could also affect the overall ability to behave safely. However, the effect of both on the accident picture seems to be small, largely because people are usually able to compensate in their behaviour for any sickness they have. As such this problem seems to require little further research.

Alcohol and other drugs. The literature on the effects of alcohol on driving is very clear in the relationship it shows between even quite low levels of alcohol in the bloodstream and an increased tendency to have accidents (2,3,59). Part of the explanation for the lower serious accident rate of women drivers may be due to a lower tendency to drink and drive (45). The effect of alcohol on driving is threefold (60,61); it impairs driving skills, it decreases the ability to judge performance and controllability, and it increases preparedness to take risks. Thus the effect is spread through several phases of the model.

The study of the effects of alcohol on industrial tasks has been far less extensive (3). There has been a marked reluctance to carry out studies of a similar extent and methodological rigour in industrial companies. The reason for this may be that companies are unwilling to face the consequences of discovering such a link, and the consequent need to try to regulate drinking, which often takes place on company premises in company subsidised bars and restaurants, or is a standard part of the industrial culture. Drinking is also a phenomenon not only of the shop floor workers, but also of senior management, sales personnel and the medical profession.

What little evidence there is for the effect of other drugs on accidents (2) points to an obvious potential effect, but with little clear proof; for example, consumption of tranquilisers is high and an effect of such drugs on performance is measurable even 24 hours after taking a normal dose. The significance of these and of the psychotropic drugs is difficult to assess; on the one hand their effect on performance is great, on the other hand the extent of consumption in industry is hard to quantify, and the contribution of the drugs to accidents hard to measure without taking blood samples as a routine test, since consumption is likely to be concealed during any accident investigation.

Anthropometrics and sensory function. The story here is much the same as for general health. From the model it is possible to predict that poor sensory functioning (such as deafness, anosmia - impaired sense of smell - or uncorrected vision) will have a detrimental effect on detection of hazards and on monitoring behaviour. Similarly people of a physical size, shape and strength that does not match the job requirements should be more at risk of accidents due to overstrain and the inadequate protection offered by protective equipment and machinery safeguards. There are plenty of anecdotal examples of such accidents occurring and general studies of mismatch between visual requirements of jobs and visual performance of incumbents tend to support this prediction (62). However, there are also examples of studies where compensation seems to occur, and people with a sensory or physical handicap have a lower accident rate than those without (2,3,63). However, the sensible conclusion must be that the physical and sensory characteristics of the job incumbent should always match the demands of the task, so that the compensation mechanism does not have to be relied on to increase the safety margin. Such compensation is most likely to break down in unusual or crisis situations, where the time to adapt to the change in circumstances will be increased by the mismatch. At the same time, concerns for safety should not be used as easy excuses to refuse jobs to people whose handicaps have no real bearing upon their ability to work safely. The safety arguments must be valid ones.

11.5.3 Psychophysical factors

Attention. One of the factors which consistently emerged from studies of accident prone groups in driving tasks was their poor ability to divide attention appropriately between a number of different sources (28,33,37). These tests simulate the need to scan the road for signs of impending accident, which may come from the behaviour of other drivers or pedestrians, or the condition or structure of the road ahead. Similarly in industrial tasks skill differences in search for hazard symptoms have been shown (64,65).

We have already referred in Chapter 4 to the need for considerably more research on the different strategies for hazard detection, and their susceptibility to training. Such research is particularly important in tasks such as driving, process operation and safety inspection, where there are many sources of information which must be scanned to arrive at an assessment of the presence of, and reason for danger.

Sensori-motor skill and memory. Good coordination between speed of perception and speed of reaction is essential to many tasks, and tests of these abilities have met with some success in distinguishing those with high accident liability (2,3,33). These skills are essential in the coordination, adaption and monitoring of the action sequences needed for routine tasks. They are closely related, as skills, to the attentional strategies just mentioned. Studies of the precise way in which they need to be coordinated to ensure the best detection of errors on routine tasks in time to prevent them becoming accidents would make a useful contribution to future prevention. The observational study of air traffic controllers (66) mentioned in Chapter 3 (pp 57-58) provides a good example of the sort of research needed. It could also be extended to study whether some individual strategies in monitoring were more successful than others.

It would also be expected that a good short term memory would prevent people losing their place in action sequences if interrupted. A failure of this may be instrumental in some routine errors and in the increase in accidents among those around the age of sixty. However, no proof of this is to be found in the accident literature. There is also no relationship found in the literature between simple speed of reaction and a lower accident rate. Here again people seem to be able to compensate for poor memory and slow reactions by extra care; it is only when more complex interactions are studied that the compensation mechanism is likely to break down.

Fatiguability and vulnerability to stress. The relationship between fatigue and accidents was established by the early work of the Industrial Fatigue Research Board in the UK (43,67). Vernon suggested that susceptibility to fatigue varied between individuals, particularly with age. People are able to compensate for fatigue in the short-term to a remarkable degree, by concentrating their attention on the important aspects of the task, and making extra effort (68), but this cannot go on indefinitely. The effect of fatigue is most noticeable first on routine tasks (where little conscious attention is being deployed) and on ones where danger is peripheral to the main task (69). The effect of fatigue may therefore compound the effects of poor distribution of attention mentioned above. The tendency will be to miss the signs of danger which are peripheral to the task, to miss out on some of the monitoring of routine tasks, and so to be vulnerable to slips, and to make more unintended movements (70). A number of studies also show that those who have a higher accident liability may be more susceptible to stress, and may show signs of agitation and non-functional behaviour when tested under tight time conditions, or in an emergency (3). This would seem to be a lack of ability to adapt behaviour to more rigorous conditions, and to know how to divide the attentional resources between subtasks in order to maintain the best performance for as long as possible. Rasmussen (71) suggests that skill-based behaviour is particularly vulnerable to stress and high workload which lead to preoccupation and failure to monitor the action sequences properly.

The general effects of stress will receive more attention in Chapter 12. The research needed to say anything further about individual differences in stress tolerance and its effect on accidents could only be carried out effectively on task simulators. Time stress and competitive stress can be reasonably simulated on such machines, but the full pressures of real work environments are in practical terms not simulable.

11.5.4 Psychological factors

Intelligence. Intelligence is usually defined as the ability to carry out abstract reasoning and to see relationships between concepts. As such it might be expected to have a relationship with the ability to avoid accidents at a knowledge-based level of operation. The industrial population in any given job has frequently already been selected on factors such as qualifications, which are related to intelligence, and so the range found in any one job is likely to be relatively small. This may explain why most studies have found no relationship between intelligence and accidents. About the only study finding a relationship is one of airforce pilots (72) where the demands on knowledge-based operation are particularly high. It might be worth looking for such a relationship among process operators during unexpected and unusual fault conditions. We also suggested in Chapter 4 that the style of intelligence (convergent or divergent) would have an effect on the detection of unusual hazards, and on the ability to produce effective solutions to problems. In order to work successfully at the knowledge-based level people must have a certain tolerance of ambiguity, and the ability to postpone a decision until the whole range of possibilities has been explored; they must also be able to think divergently, outside the normal rut of already learned rules. Again such characteristics would only be likely to be reflected in a lower accident rate in the very special circumstances of emergencies, unusual situations and the prediction of problems in new designs or technologies. Nevertheless, research on these component skills might pay useful dividends.

Personality variables. Many studies have attempted to relate personality variables such as anxiety and aggression to accidents. Shaw & Sichel (10) reported significant success in reducing accidents among bus drivers by incorporating a projective test to measure these and other related personality variables. The test was a modification of one used in clinical practice to detect personality disorders (Murray's Thematic Apperception Test). In it people are given pictures of ambiguous situations in which usually more than one person is depicted. Subjects are asked to tell the story of what is happening in the picture and what will happen next. The result is that people project onto the picture their own feelings of priorities, expectations and typical ways of coping with interpersonal relations. From a content analysis of the stories these personality factors can be teased out. A description of the test indicates that it would be open to faking by those sophisticated enough to think what personality they should be portraying. However, experienced interpreters of the test can usually pick up such distortions, and despite this drawback the results proved to be well enough correlated with accident rate to be useful as a part of a selection test battery.

Personality factors would be expected to have an effect through motivational influences (see Chapter 10).

1. Aggression will make people unwilling to wait long enough to solve a problem before taking action, less willing to put up with inconvenience and frustration from safety precautions, and more likely to take precipitate counteraction if annoyed or interrupted by the action of another person.

2. Anxiety would result in more obsessive checking of action sequences, and a lower tolerance of danger, which could have positive aspects in increasing caution, but also negative consequences in interrupting the smooth flow of routine actions, and in precipitating uncoordinated action when faced with an increase in danger.

3. Extraversion has been linked by Eysenck (73) with a greater chance of accidents because of the greater activity of extraverts which leads them to seek out sensation and sometimes risk, and also because of their lower response to feedback, which means that they learn caution more slowly.

All these factors have been linked in one study or another with accidents (2,3), but the problem has always remained twofold: correlations are often low, and with some tasks are non-existent; and it is always difficult to measure these factors in a real life selection situation without the applicants faking their test results.

We suggested in Chapter 5 that particular frames of reference and cognitive styles will be likely to result in people either under- or overestimating their control over hazards. In that chapter we mentioned locus of control, self-confidence and attitude towards technology and rules, and in Chapter 4 field dependence (the tendency not to be able to pick unusual cues out of the environment). Quenault (74,75,76) described similar characteristics in the approach of different drivers to their task, which he correlated with accident rates. He labelled drivers as 'safe', 'dissociated active', 'dissociated passive', and 'injudicious'. The injudicious tended to make manoeuvres such as overtaking based on faulty judgments despite the fact that they took in a lot of information (looked around, used their mirror); they were poor at monitoring and adapting their own performance. The two categories of dissociated driver failed to take in enough information from the environment, and did not base their actions on what was really happening around them. The active drivers were also aggressive in their reactions and overtook a lot despite failing to check that it was safe. The passive drivers did the minimum, sometimes staying behind traffic for miles despite opportunities to overtake, failing to indicate or give way on turns, thereby causing problems for others who had to react to get out of their way.

This very brief review of personality factors indicates both the potential for their influence on health and safety, and the difficulty of obtaining consistent evidence of an effect because of problems of measurement, and the fact that different personality factors are likely to affect different tasks and types of accident. Measures of personality have been found to be notoriously poorly correlated with behavioural measures, and safety is no exception. Therefore the scope for further work in this area seems to be limited.

Life style. This factor is related to the previous one and can in some ways be seen as a summing up of many personality traits into one global factor. Tillman & Hobbs (77) first made the concept popular in their study of driving accidents, and summed up their finding in the phrase 'a man drives as he lives'. They had correlated high accident rates with a range of other global measures of social adjustment - for example, domestic disharmony and divorce, childhood truancy and discipline problems, involvement with the courts and with military police, frequent absence without leave, an exaggerated sense of one's own abilities, and admitted dishonesty at work. They found a tendency for all these variables to cluster among the group with high accidents. This general finding was confirmed with brewery workers (78), and fits with a great deal of other work (much of it of a generally poor methodological quality) pointing to some factor of global poor adjustment to work and life in a small group of people which seems to result in them also having more than their fair share of accidents (2,3).

There is confirmatory evidence from the study of childhood accidents (26) which shows that certain parental child-rearing habits, poor supervision of children, and disturbances in family background tend to go with high accident rate. The explanation may be found partly in the lack of supervision by the parents to protect the child from danger, partly in what the child learns about the controllability of dangers (that they are not very controllable). This may cause a positive feedback loop so that the child grows up expecting not to be able to control danger, and so makes less attempt to do so.

During the 1980s there have been signs that the strong link between life style and a number of health and safety problems is being given a more central role in the consideration of prevention. For example, the papers presented at a Canadian conference in 1986 covered behaviours as diverse as drinking and driving, diet, exercise and heart disease, smoking, response to environmental pollution and major hazards and set them all in a social and community framework as manifestations of the adjustment of behaviour to the rewards and pressures built into particular societies (79,80,81,82,83). This is an underdeveloped area of research so far as psychological approaches to industrial accidents are concerned, although there is considerable sociological and socio-political discussion (84,85,86,87).

A related concept is the link which some researchers have tried to make between so-called 'life events', accidents and ill health (88,89,90,91). In this approach the number of significant changes in personal circumstances over the recent past are counted up, weighted for significance, and the total correlated with accident and or sickness rate for the following period. Rahe (92) lists 42 events with their weights, ranging from death of spouse (100 points), through detention in jail (63 points), being fired from your job (47 points) and moving house (20 points) to Christmas (12 points) and minor law violation (11 points). The published studies show some correlations although not as high as was originally claimed. This indicates that the life change events, just as the life style mentioned above may act as stressors which challenge the ability to adjust to life and work, and may reduce the safety margin for coping with dangerous situations. The problem with such research at present is that it does not lead to any clear recommendations, or further study, since it is not possible to avoid many of the 'life events'.

11.6 CONCLUSIONS

This brief review of some of the factors which have at one stage or another been correlated with accident rate can only give a flavour of the range of work carried out. The reviews mentioned throughout this chapter go into the factors in more detail and provide a key to the voluminous literature for those who are interested to pursue them further.

Our conclusion from the research evidence is that there are clear indications from a number of studies of the relationship between individual factors and differences in accident liability. The relationships are frequently task specific and the correlations are usually too small to be of much use in a practical way to justify selection as a means of reducing accident rates.

Where the selection pool is large, and particularly where selection tests are already used to make choices based on other criteria such as competence and quality, there is scope to add tests which will tap qualities which can be proved to be related to accident rate for that job. However, expectations for such tests should not be very high since the correlation between test result and accident rate can rarely be expected to rise above 0.4.

In many cases it is possible from the model we have used in this book to predict that individual factors could have an effect on accidents or the reaction to the risk of occupational disease. In many cases the proof of such a link is not available. In other cases there is evidence that the potential link is not in fact found, because people appear able to compensate for a shortcoming in one attribute by changing the way in which they approach dangerous situations, or by avoiding them altogether. Thus, people who have one sense impaired can make more use of another to detect hazards and make conscious choices to seek out and deal with hazards before embarking on a task. On the other hand, their unimpaired colleagues might not take special care and might rely upon their good senses to pick up danger later in its development. Because people are so flexible and can usually reach a given goal in several ways, it is very difficult to correlate simple individual differences with global accident rate. Only research which looks at the process by which different people come to grief through accidents can offer a sure way of extending our understanding of the limits that individual characteristics place on this mechanism of compensation. The question for such research should be not 'do people with certain characteristics have more accidents than others?', but 'in what circumstances do people with certain characteristics suffer particular sorts of accident?'

The justification for the maintenance of restrictions on the employment of certain demographic groups in particularly dangerous jobs also needs further careful consideration. Where there are good medical and physiological reasons to indicate, for example, that women, young persons or an ethnic group as a whole are particularly susceptible to certain working conditions, workloads, or chemicals there is a strong reason to maintain the restrictions. However, in most cases, correlations between sex, age or race and the susceptibility result from other factors and does not reflect any causal mechanism. This means that some members of non-protected groups, in other words mature, indigenous males, will also be particularly vulnerable, and their rights to protection should also be guarded in some way. Where the suspected susceptibility is to accidents, or to more general factors such as fatigue, the relationship seems to be even more open to question. For example, prohibition of young persons from certain dangerous machines may be a satisfactory administrative solution to a problem, because it is relatively easy to police, but it may not solve the problem if the reason for the high accident rate on that machine is lack of experience. In this case the accident peak may simply be pushed into a higher age group which is allowed to operate the machines.

The ideal is to find out which factor it is which is leading to the high accident liability of the group, and then to devise a test to measure that. However, we are still a long way from realising that ideal in most situations. Therefore, in practical circumstances therefore the decision about whether to use selection as a tool of accident prevention will rest upon the relative balance of advantage in an imperfect world where selection tests are poor predictors of accident liability. The choice which faces us is either to use a strict selection cut-off, which excludes most of those who are particularly susceptible, but at the same time excludes many who would be perfectly capable of the task (for example, pilot selection for the airforce), or to use a much lower cut off which allows some demonstrably potentially 'accident prone' people to take part in the activity in order not to discriminate unfairly against the majority (arguably the case with the current driving test in many countries).

