COMMISSION OF THE EUROPEAN COMMUNITIES

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Contributions to workshops on physiological, psychological and sociological aspects of the problem

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The Scientific and Technical Research Committee (CREST) and
the Committee on Medical Research and Public Health (CRM),

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EDITORIAL NOTE

The papers contained in this publication originated in three workshops which are described in the preface.

All manuscripts received in time for publication have been reproduced here exactly as provided by the authors. In a few cases of manuscripts which were not originally in English (Hamelin, Lecret, Leplat and Lille), publication deadlines precluded extensive communication with the authors: minor editorial changes made in an attempt to clarify the translations have been reported by telephone to the authors and approved. The papers are not included in the order of presentation at the three workshops.

All material, information and conclusions are the responsibility of specific authors and not the Commission of the European Communities or the sponsoring organizations.

The programme of the workshops and summary reports by the organizers are included as supplements. Readers are requested to contact specific authors for further details of individual papers.

PREFACE

This publication contains contributions to three workshops held in 1975 and 1976 under the auspices of the Commission of European Communitie's Directorate General for Research, Science and Education, following a recommendation of the ad-hoc Working Group on Toxic and Psychological Factors in Road Traffic Accidents of the Committee of Medical and Public Health Research.

The subjects were:

.- Conditions relating to fatigue and accidents of heavy goods vehicle drivers; Crowthorne, United Kingdom (March 24/25th 1975),

.- Psychobiological factors in the breakdown of driving skills; Dublin, Ireland (January 14/15th 1976), and

.- Influence of drivers fatigue on road traffic accidents; Dourdan, France (September 30th/October 1st 1976).

The workshops aimed to assess the current situation and knowledge of particular facets of the subject, to review the research methods used in the various laboratories of the European Community, to determine the need and desire for inter-european collaboration and to allow scientists to exchange freely results and views on their research topics. The field purposely left broad, some overlapping was to be expected considering the wide variety of human factors which are potential determinants of road traffic accidents.

The European Commission wishes to thank all contributors and in particular the persons responsible for the organisation and conduct of the workshops, notably Ms Francoise Lecret of the Organisme National de la Sécurité Routière, Monthlery, France, Dr J. Bull of the Medical Research Council Unit at the Birmingham Accident Hospital in the United Kingdom, and Dr J. Cullen of the Department of Psychiatry, University College in Dublin, Ireland.

CONTENTS

FOREWORD

G. Henneberg
Chairman ad-hoc Working Group on
Toxic and Psychological Factors in
Road Traffic Accidents

The urgency of resolving the problem of traffic safety in the countries of the European Community and in particular its public health aspect led the Commission of European Communities through its Directorate-General for Research, Science and Education to devote its attention to the scientific treatment of this subject. An ad-hoc Working Group was formed through the Committee of Medical Research and Public Health with the mandate to analyze the psychological and toxic factors in road traffic accidents and to elaborate if possible recommendations to reduce them.

Man is one of the principal causes of traffic accidents, but as a road user he also assumes all the risks. Yet, it is surprising to note how many still consider road accidents as imposed by Fate !

In Europe, traffic accidents are the third major cause of death, the others being, in order, cardio-vascular diseases and cancer. Every year more than 50,000 persons are killed and over 1.5 million are injured only in the 9 member countries of the Community. In terms of life expectancy, road traffic accidents are even more serious than cardio-vascular diseases or cancer since they are the principal cause of death for males aged 15-24 years.

Besides the fact that traffic accident victims occupy up to 10% of beds in some hospitals and that a major proportion of fully incapacitated persons are road accident victims, there exist an unquantified psychological damage to the rest of the population and an actual suffering which cannot be measured. In various countries estimates have been made of the material damages, the economic losses and the health expenditures caused by traffic accidents to the community at large, and these were reported to be over one percent of the gross national income.

