Author's Note (2008)

This document has gone out of print long ago. Despite its limited circulation it has, for some reason, become quite popular as is evidenced by a relatively unusual quotation rate and by the fact that every now and then I receive a request for a copy of the original.
In view of its apparent survival value I consider it my prerogative to present a new edition of 'Dealing with Danger' on the occasion of the thirtieth anniversary of the epochal events of which it is the sediment.

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Dealing with Danger

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Traffic Research Centre, University of Groningen

Summary Report of the

Workshop on Physiological and Psychological Factors in Performance under Hazardous Conditions with Special Reference to Road Traffic Accidents

held in Gieten (The Netherlands), May 23-25, 1978
The Workshop was sponsored by the
Medical Research Committee of the
Commission of the European Communities

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Abstract

Road traffic accidents are among the principal factors influencing public health. In the past most efforts were focussed upon improving vehicle-and road quality. Now these two components of the Human-Road-Vehicle have become so reliable that improving the human factor in the system is more indicated, also because further 'hardware' improvements will be extremely costly. Thus far, however, the total research effort of the life sciences, the behavioural sciences and the social sciences has remained quite limited. Moreover, with very few exceptions the present degree of cooperative effort at the international as well as the national level is rather poor. Yet several initiatives for international cooperative programs have recently been taken in order to change this state of affairs. The Commission of the European Communities, for instance, has launched such a program through its Medical Research Committee (MRC). The present report results directly from MRC's activities.

This report deals with task performance—especially that of traffic participants—under risky circumstances. Risk is a rich and varied concept that, unfortunately, has not yet been well defined in relation to human behaviour on the road. Three aspects of traffic behaviour and three aspects of risk should be taken into account. At the *strategic* (trip planning) level dealing with danger predominantly consists of *risk acceptance;* at the *tactical* (manoeuvring) level it is mostly a matter of *risk taking;* at the *operational* (basic skill) level it is *coping with threat,* or perceived danger (Sec. 3.1.)

Human information processing research has been mostly in terms of risk acceptance and risk taking, while psychophysiological and bio-medical research has dealt mostly with stress and with threat-coping mechanisms. Integration of these two approaches and complementary research are badly needed.

From the considerations advanced in this report it may be concluded that the following special efforts are needed:

(1) Outlining a theoretical and methodological framework, including the definition of standard task conditions for performance under risk; operational definitions of the various aspects of risk; standardization of measurement procedures and of multivariate data analysis techniques;

(2) Standardizing endocrinological and pharmacological assessment routines;

(3) Stimulation and cooperation in empirical studies regarding
- perception and evaluation of subjective risk and threat;
- the interactions between task-related factors (process variables) and individual physiological and personality-determined response patterns (state variables);
- the temporal dependencies, including the effects of the circadian and other biological rhythms, the work-rest cycle, and the temporal structure of tasks;
- the design and implementation of public health, legal, and educational countermeasures that derive from the research under consideration.

Dealing with danger

1. INTRODUCTION

1.1 Background

This report derives from a two-day Workshop on "Physiological and Psychological Factors in Performance under Hazardous Conditions with Special Reference to Road Traffic Accidents". This Workshop was organized by the Traffic Research Centre of The University of Groningen (The Netherlands) under the auspices and sponsorship of the Medical Research Council of the Commission of the European Communities (CEC). Some 30 active researchers from various backgrounds, mostly medicine, physiology and experimental psychology, took part in this Workshop, the fourth of its kind (see Sec. 2.3), which was held in Gieten (The Netherlands) on 23-25 May, 1978. This Workshop brought together leading experts in the areas of traffic safety, stress research and individual decision making: They exchanged their views on the research needs in the field under concern and the feasibility of increased international cooperation in this area, possibly through a CEC concerted action.

This report contains an integrated summary of the discussion—plenary, sectional, as well as after hours. It does not give full credit to every participant's contribution but has been complied on the basis (a) of the documentation received from the participants or prepared by the organizers prior to the Workshop, (b) the extensive notes prepared by several of the participants during the various meetings, and (c) the notes and memory of the author, who chaired the plenary meetings. In addition a fairly considerable structuring effort went into the composition of the present text. Consequently the result not necessarily represents anybody's views on the matter in particular, although the author has made a serious attempt at remaining as faithful as possible to the expressed opinions of the participants. Drawbacks of this procedure are probably mitigated by the critical comments that several of the participants made to the draft of the report. Such comments have frequently led to improvements, although some could not be incorporated since they would have required yet another Workshop.

1.2 Size and Seriousness of the Traffic Accident Problem

Humans are permanently at risk. The estimated probability of death from all causes, per hour of living, for citizens of the European Communities is approximately one in a million. Accidents are among the more important causes of this intrinsic risk and of these traffic accidents rank foremost. The estimated number of traffic fatalities over the whole world is of the order of 250 000 per year while some ten million people are injured annually, and of these roughly 25 percent will suffer more or less severe permanent crippling effect. On the roads of the countries of the European Communities about 50 000 persons were killed in 1975 and one and a half million injured. Approximately 10 percent of all hospital beds are claimed for the victims of traffic accidents, a percentage that is roughly twice as high as one would proportionally expect on the basis of the time that people spend on their daily travel. Road traffic accidents therefore constitute a major public health problem, ranking third in the list of major causes of death, after cardiovascular diseases and cancer. This, notwithstanding the fact that relatively speaking the safety of the traffic system has steadily increased over the last

30 years: whereas in 1950 in the Netherlands one fatal accident happened on the average very 10 million automobile kilometres, at present no less that some 25 million kilometres travelled automobile are needed to produce one fatality. Due to the massive increase in mobility, however, the absolute numbers of dead and injured have increased to a level that is considered unacceptable from the public health point of view.

1.3 Safety Countermeasures

The concern for road traffic accidents shown both at the national and inter national level, is therefore highly appropriate. In many countries considerable amounts of money and effort are being spent on countermeasures for improving road safety. Unfortunately such efforts have not always stood up to expectation. Worldwide a considerable drop in the road accident rates was observed between 1972 and 1975. Now the earlier trends seem to have been resumed and the annual numbers of people killed and injured are going up again. Yet, during this period continual and sometimes strenuous efforts were made to improve safety. Apparently, however, too many factors in accident causation are still unrecognized or at least not well enough under control to create a consistently downward trend in the mortality and morbidity rates of travelling.