We have expressed great pessimism about the value of selection for practical prevention purposes. This should not be taken as a denial of the importance of research on individual differences to the advance of theory in the area. If such individual differences can be clearly demonstrated, and thoroughly investigated, they can throw considerable light on the relative success of the mechanisms by which people control danger. To do this requires deeper analysis of accident processes and a psychologically meaningful classification of accident types. The model in this book provides one such basis.

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CHAPTER 12

SAFETY BY DESIGN

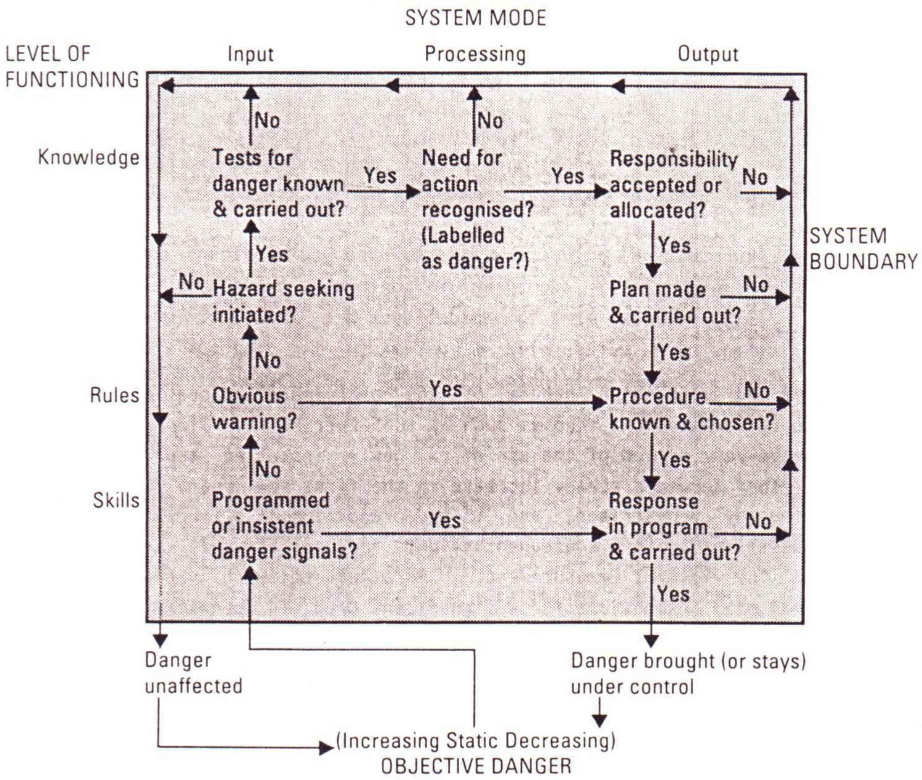

Figure 12.1. Behaviour in the face of danger model - safety by design

12.1 INTRODUCTION

Throughout the book we have stressed the interaction between individuals and the environment in which they live and work. Individual behaviour may be seen as a continuous attempt to maintain control over surroundings, to predict what is going to happen next, and to influence it. The human being is a very open system, taking in information from the environment to update the internal model of the world, and acting to modify that world to meet objectives which the individual has. This means that changes in the environment will be a major source of influence on behaviour, and deliberate design decisions offer perhaps the greatest chance of systematically improving safety.

We dealt in Chapter 9 with the negative aspect of this adaptation process when we discussed risk compensation theory. There we presented evidence which showed clearly that design changes could result in major changes in behaviour. The problem in some cases was that the change was to increase the speed of driving, or the amount of production, when the purpose of the design change had been to improve safety. The conclusion of that discussion was that such trade-offs were important and did occur, but that an overall gain in safety was still apparent in many cases and could be maximised by deliberate attempts in the design process to counteract compensation. We indicated in Chapter 9 that adaptation was a continuing process driven by feedback, learning and experience. The design and layout of the work and living environment is the relatively still point of this turning world. It is the point around which behavioural adaptations occur. However, it may also be subject to redesign attempts by individuals who do not want to modify their behaviour totally as the design demands. Such operator redesign is the rule rather than the exception in most industrial settings. For example, the review of nuclear power control rooms conducted after Three Mile Island (1) found many such changes even in that high technology industry.

The slowness and continuing nature of the behavioural adaptation process is illustrated by longitudinal studies such as that carried by Older & Basden (2) over a twelve-year period of the use of a newly installed zebra pedestrian crossing. They showed a steady increase in the first few years in the use of the crossing by pedestrians, and in the proportion of drivers giving way to waiting pedestrians, with a subsequent slight fall which still left the usage well above the initial measurement. Parallel research showed that zebra crossings had been responsible for a significant drop in pedestrian fatalities and casualties (DSIR 1963).

Specific aspects of the design of the physical, social and organisational environment have been discussed in each chapter of this book. For example, the value of standardisation in the design of the operator-machine interface was stressed in Chapter 3; the design of warning systems was discussed in Chapter 4; the need to look to software decision support systems was urged in Chapter 5; in Chapter 6 the division of tasks and responsibility was covered; Chapter 7 dealt with checklists and work procedures; in Chapter 10 we considered the influence of the social environment, and in Chapter 11 the interaction of anthropometry and design. In this chapter we do not wish to repeat in detail what has been said in earlier chapters; nor do we intend to try and provide a detailed guide to design for human factors. Our purpose is to provide a resume of the main principles which need to be considered in arriving at the design of work environments which are likely to enhance safety and to offer the best integration with the individual characteristics which we have discussed. For further details the reader is referred to standard texts of ergonomics (3,4,5,6,7,8) and of safety (9,10,11) and to such journals as Ergonomics, Applied Ergonomics, Human Factors, and the Journal of Safety Research, which have increasingly carried both general and specific articles on the effect of design on safety. We have tried in Appendix 1 to summarise what our model has to say about the design of tasks and environments for the individual. The appendix is set out as a series of questions for designers, whose answers should lead to deep thought over the way in which the system and the individuals in it should interact.

Ergonomics stresses the need to adopt a systems approach to the design of any equipment, task or organisation. This considers in turn the definition of the objectives of the system and of the functions needed to satisfy those objectives, allocation of those functions between hardware and people on the basis of rational criteria, followed by parallel design of the hardware and tasks and of the interface between them, including the procedures for running the system, selection and training of the people, final integration of all the system elements, and test and evaluation of its working (12). All these elements are important in achieving a safe design which optimally combines people, hardware and software. The ones which link most closely with the subject of this chapter are the allocation of tasks between hardware and people, and the design of the interface between them.

12.1.1 Automation and allocation of functions

In Chapter 2 we castigated an approach to safety which could be summarised as 'if it moves automate it'. This is based on an assumption that machines can always be made more reliable and more predictable than humans, and that it therefore always makes sense (in terms of safety, if not of economics) to replace humans by machines where that is technically feasible. Where total elimination of the human from the operation of the system is possible, the gain in safety is often impressive, but the unquestioning use of such an approach is open to criticism. A disadvantage of such complex systems is that the maintenance and repair of them is often also more difficult, and the personnel who are responsible for that work may be subject to much higher levels of danger than if the system was simpler. Danger previously spread over many operators may be displaced and concentrated on comparatively few maintenance staff. The result of this risk adjustment may be a net gain in safety, but it will be less than an initial simple analysis might have suggested. In practice such total elimination of the human is rarely feasible, or is not felt to be desirable because the hardware cannot (yet) be designed to cope with all unexpected circumstances and breakdowns (13). An operator is therefore left in the system to do what the hardware cannot. These remaining tasks are often either limited and boring, or ones which are only called upon very rarely, and hence make enormous demands on the operator's ability to recall what to do and how to do it successfully under emergency conditions. A more systematic allocation of functions looks at the relative strengths and weaknesses of the human and hardware components. Figure 12.2 shows the list produced by Fitts (14) who was one of the first to advocate this approach.

PROPERTY	HUMAN CAPACITY	MACHINE CAPACITY
Speed	Inferior	Superior
Power	Two horse power for ten seconds	Consistent at any level
Consistency	Not reliable, needs to learn, subject to fatigue	Ideal for: routine, repetition, precision
Complex activity	Single channel, low throughput	Multi-channel
Memory	Large store, multiple access, best for principles, strategies	Best for literal reproduction and short-term storage
Reasoning	Good inductive, easy to reprogram	Good deductive, tedious to reprogram
Computation	Slow, subject to error, good at error correction	Fast, accurate, poor at error correction
Input	Wide range and variety of stimuli dealt with by one unit (eg eye) Affected by heat, cold, noise and vibration Good detection of: pattern, very low signals, signal in noise	Some outside human senses (eg radioactivity) Insensitive to extraneous stimuli Poor pattern detection
Overload	Graceful degradation	Sudden breakdown
Intelligence	Can adapt, anticipate, deal with unpredicted/unpredictable	None, cannot switch goals or strategies without direction
Manipulation	Great versatility and mobility	Specific

Figure 12.2. Fitts list

Even this sort of analysis does not go far enough, because it looks only at the individual subtasks on their merits, and does not consider the total task content which is needed to keep the operators interested, challenged and motivated. Allocation of functions needs to take place based on both specific and global criteria. Some tasks may need to be allocated to people, rather than to hardware not because the people are better at them, but for global, motivational reasons, or to allow them to build up or to maintain the skills necessary to intervene if the hardware fails. In such cases hardware can often be designed which will play a supporting or back-up role to the operator. This will usually bring the total system reliability up to a higher level than considering allocation just on the basis of small sub-tasks.

Such a design philosophy is increasingly being used in high technology process industry (15), and in other tasks where the operator's role was becoming reduced to monitoring of hardware (such as pilots or train drivers). To illustrate some of the important issues we shall give a brief description of one such system, the automatic warning system in train cabs.

12.1.2 Automatic warning systems on trains

In the post war years railway companies became increasingly worried by a series of accidents in which drivers of trains passed signals set at danger, or failed to respond adequately or at all to speed limit signs or indications that something was amiss (16,17,18,19,20). One potential problem which was identified was that drivers could become inattentive or even fall asleep during long journeys. When single manning of engines became common there was the added concern that the driver could suffer serious illness, coma or heart attack and become incapable of driving the train. Early devices to cope with this problem were the deadman's handle which required continual pressure from the driver to maintain power to the train. Release of the handle would result in emergency braking. Later versions of the equipment provided for more sophisticated support from the hardware. Devices alongside the track automatically transmit information to the train about the state of the signals and speed limits. Passing of warning signals results in an audible warning to the driver to call his attention to the information. If the driver does not respond to these soon enough or with sufficient braking the system automatically intervenes and begins an emergency braking, which the driver can no longer cancel. In stretches of track where the automatic signalling is not in place, or where the driver is required to proceed slowly, the system checks the continuing attentiveness of the driver by requiring regular pressing of a knob, in the absence of which emergency braking is again carried out.

For most of the time such a system allows the driver to drive the train as though there was no hardware, but to know that there is always a safety net to cope with emergencies. However, the system is not without its problems. The continual need to prove wakefulness by pressing the knob at slow speeds and outside automatically signalled areas of track is experienced by some drivers as threatening and annoying. Since there is built into the system the facility for the driver to override it and to switch it off in case of hardware breakdown or emergency, this annoyance can be worked out by switching the system off at other times. There may also be the tendency for the driver not to look out at the signs along the track so much, but to rely on the automatic system to transmit the information to the cabin before responding. This means that drivers may be less likely to see unusual circumstances, such as people, animals or obstructions on the track, for which there are no automatic warnings.

Complete automation of the train driving task is currently neither technically nor economically feasible. It would demand either enclosure of rail lines to prevent uncovenanted intrusion of cows, people and objects fallen on the line (possible on underground metros but not on cross country routes), or development of highly sophisticated sensors to detect them, as well as the presence of maintenance gangs. The psychological impact of driverless trains on passengers is a further factor in the equation. A combination of driver and hardware is the only viable solution. The detailed design of the system and its driver-machine interface than becomes important, because of the need to preserve the driver's feeling of control. The hardware must not be too intrusive or it will be viewed as a 'spy in the cab'. On the other hand it must offer a significant improvement on the reliability of either driver or hardware alone.

The solution to such a problem lies not only in the design of the hardware itself, but in the way it is introduced, the way the drivers are trained, and in the organisational system within which it works. For example, whether and how drivers are involved in reporting and correcting defects or whether the output of the hardware is used to control obedience to rules.

12.2 ORGANISATION OF THE CHAPTER

The environment in which people work can be divided broadly into four elements, shown below:

1. the physical objects with which people work, such as machines, tools, transport, and the buildings, roads etc in and on which they use them,

2. the physical environment in which people work, the noise, light, heat, dust, pressure etc, and the time scale over which they are exposed,

3. the procedures, rules and software with which people work,

4. the social and organisational environment in which work takes place, the division of tasks, design of information and incentive systems and the policy which governs that environment.

Divisions between the four compartments are not watertight: for example, that between 1 and 3 is becoming increasingly vague in the light of developments in information technology and expert systems; the time scale of exposure to fatiguing environments depends upon organisational factors such as shift systems and task allocation, and upon work load. However, the categories provide a convenient basis for discussion in the rest of this chapter.

12.3 DESIGN OF PLANT, EQUIPMENT, MACHINERY, TOOLS AND BUILDINGS

The effect that the design of material objects has on their safe use can be derived from the models of the accident process and of human behaviour that we have used in this book. The following principles can be enunciated:

1. inherent danger sources should be eliminated or replaced with safer energy sources or substances. Those which must be present should be kept under control or isolated as far as possible by design;

2. design should enhance where possible, and in any case not hinder, the collection of information necessary for people to control any danger present;

3. there must be clear warnings of when and how hazards arise and of any deviations from normal operation and how to correct them;

4. the dynamics of the plant or system should be such that there is time to recover from the deviations before the harm process begins;

5. design and method of use must conform to the expectations and stereotypes which people have acquired and not make large demands on limited human functions;

6. design, layout and use should match the anthropometric characteristics of each user as closely as possible, or be adjustable for the total user population;

7. design should incorporate deliberate provisions to discourage misuse and defeating of safety features, by making such behaviour not cost-effective.

In the following sections we shall illustrate each of these principles in turn.

12.3.1 Inherent dangers

One of the main principles of safe design is to limit the amount of energy used in a process, and to replace highly toxic with safer substances, which, if they escape can do less damage (21). Examples of this principle were given in Chapter 8. This principle has more to do with the economics than the psychology of health and safety. Pressure has to be exerted to encourage a market to change to inherently safer products and processes. If the gain in safety compared with the investment cost can be shown to be very high then this can occur through the operation of market forces. In many cases this is not so, and the safety gains have to be actively marketed. This involves the makers of the safer product comparing it favourably with the products of their competitors. Such advertising has been an increasing feature of the marketing of cars, with the introduction of anti-lock braking, of crash- resistant passenger compartments, and radial tyres. It is also a feature of some consumer machine tools such as chainsaws (22).

The prevalent negative image of intrinsic safety as an extra cost is frequently not borne out in practice. For example, radial tyres, as well as being safer than cross-ply, also last longer per unit cost. If manufacturers respond automatically to requests for greater safety with the insistence that this will increase costs, it may say more about their conservatism than about the true medium- term cost picture. It may simply represent unwillingness to disturb a comfortable market position through innovation.

Where market forces will not provide sufficient pressure to introduce inherently safer products, other pressures such as legal powers, need to be called upon. These range from specification of product norms and certification of products as safe (the national, European and international standards bodies and certification authorities), through use by government inspectorates of their powers to demand improvements and pressure brought to bear by legal compensation claims from those injured or made sick, to outright banning of products such as blue asbestos.

12.3.2 Information intake

In order to control danger people must be able to take in information about their surroundings as easily as possible (Chapters 3 and 4). This places two demands on design; that it should not cut people off from important information sources and that the information should be so grouped and presented as to be easily assimilated.