Road traffic accidents are therefore a modern disease which should be considered as such and studies made for its prevention, cure and rehabilitation. So far, most attention has been given to technical and engineering aspects of this complex problem. In the medical field, only pharmacological and toxic problems have been approached systematically. The Working Group set up by the Commission of European Communities had as a task to fill this gap through the combined work of specialists in a number of disciplines scattered in laboratories of the European Community and elsewhere. The group of experts appointed by national authorities of the 9 member countries met and discussed ways and means of carrying out its mandate. It suggested the organisation of workshops where bench-scientists actively engaged in research in the various fields contributing to the elucidation of human factors involved in driving accidents could meet and discuss freely their work, results, conclusions, opinions and views. The main line of thought being the human factors, psychological and physiological, sociological and behavioural which influence the driving ability or the safe behaviour of road users, through a decrease or block in mental decision and subsequent physical reaction.

Three workshops were held, some participants were called upon more than once to contribute their experience and results, yet not all persons interested could be invited to attend. Moreover it appeared that most of the participants either had only known of each other through the literature or in fact were unaware that such studies had been or were carried out. Speakers were informed then that no record was made of their contributions or comments, but, following the availability of the reports of the organisers and discussions with some participants, it appeared that a publication containing the gist of the contributions made would be of value to other scientists studying the influence of human factors on road traffic safety. Participants to the workshops were therefore invited to submit in 1978, a shortened version of their contributions. Their immediate acceptance and interest makes the decision to publish these Proceedings, even with such delay, more convincing. It is hoped that further direct exchanges between readers and the establishment of fruitful collaboration will follow.

SYSTEM APPROACH FOR TRAFFIC SAFETY AND FUNDAMENTAL CONSIDERATIONS AS TO PSYCHO-SOCIAL FACTORS IN TRAFFIC SAFETY

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ABSTRACT

The need for a more holistic, multifactorial and multidisciplinary approach is stressed, implying an epidemiological and a so-called system approach, broadening and deepening at the same time the accident research into behaviour-research. Traffic with its various components is as well understood as a system as is the human organism in itself. As well within each component as between them there exist manifold dynamic interrelations implying tensions and conflicts which in the end lead to dangers and accidents. As to psycho-social factors a differentiation is made between the general mental capability and the "personality" in the narrower sense. This concept of personality must not be understood as a rigidly stable structure, but is to be seen complemented by time-dependent and transitory factors, which are of great importance for traffic behaviour.

As complex phenomena, to be mastered, require complex measures, a range of different influences on human behaviour should be used comprising f.e. among others educational and ecological factors. The view of a system approach with appropriate pinpointed and balanced measures imply the consideration of comprehensive biological and social-cultural tendencies as well as of specific possibilities of certain service systems within (national) value systems and - last not least - cross-national connections.

SYSTEM APPROACH FOR TRAFFIC SAFETY

Traffic accidents leading to high numbers of killed persons and permanent incapacities in our modern world, have become an epidemiological or even a pandemiological problem.

At the same time - because of increasing bureaucratic administration and intense specialisation man as psycho-physical unit in a social environment has more and more been lost out of sight. This explains the call for a holistic approach in which the different components of human life (physiological state, psychological attitudes, social situation, cultural background, environmental factors a.s.o.) and their interactions are taken into consideration. Simple facts and statistics are increasingly complemented by examining the dynamics of so-called systems, understanding as system a complex set of elements that are actively interrelated and that operate in some sense as a bounded unit, so that changes of one component may result in changes of many other components. These dynamic interrelations, the whole interdependences of system components are without doubt more important than isolated phenomena. For even great masses of data made available by advances of computer technology are only of limited use as long as they are insufficiently linked. To stress it the way Kant did: Facts without comprehensive insight are blind; only insight without facts is unsubstantiated, empty.