In the past the highest cost-effectiveness of countermeasures has apparently been found in improvements of roads and vehicles. Thus, for example, the construction of dual carriage ways with median barriers, better lighting at intersections, and high-friction road surfaces have had a considerable effect on the reliability of the component *Road* in the Human-Vehicle-Road system. Similarly technical innovations in tire construction, power assisted and anti-lock disc brakes, roll-over bars and collapsible steering columns have greatly improved the protection offered by the vehicle (as earlier did the safety belt for motorists and the crash helmet for moped riders).

1.4 The human component in the traffic system

As a result of such countermeasures the relative contribution of the three system components Human-Vehicle-Road to the causation of accidents must have changed. Several empirical studies, among others by the Transportation and Road Research Laboratory, indicate that the human operator is at least partly responsible (in the technical sense) in the majority of accidents.

Moreover, the costs of effective further technological improvements of road and vehicle, as they are known at present, may be prohibitive. Some such improvements would require gigantic investments in non-intersecting automated highways, complete separation of different traffic categories in downtown areas, and similar programs. The alternative, that is, integral public transport in a high density demand sensitive system is equally costly. In the light of society's other priorities it is to be expected that few countries will be able to afford such 'ultimate' solutions.[1]

In this light it is extremely important that further improvements of traffic safety come from countermeasures directed at the human component. In the past most research activity in this area remained restricted to applied studies of behaviour (e.g. driver education, enforcement campaigns). New developments in various fields such as psychophysiology,

[1] Actually, little is known about their relative safety and the consequences of system failures due to technical defects, strikes or sabotage. Also the possibility of coping with traffic unsafety by reducing society's present level of mobility is left out of consideration.

psychophysics and endocrinology appear to have enhanced the likelihood of successful countermeasure design aimed at the human component in the traffic and transportation system. Thus a concentrated research effort, based on the mutual understanding and cooperation of investigators from various disciplines in the life sciences, the behavioural sciences and the social sciences, as well as engineers, on a scale that has not been established yet and that will be difficult or economically even undesirable to realize at the national level only.

1. 5 Current international activities

1.5.1 Programs of supranational agencies

It appears that an increase of the research effort in the human factors domain has been developing at the national level over the past several years. A similar movement can be observed at the international level. The 29th World Health Assembly gave the WHO Regional Office for Europe mandate to develop a world-wide program in this field. The Regional Office was asked "to promote and coordinate further research required on human and medical factors involve, in traffic accidents, to devote attention to the human and environmental factors influencing the risks of accidents for all categories of road users and to cooperate closely with intergovernmental organizations active in this field".
Apart from WHO, there are several other intergovernmental organizations that have programmes dealing with road safety:

- The UN-Economic Commission for Europe, who have a working party on road transport. It organizes meetings between experts in traffic safety and vehicle construction accidents.
- The Council of Europe considered, among others, vehicle construction and also publishes statistics of road traffic inspection, road safety education legislation, the implications of ill health and certain psychological behaviour patterns on driving performance.
- The Organization for Economic Cooperation and Development (OECD) in their program of cooperation in the field of road research call meetings of experts to define the necessary scientific and technological basis for governments to take decisions on specific road problems.
- The European Conference of Ministers of Transport (ECMT) aim at coordinating and harmonizing the field of transport at the European level, including safety related issues.
- The North Atlantic Treaty Organization (NATO) has also paid attention to road traffic problems through in-depth surveys now completed.

On the basis an appraisal of the activities of these organizations it can be said that at present, except for the WHO and OECD, no coordinated research is carried out in Europe in the field of human factors involved in road traffic accidents.

1.5.2 Reasons for the relatively low level of effort

Ultimately the nature of the problem, seen from the Public Health point of view, is simply to reduce the losses in terms of life and injuries. Scientifically the problem amounts to an investigation into the factors (organismic as well as environmental) that contribute to system malfunction at the interface between man and task. In this framework road user behaviour has been studied from various viewpoints, from endocrinology and psychophysiology to the

psychology of judgment and choice. Only recently these research efforts have begun to become more systematic as is, for instance, shown by the relative youth of the journals dealing with accident research and of the special task forces dealing with safety problems.

This state of affairs is not primarily due to a lack of funds; more serious is the shortage of qualified and experienced scientists in the field. Traditionally the field of traffic safety has been looked at mainly from the engineer's point of view. Neither social and preventive medicine nor physiology and endocrinology, nor even psychology and sociology have thus far devoted enough basic research effort to the problem area to strike a better balance between the technological and the human sides of the problem.

As a result it is still very difficult to place the relevant research findings from these diverse disciplines in a common theoretical and methodological frame of reference, that would bring out the multiple interrelations between the behaviour of the road user, his physiological state, and the environmental conditions under which he is operating. And even where sizable programs are under way there is frequently a pernicious shortage of communication *between* research groups, due to geographical or conceptual distance, shortage of funds, or simple ignorance of each other's activities. It is unfortunate that too many of the contacts between active researchers are taking place after their research is completed., (e.g. by exchanging the written reports), rather than in the planning stages and during the actual investigation.

1.5.3 The activities of the Commission of the European Communities

The Commission of the European Communities through their Medical Research Committee (MRC), specifically the *Ad Hoc* Group on Toxic and Psychological Factors in Road Traffic Accidents, have considered the problem. They have contributed to its solution by organizing workshops and seminars attended by scientists actively engaged in research in a number of disciplines relevant to the understanding of factors that contribute to the impairment of driving skills and the causation of accidents. It was concluded that greater knowledge of the processes involved in road user perception and decision making may lead to significant reductions in the frequency and severity of traffic accidents. The basic approach in the CRM's activities has thus far been to concentrate on the aetiology of human errors with particular emphasis on bio-medical and psychological rather than ergonomic factors. Particular attention has been given to the role of fatigue in the impairment of driver behaviour. The impairment of driving skills was considered under its perceptual, motor and intellectual aspects (treatment of information, appraisal of situations, decisions, etc.) and their relation to physiological or biochemical processes.