Various features of equipment design can isolate people from information. Protective clothing, in order to be impervious enough to keep dangerous dust, chemicals, noise, sharp or hot objects from entering the body must place an isolating layer over the sensitive entry ports to the human body, which are also usually the ways in which information enters the senses. The eyes are vulnerable to dust, flying particles, and ultraviolet light and so need to be protected in operations such as welding, grinding, or chipping. Goggles or face shields, especially if they become dirty, scratched or misted, can also cut down the visual field, and the amount of light entering the eye, and so cause information to be missed. Similarly, ear defenders affect the ability to localise some sounds, and may alter the signal-to-noise ratio of others if they preferentially cut out certain frequencies. Gloves make it difficult to operate delicate controls, pick up small objects or gauge the texture of objects.

Other protective devices such as machinery guards or noise control enclosures may make the work to be done, or the adjustment of machines more difficult because they hide parts of the machinery behind screens. This may also obscure danger which is present. Such isolation of people from their surroundings may make them less aware of the danger that is present there and so be more inclined to act dangerously. Svenson (23) suggests that the enclosed world of the car, with its increasing tendency to resemble a comfortable sitting room, complete with stereo and air conditioning may reduce the awareness of the danger of roads. Similar isolation of crane operators and plant operators in control rooms cuts them off from ancillary sources of information such as sounds and smells which may tell of danger; it may also result in their mental images of the plant becoming less related to reality. To overcome such a sense of isolation, the operator needs to go out at intervals to work on the plant, or at least walk round it.

With increased sophistication of equipment, mechanisation and automation, the range and complexity of the information which is relevant to the control of the equipment increases enormously. Instrumentation engineers try to arrive at an economic and practical compromise between swamping operators with information and starving them. Too much is just as bad as too little. The plant operators at the Three Mile Island nuclear plant expressed the wish that they could have thrown most of the panel displays and alarms out of the window when the incident there occurred, because so many alarms went off together. The naive driver of a car with an oil pressure gauge whose gyrations he or she cannot interpret feels much the same, and may long for a plain and simple warning light to indicate when something definitely needs checking. In designing alarm suppression or interpretation displays the designer has to bear in mind the mental models of the operator in respect of the way the plant runs, and hence the type of information and presentation format which will be most meaningful (24). For example, one display type now used shows all the main plant parameters on a single display, each parameter being a point of a polygon, which is symmetrical when all are within limits, but becomes distorted in characteristic ways when given deviations occur. The task of the operator is to try to restore symmetry (25).

The hierarchy of information presented is also important, as is the way that the operator can select parts of it and ask for more detail. People have become so used to the standard source of reference, the book, which is accessible either through an index of keywords, or by use of the contents page, or by quickly leafing through it, that other forms of information storage such as the computer seem strange and difficult to use unless they conform to similar conventions. Hence people tend to get lost inside a computer data base or program, because they do not have a clear overall picture of it, and how to get to the index or contents menu.

Grouping of information on panels or VDUs presents a similar problem of recognising the operator's model of the process, and what information belongs together. The days of the symmetrically arranged control panel of identical knobs and dials laid out according to the logic of the physical layout of the plant has hopefully now given way to much more functional grouping of information relating to particular activities. However, this grouping is not always easy because activities during normal operations may require one grouping, while emergency manoeuvres may dictate another, and some compromise (or two separate panels with duplicate information differently arranged) has to be arrived at.

12.3.3 Warnings of danger and deviation

The most important information for safety is that which indicates that there is danger present which must be controlled. In Chapter 4 we discussed the problem of designing warning systems in cases where the hazard did not inherently look, smell, sound or feel dangerous. The ideal warning is one which is only present when there is really danger and never when there is none. Static warnings of intermittent dangers (such as radiation symbols on a door of a room where radioactive sources are only sometimes used), or alarms which go off when there is no danger present, operate as false alarms and gradually become devalued. They come not to elicit the precautionary behaviour on their own, but only to act as (increasingly weak) alerting signals to look out for other signs as to whether the danger really is there. Signs of this devaluation of information sources can be seen in the increasing tendency in some countries to treat the red traffic light at pelican crossings, or even the red light at ordinary crossroads during periods of quiet traffic merely as warnings and not as mandatory stop instructions, and simply to drive or cycle through them. In order to limit such devaluation of the warnings or signals they can be switched off, or reduced in status from red mandatory signals to orange flashing warnings when the danger is less great. However, ultimately there has to be a degree of control and policing activity by the relevant enforcing body if devaluation is to be avoided.

In order to be effective the warnings have to be subject only to one interpretation, and the 'language' of the sign must be as simple, conspicuous and comprehensible as possible. Pictograms have now become an international code (26) with conventions, such as those shown in Figure 12.3, for advisory, mandatory, warning and prohibition messages. Standard symbolic representations are also increasingly used for such items as cars, motorcycles, men and women, fire, corrosive and toxic hazards. When words are used, for example, in warnings on consumer products, it is important to choose ones which form part of the vocabulary of the vast majority of the population (27), and not ones such as 'emetic' (which few people recognise) or 'inflammable' (which a significant number interpret as not burnable by extension from other similarly formed words such as 'inedible', 'incredible' or 'inappropriate').

Figure 12.3. Examples of standard symbols

Enhancement of the information needed to judge critical parameters of a system is a way of giving better warnings. We have already referred to it in relation to process plant instrumentation. Road design has also taken the concept a long way in the use of rumble strips or yellow road hatchings at decreasing intervals to give an enhanced judgment of speed in approaching a roundabout or leaving a motorway (28). In the design of some consumer apparatus the similar 'echo' principle is visible. For example, more telephones now incorporate a display of the number dialled as a check on whether an error has been made; many computer software packages incorporate specific confirmation sequences asking whether the user really wants to carry out a given function before it is irretrievable (for example, formatting or wiping files from a disc).

12.3.4 Design for error tolerance

A principle of design which is increasingly being emphasised in nuclear and chemical technology is the need deliberately to build recovery possibilities into process control. This principle is based on the belief that human error (and indeed technical failure) is an inevitable feature of designs, which it would be economically, and also technically, impossible to remove (15,29,30). Rouse & Morris (31) state this principle as: 'errors are not inherently unacceptable; however it may be that the consequences of error are unacceptable'.

The second line of defence is therefore to construct systems which take a significant time to develop from the first signs of deviation to the occurrence of damage. This provides time for people to intervene and to recover the situation. Thus the Central Electricity Generating Board in the UK in its plans for the Sizewell B Pressurised Water Reactor (32) explicitly built in a period of thirty minutes from the occurrence of a reactor scram during which no intervention from the plant operators was claimed as necessary to retain the reactor on track towards a safe state.

Such a design philosophy requires that warnings of deviation from normal come as early and as unequivocally as possible, that the consequences of actions which the operators make are indicated to them to give them a chance to reconsider before committing themselves - as in the example in the previous paragraph - that software back-up be developed to aid in recognition of the deviation, and finally that in certain circumstances the hardware should intervene and if necessary take over. These points are well illustrated by the description of the automatic train warning system (12.1.2 above).

Coupled with these points is the need to make the system or technology as predictable as possible, so that there are not likely to be sudden changes in the level of danger - for example, when something breaks or collapses without warning. Gouldner (33) refers to the warning function of wooden props in this respect in the gypsum mine he studied. Although the miners thought of them mainly as physical supports to the roof - stopping it collapsing - the mine engineers had a much lower expectation of them, and considered that their main purpose was to give warning, by the creaking, cracking and bending, of an imminent collapse in time for evacuation to occur. Steel props do not have such a property.

Another element of predictability is the avoidance of unnecessary variability in the environment. Accidents on stairs illustrate this. One of the contributors to falls is unevenness in the height of risers and the width of treads resulting, for example, from the use of winding stairs rather than straight flights with a landing to cope with any need to change direction (34).

Warnings are of no value unless recovery is possible. In the example of falls on stairs the banister rail provides a chance for people who begin to fall to save themselves before injury occurs. This is a recovery very late in the accident sequence, in the unstable stage in MacDonald's model (21, Figure 1.3 in Chapter 1), but is still an important opportunity to avoid injury. Appleton (35) quotes a design feature on cookers which functions in the same way as a last minute possibility for recovery after, for example, a pan of fat on the cooker has caught fire. This concerns the positioning of the control knobs which turn off the source of heat. On most electric cookers they are at the rear of the cooker, and so inaccessible with a burning pan on one of the plates; on gas cookers they are mostly at the front, and therefore more easily accessible. (On the other hand this emergency safety measure would conflict with the need to keep the knobs out of the way of children, who might play with them, and thus make another emergency more likely). The same principle of accessibility applies to the siting of emergency stop buttons on equipment so that they are within reach of an operator who has become caught up in the machine.

Clearly it is far better to build the recovery possibilities into an earlier stage of the accident sequence. This demands the positioning of both warning displays and the controls to recover from them in places where they can be easily seen and accessed. Such a policy can reduce the chance that an incident runs its full course to disaster (36).

12.3.5 Standardisation, stereotypes and workload

In order to avoid either inadvertent selection of the wrong action sequence during routine tasks or the chance of being led astray from one sequence to another, design of plant and machinery must conform to the expectations that people have of them. People build up expectations of how things work from their past experience of similar objects. The stronger those expectations the less likely people are to check them out before acting. A number of examples of such stereotypes were given in Chapter 3. Some seem to be based upon strong and fundamental relationships; for example, that controls should generally move in the same direction as the functions they are controlling, (moving a lever to the left should cause a needle or crane boom to move to the left). Such strong stereotypes seem obvious, and yet they are still violated. For example, some cars require a forward movement of the gear lever to select reverse gear; some fork lift trucks require a forward movement of a lever to raise the forks. Other stereotypes, such as colour coding of electric wires, or gas cylinders, are learned by experience. However, contradiction of these also produces a high chance of error among the population which has learned them.

Conformity with standards and stereotypes in design is a major contributor to the predictability of a task, and thus fits with the philosophy outlined in 12.3.4 above. The design then lives up to the expectations of the user.

A further aspect of the allocation of tasks between humans and hardware comes under this heading. Hardware design should not place unreasonable demands on limited human capacities (see also Figure 12.2). For example, tasks which require individuals to memorise information at one stage for use at a later one, or to remember unaided where they have got to in a long sequence of subtasks will result in high error rates. Checklists are one way of overcoming such reliance on limited human capacity but they require conscientious use by the operator. If the operator is not scrupulous about always following an action by ticking off the checklist, never allowing an interruption to split those two actions, and never reversing their order, errors are still possible. It is far better to incorporate into the design where possible a built-in indication of the result of the last action.

12.3.6 Anthropometrics and comfort (Chapters 7,10,11)

The importance of matching design and layout with user anthropometrics can hardly be overstressed in view of the number of occasions on which it has been found to be a deciding factor in the use of protective clothing or of machinery safeguarding, and in avoiding strain and loss of productivity. Surry (37) cites classic examples of the redesign of the cab of an overhead crane in a steelworks, and of hand pliers in electric assembly plant, in which the old design imposed great strain on muscles and joints which had nothing to do with the actual operation itself, but merely with bad layout and design. Application of biomechanical principles can minimise the forces required to be exerted for a given effect, the static muscular load required to maintain the body in a poor working posture, and the need to exert force in or to move through awkward positions (38,39).

For detailed consideration of anthropometrics and its application to design the reader is referred to standard texts (4). One of the questions which is dealt with extensively there is the need to design for a population which contains considerable variation in size, shape etc. The ideal is to design so that the machine, seat, etc can be adjusted for each person, or to provide items in different sizes and fittings. Where this is not possible, design for the greatest possible range of people is necessary. From the safety point of view the range chosen is vital. If the cut-off is chosen as 95% of the general population, and the dimension in question is to be used to calculate the safety distance from a barrier or guard to the danger point of a machine, the word 'cut-off' may apply only too literally to some of the remaining 5% who may use the machine. Booth & Thompson (40) researched the standards used in this field and showed that some groups such as non-caucasians with long arms or slim fingers and wrists were not protected. Safety places greater emphasis than production criteria on the extremes of the range of people who will use the equipment; the fattest people who cannot get out of an escape hatch, the shortest people who cannot safely lift weights onto a shelf, the tallest people who can reach over barriers, or the weakest people who cannot operate levers or handwheels without straining themselves. However, standards cannot cope economically with a hundred percent of the range of the population. There has still to be an onus on the buyer of any equipment, no matter to what standards it conforms, to make sure that it will not be used by people who, or in circumstances which, fall outside those norms.

When it comes to personal protective equipment the fit and comfort of the devices is more important still, since much equipment relies on close fitting for its effect. This is particularly so for goggles, respirators and face masks, which must fit around noses of all shapes and sizes, and seal on the face. Beards and glasses present particular problems, as does the wearing of safety helmet and/or ear defenders. However, it is the variety of the shapes and sizes of face which presents the most problems (41). In Western Europe, respirators are primarily made for male caucasians and there are few, if any, which will fit such minority groups as Asians, Africans, or indeed many women sufficiently well that the nominal protection factor claimed by manufacturers is even approached. Since most personal protective manufacturers are also located in Europe and North America, the equipment imported by many third world countries is also unsuitable for their populations.

Even if it is possible to obtain a good fit, the comfort of protective equipment is far from guaranteed. Indeed there is often a conflict between the two criteria; ear defenders must fit tightly to the head to seal properly round the ears, but that gives discomfort and headache. Face shields must also seal well, but thereby may be more inclined to steam up. Therefore, there is often a balance to be struck between comfort and protection (42,43,44). Ear defenders have a much higher nominal protection factor than do either ear plugs or glass wool, but they are generally less comfortable, and so are less likely to be worn. The effect of even short periods of lack of use reduces the protection in practice to such a degree (Figure 12.4) that the protection from the theoretically less effective ear-plugs in practice can easily exceed that of ear defenders. For example, the 10dBA protector worn 90% of the time is as good as the 20dBA protector worn 75% of the time.

As we discussed in Chapter 10 the price of discomfort and inconvenience is the creation of an incentive for people not to use or actively to defeat the safety devices or safe methods. While people can become inured to discomfort to a certain extent and can be encouraged by continual supervision to keep on suffering it, the long-term aim of any health and safety programme must be to remove that discomfort.

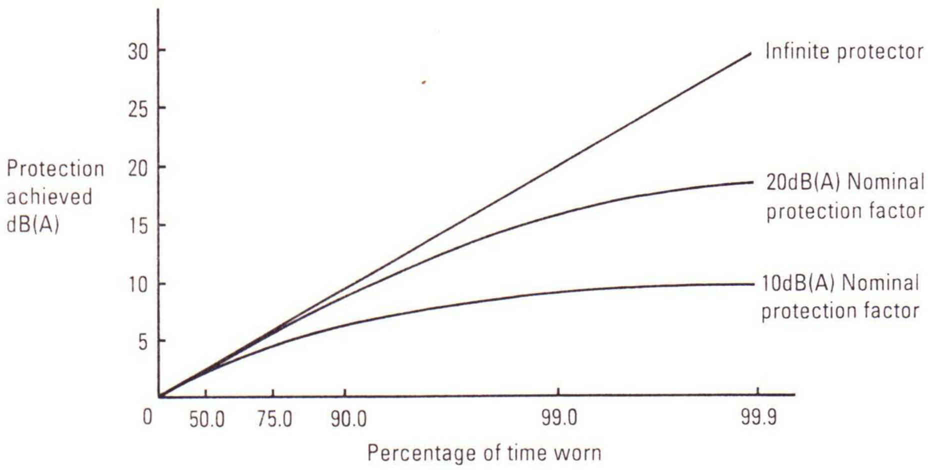

Figure 12.4. Protection in practice afforded by wearing ear defenders of different nominal protection factor for varying lengths of time (source 42, Else 1973)

12.3.7 Misuse and defeating (Chapters 7,10,11)

We have suggested that there are often incentives to defeat safety measures, and to use items in a way for which they were not intended and which are not suitable (such as the hammer used as a screwdriver, the forklift truck as a platform from which to work or the high pressure air hose as a way of cleaning down clothing). The responsibility of the designer to anticipate and attempt to prevent such misuse is going through a period of rapid change. The old dictum of 'caveat emptor' (let the buyer beware) is gradually losing its grip. In its place are coming attempts to encourage designers to do more than in the past to predict and to prevent such misuse, but which will not go to such excessive lengths that the designer no longer has an incentive to innovate. The provisions of the British Health and Safety at Work Act (45) are an illustration of one approach. In Section 6 of the Act manufacturers (which for our purposes can be taken to be designers) are required to undertake research into the hazards of their products and machinery, to design them so as to minimise those dangers, and to make information available to users on those that remain, as well as on correct methods of use. In the USA product liability cases have taken the liability of designers further in insisting that unsafe use must be specifically warned against; but this lays a huge burden of creativity on the designer to predict all possible misuse. The oft quoted use of a microwave oven to dry a pet poodle after a shampoo, and a personal observation of a chainsaw adapted to power a skateboard are but two examples of the problems that could result.