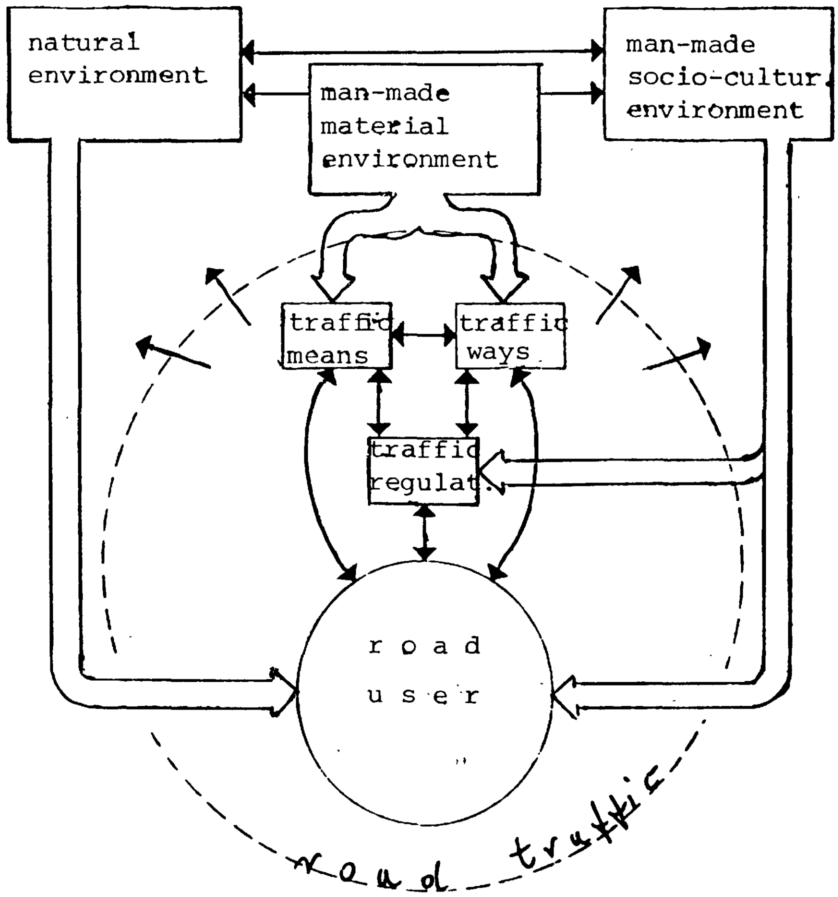
So there is a rising need for system orientation as intellectual attitude towards phenomena and problems, for a situation-, context-, problem-, task-oriented approach, which implies necessarily an interdisciplinary cooperation.

Traffic is to be seen as such a system, too, consisting more or less of the components road-user, traffic-means, traffic-ways and traffic-regulations (fig. 1).

As well within each one of the components as between them there are manifold interrelations. It's important to realize that man as psycho-physical organism, as a unique, relatively stable dynamic system himself, is without doubt the central, but at the same time the most sensitive component in this system, not only by using, but also by planning and executing traffic. Road traffic is on the other hand a subsystem within the whole life of society. Its environment may be understood as a kind of super-system comprehending

- natural (a.o. biological, geographical, climatological, meteorological),
- man-made material (general technical and communicational possibilities) and
- man-made socio-cultural (economical, social, cultural, normative)

influences, the latters showing themselves in typical life-styles and general behaviour patterns as well as in typical styles of driving, typical traffic behaviour, typical driving fig. 1: The traffic sub-system in a society



faults and typical accidents.

Between these spheres there exist again various interrelations, complemented by complicated interrelations between the societal super-system and the traffic-system.

As to the causation of traffic accidents it must be realized that it is hardly ever possible to reduce the taking place of a traffic accident to one single factor. An accident results rather at the intersection of several causal chains. Therefore it is essential to proceed from a multifactorial and multidisciplinary approach, broadening and deepening at the same time the accident-research into a behaviour-research. We have to ask ourselves <u>why</u> young beginners as motorists have particular peaks in certain accident-"types", for example by getting off the road. If we find that speed plays a role in the causation of these accidents we must ask ourselves why they are inclined to choose an inadequate speed.