These topics were discussed in three workshops. One was held at Crowthorne (UK) in March 1975 on the topic of working conditions of heavy goods vehicle drivers. The second, held in Dublin (Ireland) in January 1976, dealt with psychobiological factors in the breakdown of driving skill, and the third, held in Dourdan (France), in September 1976, considered the role of physical and mental fatigue in accident causation. The results of these workshops made it very clear that there is indeed a need for a more integrated approach to these problems, not only at the level of research methods, measurement techniques, experimental design, and data analysis, but particularly at the conceptual level. It was felt that in the absence of a sufficiently developed conceptual framework the effectiveness of coordinated research might suffer. Therefore a fourth workshop was held in Gieten (The Netherlands) in May, 1974. The goal of this workshop has been to bring out in more detail the 'unifying' structure—or perhaps the prevailing lack of structure—underlying the various approaches taken to tackle the general problem of task performance in hazardous situations and in particular in traffic. It was expected that such factors as fatigue, working conditions and bio-medical state of the organism as had been discussed in the previous workshops could

be shown to be part and parcel such a coherent structure.

2. DEALING WITH DANGER

2.1. *Three levels of risk and three levels of task performance*

Travelling entails risks. Nevertheless the road user tends to *accept* these risks although they may be considerable. In many cases he even *takes* risks deliberately engaging in behaviour that will elicit danger. Once a danger becomes manifest he has to *cope* with it, by finding an evasive manoeuvre that will eliminate the accident potential from the situation. It will be clear from this description that several facets of risky behaviour should be distinguished, and that the term has several connotations that might better be distinguished by consistently using different terms.

- By *danger* we shall mean a situation or activity that will result with certainty in a loss of life, an injury or a material loss, if no successful evasive action takes place. The seriousness of the loss incurred may be deterministic or stochastic, depending on the nature of the situation (driving straight into a concrete wall at 50 km/h will result in a loss of life with some probability).
- By *threat* we mean perceived or subjective danger; this may or may not be compatible with the actual presence and size of a danger. *Threat* is what the organism must cope with, and the perception of and coping with threat may be innate (fear of loosing equilibrium), or learned (fear of dogs).
- A *hazard* is to be understood as a situation or activity in which dangers will occur with some probability. Thus, normal driving constitutes a hazardous activity, but will not necessarily become dangerous.
- The probability that a danger will become manifest constitutes an objective risk that usually can be determined statistically. The degree to which the *person* is aware of the hazardous nature of his activity, and maybe even of the size of the risk (probability of danger) involved, is called *subjective* risk. If the person, while being aware of a risk nevertheless engages in the hazardous situation (activity) we shall speak of *risk acceptance.*
- Risk acceptance therefore refers to an evaluation of latent dangers. It covers both. the possibility of passive encounters with dangers, and the possibility of active *risk taking*, that is, performance of activities that will increase the objective risk (though not necessarily the subjective risk) of a danger becoming manifest. If a danger actually occurs, the situation becomes one of *coping*, that is, finding an appropriate evasive manoeuvre to avoid direct contact with the object(s) constituting the danger. In general this means avoiding the direct contact between the human body with a strong source of (kinetic) energy, but in a wider sense also 'mental' events (the after-effect of a near miss, causing someone else's accident, etc.).

Thus we distinguish three stages in the subjective evaluation of risk in traffic:

- *risk acceptance:* in which the risk is specified in terms of the probability of a danger occurring during a particular time interval;
- *risk taking:* actively engaging in behaviour that does increase the probability of a danger becoming manifest; and
- *coping with threat:* information intake, decision making and performing an evasive manoeuvre aimed at avoiding acute, perceived danger.

These three stages cannot always be distinguished completely unequivocally but functionally they may be related to the three control levels that characterize the traffic task : the strategic level, the tactical level and the operational level.
The *strategic level* defines the planning stage of a trip, incorporating the determination of trip

goal, route and vehicle choice, and evaluation of the costs and risks involved. Frequently considerations at this level will remain more or less implicit, guided by coarse rules of thumb based on prior experience. The habitual home-to-work trip is usually treated in this manner. During the trip the progress that is being made will be matched against the overall plan at the strategic level, and thus will determine to some extent the manoeuvring that is controlled at the second, the tactical level. Although largely determined by the prevailing circumstances that have to be negotiated during the trip, manoeuvres such as speeding up and slowing down, turning off and overtaking, have to match the prescriptions of the overall strategy of the trip. The actual behaviour that is displayed under the strategy and tactics of the trip is under control of a third, operational level. Here the basic skills of steering, braking, etc. come directly into play.

In principle it may be assumed that each of the three facets of dealing with risk may influence decision making and behaviour at the strategic, the tactical and the operational level alike. If the decision is made to go on a particular trip, one accepts an aggregated trip risk; if one decides on an overtaking manoeuvre, a more specific risk is accepted and similarly, for the basic skill level, negotiating a sharp curve at the posted speed limit involves the acceptance of a certain risk of skidding.

The same reasoning holds for risk taking and for threat coping. Not all possible combinations of risk level and performance level may be equally important. Although a much more elaborate analysis of these relations would be needed to bear this out, it appears that risk acceptance plays its most explicit role at the strategic level, risk taking at the tactical level, whereas threat coping would seem to be related more closely to the operational level.

2.2. The structure of risk research

It should be pointed out also that the majority of behavioural research on behaviour under hazardous conditions has dealt with risk acceptance and risk taking rather than with coping behaviour. This is not entirely surprising in the light of what might possibly happen to subjects in such experiments.

Yet the situations and conditions in which road users face acute dangers, and in which coping is required, are of the most direct importance for the occurrence of accidents. Consequently a much more thorough study of the physiological and psychological factors that determine threat coping behaviour in traffic conditions is called for. Research on stress. and coping with threat figures, in fact, quite prominently in other areas of human (and animal) bio-medical and psychological research. The results of that research should have considerable value for insight in the causation (and avoidance) of traffic accidents. On the other hand more effort appears to be called for in *the area* of cognitive factors of *threat coping behaviour.*

Before entering into a more detailed analysis of the various determinants of risky behaviour in Sec. 3, it should be emphasized that we are dealing with a multivariate phenomenon of considerable complexity. In order to aid comprehension of the following parts of this report it seems useful to summarize the various approaches to the study of risk as in the diagram of Figure 1. This diagram is also intended as a classification of the approaches that may be expected to act together in the framework of a concerted action of research workers in the various disciplines.