If the liability of the designer is difficult to regulate legally, there is no denying the opportunity at the design stage to anticipate and to prevent some of the ways in which machines are misused and safety devices defeated. The practice shown in Figure 12.5 is perfectly predictable as a way of defeating a microswitch designed to prevent operation of a machine with the guard open. The switch is linked to the drive of the machine which is cut off when the microswitch is open; the plate held in place with the G-clamp simply defeats it.

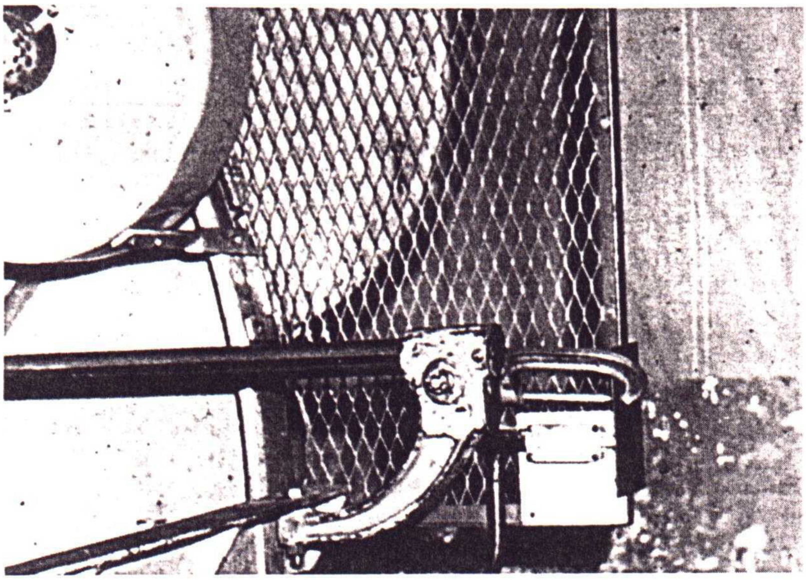

Figure 12.5. Defeat of a microswitch by an operator who needed to open the guard frequently to unclog the machine (source 46, Hale 1972)

A better design would make the microswitch less accessible or double it with a second switch which had to be in the open position for the machine to work or to use an intrinsically less defeatable safety device, such as a positive interlock. An even better design would obviate the need to open the guard to unclog the machine, or would ensure that it did not get clogged so often that the incentive to defeat the guard was great.

A similar defeating of the purpose of safety measures is seen in the transport sphere in the general failure by pedestrians to use footbridges and subways to cross roads (47). The extra effort is too much, especially for those who find steps a problem; subways at night are often seen as dangerous places, and the final equation comes out strongly in favour of crossing at the same level, even if it means climbing over barriers placed to prevent that behaviour.

The two general principles which can be derived from such examples are; remove the incentive to defeat the safety device or to misuse the object; make the process of defeating and misuse as difficult as possible.

12.3.8 Conclusion

We have made use on a number of occasions of words such as standards, norms and stereotypes, which can act as guides to the designer to produce machines or tools which will fit with both the anthropometrics and the expectations of users. This implies a responsibility on the part of designers to seek out and to use such standards and on the part of the ergonomics community to make them available (48). It also implies a responsibility on the part of the standard setting bodies at all levels to incorporate such aspects in their standards. The current practice is still far too inclined to incorporate only the technical aspects of a design into a standard and to take little or no account of the practical considerations of comfort and convenience. If the features which contribute to comfort and ease of use are not covered by the standard then it is not surprising that manufacturers pay little attention to them in their designs. This concentration on technical factors is also apparent in the information provided by manufacturers about the performance of equipment. The nominal protection factor (npf) of protective equipment often has little to do with the protection achieved in practice, and yet may mesmerise the unwary buyer into thinking that the problem is solved provided that the npf brings the measured level in the workplace below the relevant limit.

The emphasis throughout this section is that the designer needs to treat the user or operator as an intelligent, but always fallible contributor to the system. The role of the designer is to anticipate how that person will think and act, using a model such as the one presented here to predict how the relevant decision and control processes can be assisted, supported, and where necessary guided and steered so that unsafe conditions are as far as possible shut out. If the designer does not consider the user as an equal partner the result will often be to provide a challenge to the ingenuity of the user to modify the design despite the designer rather than with his or her full knowledge. In other words the design of objects and processes is not a once for all process which ceases when the object leaves the manufacturer; it is a continuing process which encompasses the whole phase of use. The feedback loop between user and designer is particularly important in achieving optimum safety (49), and is a loop that too frequently is poor or lacking.

It is appropriate to conclude this section with reference to the work of Kletz, since he has done much to impress upon the designers employed in the chemical industry that designing for safety is not only vital, but is not as simple as it may at first sight seem. The copious collections of design and operational errors which he has put together (50,51) demonstrate that common sense in design is neither so common as it should be, nor is the first apparently sensible reaction necessarily the right one. Designers too suffer from the sort of misconceptions and incorrect mental models of processes that we discussed in Chapter 5. In particular, Kletz stresses the role of designers to fulfil the function of the memory of the organisation, which holds the lessons of past failures and near misses in its constantly improving compendium of standard techniques.

12.4 PHYSICAL ENVIRONMENT

In addition to the specific design features of the environment in which people work, and the machinery and apparatus with which they work, there are a number of aspects of the physical environment which exert a general effect on behaviour. They make it more or less likely overall that a person will interact adaptively with the environment. These features work for example through distraction of the individual from what should be of concern, general overload of the human system, or a reduction in responsiveness through fatigue. In Chapters 10 and 11 we dealt with the general effects of loss of motivation and morale on performance and absence, as well as the general effects of ill health or sensory limitations. In this section we shall briefly consider distraction, fatigue and physical environment.

12.4.1 Distraction

Inherent in the way in which human perception works through a selection of information sources and inputs is the possibility that the choice can be incorrect. One source of incorrect choice occurs when an irrelevant stimulus captures the attention. This happens if it is particularly loud, bright, rapidly moving, or extreme in some other way. Correct distribution of attention can also be made difficult if the information being sought is presented against a background of 'noise' either literally in the auditory sense, or figuratively in the visual sense of a jumble of irrelevant stimuli. A design criterion, which has also been implicit in what was said in the previous section, is to minimise this noise, and to design the environment to exclude as far as possible irrelevant and distracting stimuli. This is particularly important for tasks where careful concentration is required, such as process control rooms, study facilities, or places where precision work is conducted.

12.4.2 Fatigue, overload and arousal

Some of the first scientific studies of health and safety concentrated on the problem of fatigue (52,53,54). Limitation of fatigue was also one of the original incentives for factory legislation over a century earlier (55) when the hours of work of pauper apprentices were first regulated by law. At that time, and in the subsequent Factory Acts and mines legislation which regulated the hours of all children, young persons and women in specified trades, the main concern was for the general health of the population. Long hours in insanitary conditions were seen as a breeding ground for the infectious diseases such as cholera which were then rife. There was also concern that such conditions stunted and distorted the growth of children, rendered women less able to bear healthy children, and therefore threatened the survival of the labouring classes, from whom also the recruits for the army were drawn. It was only later in the century that the UK factory inspectorate began to appreciate the link between long hours, fatigue, output and accidents. They then began to use as an argument in favour of shorter working hours the resultant gains in productivity. This was specifically used to counter the arguments of some economists that long hours were necessary since it was only in the last hours of the day that the profit was made (56,57).

The research of the Health of Munitions Workers Committee attempted to prove these contentions scientifically, and was extended later by the Industrial Fatigue Research Board (later the Industrial

Health Research Board). Researchers such as Vernon (58,59,60) established the link between hours of work longer than about ten hours per day (depending upon the workload) and an increased liability to accidents. This was noticeable for all workers, including adult men - who were not protected by any legislation on hours of work. Vernon quotes a figure of an increase of two and a half times in total accident rate with an increase in weekly working hours from 60 to 72 hours. Subsequently the normal working week has been reduced well below that figure in most industries. However, the amount of overtime worked has often meant that the total work time can still approach the figures where marked effects on accident rate appear (61). These effects of overtime have been clearly demonstrated in more modern times (62,63). Even over short periods of continuous working it is possible to show an increase in errors made. Branton (64) demonstrated this by measuring 'unintended hand movements' (a measure of deviations from normal working methods) during routine machine shop work. He showed that a significant increase was observable after only twenty to forty minutes depending upon the task. The increase was preventable by the introduction of a short pause of as little as a minute before this time. The pauses had to become longer as the day progressed and the total work time built up.

Much research has been done on the effect of long periods of vigilance on performance, and the interaction of this with lack of sleep and other general environmental factors (6,65,66,67,68,69). This research shows the decline in performance on tasks as a function of time, and the ability of people to stage temporary, but impressive recoveries from the effects of fatigue by concentrating their energies on clearly defined and short-term goals, such as completing a short test. The studies show that peripheral activities are the first victims of fatigue, as the attention is concentrated more and more on the aspects which the person considers central; thus Davis's (65,66) pilots tended to forget the occasional fuel and other checks as their flying hours on the simulator were increased, and to concentrate more and more on the central task of flying (this was before autopilots were used). As fatigue sets in the percentage of risky manoeuvres increases (by fifty percent during the fourth three hour driving period studied by Brown, 67), irritability increases, people persist less at boring tasks and choose options which require less effort. However, the fatigue tends to be fairly task-specific and a change to another task using different faculties produces a considerable recovery.

The picture of fatigue that emerges is of a gradual exhaustion of the monitoring and attention facilities, so that performance becomes more variable and errors increase. The errors seem to occur mainly at the stages in the model where monitoring and switching between different levels of functioning occurs, as well as in the process of decision-making described in Chapters 5 and 6.

In view of the general reduction in working hours in the population it might be thought that information about the effects of hours of work was of decreasing importance. This is not so for two reasons. First there are a number of jobs where long hours are still an accepted norm. It is perhaps ironical that many of these are to be found not in the industries where nineteenth century reformers battled against overwork, but in occupations which have never been regulated. Hospital doctors and anaesthetists during their early hospital internship are an example of a group where long periods of being on call can lead to excessive actual hours of work, and to errors (70). Other professions where people are on call exhibit the same phenomenon. Examples are engineers and process control operators during emergency conditions, managers during crises (or even outside them if they are workaholic) or the masters of ships or oil rigs who are never off duty. Very little research has been done on these professional jobs to see what effect such long working hours has on either productivity, the quality of decisions, or the occurrence of significant errors. All that can be said is that the potential is certainly present.

The increased attraction of the compressed work week in some industries - for example, four days of ten hours each in place of five of eight hours - has caused the problem of fatigue to appear again. Jobs such as oil exploration and exploitation, large scale construction and diving work involve problems of access to work sites and tight deadlines which provide high incentives to work long hours for several days at a stretch followed by longer periods to recover. Research shows that recovery does not always occur before the next work period on such a schedule (71).

A factor which complicates the issue of fatigue is that of shift and night work, which overlays the problem with the need to shift the period of waking to one when the body is normally asleep. Adjustments to this upset can cause health effects, which it is beyond the scope of this book to discuss (72,73). Evidence for effects upon the diurnal rhythm and on accident liability is somewhat equivocal. For example, most comparative studies show a lower accident rate on night shift than on day shift, which is contrary to what might be expected, but which is probably explained by the slower pace of night work and the different mix of jobs done (74).

12.4.3 Physical environment: heat, light, noise

Early work by the Industrial Fatigue Research Board looked at the optimum conditions of heating, lighting and other physical working conditions for work productivity and errors (58,75). The results suggested bands of acceptable conditions for different types of task. Subsequent research has refined those conditions, on the basis not just of errors and accidents, but of comfort and productivity. The reader is referred to texts of general ergonomics for more details of these limits and their measurement (4,6,37,74). Excessive exposure to heat, cold, glare and noise also cause physiological and health effects which are treated in occupational health texts (76).

The effect of environmental conditions is partly specific and partly general. Cold conditions can lead specifically to loss of sensation in the fingers and so to clumsiness; heat leads to sweating which interferes with vision and grip; noise can mask sounds and cause distraction; while poor lighting can make it hard to see information. The general effects are closely related to those mentioned under fatigue (12.4.2 above). Environmental conditions can impose an extra workload on the body, and thus lead to a faster onset of fatigue. They can also lead to lessened arousal (heat), or counteract that loss of arousal (noise). There is therefore a general design need to keep the physical environment within limits to prevent both fatigue and errors. Where environment cannot be controlled (as in outdoor work) protective clothing and task design can create acceptable microclimates for operators, and/or make tasks less sensitive to their errors.

12.4.4 Stress

Work undertaken during the 1960s and earlier on the topic of stress and accidents stemmed from two traditions already discussed in this book. One tradition was that of accident proneness - where researchers sought to extend the concept to incorporate other 'human' variables (that is, stress as a cause of proneness). The other tradition had its roots in the psychoanalytic approach to accident causation. This second influence upon researchers of the 1950s and 1960s was summarised in 1971 thus: 'It is amply demonstrated that industrial workers having emotional stress may unconsciously arrive at injury as a solution to their psychologic dilemma' (77).

Typical of work undertaken during the 1960s were studies which:
- sought to determine effects of the domestic environment on work accidents (78)

- sought to establish a typology of psychosomatic aspects of accidents (79)
- identified non-specific effects of stress upon accidents (80)
- noted recent acutely disturbing experiences as a factor in accidents (81).

Selzer et al's study (81) was typical of those early studies, using a combination of case reports and accident data. In this case drivers who had caused fatal accidents were matched with drivers who had not. However, matching for outcomes means that judgements about the stress that drivers were under is made with hindsight after the accident and there is no attempt to match for psychological state prior to an accident. Rogg (78) interviewed a sample of drivers who had had accidents and identified 'stress' as a factor retrospectively. Without a comparison group, such studies are unhelpful in progressing understanding of the possible role of stress in accidents.

A number of problems of studying possible links between stress and accidents may be identified as a result of these early studies.

1. Adequate operational definitions of stressors (factors which might affect individuals) and strain (effects upon individuals) are required so that they can be measured.

2. Possible effects of confounding factors - such as shiftwork - need to be identified and controlled for.

3. A generalised study linking stress with accidents is of little or no practical use. Specific (testable) theory is required which can predict occasions when specific stressors will increase the likelihood of accidents occurring. Only then can practical counter-measures be planned.

4. In order for controlled studies to be undertaken, it is necessary to identify not only;
   a. cases where stress is a factor in accidents, but also;
   b. accidents where stress is not a factor,
   c. a 'normal' level of stress which is not associated with accidents - otherwise reasoning remains circular - stress causes accidents; there is an accident; therefore stress must have been present.

5. Retrospective designs using accident data are inadequate - prospective studies are needed to determine whether identified stressors have observable effects upon accidents.

The methodological and conceptual problems of undertaking adequate studies in this area, together with the decline in the accident-prone and psychoanalytic traditions in accident theorising, may well account for the relative dearth of research into stress and accidents since the 1960s. However, there are signs of a revival in interest, although it is likely that the approach may be different to that identified above. Much of the literature is reviewed by Stone (82), who equates strain upon an individual with 'mental injury' - analagous with physical injury. This approach sees strain and its organisational correlates as undesirable in themselves, which therefore require correction. Stone also identifies measures to reduce them under existing legislation. This more practical approach obviates the requirement to seek proof of a link between stress and accidents.

12.5 DESIGN OF WORK PROCEDURES

Work procedures concern the way in which people are required to interact with each other and with the other system elements (hardware and software) to achieve system goals. The need to define work procedures clearly, to make them comprehensible and to train people in them has already been described in Chapters 3 and 9. A number of design principles for such procedures can be derived from the model, and from the discussion in those chapters:

1. avoidance of crosstalk between procedures
2. allocation of responsibility and communication
3. software back up for decision making
4. accessibility of procedures.

We consider below each principle in turn.