Endeavours in traffic safety must therefore imply a concrete behaviour research in combination with an epidemiological and a system approach.

In the frame of the mentioned very complex interrelationships there always exists the possibility of tensions and conflicts , the latters manifesting themselves mainly as inconsistent, opposing, sometimes antagonistic and incompatible behaviour-tendencies within the decision system of the road user, which implies dangers and accidents: driving in a hurry on an icy road, wanting to save money and to own a good car, discrepancies between situational requirements and physiological limits of man, between theoretical knowledge and practical behaviour-tendencies, between the needs for following established regulations and a self-assertion, between so-called objective and subjective safety (Klebelsberg), between contrasting aspects of propaganda, between auto- and heteroregulation.

The decision-process appears more or less as a mental behaviour in a so-called risk-situation, as a resultant of the expected gain on the one hand and of the subjectively estimated probability and weight of a disadvantage in the context of the actual system-conditions on the other hand (fig. 2).

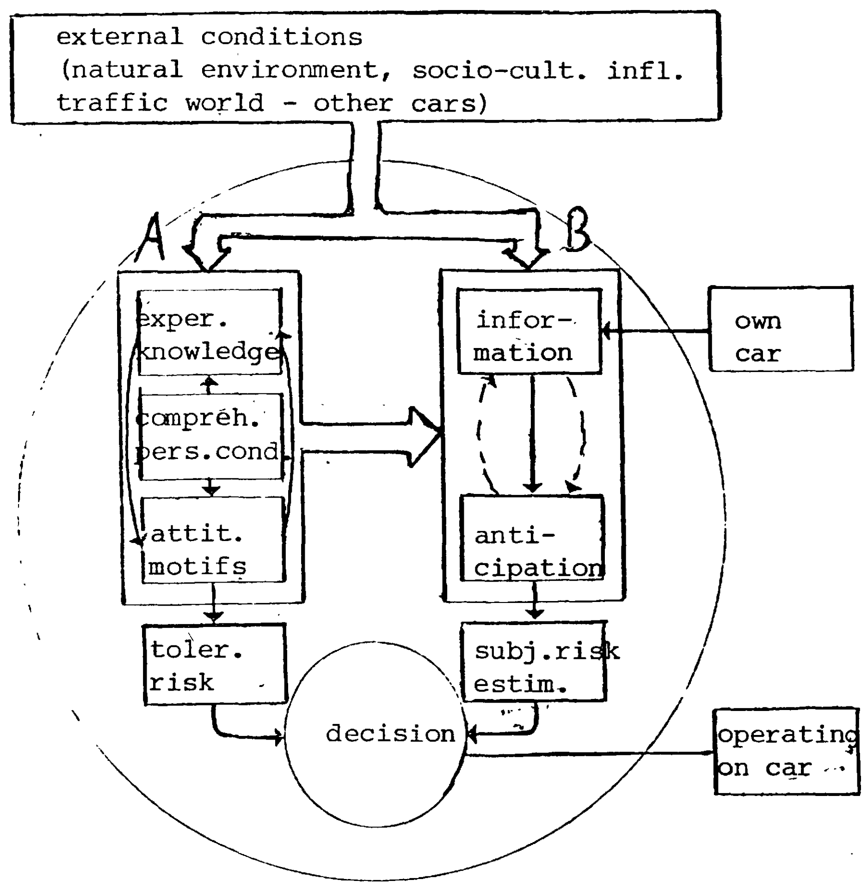
The behaviour of a road user is influenced by personal conditions , which depend on their part again on general environmental conditions (experience, state of apperception attention, motives, attitudes, or more general: age, sex, health). These conditions determine the level of a so-called tolerated risk.

At the same time the road user collects when driving information from the environment about the concrete situation, and comes to certain predictions or anticipations, he makes a (subjective) estimation of a given risk.