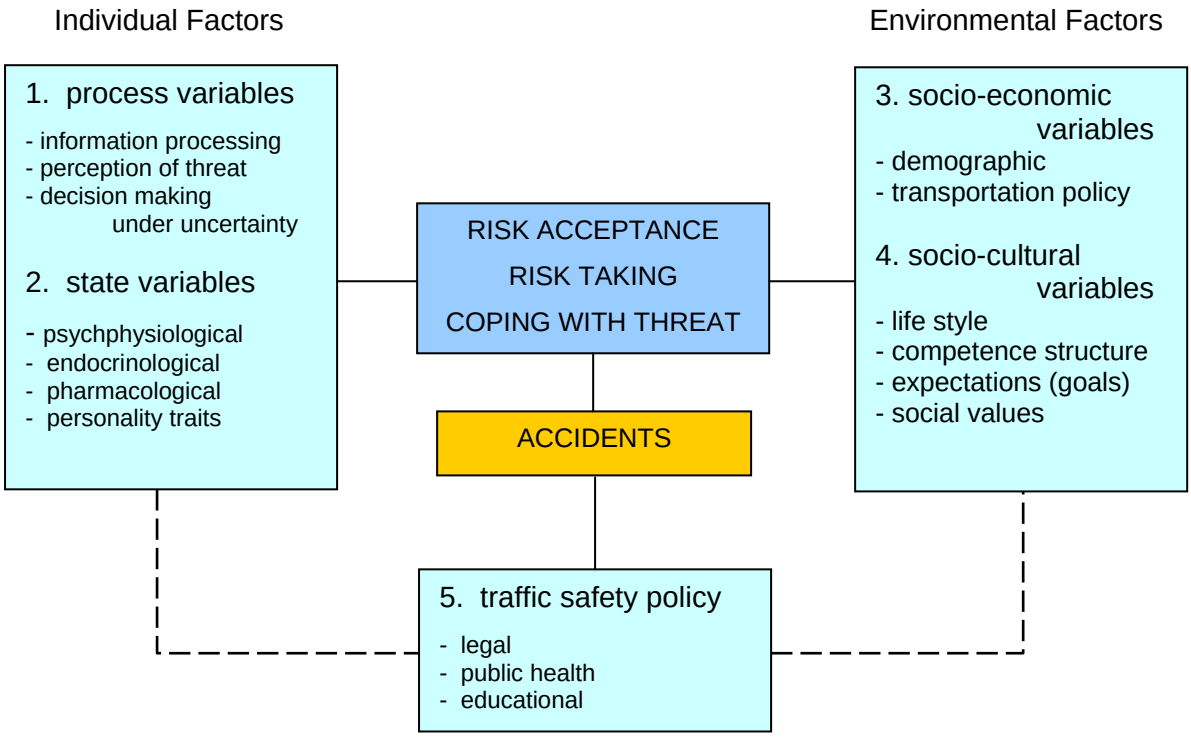

Figure 1 – Diagram showing the interrelation between various research approaches to the problem of risk and accident. Dotted lines indicate two-way, indirect influences.

Under each type of factor (1-5), categories are mentioned of the variables that have been studied and whose effects on the three levels of risky behaviour defined in the previous section are to be considered. Although the following discussion will be devoted mostly to the effects and interactions of the variables mentioned under 1 and 2, it should be emphasized that important interactions may exist between, for example, the state variables (2). and public health or educational policy factors (5). Thus, under the prevailing traffic regulations very frequently inappropriate actions are being rewarded while correct behaviour is in fact punished. Thus, car following at close range, a very common form of risky behaviour, pays because it enables rapid overtaking, while keeping the appropriate distance leads to cutting in by overtaking cars, forcing one to slow down to create distance again.

Research efforts in each of the areas displayed in the diagram are mostly restricted to one or two disciplines. Thus, the state variables have been the almost exclusive domain of physicians, pharmacologists and psychophysiologists. Process variables have been studied mostly by behavioural scientists and engineers, socio-economic variables by geographers and economists, and the socio-cultural variables by sociologists and cultural anthropologists. There is clearly a need however, that was felt by all participants in the Gieten Workshop, to cross the boundaries between those disciplines.

3. RESEARCH THEMES AND UNANSWERED QUESTIONS

The following sections review briefly what research problems are currently under study, and what questions need to be answered. Although in each section only one particular line

of research is discussed, it should be emphasized that many interrelations exist *between* the topics of these sections; in actual fact we are dealing with a network rather than with a single chain of relations.

3.1. Process variables

3.1.1 Information processing

Over the last ten years considerable progress has been made in the analysis of human information processing. Although a great many models have been proposed, they all appear to share a number of basic characteristics. Two basic processing modes have come to be distinguished in particular:

- The *controlled* mode which is under conscious attentional control, and therefore proceeds comparatively slowly, step by step, while requiring mental effort.
- The *automatic* mode, in which processing is based on innate or acquired "programs" or "habits" enabling the organism to deal flexibly with a wide range of known circumstances. Automatic processing proceeds very fast ("immediate") in a parallel fashion and apparently requires no mental effort. On the other hand the way in which these automatic "programs" operate is not accessible to conscious scrutiny, but belongs to what has been called "implicit knowledge".

The dynamics of information processing in these two modes during task performance are determined by the degree of skill at that task. Except for innate perceptual, cognitive, and motor abilities that spontaneously become automatic during the development of the organism, all skills are learned.

During learning, performance becomes more and more automated (and at the same time more and more inaccessible to introspection). On the other hand, when during the performance of an automated skill a discrepancy between the intended and the actual outcome of the activity is observed, controlled processing will abruptly take over and the person will begin a search for more effective ways of facing the situation. It should be clear that this transition from automatic, quick and skilled performance to slow, cognitive, and effort requiring processing can have disastrous consequences in dangerous circumstances: coping with threat requires skills that are not normally taught to road users.

3.1.2 Decision making under uncertainty

The general problem of decision making as a problem of information processing has been studied in a number of rather basic probabilistic tasks, mainly gambling situations. In these tasks both risk acceptance and risk taking have b*een* studied (depending on whether or not a hazardous increasing activity was requested of the operator). Mostly the tasks were chosen in such a way that the risks involved could be quantified objectively. The outcomes of such uncertain tasks were never really dangerous, although frequently the consequences did involve punishment such as losing money or having to perform an unpleasant activity for a given period of time.

It has been demonstrated that subjects in such circumstances do not estimate: risk according to the optimal decision rules of statistical decision theory, if only for the simple reason that human information processing capacity is not large enough to take all relevant factors into account. Considerable insight has been gained recently in the strategies and heuristic rules of thumb that *people use* to estimate risks.