12.5.1 Procedures and crosstalk

Chapter 3 described the way in which people build up a repertoire of action sequences or programmes to cope with frequently encountered situations. The choice between the sequences and the monitoring of their progress occupies the limited capacity of the attention system. If the monitoring is not sufficient there is the danger that control of behaviour can be captured by other sequences. This may occur if two sequences share common sections or subroutines. At the end of the common sequence the more frequently used action programme may take over instead of the one required. In this case behaviour is channelled into a totally wrong routine which may run on for some time before it becomes apparent to the individual that anything is amiss. One way to try and reduce this is to ensure that there is a minimum overlap between different sequences (that is, between different work procedures) which lead to different goals. This is especially important where a sequence is rarely used, but must then be used correctly, for example in an emergency. This application of Reason's theory (15,83) is still in its infancy, but an example may demonstrate its potential. This is taken from a study of driving behaviour at a crossroad at Winsum in Friesland (84,85).

The crossroads (known as a Krimpenerwaard design) is laid out as shown in Figure 12.6.

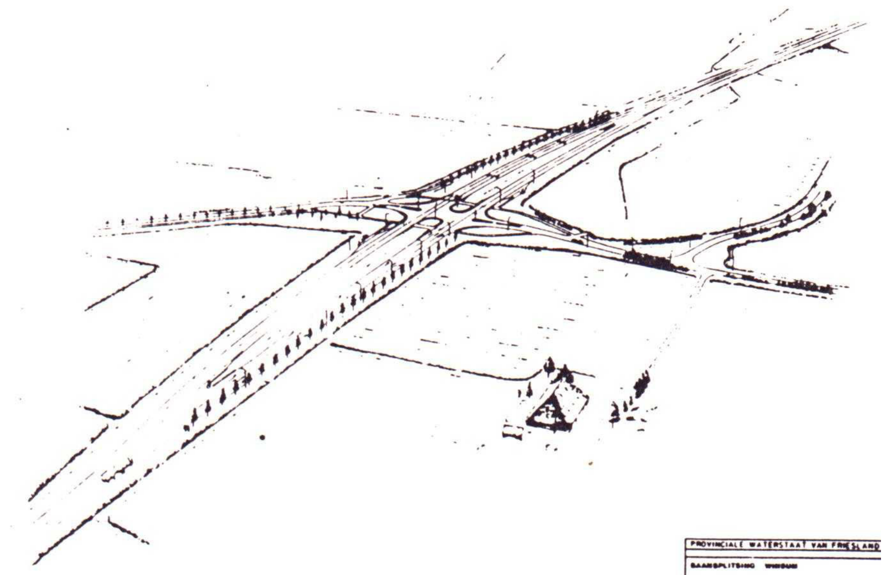

Figure 12.6. Krimpenerwaard crossroads (source 84, Oude Egberinck 1986)

The majority of accidents occurring at the crossroads were collisions between traffic from the minor road either crossing or turning left onto the major road, and colliding with fast traffic on the second carriageway. Twenty-seven of the 31 accidents in a period of 5 years were of this type. The police reports of previous accidents were available, as were the detailed results of earlier experimental studies of speed and crossing behaviour at the site (86,87,88). Videos were taken at the crossroads over a period of months to study 'normal' behaviour, and a number of drivers were stopped and questioned about their crossing behaviour after unobtrusive observation of what they had actually done.

The design of this type of crossroads is based upon the assumption that there will be a much higher volume of traffic on the major than the minor road, and that the minor road will carry a significant proportion of long slow farm vehicles, which require the lengthy central reservation and the splitting of the carriageways so that they can cross one lane at a time. In fact the traffic intensity on the minor road at Winsum is higher than that on the major road, and the majority is fast passenger or light goods traffic.

The accident analysis suggested that, in at least 16 cases, the driver of the car on the minor road had looked right, but not seen the approaching car on the major road. All the accidents occurred to drivers who were very familiar with the crossing. A small study of drivers using the crossroads on the minor road showed that 80% were familiar with it, and passed it at least once a week. For them it is therefore reasonable to assume that the task was of a routine, practiced nature, and that they had firm expectations of the traffic density. The behaviour and the accidents which occurred during it therefore appeared to match all the criteria of skill-based behaviour, with an element of rule-based choice of action program.

The ideal behaviour of the experienced, conscientious driver of the well- maintained car (the picture of the user which the designer of the crossroads may well have had) is shown below.

1. Approach crossroad and observe (from signboards, road layout + memory of where in the journey you are) that Winsum crossroad is ahead
2. Select appropriate Krimpenerwaard crossing program
3. Slow speed (and change gear)
4. Look left
5. If traffic is approaching and there is no time to cross safely in front of it, then stop and give way (switch to more conscious level of control)
6. If no traffic is approaching, or there is time to cross safely in front of it, then accelerate (and change gear)
7. Slow speed (and change gear)
8. Look right
9. If traffic is approaching, and there is no time to cross safely in front of it, then stop and give way (switch to more conscious level of control)
10. If no traffic is approaching, or there is time to cross safely in front of it, then accelerate (and change gear)
11. Reselect normal road program.

It is immediately obvious that the program in question consists of two halves which look very like each other (steps 3-6 and 7-10). Each half also resembles closely the program for crossing an ordinary crossroads without separation of carriageways; this would consist of steps 3,4,8,9 and 10). Indeed, the observational studies indicate that most drivers do carry out at least an attenuated version of this double 'ordinary crossroads' program, looking briefly to the right before the first carriageway and to the left before the second. It is not possible from the currently available data to say whether drivers who do look right before the first carriageway actually look at the first or the second carriageway. If they are indeed using the 'ordinary crossroads' program they would tend to focus, during that glance, on the first, and would therefore be more inclined to miss any traffic coming on the second. Even though they have looked right, they will not have seen.

If we now assume that the level of attention given to the driving task is somewhat lower than ideal, partly because of the expectation that no traffic will be present, a number of possible faults become predictable:

Either: 1. The driver selects the 'ordinary' crossroad program instead of the Krimpenerwaard program; carries it out for the first carriageway and notices too late that there is a second carriageway. If this occurs we would expect occasionally to see a driver turn left up the first carriageway instead of the second, if that had been the intention; if the intention had been to go straight ahead we would expect occasionally to see a total failure to look left or right or to stop at the second carriageway. Observational evidence suggests that the former very seldom occurs, the latter more often.

Or: 2. The driver selects the correct Krimpenerwaard program, but loses his or her place in it, and goes straight from step 5 to 10, or from 6 to 11. Again we would expect to see no observation or stopping at the second carriageway.

Or: 3. The driver is using the double 'ordinary crossroad' program suggested above, in which step 8 is duplicated between steps 4 and 5. As a result of this duplication one or both occurrences of step 8 may have become weakened (shortened in length). Indeed the earlier experiments found that looking to the right occupied less time than looking to the left. For the reasons suggested above the glance to the right will be less likely to pick up the presence of the approaching car. Early detection, whilst the car on the major road is more than 150m from the crossing is also difficult in itself, and more so because of the openness of the landscape at that point. It is also possible that the very occurrence of the first glance to the right, and the failure to see any car during it may set the expectations to such an extent that step 10 is primed to occur, and the second glance has great difficulty in overcoming this and setting step 9 in motion. In other words the two glances are worse at detecting traffic than one. Where the expectation of lack of traffic is very strong, such a program could result in failure to slow to a speed at which the stopping manoeuvre before the second carriageway is possible within the reaction time of the driver. If this theory is right, a better design of crossing, and of work procedure would be either to return to the 'normal crossing' or to make the two halves of the crossing manoeuvre much more different, for example, by staggering the crossing and requiring traffic to follow a crossing manoeuvre with a right turn or merging manoeuvre (see Figure 12.7).

This is a design derived from safety considerations, and does not take account of other criteria, such as traffic throughput. It also increases the complexity of the driver's task at point A, since conflicting traffic can be in any one of three lanes, instead of two in the old design. As such, the 'improved' design requires testing. The purpose of including it here is merely to indicate the potential of deriving both a physical design and a work procedure from the theory.

In principle, the same ideas can be applied to the assessment and design of process control procedures, or to any other work procedure by seeking out similarities in programmes.

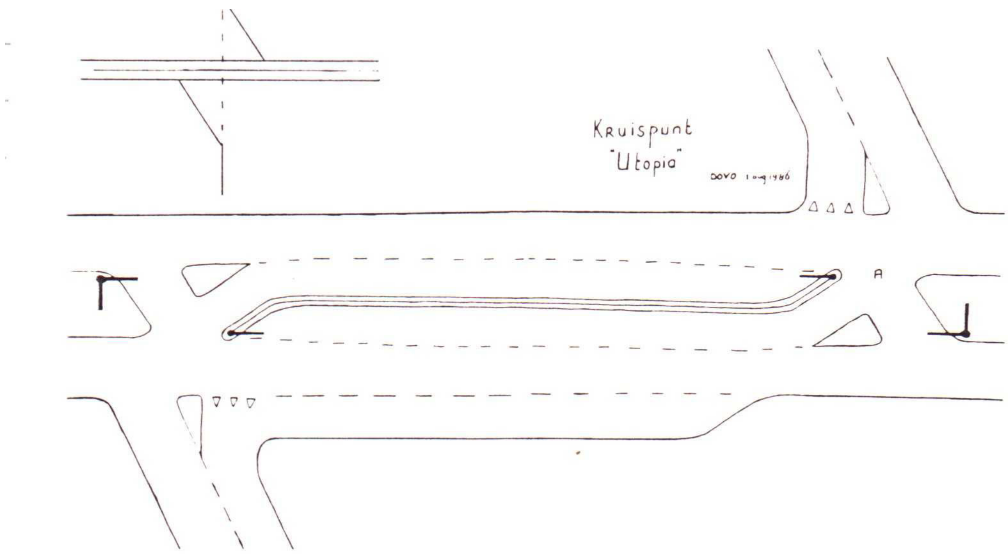

Figure 12.7. Possible improved crossroad layout (source 89, Stoop & Quist 1986)

12.5.2 Allocation of responsibility and communication

Chapter 6 dealt extensively with the problems of ensuring that people correctly accept or allocate the responsibility for particular safety actions. As Robinson (90) pointed out, this can be a problem where, for example, safety rules forbid operators to carry out minor maintenance work or setting, because they have not been trained to do it, and yet production deadlines press them not to delay by calling a supervisor or fitter, but to do it themselves (90). In many countries the importance of the clear allocation of responsibility for all safety activities in job descriptions has been recognised in legislation or good practice (45,91). The application of that principle in practice lags far behind (92,93). As Robinson's example suggests, there is a large difference between theoretical allocation of responsibility and what occurs, or is reasonable to expect in practice. It is the allocation of tasks related to unusual circumstances and peripheral activities which presents the most problems, both in terms of predicting what those tasks will be and when they will occur, and in deciding who can best do them from the point of view of the skills required and of their availablility. This is a comparable problem to that of deciding whether normal process staff in the nuclear industry should handle emergency situations, or call upon a special safety back-up team.

If processes operate for 24 hours or maintenance, repair or construction work must be carried out on a system, responsibility must be handed over from one group to another. The tasks of checking for safety and adequacy of the work site before and after the changeover need to be carefully allocated, so that there is no confusion and consequent omission of a vital check. The work permit procedure has been devised to regulate that process, with the steps being formalised by signatures. The clear definition of such a procedure, all the while keeping it to the minimum necessary in order to avoid abuse and disuse of it, is not simple (94,95). If people cannot see the need for an elaborate procedure, or if use of it is not supervised, the system will rapidly fall into disuse.

12.5.3 Decision support systems

We described in Chapter 5 the susceptibility of the human decision-making process to biases and distortions from a range of sources. The development of information technology and expert systems is now beginning to make possible the design of back-up software systems which support and guide that decision process through procedures which promise to counter some of those biases (15,96,97). The systems suggested by these authors include those listed below:

1. For each operator or group of operators an expert system based on the rules each uses to understand and predict the behaviour of the plant. These could be fed in to the system at leisure, and then used as a back-up by the operator, who would type in the visible symptoms and proposed action in relation to a problem. The system could check the proposed action against the reasoning in its own system and indicate discrepancies. In particular, it could point out cases in which the operator's decision-making was being driven by the availability and psychological salience of information rather than by its objective importance.

2. Related to, or as part of the above, a system which would respond to the input of symptoms by presenting the total range of causes with which the pattern was compatible, in order to avoid the tendency of operators to tunnel vision, driven by their preferred hypothesis. The system could stress particularly the signs or symptoms which contradict any given hypothesis.

3. A more directive expert system would ask the operator for specific information, pursuing its own reasoning until it could come to a decision as to the nature of the problem.

4. Support systems which allow an operator off line to test out the consequences of proposed actions to see whether they produce the desired result.

A number of these principles can be adapted to rather less esoteric technologies as decision support systems for problems in lower technologies. For example, interactive systems for accident investigation can direct the investigator's attention to questions which are of particular relevance to given types of incident. Computer-aided design systems can be equipped with modules which test designs against safety norms and indicate discrepancies and the scope for improvement. Data bases can store and sort both descriptions of safety problems, and the range of possible solutions to them, and so broaden the scope of the search for solutions. The coming years will doubtless see many more applications of such new technology to the areas which this book covers.

12.5.4 Accessibility of procedures

A time-honoured saw runs: 'if all else fails, read the instructions'. This captures a besetting problem of the designer of work procedures, that people do not willingly follow them if they think they can work out a quicker or easier way. This is analogous to the problem of the misuse of objects and the defeating of safety devices which we discussed above (Section 12.3.7). The solution is much the same, to make the safe procedures and information as easily accessible as possible, and the unsafe as difficult as possible. The skill of writing procedure manuals, instruction manuals or leaflets is to start from the user's frame of mind and picture of the problem (98). This means that descriptions starting from theoretical explanations of the machine or computer program, or from a level of understanding of the expert will get nowhere except into the waste bin. There is no point in telling a user to enter data in alphanumeric or ASCII hexadecimal codes if he or she has not worked out how to switch the machine on and load the program from disc.

The quality of instruction leaflets and their coverage of safety requirements is immensely varied. Some packages are limited to a warning symbol and a short statement of the type of danger, others describe in detail how it can occur and the precautions to be taken to prevent it (27). The reading age required to understand instructions can also vary enormously, and be totally inappropriate for the intended user population. We would repeat the plea that norms, standards and guidelines for products should look not only at the technical specification, but also at the quality of the instructions and procedures.

12.5.5 Conclusions

This section has dealt with work procedures in a very summary manner, only drawing out points relevant to the detailed design of action sequences and the allocation and communication of responsibility for sub-tasks. The incorporation of such features into the detailed design of tasks assumes a level of forethought and planning which is significant. Only tasks in large organisations and high technology processes are subject to such a degree of conscious scrutiny. The principles embodied in health and safety legislation since the early 1970s have tried to spread this concern to other industries. The purpose of safety policies and plans (45,99,100) is to make all organisations plan their activities with regard to safety in this systematic way. The final section of this chapter takes up this point of organisational planning and design.

12.6 DESIGN OF ORGANISATIONS

The level of analysis we have used throughout this book has been that of the individual or group. It would not be possible to do justice here also to the organisational level of health and safety management. The reader is referred to books on safety management for further discussion (9,91,101,102). However, it would also not be right to leave out this level altogether. We have already indicated that policy and the allocation of tasks plays a vital role in the control of danger. We discussed in Chapter 10 the role of incentive schemes, and of the social pressures generated by work groups. In Chapter 9 we considered feedback from incidents, accidents and occupational diseases into the redesign of the system. Each of these topics could be expanded greatly in order to show how they can best be designed at an organisational level.

To structure this book we have used a model which considers the individual as an information processing system. It is also possible to see the organisation and the various departments in it in the same way. In Chapter 1 we suggested a schema which links action at different levels from the individual, through group, departmental, factory, company and industry to the international, each a nested information and feedback loop. We are suggesting that the structure of the model used in this book can be applied at each of these levels. This means that if it is to control the dangers within it, the organisation needs to design and put in place each of the functions that we have talked about in earlier chapters.

1. Systems to detect potential hazards, predict where they will occur and monitor the situation to uncover their occurrence.
2. Systems to plan and monitor routine activities to ensure that they remain under control and to detect and correct deviations in them.