These two chains of decision lead to a certain action on the car which works - in a feedback-loop-as a part of information for following decisions.

The higher the subjective risk appears and the lower the

fig. 2

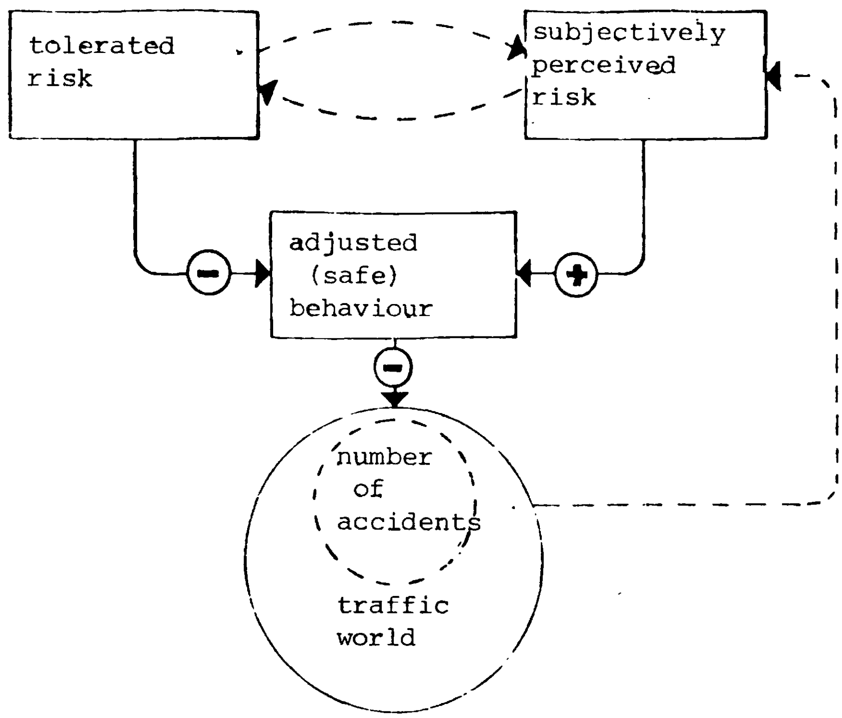


risk is, the road user is generally inclined to fall in with, the more he will behave adjusted and cautious (Wilde, fig. 3).

The knowledge about the differences between aspects of objective and subjective safety with different phases following each other (dominance of subjective insecurity, dominance of subjective (over)-security, correction of subjective over-security, dominance of objective safety; Klebelsberg) as well as the insight in the necessity of situational sensibility and actional flexibility are in this connection highly important.

FUNDAMENTAL CONSIDERATIONS AS TO PSYCHO-SOCIAL FACTORS IN TRAFFIC SAFETY

From the more psychological sight there is on the one hand often made a difference between a general mental capability (efficiency) of a driver and his "personality" in a narrower sense. As to fig. 3: Risk compensation hypothesis (modified after Wilde)



the general mental capability there is - in the sense of information-theory - often made a secondary differentiation of a sensorial and motorial range and the processing as a central integration and regulation of human experience and behaviour. In this respect there are various factors to be taken into consideration: the somatic intactness of relevant organs and their normal functioning, the point of view of responsiveness or susceptibility, the factors of speed, quality and stress-capacity, all these factors being of importance for sensorial and motorial processes as well as for the cerebral processing and - at the same time-dependent on manifold environmental factors. As far as we know at present the influence of intelligence (not so much in the sense of classical education but more in the sense of a general mental functioning as showing up in a good distribution of attention, in a certain mental spontaneity, activity and flexibility, in a differentiated insight, the capability of anticipation, the perseverance of vigilance a.s.o.) on good achievement in traffic is relatively little in the range of the average and high intelligence, but from a certain point of decreased intelligence there is more and more found a negative influence on driving records.