Most of this information has been obtained under strict experimentally controlled conditions. This certainly puts a heavy restriction on the generalization of the experimental results. On the other hand, introspective accounts of subjects obtained in more real-life circumstances have been shown to be highly unreliable. Frequently subjects are not able at all to report on their grounds for a particular choice. And if they are, these introspective reports mostly suffer from over-rationalization. Among the common unjustified beliefs expressed in this way are the gambler's fallacy (it won't happen to me here and now, because I already had an accident last month) and over-confidence in one's own competence and experience. One reason for the relative rarity of the ability to provide conscious reports on risk estimation is that the production of such conscious estimates will require a considerable amount of effort, at the expense of other parts of the task to be performed.

3.1.3 Conclusion and needs

The nature of the risks involved in road traffic and the low probabilities of manifest threats make it far from certain that the available research findings do at all apply to the situations of risk acceptance and risk taking by road users. Furthermore, it is still far from clear what in fact are the perceptual cues that are used for risk estimation. Similarly there is no theory that accounts for what cues do in fact constitute a "threat". Certainly these cues are not just simple characteristics of the situation.

Some evidence supports the idea that, in risk taking and risk acceptance, individuals may think of some plausible 'scenario' for completing their trip according to a particular plan or *strategy*. (This conforms to the concept of the strategic level of traffic behaviour discussed in Sec. 2.1.). The estimated risk is a weighed outcome of the dangers recognized during the construction of such a scenario. In view of the rather incomplete picture of *risk* that is now available, especially in the light of read user behaviour, attempts should be made, not only at translating the theoretical concepts of the theory of human decision making into (traffic) safety related terms, but also at providing an adequate research paradigm in which risk may be studied under conditions that are sufficiently realistic to induce the appropriate levels of threat and arousal.

3.2 State Variables

3.2.1 Arousal

The physiological concomitants of behaviour under acute threat have been studied quite extensively in both animals and man. Coping with threat has the following, very general characteristics:

- interruption of activity in progress;
- increase in arousal; and
- lessened attention for environmental changes that are not perceived as a constituent part of the threat (attention for those stimulus conditions that are seen as belonging to the threatening situation will increase).

The characteristic increase in arousal will normally have an emotional 'colour' that depends on the nature of the situation. If there is an interruption of an activity that the organism considers as appropriate under the given circumstances the resulting affective connotation of increased arousal will be negative even if the cause of the interruption is not an acute threat; conceivably this mechanism accounts for much of the aggressive behaviour on the road especially in combination with sleep deprivation. The effects of a state of high arousal may

be quite dramatic. It can have both immediate and long term consequences for the organism.

A considerable body of knowledge exists regarding these effects in a large number of situations. First, pharmaco-endocrinological studies have shown considerable influence on the plasma and urine levels of a number of hormones and other psycho-active substances. In the second place, attention has been given to the quite marked differences in the way individuals react to stress and threat, differences that can not be attributed merely to differences in "personality" or to "irrational" factors, but that can partly be traced back to differences in the endocrinological and neurophysiological response patterns. Furthermore, these arousal-related processes interact fundamentally with biological rhythms. The basic 24 hour, circadian, rhythm in particular, deeply affects the secretion, the metabolism and the behavioural consequences of such substances as cortisol, testosterone, adrenalin, the hormones of the hypothalamic-pituitary complex. The menstrual cycle also is known to exert a powerful influence on behaviour; including driving. Biological rhythms also affect the activity of drugs. In Sec. 3.2.2 to 3.2.5. some of these interactions will be discussed.

3.2.2 Pharmacological and endocrinological effects

The research on state variables has made considerable progress with respect to the study as to how certain bio-medical variables affect task variables. Thus there are studies of the interaction between psycho-active drugs, (such as tranquillizers, sedatives and certain psychotomimetics), physiological states, and personal dispositions and traits, including such factors as age and sex. In as far as these influences have been studied in relation to traffic accident causation, insufficient distinction has been made between the various aspects of risky circumstances: risk acceptance, risk taking and threat coping. Such a distinction appears relevant, however, in the light of studies of the effects of certain commonly prescribed substances, such as barbiturates. It has been shown that such drugs have independent effects on coping behaviour and risk estimation (or at least, expectancy of future events): Performance under threat will remain unaffected while,. on the other hand, these drugs will make the person more careless about the future consequences of his behaviour. In other words: risk acceptance and risk taking may be affected, while threat coping is not.

Other pharmaca may have rather different effects; amphetamines, for instance, tend to induce less efficient performance while noticeably postponing subjective feelings of fatigue and depression, at least in tasks where the subject can set his own rate of performance.

In recent years a new and much clearer light has been thrown on the role of hormones. While the predominant view used to be that hormone level should be considered as mere response variables, it has now become clear that they play a crucial role in cognitive information processing under stress. One succinct summary states that "One can expect that alterations in the level of these hormones affect ongoing behaviour. Acquisition and extinction of conditioned behaviour indicate a behavioural adaptation to environmental changes. The influence of pituitary neuropeptides and glucocorticosteroids on acquisition and extinction of conditioned behaviour should therefore be considered in an adaptive framework. ACTH and related neuropeptides playa role in motivational, learning and memory processes, while corticosteroids facilitate discrimination and thereby the elimination of non-relevant responses."[2]

These recent findings are currently the subject of intensive theoretical discussions and of sophisticated attempts to develop models that may account for the observed relations between behaviour, arousal and the endocrine system.

[2] D. de Wied, (1977). Pituitary adrenal system hormones and behaviour. *Acta Endocrinologica*, Supplementum 214, pp. 9-18.

Conclusions and requirements. The conclusion drawn from the available evidence is that there is a large number of findings of a rather limited scope that nevertheless would seem to fit a common framework (in terms of the models to be discussed in the Sec. 3.3.). The existing knowledge is still too fragmentary however, and should be supplemented by means of standardized screening routines for hormone levels and for existing and newly developed pharmaca. Such screening procedures should include physiological, a pharmacological and behavioural criteria. The need for a common theoretical framework for such routines is quite evident. The large number of poorly structured research findings already available in this research area bears out the necessity for closer cooperation between the life scientists and the behavioural scientists. The techniques of quantitative analysis and multivariate data-processing required for such screening procedures have reached a high level of sophistication in some specialized institutes and this knowledge, as well as the actual analysis procedures should be made available on a much wider scale to other investigators in the field.