3. Systems to make decisions about action needed to control new dangers, to assess their size, develop solutions to them, allocate responsibilities for those solutions and to monitor their introduction.
4. Systems to involve appropriate levels and types of staff in the decision- making process and in the monitoring of safe systems, so as to ensure the appropriate motivation to carry out those actions.
5. Incentive systems in the way of informal praise, discipline, pay, promotion etc to reward safe behaviour and to discourage unsafe behaviour and decisions at all levels and in all functions.
6. Systems to monitor the success of the danger control and to act as the memory of the organisation, so that it does not make the same design mistakes at regular intervals (51,103).

A comprehensive safety policy and plan for an organisation must contain all the above elements. The principle can also be taken further up to the national and international levels, where the legal and governmental frameworks provide for the same functions; for example, the registration and testing of new chemicals before they come on the market (104,105), decision-making about new technologies and their siting (32,106,107,108,109,110), product and employers' liability (111,112), the role of the labour inspectorate in the enforcement of legislation (57,113) and the monitoring and research needed to assess the larger systems impact of technologies and their control (for example, acid rain, nuclear waste disposal, energy technologies and energy saving).

12.7 CONCLUSION

This brief sketch of the contribution of design to safety has taken a very wide definition of the term. We have referred to many activities whose perpetrators might not consider themselves designers. Such a broad grouping of topics has been deliberate. The restriction of the term 'designer' to those who deal with hardware is another symptom of the limited and divided view of safety which we have argued against throughout this book. The organisation and methods expert, the management consultant, the legislator and the software writer are equally powerful influences on the ultimate shape and operation of the environment and of the systems within which people will attempt to control danger. The activities of all these groups must be coordinated to provide successful implementation of safety measures, and to avoid the problem that attempts to promote safety in one direction result in a worsening of safety in another. The questions which are set out in Appendix 1 for designers of the tasks of individuals will also have their parallel in the design of system functions at this organisational level.

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CHAPTER 13

CONCLUSIONS AND FUTURE DIRECTIONS

13.1 INTRODUCTION

A substantial amount of research has been carried out into individual behaviour in relation to danger. Since the end of the 1960s its emphasis has changed dramatically. Reviews at that time (1,2,3) concentrated upon individual differences and a research approach rooted in the accident proneness tradition. Since then exploration of cognitive aspects of human behaviour in the face of danger has been dominant. The ways in which people perceive and understand dangers to life and limb, and the external factors which affect these cognitions have received most attention. This book has attempted to review that research and to place it in a framework which will help the field to move forward. The research has been heterogeneous. It has usually been either atheoretical or else has been derived from theory rooted in a specific sector of the social sciences. This has meant that findings and insights from different studies have often been hard to compare. The model we have used to structure the book is a first attempt to overcome such fragmentation. It must therefore be treated as an interim one, which must be tested, and one which will undoubtedly be altered in future. The very volume of research now available has meant that our treatment has had to be superficial in several areas. It is a reflection of the growing maturity and popularity of the field that it would now be possible to write separate books on most of the topics which have each formed the basis for a chapter in this one.

As the previous chapters have shown, the picture is still far from clear in a number of areas. While new insights have generated promising new approaches, they have usually posed more questions than they have answered. The hackneyed cry of the academic for more research effort in order to fill the gaps is particularly justified in this field. In this chapter we try to draw out the main points of the current state of knowledge of, and approaches to human factors and safety, and to summarise the main areas in which we see the need for future work. If this book helps to provoke such thought and future work it will have achieved a major part of its purpose. Because the giving of future directions and predictions always involves a large degree of prejudice, preconceptions and wishful thinking, this chapter is more personal than the preceding ones. There are doubtless many other conclusions that can and will be drawn from the corpus of literature we have reviewed.

We have divided our conclusions broadly under two headings, which are preceded by a summary of the main points from the book. Our two headings are:

1. further work to understand and model human behaviour in the face of danger and the interaction of individuals with technology and society out of which harm to people and property arises,
2. work to ensure the application of the knowledge that already exists, and to evaluate the contribution made by different preventive strategies to the reduction of occupational and other accidents, diseases and damage to property and environment.

In many respects it is under the latter heading that the most difficult challenges lie. Throughout this book we have shown how the mental image which people have of a safety problem affects the decisions that they make about action. We have concentrated upon the effect that this has upon actions aimed directly at safety; the actions of potential victims, of designers and of supervisors. However, these same mental images also play a major role in the thinking of those who make policy relevant to health and safety. They determine whether research funds are provided to study particular problems and they influence the way in which those problems are formulated; what sort of people are made responsible for health and safety within organisations; what role - and hence what training - labour inspectors are given, what budgets are made available for accident prevention, and what role government, unions, experts and managers are required by legislation to play. For example, if a government or a company management believes that health and safety is mainly a matter of persuading people to obey largely common sense safety rules, they will concentrate on education, supervision and discipline of potential victims. They will refrain from what they see as coercive and largely irrelevant legislation or rules to alter the working environment, to impose standards on machinery and products and to impose liabilities on designers, suppliers and manufacturers.

One such mental image of the health and safety problem is the idea that 'the free market' of informed buyers of goods and work will achieve an optimum level of health and safety; that people will not willingly take risks if they truly know how serious they are. Research in the USA in the 1970s and 1980s (4,5,6) has demonstrated that this particular concept or model of how a desired level of safety is achieved is misconceived. The research has shown that the reality of free consumers and manufacturers, employers and workers negotiating an acceptable level of safety does not exist, and that the market economy results in gross distortions of priorities for health and safety and a distribution of risk and of harm which is neither equitable nor good for the long term aims of society. In many respects this research is fighting over again the battles which rumbled around the first introduction of factory legislation in Britain (7,8,9); the issues of laissez-faire, freedom of choice, responsibility, and the economic imperative.

Central to such debates stands the model that people have of the individual human being and the freedom that each person has to choose and to control their own and other people's behaviour. The model we have used to structure this book shows clearly where we stand on this issue. It accords a central place to the concept of control. We have depicted individuals as seeking for control of the environment in which they live and work. The problem of accidents and occupational disease can then be seen in terms of the loss of that control through incomplete knowledge and understanding, overload, biases in decision-making, and pressures from outside and inside the individual system which make other courses of action more attractive. If this model is accepted and stands the test of further research then it implies a radical change in the way in which some safety problems are seen. It makes appeal to rational and cognitive processes and implies that people must be involved in and convinced about the preventive strategies which are used. It stands in contrast to two other pictures of the problem:

1. people as automata, driven by conditioned responses to pursue a (limited range) of purposes, and therefore subject to being drilled and manipulated by others to behave in particular ways. The solution to safety problems in that picture lies in controlling the levers of conditioning, incentive and reward systems, educational and learning process and feedback of results;
2. people as battlegrounds of conflicting emotions, often partially or wholely suppressed, but liable to break out occasionally and to result in irrational and sometimes self-destructive actions. The solution to health and safety problems in that picture lies in controlling those outbreaks and finding safe outlets for the suppressed emotions.

We have described those other two pictures in somewhat value-laden terms, as is the wont of opponents of a theory. As we said at the beginning of the book, we have presented an approach which seeks to redress the balance which we feel has, in the past, lain too much in the favour of those two pictures, drawn respectively from behaviourist and Freudian traditions. Lest we overstate our case too drastically, we acknowledge that there are occasions when a cognitive analysis of the problem does not produce as much insight as an analysis from one of these other viewpoints. Both behaviourist and Freudian theories can find a limited place in our model. The behaviourist view fits most clearly with operation at the (semi)-automatic level of action sequences in routine tasks, and with the way that choices are made between such sequences at the skill- and rule-based levels of performance. The Freudian view fits less well into our framework, except in so far as it comments upon the motivations which influence decision-making. Our model hardly deals at all with the 'irrational' element of behaviour; accidents where people in fits of aggression, frustration or anxiety committing acts of clear risk-taking, which they themselves would - and indeed often do - condemn in more sober moments. Such outbursts of emotion as contributing factors in accidents clearly do occur. For example, horseplay is a feature in a small proportion of accidents, particularly to young males (10). We would maintain that the percentage of accidents in which such emotional factors are dominant is relatively small, although is one which further research should investigate. Where occupational disease is concerned such emotional factors probably play an even smaller role, since the effects of such hazards are usually the result of long exposure to toxic substances or unhealthy environments, implying the involvement of fixed patterns of behaviour, rather than irrational outbursts.

Our view of the role of human factors in the occurrence of occupational accidents and diseases is based on what we have proposed as the fundamental nature of the accident process as a deviation from the normal that only proceeds to fruition and leads to harm on statistically rare occasions. In most situations the system remains within the bounds of control. On those occasions when it goes out of control the process is either so insidious (as in the case of many occupational diseases), ambiguous or sudden (as in the case of accidents) that the normal processes of control are deceived. These are therefore often occasions which stretch individual capacities to their limits. Only after the event is the progression of the process ever entirely clear (and not always even then). The boundary between a normal situation and the beginning of the accident process is often unclear at the time, and hence 'danger' is a complex and subjective 'construction' about which people will be bound to disagree.

Many managers, labour inspectors, legislators, and researchers have become so used to looking at the health and safety problem from after the event that they do not fully realise or accept the existence of any a priori ambiguity. Hence they may be inclined to adopt superior and paternalistic attitudes to the 'careless and negligent' victims who were not smart enough to see what was coming. Our model and the discussion in the earlier chapters has, we hope, made the complexity of the process of control of danger more visible, and has shown that people at all levels are subject to similar biases, errors and inadequacies which lead to harm. The designer, the manager and the legislator find it just as difficult as the worker to predict and to recognise where problems are going to arise. The spirit of all being in the same boat on a difficult and treacherous sea is, we believe, a much more healthy one than the atmosphere of recrimination, attempts to lay blame and shuffle off responsibility which has pervaded some earlier discussion of the subject.

However, our model does not deny or try to play down the fact that the control of danger results in conflicts; between motives and courses of action within one individual and between different individuals or organisations trying to maximise their gains from a system or to consolidate their positions of power. The process of weighing costs and benefits which is described in the model can always result in different actions being attractive to different individuals or groups, so leading to conflict. We have also stressed throughout the book that the preservation of health and safety is only one, and usually a background goal of both organisations and individuals, which is weighed against a number of others and which only becomes salient under certain conditions.

Above all ours is a dynamic model of the individual in the face of danger. Accidents rarely 'just happen' to people, like bolts of lightning from the blue; nor do people go out and provoke them as some sort of self-punishment for original sin. They arise out of the complex interaction of events which people are actively trying to control. It follows that attempts to make the situation better must take account of that control process and involve individuals in improving their own already good control. Safety improvements cannot simply be externally imposed.

13.2 SYSTEM DESIGN AND THE HUMAN AS CONTROLLER

Our picture of the individual is as a processor of information who occasionally makes errors and causes the system to deviate from an ideal or designed state, but who is also well equipped to detect and to correct errors and to restore the system to normal. Accidents, occupational diseases and damage are the end result of failures of those control processes. The occasions when control is irrevocably lost are rare compared with those on which it is regained. In the vast majority of cases the detection of deviations goes well and the system remains under control. The positive contribution of the individual to safety far outweighs the negative.

A major task of prevention activity is therefore to enhance the normal process of early detection of, and recovery from deviations. The task is not to try to prevent all errors, nor to try unquestioningly to replace the human with engineered replacements. Our viewpoint tries to decriminalise error. One of the most deadening influences on health and safety has been and still is the equation between error, fault and blame. The occurrence of harm simply implies that the control capabilities of the whole system have been exceeded. The final weak link may often be the victim's own behaviour, but the accident has often become so predictable long before that point is reached, that the final failure is frequently irrelevant to the action which needs to be taken to prevent a recurrence. Use of a deviation model of the accident process helps to concentrate attention on the initial occurrence of a deviation from normal, rather than on this final action of the victim. But even here reflex attribution of blame to the person or subsystem responsible for the deviation must be avoided. It must always be asked whether prevention of the deviation was possible within the constraints of the operating conditions prevailing, or whether attention should not rather be given to preventing such operating conditions arising.

13.2.1 System controllability

If the health and safety problem is seen as a breakdown of control, the first priority is to describe the circumstances in which such breakdown is most likely and then to try to steer technology away from creating such conditions. A prerequisite for major harm is that there are large quantities of energy locked up in a system, which can be released if it goes out of control. A first line of prevention is to reduce this total energy. A second line is to keep it under control. Perrow (11) describes the characteristics of technology which he argues create a high potential for disaster. These are complex, energy-rich technologies or systems with many subsystems whose interaction is hard to predict, and which can interact rapidly in what he calls a tightly-coupled way to produce sudden and large deviations. He identifies nuclear power plants, chemical plants, air transport and nuclear weapons as complex tightly-coupled technologies, which he regards as intrinsically susceptible to insufficient control. Perrow advocates a general prevention strategy of moving from such tight coupling towards looser systems through which disasters do not propagate so rapidly (contrasting mining with nuclear power), or of moving from complex to simpler technologies (contrasting air with rail transport, nuclear power with hydroelectric dams). His argument is not that these alternatives are without danger, both potential and actual, but that they are intrinsically more open to control, and so could be, if run to the best standards, protected against the major disasters which so dominate current health and safety thinking and public opinion. Tightly coupled complex technologies, even with the highest quality of management, are not forgiving, and when it is lacking, as the Chernobyl nuclear disaster in 1986 demonstrated, the results can be catastrophic.

Perrow advocates the removal of tight coupling on the causal side of the equation, but points to the need for a tight feedback loop to learn from incidents or near disasters. Loosely structured complex technologies suffer from a poor feedback of information about problems which does not get to those who can do something about them. Hence, acute hazards continue to exist, and people continue to be exposed to chronic dangers despite the fact that solutions are known and could feasibly be introduced (12). Incident reporting and analysis systems are therefore crucial in disaster prevention.

A number of the points made by Perrow about complex systems parallel those which we have portrayed in our model at the individual level. There must be the time and the opportunity for people to pick up the signs that something is going wrong and to react to put it right. The feedback loop between individuals and the hazardous processes that they are trying to control is a vital one. As technology has developed from the craft, through the machine, to the computer age so has the directness of this feedback about the task and its dangers been reduced (Figure 13.1).

The direct link between the designer-craftsman and the machine or tool was the first to become stretched when these two roles were separated, with consequent problems for feedback about the adequacy of designs for the practical world. This was followed by the loss of direct contact between the operator and the work, and then between the operator and the machine. Directly obvious signs of deviation and danger have therefore had to be replaced by indirect and artificial ones, through instruments. This in turn enhances the importance of the element of trust between operator and technology. The systematic design process has to try to restore those lost feedback links as reliably and directly as possible.

With mechanisation and then automation came an enormous improvement in accident figures, as the problems of heavy work in direct contact with hazards and the concomitant problem of fatigue were overcome. As this occurred the concentration of research also moved to the newer technologies, often without fully solving the old problems (13). The forefront of research in human factors now lies with information technology, the diagnostic problems of process control operators and the errors made in man-computer interaction. Yet the largest numbers of accidents and ill health problems still lie in the least technologically advanced sectors such as agriculture, fishing, construction and demolition work, and the least automated small firms in the metal and chemical industries. These and other forgotten groups of workers are rarely the subject of either research into the reasons for their health and safety problems, or investment in the introduction of solutions which are already known (15). The reasons for this neglect must be sought partly in the mental pictures of health and safety priorities held by managers in those industries, and by those responsible for the production and implementation of government policy. Other reasons lie in the very features of such industries which make them resistant to technological innovation, the small size and conservatism of the companies which make them up, and the transience of the work and its vulnerability to the natural and economic climate.

What we have just said about 'forgotten' groups of workers still subject to high accident rates raises a general question of policy. Currently there are large differences in the accident and disease rates of different activities and industries.