The "personality"as individual particularity, as a relatively stable value-oriented functional system of connections, a dynamic process with proceeding integration, centration and stabilisation, is again a sub-system influenced by extremely manifold conditions and connections, especially by the so-called socio - cultural environment: The mentality of achievement and success as an immanent strive for forcing one's own views may correspond to similar behaviour tendencies in traffic as well as those who fail in this world of success are obviously often striving for a kind of compensation in traffic. It is evident, that especially those drivers admit to be often or even very often angry about others who have in themselves more conflicts. So we have the paradoxical result that whoever looks for compensation for all what happens to him, what he misses in life, finds this compensation least; on the contrary they usually add new troubles to their old ones.

As far as we know at present we cannot speak of a specific accident-prone personality. There is no speical structure for faulty or delinquent behaviour, but again and again we find the extreme poles of personality dimensions being responsible for a certain kind of accident proneness. The more a personality trait finds itself at the pole of any dimension whatsoever, the higher is the probability for a person of endangering oneself and others, whereas a balanced structure of personality without extreme dominance of one trait or substructure is to be seen as a favourable precondition of a positive driver record.

Together with situational effects the following qualities play a role in the compensation-process of (physical) handicaps: an active positive contact to environment and a fundamental social attitude, a mental balance and a certain composure and behaviour control, a willingness to take efforts, selfcritisism and openmindedness towards reality, a personal reliability and responsibility with tendency to rational decisions in risk-taking situations.

There are a number of psychological, sociological, biographical indicators that may shift the predictive basic probability for a future behaviour in a positive or negative direction. As positive indicators are f. e. found: professional stability, harmonious familiy-life, subjective job-satisfaction, good relations to parents, positive attitude towards school, little influencibility or suggestibility. As negative indicators have shown up: peculiar, excentric, conspicuous events in childhood, correctional education, demands to welfare authorities, difficult economic conditions, unharmonious family-life, bad cooperation with collegues, frequent change of jobs and places of residence, tensions and troubles with superiors, little participation in any public groups, not having finished school, little care for health state, extremistic opinions, little endeavour for refresher-courses a.s.o.

Beyond this personality system in the narrower sense there exist often very important time dependent (youth, older age) and temporary, transitory factors, that influence behaviour in general and traffic behaviour in particular (fatigue, mood). It appears evident, that man who are stressed, overworked, fatigued, frustrated, handicapped by different sorts of troubles or who are passing through some kind of individual crisis are more in danger in traffic too, though - on the other hand - conflicts and sorrows cannot been understood independently from the individual personality structure.

At the end of this continuum extending from relatively stable personality traits to time-dependent and transitory factors there are the concrete immediate situational facts that influence the driver behaviour to a very high degree.

The importance of a system approach as to psycho-social factors can be shown in the examples of special road user groups, called high-risk-groups (young beginners as motorists, elderly road users, persons with repetitive infringements on the basis of polytrope delinquency, drivers who have the tendency to consumption of alcoholic beverages or drugs) or in the examples of certain phenomena in road-users behaviour (fatigue, aggressiveness), where there are more or less a row of various (physiological, ethological, psychological and sociological) factors, that have to be taken in consideration.

BALANCED, SYSTEM-ORIENTED MEASURES FOR TRAFFIC SAFETY

Traffic is a very complex phenomenon, traffic behaviour is multiply determined. So measures to influence road users' behaviour must be considered in the frame of system-conditions. No influence can be considered in an isolated way, but must be understood in the context of other measures and in the context of contributions of other disciplines, combining in a holistic frame of reference among others epidemiological, biological, physiological, medical, psychological, sociological, cultural aspects as well as aspects of the physical environment.