3.2.3 Individual differences

A number of years ago the alleged relation between accident involvement and personality, embodied in the so called "accident prone" driver, came under severe methodological attack. As a result the concept of accident proneness as a stable personality characteristic was generally abandoned. Research has shown instead that accident proneness should be considered as a temporary state, resulting from such variable conditions as age and level of experience on the one hand., and conditions such as illness, difficulties in social relations, or unemployment on the others. In the light of a considerable body of recent findings, however, it seems that the case may have to be reopened: important individual differences have been established in the psychophysiological and endocrinological response patterns to stress.

Response patterns depend on age as well as on sex. Also, people scoring high on neuroticism tests will respond differently, depending on whether they are extraverts or introverts. The neurotic introvert is found to be highly sensitive to threats of damage and to the cost of failure. The neurotic extravert on the other hand is sensitive to promised benefits and will pay little attention to expected damage. This latter pattern resembles that of people under the influence of alcohol or fatigue. Extraverts require external stimulation to raise their arousal level and, consequently are highly susceptible to underarousal and drowsiness in situations where such external stimulation is absent.

Extraverts may, for the same reason, also suffer relatively more than introverts from the very common state of underarousal that is initiated by the increase in parasympathic activity following a heavy meal.

Conclusions and requirements. In summary it should be emphasized that there are considerable differences between individuals in the pattern of basic physiological responses. These differences appear to be so large that they are very likely to influence the behaviours related to accident causation in an important way. Consequently there is a need to reconsider the case for "accident proneness". The available evidence requires, however, a much more subtle analysis than has been undertaken in the past and, if anything, should reveal a differentiated picture of certain individuals incurring certain threats (but not others), at a certain time (but not at another).

Bio-medical research—endocrinological and psychophysiological—has already done much to unravel a considerable number of effective factors influencing behaviour in hazardous conditions and under threat. The precise effects of these factors, and especially their combined effects need to be investigated in much greater detail. At present they are most likely to appear as the "irrational" aspects of behaviour and, unfortunately, to be treated

as such. At the same time clear recognition should be given to the fact that cognitive factors may obscure the direct influences of physiological states on behaviour as in the overestimation of one's own skill by the inexperienced driver to whom we turn next.

3.2.4 Experience

Lack of experience is an important factor in accident causation. There has been considerable research activity in the area of perception and cognition in experienced and inexperienced drivers. Very little is known however about the differences in threat coping behaviour. It is evident that what constitutes a danger for the beginner, not necessarily does so for the expert driver, while on the other hand the novice driver may remain unaware of threats that are easily recognized by the experienced driver. The available escape repertoire of the latter has become largely automatic: the situation itself immediately suggests the possibilities for recovery. And since the experienced driver's information processing is largely at the automatic level we should expect relatively little increase in his general arousal level.

This may offer an explanatory framework for the characteristic differences in coping behaviour by expert and novice drivers. Given a particular traffic situation the novice's general arousal level is likely to be high. High arousal is likely to induce anxiety and aggression as motivational states. The appropriate coping behaviour in this case is to search for "outlets", which may take the form of strenuous, controlled attempts at mastery. The task load may easily exceed the available capacity in these attempts thus creating an increased accident probability.

The experienced driver on the other hand will have a low arousal level, and consequently is more prone to suffer from boredom and drowsiness. Coping with these afflictions may show in searching for thrills. Behaviourally this may work out in fast or careless driving, or more generally: inattention and driving close to the minimally required safety margins. Again, this will lead to an increased accident probability.

In this case too there may be a differential influence of more permanent organismic or personality dispositions. Sensation seeking as a means of dealing with underarousal is likely to occur more frequently in extraverts who depend on external impulses, than in introverts who can raise their arousal level by internally generated stimuli.

It is clear that the relations sketched in the foregoing discussion should be substantiated before they can truly serve as an explanatory framework. One of the complicating factors is that it is not only objective experience, but certainly also subjective experience that will determine the levels of risk acceptance and risk taking. Overestimation of one's own level of experience is common in young drivers and after alcohol intoxication.

Conclusions and requirements. The research and ideas discussed in this section call for an intensive follow-up of individual differences in physiological and behavioural responses to external inputs as well as internal (partly time dependent) organismic and psychological dispositions. Such an undertaking would require multivariate research and data analysis which can only be successful if carried out at a sufficiently large scale. Such an effort requires the establishment of generally available standardized screening procedures both physiologically, pharmacologically and behaviourally. It also requires the establishment of a standardized data bank that is available to researchers, for multivariate statistical analyses.

Such a cooperative attempt at standardization should be guided by the combined efforts of representatives of the various disciplines, to integrate their specific points of view as much as possible in a common descriptive and explanatory frame of reference.

3.2.5 Temporal factors

The effects of biological rhythms on behaviour have come under close scrutiny in recent

years, and the endocrinological features of the sleep-wakefulness pattern are being studied intensively. It is to be expected that in the task performed by road users such factors also play an important role.

Reaction time, detection of signals (threats), and the quality of coping behaviour are affected by the time of day. It can make a large difference whether a drug is taken in the morning of in the afternoon. Furthermore physiological and the behavioural variables (e.g. the levels of testosterone and ACTH) have been found to be marked influenced by the time-on-job as well as by the pattern of the work-rest cycle. Moreover, the structure of the task may be such that stressful activities are concentrated in a particular period of the work cycle, say at the beginning or towards the end. Thus, some drivers may have the afternoon rush-hour towards the end of 8 hours of driving, whereas others may have it early in their work shift. In this framework the reverse effect of expectations on these time dependent factors should be considered also. For example, studies in which people were expecting a six hour drive that was then suddenly extended with another 4 hours the subjects have shown that subjects experience considerable difficulty in reallocating their energetic and motivational "resources". It seems plausible that the overall state of the organism is controlled on the basis of the experience with the 'normal' requirements of the task as well as with (implicit) knowledge about the habitual circadian activity cycle. Here again, people supposedly produce a 'scenario' of the time course of their activities and then find some division of 'energy' according to sane habitual optimality (or satisfaction) criterion. A mismatch between the actual and the expected courses of events will then cause a considerably imbalance (plus an increase in arousal) before a new equilibrium can be established by reallocation of resources.

On a scale that is relatively minor, although not necessarily inconsequential, such effect may readily be observed when the road user is delayed due to, for instance, a congestion. This creates what is known as time stress, a condition that tends to be cumulative, and about which much more should be known.