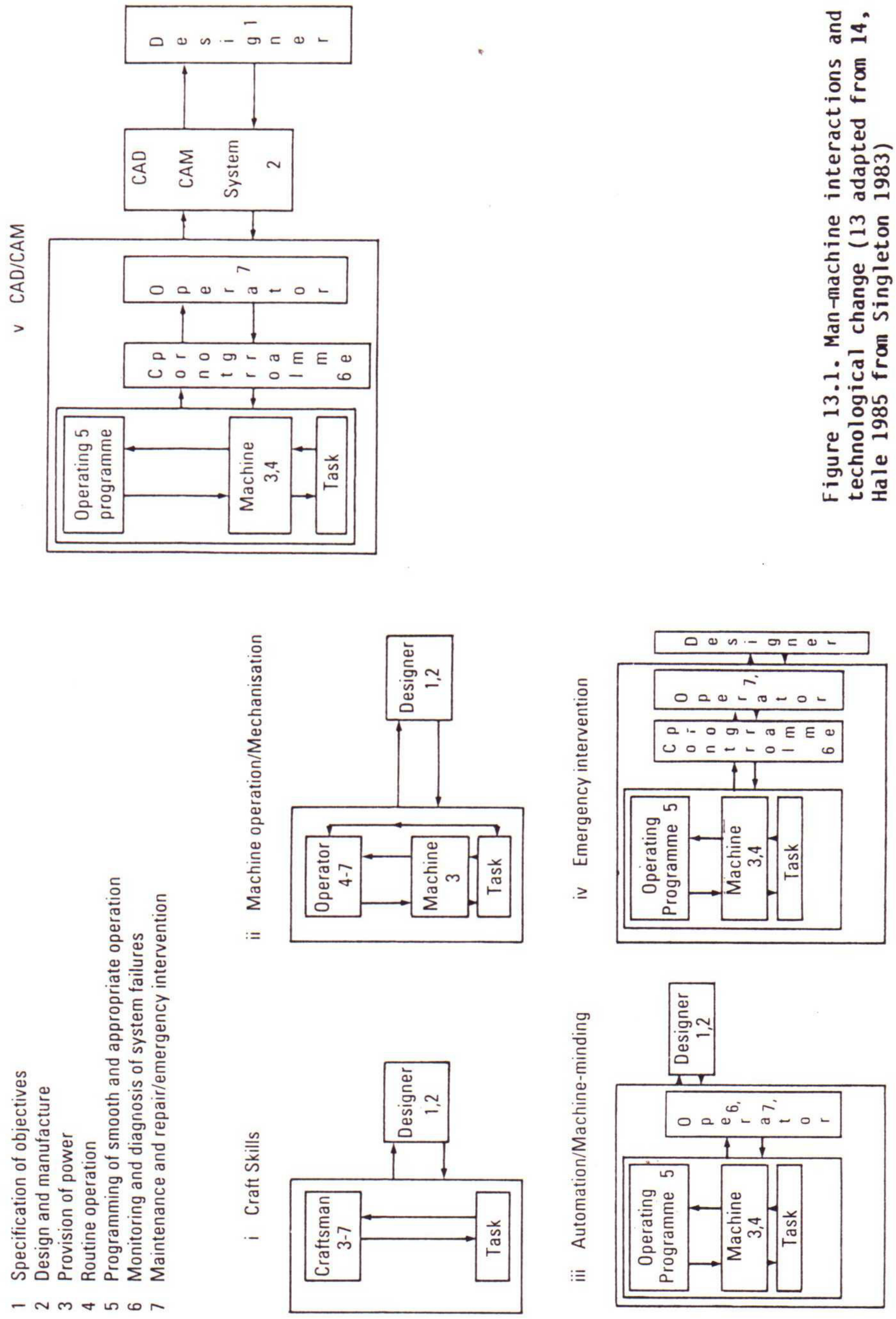

Figure 13.1. Man-machine interactions and technological change (13 adapted from 14, Hale 1985 from Singleton 1983)

The proponents of nuclear technology, for example, point to such discrepancies when they wish to make the case that their technology is acceptably safe, and should neither be delayed, nor be subject to yet more safety systems. The other side of the same coin, if that argument is accepted, is that far more money should be spent in bringing the risk in the tasks and activities which come high in such comparison tables down to a lower level. A fundamental but unresolved policy issue is whether such an equal risk policy should be pursued. The bulk of the research which we have reviewed here shows that peoples' current beliefs and ways of thinking about danger do not unquestioningly support such a policy. They appear to be content to accept inequalities in risk between activities provided that the benefits from the technology are concomitant with the risk, and that other criteria such as 'informed consent' and 'free choice' are fulfilled. Here again we see the importance of controllability as a criterion in determining priorities. The problem with such criteria comes through the prevalence of illusions of control (Chapter 5), which render some hazards more and some less acceptable than the accident or disease figures would indicate. Health and safety policy is a constant search for an acceptable compromise between these conflicting views of priority.

13.2.2 The workings of the human controller

Essentially, individuals identify situations and classify them into distinct categories before matching them to available action sequences in their repertories. Perception and cognition work by establishing similarities and differences between situations, playing up some differences which are important to the classification system being used, and playing down others which are not considered relevant. Information is therefore perceived in terms of its meaning for the classification system.

Once the individual has identified what situation is being faced, behaviour is usually delegated to the (semi)-automatic action sequences. These sequences are then monitored and controlled through allocation of the limited resources of attention. Once a course of action has been chosen there is an inertia built into the system. People do not like to admit that they were wrong. New information will be interpreted as long as possible in terms of the current diagnosis, and will even be distorted to fit it. There may also be pressure to come rapidly to a diagnosis or classification. Even if this is not encouraged by time or production pressures it will be encouraged by the general bias against ambiguity and towards subjective clarity which we described in Chapter 5. The human system then works like soft-ware in a computer which has certain default values programmed into it for use in the absence of real-world data. For example, word-processing programs have a default page layout which will set the width of margins and line spacing in the absence of specific instructions to the contrary. Similarly, the human system has expected features attached to people (layout of face, number of limbs, items of dress) which will be remembered as having been present unless specifically striking exceptions are present and noticed. However, unlike the computer, the human takes a considerable amount of convincing in some situations to replace the default values with data coming from the real world. Expectations can override much evidence to the contrary. All these characteristics place a premium on very careful control of the learning of action sequences and the programmed default values. It is important to teach people when and how sequences could be confused and that one sequence could capture control at the wrong moment. But above all, it is vital that task and equipment design should avoid provoking such confusions so that the attention system is neither fooled by a design which contradicts stereotypes, nor by procedures which overlap unnecessarily with one another. A further need is to ensure that problem diagnoses are not too hastily arrived at and that contradictory evidence is highlighted. This may be done through careful training in self-monitoring or by design of supervisory or software support systems.

The transition between rule- and knowledge-based behaviour requires particularly careful handling. An emphasis on strongly learned and strictly enforced rules may improve safety in highly predictable environments, but may inhibit creativity and make it more likely that people will fail to behave adaptively when the rules no longer apply (16). The choice between training for rule-learning and training for interactive knowledge-based behaviour will often depend on how easy it is to design the system in other respects so that it does not deviate from situations for which there are known rules. Even in technologies where production line techniques have resulted in far-reaching division of labour and narrowly defined repetitive routine tasks, such design is not easy, and deviations from normal (such as breakdowns, off-specification raw materials or machines going out of adjustment) will occur. Above all, many people react against imposed rules by making their own modifications to their jobs to suit their own individual preferences. All of this speaks both for the need for broader training than just at the rule-level, and for clear warnings of deviations from normal, together with procedures for handling them (for example, by calling in specialists).

This transition between levels is made more difficult because people's decision-making processes are for the most part conservative. They generally try to make do with existing learned rules and only resort to creative and interactive problem-solving when the rules clearly do not work. Operation at the knowledge-based level requires the expenditure of considerable energy and so cannot be sustained for long periods. There is inertia against switching knowledge-based reasoning on, but once it is working, new concepts and rules can be 'constructed'. We suggested that this is what people do when they are asked to think about the probability of hazards - that is, when they try to translate their working rules about whether a system or technology is under control into an unfamiliar construction known as 'risk'.

Most of the time people use their existing frames of reference to assess situations. These frames differ between individuals and between groups. The evidence of clashes between 'lay people' and 'experts' over hazards suggests that two very different frames are being used and we have suggested that that of the 'experts' is much narrower and also more oriented to past judgments of what has gone wrong (that is, it is more empirically based). 'Lay people' look more to their expectations of the future, and place their trust in control mechanisms which they can see.

The same processes of seeking after control help to explain the way in which people allocate responsibility for safety, health, accidents and disease between various individuals and organisations in the system. Social groups are a major source both of those frames of reference, and of the motivational pressure which holds people to them. Groups are therefore a strong force for conserving safe behaviour once learned, but may provide a strong resistance to change from old unsafe to new safer practices. Small, cohesive groups may become elitist and put up enormous resistance to outside influence, especially to information which is aiming to prove that the group is not capable of making good decisions (17,18).

Decisions between courses of action are based upon the balance of gains and losses that can be expected from them. Any understanding of behaviour in the face of danger, and any attempt to influence it must therefore be based upon an analysis of what those gains and losses are for each alternative. Once this is known the system can be redesigned to alter the balance. When decisions are made very consciously, a wide range of criteria may be considered, and both their short- and long-term effects may be weighed carefully. In most circumstances such deep consideration does not occur and the choice between programs is made on the basis of the short-term expected effect on a limited range of factors (bounded rationality). For example, I may increase my speed to pass a car simply because it is going just slower than I want to, and I may not consider the effect of my action on petrol consumption, car wear, eventual journey time or safety.

The whole system is subject to feedback loops through which individuals learn from experience to adjust their behaviour in order to achieve their own goals in the easiest way possible within the constraints which they perceive. These feedback loops can mean that changes to the environment intended to achieve greater safety are turned to other ends by the individuals in that environment, so that a degree of 'risk compensation' might occur.

This brief summary of the implications of the model leads to the two final sections drawing out the implications for future research to improve the model itself, and to apply its insights to practice.

13.3 THE FUTURE OF THE MODEL

13.3.1 Status and boundaries

This book has been structured around the model which we developed in Chapter 2. The history of the model can be traced back through a number of previous formats (1,2,19,20). In the development process it has retained a basic structure, but has been elaborated and expanded. The very process of writing this book has made us more acutely aware of some of the limitations of the model. For example, the areas into which we have divided it do not always have the sharp edges which we may have implied. At the knowledge-based level the very order in which the processes of search for hazards, assessment of their importance and decisions about actions are made is far from clear on the basis of the research evidence. Indeed it is certain that there are many iterative feedback loops within that assessment process. The divisions between the three functional levels in the model also need to be tested much more rigorously against practical examples. As knowledge in this area increases we would expect the process of elaboration and expansion of the model to continue. Therefore, what has been presented here is merely a convenient snapshot which helps to take stock of the field and to show where it should go next.

It is as well to specify at this stage what the model or its successors cannot and will not be able to do. It is a mid-range model. It does not concern itself primarily with the micro-level of individual differences in behaviour, except to suggest that they can be accounted for by differences in:

- the repertoires of action programmes
- the weight given to different factors in decision-making
- experience and its effect on the way in which choices are made and the system monitored.

Use of our model will, therefore, never permit predictions of behaviour by a given individual on a given occasion. The best it can do is to predict and explain average group responses. Neither does the model pretend to handle all of the macro-level influences which come to bear on an individual's behaviour. Such factors as social groups, organisational and cultural influences have multiple effects at different stages of the model. The model can help to unravel and to explain those influences, but it would become too unwieldy to show all of their effects in detail. Our aims for the model are more modest. We have used it to clarify our thinking about the way in which the field fits together, and we hope that it can serve a similar purpose for others.

We have also suggested that the model is applicable to behaviour in the face of all health and safety hazards, not just at work, but on the road and in leisure pursuits. Although we did indicate in Chapter 5 that there were differences in the way in which people construed different types of hazard, we suggested that this difference was merely in the strength of the different factors involved. At the same time we rejected an extension of the model to cover behaviour towards risks to financial or social well-being, and expressed some doubts as to its applicability to threats to mental health and well-being caused by stress. All these conclusions currently rest on inadequate evidence. The research we have reviewed is so heterogeneous that it is seldom possible even to find comparable studies which have looked at two different types of hazard and people's reactions to them. Therefore, a task for future research is therefore to approach this question of comparability of hazards more systematically. It is one which is currently arousing more interest. Governments are trying to come to more systematic policies governing risk in different spheres of activity. Prevention agencies are looking to related fields for new and effective prevention ideas. The proceedings of a conference in Edmonton in 1986 (21) are indicative of the way in which the debate may go. That conference brought together researchers and practitioners from the fields of traffic safety, drug abuse and alcoholism, community health and occupational health and safety. The papers revealed an encouraging overlap in approaches and methods which appeared tantalisingly similar at both individual and community levels (without actually offering the possibility of direct comparisons). A major conclusion from the conference was that life style and the community which conditions it play a significant part in many of the problems discussed. Common issues were people's adjustment to rules and their norms and attitudes towards responsibility and self-reliance. The rewards and punishments offered by the larger system, whether community or national, in response to given behaviour from its citizens was also a common theme.

Other boundaries of consequence to the model are geographical and cultural. The research which we have reviewed stems almost entirely from Europe and North America. Our limited experience of working in, or teaching students from countries outside that area has convinced us that their different cultural backgrounds and levels of industrialisation raise a large number of questions about the applicability there of some of the specific research results we have reviewed. Even in countries so culturally close together as Britain, the Netherlands and North America there are significant differences in the weight given to such factors as individual responsibility, sovereignty and the importance of environmental pollution. Application of our conclusions to Asian, African and Arabic cultures must raise more questions still, not only about the relative weight given to different factors in assessing hazards, but about the very structure of the frames of reference in which those hazards are considered. For readers from those cultures we would offer the contents of this book as no more than hypotheses to be critically tested. Such cross-boundary comparisons offer scope and hope for future development at both a theoretical and practical level.

13.3.2 Research needs

If it is accepted that the basic structure of our model is broadly correct there are still large unknown areas within it which require research effort. The list that follows is a personal one, and we would not claim that it is either exhaustive or definitive.

Accident studies. Hardly any studies have been conducted which have used this model or any of its predecessors as a way of collecting data on either accidents or incidents. The exceptions have been remarkably fruitful in furthering both theory and practical thinking in the area (22,23,24) as have the studies which have used such models to classify data on already collected incident information (18,25). Systematic collection of data using the categories from a more up-to-date version of the model would offer a further opportunity to refine it, as well as offering practical insights into the steps which are most likely to go wrong. It would allow more authoritative statements to be made about the similarities and differences between the processes leading to minor and severe injury accidents. This is a question which is fundamental to a theory such as Heinrich's (26) and to decisions about the allocation of resources between different sorts of hazard.

A classification of accidents according to psychologically meaningful categories would also provide the opportunity to reopen investigation of the importance of individual differences. The loose ends of the accident proneness theory could be tied up by studies to determine whether different people exposed to a range of hazards succumbed to different types of accident. This could show whether some people were relatively weak in dealing with particular facets of the assessment process, and so should not be placed in positions where such facets play a crucial role in averting disaster (for example fault diagnosis in process control rooms or optimum distribution of attention in complex tasks such as driving).

However, accident studies can offer only a limited perspective on behaviour in the face of danger. Serious accidents occur only rarely, and hence research projects which use them as primary data must be either lengthy or cover a large exposed population. Collection of accident data is also handicapped by the general aura of mistrust and concern for face saving, avoidance of blame and quest after compensation. By their very nature accidents are sudden and disturbing events which people find difficult to remember in detail (27,28). If the accident occured in a routine task the individual was, almost by definition, not monitoring the activity which preceeded the accident well enough to report it accurately. This problem of recall of routine behaviour is shown, for example by comparisons of observed behaviour at a crossroads with reports given in answer to questions posed a few moments later when the motorist was stopped by the roadside (29). Nearly forty percent of the motorists gave a report of their behaviour which did not match the observations. The trauma of an accident also sets in motion attempts by those involved to explain to themselves their own and other's behaviour and to justify how the accident could have occurred (30). Such processes of self-justification inevitably distort information, and the result is that reports of accidents are limited in their reliability as research evidence. Despite the fact that accidents are the ultimate criterion for the evaluation of the relevance of a particular factor, and of the success of any prevention measure, it is unlikely that understanding of behaviour in the face of danger can be increased beyond a certain level of detail by their study. Further research of a theoretical nature will have to rely on studies of 'normal' behaviour which leads to observable success or failure in preventing or recovering from deviations earlier in the accident process.