Like in medicine where the preventive approach of health education comprises the influence on the - still - healthy person and his environment (f.e.hygienics) , modern traffic education comprises both, the influence on the road user and the influence on the ecological factors, f. e. too by motivating and activating the ind vidual to cooperate in this constructive way in organizing a traffic-world which is safe and more adequate to human beings (adaptation of man to traffic and of traffic to man). At the same time the so-called by-effects of certain measures have to be taken into consideration. For the advantages of an isolated measure may be outweighed by undesired and undesirable secondary effects or unexpected effects in quite another part of the system.

To complete this conception two further points of view may be added: First to judge the possible contributions of the health services system, which is a specialized macro-component of society, it is important to consider the parameters governing the life in a respective country, above all the overall value system of a culture which determines the priorities (concern for human life and welfare, budget allocations, priorities for a curative or preventive medicine, influence and power of certain organized interest-groups).

Information and insight gained by empirical, conceptual or exploratory system approaches may provide the basis for rational decisions and "modern" comprehensive planning, including broader evaluation (analysis of the input-throughput-output mechanisms, evaluation of the cost-benefit-ratio, need-demand-resources-relationship). Here too studying single components in isolation must fall short of the objectives of modern sociomedical research, whereas a broader result is to be expected by improving system quality in harmonizing the components' interrelations and adapting the different components to each other.

A second and last point is that nowadays the comity of nations is to be understood as a kind of system in which whatsoever happens to one is potentially or actually relevant to others. So in cross-national comparisons relationships may show up (a.o. specific situational, structural or social variables) which otherwise could not be worked out so clearly.

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THE INFLUENCE OF DRIVERS FATIGUE ON ROAD TRAFFIC ACCIDENTS(*)

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ABSTRACT: Some of the prospective studies and a few of the essential problems to be considered are recalled briefly in this introduction, to a workshop on the subject.

The concept of fatigue is an old and lively one. The fact that no one has yet been able to define it or give it a precise connotation makes, by a sort of Zeigarnik effect, that it keeps being refered to. The excellent analyses and reviews on the subject by Bartley and Chute (1947 and the more recent studiens of Cameron (1974) can be quoted without further comments. However, a relatively broad definition of Pieron should be mentioned, i.e. "fatigue is a set of manifestations produced by a task or by some function prolonged beyond a definite limit". This definition does not allow to explain through fatigue these manifestations, otherwise it would constitute à circular explanation denounced by Murrel (1965) which consists in defining fatigue by its manifestations and explaining these manifestations by fatigue! These manifestations which vary in nature - physiological, psychological, behavioural - must be understood, as suggested by Bartley and Chute as matters of organization and functional relationships. We are concerned here with evaluating the role of fatigue in traffic safety, determining which measures could be envisaged to reduce this fatigue and which consequences one can expect as far as an improvement or road safety is concerned. The influence of drivers fatigue on road accidents can be examined from various angles.

The general topic can be subdivided in four parts:

.- Fatigue indicators: How can fatigue be characterized?

.- Fatigue determinants: Which are the conditions which cause or induce the appearance of fatigue?

.- The role of fatigue in the genesis of dangerous situations: How is fatigue influencing driving and can it cause accidents?

.- Methodological problems created by linking security and fatigue.

(*) Extracted from introductive paper presented at workshop on same subject.

I.- FATIGUE INDICATORS

Fatigue indicators, i.e. signs which may reveal characteristic manifestations of a prolonged activity are very varied and their study extends beyond that of driving vehicles. But we have to consider here only relevant indicators or symptoms of disturbances which are supposed to influence considerably driving ability. These indicators are more and more elaborated on the basis of symptoms (manifestations) appearing during driving.
One can distinguish however between those expressing parameters of internal activity of the organism and those derived from behavioural organisation.

.- Indicators expressing parameters of internal activity of the organism.

Various physiological indicators such as cardiac rythm, arrhytmia, EEG, EDG, electro-myograph, etc... will record the internal activity of an organism, and the importance some of these measurements may have in studies on driving and in observed effects on results, whether expected or actually obtained, should be considered. It would be of interest also to consider how far studies carried out in different places but using the same indicators can be compared or correlated.