Conclusions and requirements. Particular attention is required to the integration of available knowledge about the temporal relations between the state variables and S-R variables in hazardous behaviour. Moreover, it is most important that new research in this area be stimulated. The following topics should be distinguished:

- Recovery functions. It appears necessary to study the recovery course of various processes after imbalance in their regular state has occurred. This pertains especially to the following:
  - Long term physiological states (e.g. disturbances of cyclical processes). Thus, for example, further insight should be obtained in the effects of fatigue and sleep deprivation: how and to what extent is a loss of sleep accumulated over several days compensated;
  - Short-term physiological states. How do people recover from coping with threat, both in the physiological sense of regaining their normal level of arousal, and in the sense of behavioural variables.
- Effects of time of day and biological rhythms. The many recent insights in the rhythmic variations of the physiological processes in the body, and the influences these variations have on human performance should be integrated in the area of (traffic) accident research. It is clear that bio-medical or physiological dispositions will work out differently in behaviour, depending on what time of the day or what day of the month it is. The phasing of the physiological and task cycles should receive more explicit attention. Also more should become known about the individual differences in the patterns of interaction between state variables and process variables

- Longitudinal studies. It may also be necessary to look more closely into possible effects on larger time scale. Longitudinal studies may reveal typical regularities in the patterns of physiological activity, medical conditions and in patterns of behaviour (in coping with traffic, or more generally with threatening conditions of any kind) that could serve as the data base for a typology of coping behaviour, or as a predictor of future performance.

3.3 Theoretical issues

It has already been pointed out that currently no general theoretical framework is available which might accommodate the available findings regarding physiological and psychological determinants of accident related behaviour. There are, however, several models with a much more limited scope that attempts to account for part of the problems. that have been discussed in this paper. These models can be roughly divided into two types that can be subsumed under the same headings as the research discussed in the previous section, namely, process models and state models.

3.3.1 Process models

This class of model tries to account for the behaviour of drivers in hazardous situations as a function of the likelihood of danger occurring. They start from the assumption that people somehow evaluate the situation they are in (or will be in) on the basis of information perceived or inferred. Three such models can be distinguished.

- *The "constant risk" model.* For a given trip a subject sets a criterion level for risk acceptance and risk taking that is acceptable to him, depending on trip goal, social norms and stress tolerance. If the situation is subjectively less demanding than is acceptable according to the preset criterion, equilibrium will be re-established by faster driving, less careful tracking, etc. If the situation brings the perceived risk level above the criterion, compensation will be found in slowing down, etc. (This model predicts that no safety improving countermeasure can have a lasting effect unless we succeed in changing the subject's criterion level.)
- *The "learning" model.* In this conception behaviour is shaped under stimulus control. The subject learns, by trial and error or cognitive mediation, to discriminate threats from safe stimuli and will develop avoidance behaviours towards threats. By conditioning it may be possible to develop avoidance responses to hazardous situations without the threats being manifest.
- *The "threshold" model.* In this type of model it is assumed that subjects have an internal representation of what constitutes a danger in general. Incoming information is' compared with this representation and the outcome of this comparison is tested against an acceptance criterion for threat. Depending on the outcome of this test a decision will be made to act, to refrain from action, or to wait for further information. Risk acceptance and risk taking behaviour can be modified by varying the comparison and criterion parameters as well as by varying the efficiency of the behaviour following the decision to act.

3.3.2 State models

State models account for risky behaviour and threat coping in terms of physiological and

other more or less permanent dispositional factors (e.g. personality). Two types of models will be distinguished here.

- *Homeostatic recovery model.* A perceived threat will lead to a change in the prevailing physiological state; this will determine the physiological response that may of may not be advantageous for successful coping. The physiological response in itself, however, will affect the subsequent state of the physiological system, and in this way a feedback cycle is established.
- *Compensatory model.* This state-related model is more task oriented: there may be a mismatch between the demands of the task and the available general (or specific) arousal. The discrepancy will activate coping mechanisms such as search for 'outlets' of an excess of arousal, or 'sensation seeking' in case of underarousal (see e.g. Sec. 3.2.4 on experience).

Conclusions and requirements. This listing of the models that are in current use as the frameworks for research findings in the areas under concern could be extended with several other examples. It will be sufficient as it is, however, for indicating the necessity of exchanging thoughts on these theoretical issues. There is a noticeable overlap between underlying theoretical concepts, although each of the models apparently addresses a different aspect of the problem area. Several theorists have recently indicated the need for a more integrated view of the energetic and information processing aspects of behaviour. A closer comparison of the implications of each model could easily lead to a more integrated view, and hence to more directed research questions. Serious attempts should be made to connect these theoretical views to the various task an risk aspects distinguished in Sec. 2.1.

3.4 Social, Cultural and Political Factors

Although not central to the problems discussed in the context of the Gieten Workshop, it must be emphasized that social and cultural factors too have a considerable influence on risk acceptance and risk taking, and very likely also on threat coping. Therefore, a good deal of attention to such factors should accompany the :study of the individual factors. This need can be illustrated in several ways.

First, for example, there is reliable evidence that social norms do indeed influence the level of risk acceptance and risk taking in a community. Accident levels have been found to correlate with the prevailing levels of violence and aggression, as well as with suicide statistics. Secondly, in the traffic system as it functions *in* our society, little benefit is obtained from adherence to a large number of rules: frequently compliance is even punished. (As was observed in Sec.2.2, the driver who keeps a safe distance to the vehicle in front of him is frequently overtaken, which forces him to lose even more space). Thirdly, the social influences that reach the individual through modelling after bad examples, (false) information in advertising, etc., are likely to create certain undesirable impressions the person has about his own capabilities and to offer the wrong type of reinforcement.

Such factors (or their elimination) determine the success of countermeasures. Even the strongest recommendations based on research findings will fail if their implementation does not take the broader social context into account.

Conclusions and requirements. The important questions that need close attention in this context are how we can provide people with

- effective strategies for estimating risks;
- effective strategies for coping with threat. This is a particularly relevant and urgent issue since conventional driver training has been almost exclusively directed towards avoidance training. consequently drivers have no experience in recovery manoeuvres, and as a result, when the danger becomes manifest high anxiety and panic are extremely likely to prevent correct evasion;
- effective insight into intrinsic limitations of the human organism in general as well as into their own particular weak spots as determined by their individual physiological and mental state. It is not enough to warn that "this drug may affect your driving skill" by pasting a sticker on the pill-box, since more explicit and detailed information could in fact be provided. People should be made aware of the tell-tale signs that may warn them of impending danger, both from outside and from inside. It has been shown that risk estimation is very poor in the average driver. High value should be put on a thorough consideration of what to teach and how to teach new members of the road user population.