Studies of the danger control process. The model identifies a series of stages in the process of detection and control of deviations from the normal or expected behaviour of the system. For some of these stages there is very little research information and we have been obliged to draw inferences from related literature or general theory. These gaps represent research needs.

The most important gap in knowledge concerns the signals from the environment or from within the individual which trigger a shift of behaviour from one level of functioning to another. In particular, what are the features of a situation which alert people that something is going wrong, and that they need to pay more attention to the conscious process of danger search and control? Use of the model for comparison of accidents with incidents (accidents which were avoided) on the same task would make it possible to gather information about what alerts people to take action to bring the situation back under control - factors which presumably do not function effectively in the majority of cases which result in injury or damage. It is to be expected that these factors would be different in routine, skill-based tasks compared with rule- or knowledge-based tasks. Direct observational studies (31,32) offer some possibilities, as does automatic recording of data from simulator exercises (33). Alternatively, recall of events using a diary method of data collection could be used (34,35). One conclusion from research reviewed in the book is that more serious accidents seem to happen with greater frequency on abnormal or non-routine tasks. It is therefore particularly important to study the way in which people monitor their behaviour on such tasks and how they attempt to predict and detect the first deviations which will lead to harm.

The process of searching for hazards at a conscious and deliberate level of functioning has also received remarkably little study. Experimentally controlled studies developing the work of Perusse (35,36) or of Blignault (37,38) would throw more light on the features of environment, task and individual which enable people to detect hazards and to evaluate the possibility of them leading to harm. Such studies are important at the level of physical detection of hazards in a working area, and in the detection of potential hazards in new designs. Experience is clearly an important feature in detecting hazards, but it is also possible that there are individual differences in the ability to perform such a task. This opens up the possibility of selecting specific hazard predictors and inspectors. The problem of hazard prediction is particularly relevant to the role of designers. They are increasingly held legally responsible for the ways in which their products could be used, rather than just for the way they were designed to be used. Methods of predicting likely use and misuse of machines and products are still in their infancy.

We have laid great stress throughout this book on the mental models which people use; models of how a system works, models of how the harm process occurs and what is relevant to it and models of how the system can be controlled. Very little is known about how such models or ways of thinking are learned and developed. Cross-sectional studies of groups of people of different ages and backgrounds can throw some light on the question, but a thorough answer demands longitudinal research in which groups are followed through from school to work in order to discover how their ways of thinking about danger mature and adapt to changing experience. We would also make this plea for longitudinal research studies in other areas of accident research. It could help to throw more light on the question of the existence of individual factors which play an important part in accident causation across a range of different situations, and on the effectiveness of experience and training in improving the ability to cope with danger.

We have suggested that attribution of responsibility plays an important role in the decision whether or not to take action in the face of a suspected danger. The studies of the subject so far have been largely retrospective and hypothetical (judgements by experimental subjects of responsibility for past accidents not for future safety), and have often involved artificial situations judged by uninvolved groups (for example, students). The preliminary studies of McKenna (39) and Glendon (40,41,42) indicate considerable potential scope for more field-based work which would help to throw light on what makes people decide to take action to remove a hazard. Cross-cultural and cross-industry studies would also throw light on the way in which the organisational, political and insurance climates affect such judgements of responsibiity. Such research would be useful if directed at the workforce, but it would be far more relevant to look at the way in which such judgments are made by managers, designers and policy makers. First line supervisors are frequently identified as crucial links in the chain of responsibility; yet little is known about their views on safety responsibility, and that little (43,44,45) indicates how unhelpful for safety their views can be. The same research also indicates the crucial influence of organisational climate and of senior management views on supervisors' beliefs and behaviour. The judgments of designers, manufacturers and buyers of plant and equipment on the topic of responsibility are visible in what they consider 'reasonably practicable' features to be built into or added onto their products to protect safety (46). Views of enforcement authorities and the law can be inferred from cases which they take to the courts and judgments given (47,48,49). However, remarkably little empirical research has been done on these topics to distinguish, in respect of allocation of responsibility, between what the law says should occur, what actually occurs and what might be best for health and safety.

13.4 IMPLICATIONS FOR PRACTICE

13.4.1 The approach to prevention

Throughout this book we have stressed the dynamic nature of human behaviour, responding to changed circumstances or changed goals in a way which is usually adaptive. Anyone concerned with the prevention of occupational accidents and diseases must start from this viewpoint and reject a static one. It is futile to design, to legislate or to manage in the expectation that decisions or actions taken at one point in time will have a permanent and undiminished effect on future actions. All that can be expected is that such activities will nudge behaviour in a particular direction for a certain period of time; designs can encourage safe, and discourage unsafe behaviour; training and reward systems can increase the likelihood of safe behaviour; rules and laws, if clearly and carefully formulated and enforced will limit unwanted behaviour; procedures and management systems can keep unsafe behaviour within bounds as long as they stay relevant and are monitored to encourage people to follow them. However, all these preventive activities require monitoring, refreshing, correcting or replacing after a time. A large part of health and safety practice will therefore always consist of inspection, auditing and corrective action.

Given the creative way in which each of us constantly tries to modify our physical and social environment to make life easier, pleasanter or more rewarding for ourselves, it makes sense to see the role of those interested in, or charged with prevention as being to aid and abet, guide and encourage that individual control. If their role is seen, in contrast, purely as an attempt to impose safe ways of behaving onto an ignorant, careless or recalcitrant workforce (or onto an uncaring, irresponsible, money-grubbing employer) it is bound to invoke considerable resistance and to challenge individual ingenuity to evade the external agents charged with the imposition. A positive, assisting role can work in many situations, particularly where the conflicts between safety and other motives, or between the safety interests of different individuals or groups are not too sharp. Where they are, the task of prevention becomes unavoidably political, since it must either make fundamental design changes to the system to remove the conflict, or impose and enforce rules to protect the interests of one group against another (and even to protect people against themselves).

13.4.2 Analysis of health and safety problems

Prevention in practice depends upon good analysis of the antecedents to accidents and occupational diseases in a particular situation. We lay particular emphasis here on the discovery of the factors which lead to the initial deviation from the normal or expected functioning of the system; what causes the exposure of the person to the toxic chemical or to the threat of physical injury. Analysis of such factors has long been a weak point of the field. Accident classifications used in industry have usually progressed little further back along the causal chain than to agents of injury while occupational health has been so engrossed in uncovering the link between exposure to chemicals and their health effects that it has paid little attention to how and why exposure occurs. The advent of more sophisticated system and risk analysis on the one hand and of occupational hygiene on the other have shifted attention somewhat further back in the chain towards its proper focus. Such a shift has also underlined the fact that the two previously separate fields of health and safety are in fact one field concerned with the control of deviations occurring in technological systems. Very similar deviations lead to both health and safety threats.

To help in this process of better data generation and to provide the information upon which successful intervention in the accident and disease process can be planned, there needs to be further development of the way in which data about accidents, incidents and deviations from normal practice are collected. Most data collection systems are currently oriented towards insurance, compensation or enforcement ends (27,50) and concentrate on allocation of blame or responsibility, rather than upon identification of opportunities to intervene in the accident process and to stop it developing. To start in changing this process more data need to be routinely collected on deviations in the earlier stages in the accident process (51,52,53,54,55). The questions from the model we have used in this book can then be applied to those deviations to establish why they were not detected and recovered (see also 22,56). Similar questions about deviations and the human involvement in their initiation and detection need to be asked when hygiene surveys establish that people are exposed to unacceptable levels of toxic or environmental hazards. The questions in Appendix 1 provide a framework for such analysis.

No system of collection of data on incidents and accidents is sufficient on its own for decisions about prevention. Decisions on priority and on the costs and benefits of preventive strategies require comparable data about the number of instances in which nothing went wrong. If a person carries out a particular activity many times and occasionally it goes wrong enough to result in an accident very different interventions will be necessary to improve matters compared with instances where a person carries out an activity infrequently, but it almost always goes wrong. Data on exposure to the hazard or on demands for specific actions must therefore form as fundamental a part of the analytical data-base of health and safety as records of accidents and occupational diseases (57). However, such data are very rarely collected expressly for this purpose and are frequently not easily derivable from other data sources.

Studies which have analysed accident data in relation to exposure to hazard are united in showing that the more serious accidents tend to happen on more uncommon tasks (10,58,59). Analysis of such tasks is therefore likely to pay more immediate dividends than concentration on normal work situations. This requires the development of better methods of analysing workplaces and tasks before any incidents happen, to predict how such unusual tasks, or deviations from normal might arise. This is comparable with the development of better methods of predicting misuse of, or new uses for products and machines, called for in Section 13.3.2 above.

13.4.3 Design

Design as part of the strategy for prevention must start from the principle that the operator, user or potential victim is an equal partner in the design of the task, equipment and procedures. Safety precautions must become an accepted part of the whole control strategy, rather than something to be bolted on later. This demands great emphasis on the prediction and analysis of the tasks that individuals will have to undertake in both normal and abnormal circumstances, on the mental models that they will need to build up to recognise how to control danger, and on the ways in which they will be able and be tempted to deviate from those procedures.

The first priority is to alert the individual to the possible need to reclassify a situation from 'safe' to 'dangerous'. Warnings of deviations from normal must, therefore, appear as early as possible, and be designed to maximise the differences from normal situations. People also need to be trained in where and when to look for warnings, as well as in how to interpret them. This is part of the philosophy of designing for controllability; ensuring that deviations do not occur suddenly and develop rapidly to an unrecoverable state. A second aspect of that philosophy is one which ergonomists have been preaching since the 1940s, namely that designs should match people's expectations and operate according to their stereotypes and without making excessive demands on their capabilities and capacities.

Designers must also consciously consider the mechanisms of risk compensation; how people will adapt their behaviour to squeeze the maximum advantage from those designs. It is entirely predictable that drivers will react to straighter, wider roads by driving faster, that workers will come to rely on warning devices rather than keeping a look out for themselves, and that machine operators will try to defeat safety devices which threaten their bonus earnings. Future designs must acknowledge this and seek to design solutions to minimise these adaptations. The checklist of questions in Appendix 1 provide the basis for such a design review.

A neglected area of study has been the design of safety laws, rules and procedures to ensure their comprehensibility and utility. Laws are carefully scrutinised to assess their enforceability (whether they would stand up in court and how proveable any transgression is). Their assessment in terms of ease of interpretation and hence of implementation is often less systematic. The same is true of health and safety policy documents and rule books. It is not uncommon for company legal departments to consider whether the rules define responsibility in such a way that they could be used in disciplinary proceedings or compensation cases. Assessment of the rules for their comprehensibility, practical value and ease of use may be less thorough. In order to be of practical use rules must fit well with the mental models of those who must implement them, and must be simple enough to be consulted and understood when needed. The criteria for such an assessment need to be worked out and evaluated.

13.4.4 Selection, training and motivation

Selection has a limited role to play in furthering health and safety, although even this role has not yet been fully explored. We have suggested that a number of cognitive and personality factors such as those associated with strategies for the distribution of attention, proneness to errors on routine tasks, intolerance of ambiguity, or aggression may be indicative of a greater tendency to be involved in accidents. On particularly hazardous tasks further research might be worthwhile to determine whether selection tests could improve job allocation. However, in general, we believe that those who stress individual differences and accident proneness as explanations of accidents are usually attempting to pass the buck and to avoid their own responsibility for designing or ensuring an environment in which people with the normal tendency to make errors can work safely.

Training has great potential for equipping people to cope with the control of danger, but it must rest upon careful task analysis (60,61,62). The untapped potential lies more in training for hazard detection and assessment than in skills training (63). A particular area for future research is the development of better strategies for inspection to detect workplace hazards and to predict from designs the likely problems which will arise. Another area for research is coupled with the importance of mental models in the control of danger. We noted in Section 13.3.2 that more research is needed to study how such models are built up as individuals develop and mature. A logical development of such research is to find ways of systematically enhancing that process, so that appropriate mental models can be developed during training.

Feedback is a vital aspect of safety training. When people learn the standard elements of a task which result in good quality, high production rate and other short-term results, they acquire very rapid feedback on how their behaviour produces those results. Feedback about the effects of behaviour on health and safety is nearly always far less direct and immediate. That feedback gap must be closed by making the most of any near misses or accidents happening to others. If necessary, artificially enhanced feedback must be introduced (64,65,66) to emphasise and praise good practice and to discourage that which is bad.

The motives which most directly bear upon safety, namely fear of injury or disease and the feeling of loss of control, may be very powerful motives but, because of this very power, they are among the most difficult and delicate to influence. An ideal situation to create is one where the individual is given both the feeling that the situation is not quite under control and the knowledge of how to bring it back under control. If one of the two is missing or overdone no useful change may be produced. Fear on its own may be adequate if the desired reaction is to run away or to avoid all contact with a hazard. If the person must still work with a hazardous process and is given too high a dose of fear and not enough knowledge of control then the result will be either fatalism or denial of the danger, neither of which will lead to better danger control. If there is too much emphasis on control and not enough on fear then the result may be unwarranted overconfidence. Because of the difficulties of operating directly with fear, other important motives such as desire for money, achievement, challenge, social esteem and minimising of effort, are often easier to manipulate to improve the gain from safe behaviour and to increase the loss from unsafe behaviour. One gap in the research literature is systematic study of the way in which such other motives can be used to further safety. Descriptive studies of good and bad undertakings and the way in which their organisation, management and functioning rewards and punishes safe behaviour are needed; but more important are evaluations of safety incentive schemes, which seem anecdotally to be successful, but which have never been systematically evaluated.

13.4.5 Organisation and evaluation

The practice of health and safety takes place within an employing organisation, and ultimately both legal and moral responsibility for ensuring that accidents and disease are minimised rests with the employer. Management has little trouble in accepting and carrying out its control functions when these concern the quality and quantity of production, making a profit and ensuring the future existence of the company. Through the design of the physical and organisational environment and through supervision and control of the behaviour of the workforce those goals are achieved, or at least actively striven for. When it comes to health and safety reactions are more equivocal. While employers' organisations loudly claim the right to decide how they will pursue that goal (67,68), they are often more than ready to stress the responsibility of employees to ensure that the goal is reached. The control of behaviour to achieve production differs only in detail from that to achieve safety.

Our book has shown that the organisation required to analyse the potential problems of danger control, and to plan the organisational structure and policy content to combat them, can be formidable. It cannot be done in the odd half hour between worrying about the end of month production figures and solving a machine breakdown. It requires concentrated and continuous thought and creative problem-solving. The realisation of this has led to the increasing employment of specialists to manage this aspect of organisations' affairs.

While the study of accidents and occupational diseases and the role of human behaviour in them has reached a far greater level of sophistication in the 1980s than hitherto, much prevention practice remains based upon rules of thumb and mental models of the problem which are pre-scientific. In particular we would argue for a far greater concentration in research projects upon the evaluation of the success of different prevention methods and techniques. Safety posters are widely used despite evidence of their lack of success; incentive schemes are installed based upon their face validity and rarely evaluated; much training is given only because it seems logical to give it; design changes are introduced and often not checked to see whether they produce either positive gains in safety, or unwanted side-effects because of risk compensation. The age of information technology has produced many data banks of health and safety problems, norms and analyses, but, as yet, none which are organised to give easy access to possible solutions and the circumstances in which they do and do not work. The feedback loop to enable our health and safety system to learn from its past efforts - both successes and failures - is largely absent. It may be that such evaluation does go on inside organisations and is never published. In either case the effect for the rest of the practitioners in the field is the same; the wheel has to be reinvented, and too often it comes out square.

Therefore, our closing plea is for increased access to information, greater preparedness to evaluate and to discard outdated frames of mind, theories and prevention methods and to develop new ones. Ignorance in the sphere of health and safety is no stumbling block, provided that it stimulates the search for knowledge. It is what is already known for certain that is the enemy: because what is 'known' is never questioned, however wrong it is. Just as, in the Middle Ages, the certainty contained in the biblical creation story made the asking of many questions in biology superfluous, if not impossible, so has the certainty with which some theories about human error and accidents have been held, made advances in prevention impossible. If this book has demonstrated the inadequacy of those old theories and opened up new questions to be answered, it will have served a useful purpose.

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