Furthermore cross-national comparisons of behaviour in hazardous and dangerous situations should be made in standardized conditions. Thus a suitable data bank would be formed on situations and conditions that are likely to provoke accidents. In this way local conditions, that is, differences, in medical treatment, enforcement policies, and differences in training procedures could be found out and compared. At the national level this would require traffic accident reporting on human factors as well as on the legal aspects of an accident rather than on the latter aspects only.

Although it is less than clear, as yet, precisely how a useful data bank and standardization might be derived, the problems should at least be considered in detail and proposals drafted for actions to be undertaken. This would be of immediate importance to the question of how to implement the countermeasures that may derive

4. SUMMARY AND CONCLUSIONS

It has become clear that the problem tackled by the Workshop has wide ramifications, both for research and for traffic safety policy. It covers a major area of study in the ways the traffic participant deals with danger, and it ,has become clear that a considerable research effort is devoted by various institutes in the countries of the European Communities. This, in the author's opinion would call for a cooperative research effort. Firstly, the institutes, through their representatives participating in the Workshop have expressed their interest in exchanging ideas, methods and/or manpower.

In the second place it has become clear that the themes and approaches as that are known to be valid indicators of performance under stress, identified in the preceding sections are studied in a rather piecemeal way. There is evidently a need in this area for integrating research efforts, as well as for a more comprehensive theoretical framework.

There are two major topics emerging from the review presented in this report. The first is that of definition of risk, both objective and subjective, and its perception and evaluation in relation to road traffic. The second is the study of the psychophysiological processes underlying the way people cope with various kind? of risk and of the factors that influence their coping behaviour. While the first topic is predominantly the territory of behavioural scientists and systems analysts, the second topic is covered more or less evenly the life sciences (medicine, pharmacology and physiology) and the behavioural sciences

(psychologists and psychophysiologists).

In view of the objectives of MRC's activities thus far, and also in view of the goal set for the present Workshop, it seems that a proposal for concerted action in this area should concentrate on the latter problems area. Such an approach would call for the following points of action:

- The specification of a number of standardized task situations, both in the laboratory and in the real-life context, in which certain types of risk can be varied in a controlled way. These situations need not necessarily cover all conceivable types of road traffic risks since the threat coping processes to be studied presumably share a sufficient number of characteristics. Great care should be exercised to choose task situations that are sufficiently realistic.
- The specification of a number of standardized methods of investigation. This includes endocrinological and pharmacological assessment routines, as well as psychophysiological and psychological measurement techniques.
- Exchange of ideas about data-analysis techniques, and an exchange of equipment, especially high cost items such as experimental cars and simulators.

Together these will provide the background and base-line for the research programs currently under way in the various institutes. With respect to the content of the research programs it has become clear that the present investigations may provide a sound basis for the design and implementation of (traffic) safety countermeasures in the areas of public health, law, education and engineering. International coordination would certainly improve this potential. Even so there seem to be at least two major areas where such a cooperative effort is likely to offer particular advantages:

- The study of the patterns of interaction between task related factors (process variables) and individual physiologically determined response patterns (state variables).
- The study of temporal dependencies, including the effects of the 90 minute, 24-hour, and monthly biological rhythms, the work-rest cycle, and the temporal structure of the task. It may be at least as important to know *when* a danger will become manifest as it is to know where this will happen.

4.1 Description of a concerted action

A concerted action might aim at increasing the insight in accident causation and accident avoidance by studying the coping behaviour of the individual under hazardous conditions, specifically in the road traffic situation. For this purpose it would bring together and promote the cooperation of those institutes in the countries of the European Communities and other European countries that are already working in this problem area.

It would facilitate and optimalize the use of the available research facilities, which are to a large extent very costly and consequently unevenly distributed across the research groups. This pertains particularly to experimental proving grounds (tracks) for field studies, instrumented vehicles, screening procedures for biomedical measures (high precision blood and urine analysis), and complex data analysis facilities (multivariate statistical analysis).

It would do this by organizing regular workshops for discussing the progress of the concerted action , by exchange visits to enable the use of the facilities mentioned before and by promoting joint experiments in which the available knowledge and technology can be used in

the most effective way. The latter is desirable for ethical reasons (minimal risks to subjects) as well as for economic reasons (experimentation under (fairly) realistic conditions is extremely costly and frequently prohibitive if it is to be paid for by one institute).

Also the integration of experiments would promote the development of an comprehensive view of coping behaviour in its various aspects. The concerted action would make the information gained from research more generally available, in order to allow the derivation of practical countermeasures in the areas of public health, driving training, enforcement policy, as well as vehicle and road engineering (ergonomics). Although research in these areas would not be subsumed directly under the concerted action , it is felt that practical results for these areas will be obtained. Although the concerted action would predominantly deal with the coping situation in various traffic conditions and specifically aim at practical results with respect to road traffic accidents, its results would have relevance for other types of accidents as well. Moreover these results would be highly relevant for those medical conditions that are particularly. vulnerable to stress (especially cardiological and certain neurological disorders).

4.2 Content

The content of a concerted action as grouped around the concept of coping behaviour would be centred on three main themes:

- *The coping process:* Attempts should be made at obtaining a comprehensive model of the somatic and psychological relation involved. Studies are carried out which deal with certain factors that influence the pattern of coping. Here again factors such as time of day, time on job, fatigue, stress due to road conditions or commitments at the destination, etc. are relevant and they are currently being studied in several places.
- *Predisposing factors:* The factors that lead up to a particular coping pattern under high arousal. It incorporates studies of the organismic dispositions, personality factors and cognitive task related factors. (Among the organismic factors are permanent factors such as endocrinological ‘typology’, cardiovascular state (hypertension etc.) diurnal rhythm influences, and temporary dispositions, such as fatigue, or time on job. Personality factors have been found. to be highly specific as to their psychophysiological response, and as such are known to affect coping patterns. Cognitive and task related factors will influence both the arousal state and the appropriateness of the reaction pattern; they determine the state of preparedness as well as the quality of coping.
- *Recovery:* If coping has been successful the physiological pattern will gradually return to normal. However, the short range effects may in themselves affect immediately subsequent behaviour which may increase the risks inherent in the performance. Long range effects will tend to build up and may in fact lead to permanent or progressive detrimental effects.

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