There is a practical problem which must also be considered. It is the one inherent to the choice of the indicators most suited for different types of situations, for different types of drivers, and considering the technical possibilities of the laboratory carrying out the research. In this field of research the combination of theoretical knowledge and laboratory studies is particularly important. To what extent can they be used in the study of driving on the road, how can one limit the field of a road research laboratory studying safety problems, are two questions of major importance.

.- Indicators derived from behavioural organisation. Driving is an organized activity, a skill, and is more or less largely automatic. In this type of activity, fatigue is expressed by changes in organization and regulation. The study of Bartlet (1943) is a model for handling the analysis of these alterations and changes. Current research offers several indicators in this category, namely:

.- those which characterize behaviour independently of external stimulations (such as frequency of movements of the steering wheel, of other controls in general, variations in speed or even postural changes);

.- those which more specifically characterize variations in decision making, considering also stimulations such as differences in the overtaking criteria.

An analysis of eye movements, for instance, depending on its utilization, may come in either category. In the first if only eye movements are considered, in the second if these movements are considered in relation to the context and if it is attempted to explain them in virtue of the context.

.- Indicators of subjective fatigue

These indicators are formed by the evaluation given by the driver of his physical conditions and reactions.

There is no reason to ignore such opinions and the information they contain should be exploited as much as possible. This can be done by the definition of a scale allowing to evaluate more precisely the sensation of fatigue, and by the analysis of the observations of the drivers themselves which may lead to hypotheses concerning the origins and the manifestations of fatigue. It would be interesting to know more of the work already performed in this field so as to better define the measurement criteria and evaluate the possibilities of self-diagnosis of fatigue.

.- Finally, the study of the relationships between the different types of indicators constitute an important element in the study of fatigue, which is often characterized by conflicting variations in the indicators. A prolonged driving requires a global reaction and it is beyond hope to characterize it in a valid manner with only one indicator, particularly if one considers the compensations which could occur between the different functions involved.

II.- DETERMINING CAUSES OF FATIGUE

A study of these determining causes is closely related to the quality of the indicators used. The determinants (causes) of a drivers fatigue are many; they may be due to the driving activity per-se and/or to other activities preceeding it. Bartley and Chute (1947) rightly stated that fatigue cannot be defined in terms of the diversity of external situations where it occurs. Indeed the type of work performed by the individuals considered before the act of driving can influence the types of manifestations (symptoms) noted during the driving exercise, depending on their effects on the various functions involved. If the activities before driving were very prolonged, then whatever these may have been their effect on driving will be important. The intricacies of these phenomena make it all the more difficult to separate in the observed manifestations the determinants caused by driving only from those due to the previous activity or, more broadly, to the conditions of the driver when he started operating. These problems are of particular interest in the case of professional drivers.

Considering first the endogenous determinants relating to the driving act, it is important to establish a classification of the types of situations and to be able to determine, if only approximatively, from which moment and/or following which particular exposure they have reached criticality. Among the factors most often quoted are prolonged driving on monotonous routes, night driving, the immediate environment (noise, heat, etc.). The imperatives of driving such as time schedules for the professional drivers, duration and repetition of the routes, time-tables, etc. must also be taken into account. These demands, it is true, may be sometimes self-imposed by the driver, due to some social pressure such as keeping a certain average speed, arriving at a set time, recuperating delays on the road. This type of constraint may play an important role as will be seen later.

A second class of determinants found in the situations occuring outside the driving exercise, sometimes refered to as exogenous determinants, and cover the length and distribution of the rest and meal periods as well as the leisure activities (nature, length and frequency) of the drivers.

For professional drivers work and leisure determinants are often closely interdependant since the work organization determines the modalities of the leisure periods.

Finally, one can consider separately the determinants of fatigue characteristics of the driver considered, which obviously sometimes simply follow from the previous determinants. Here one can refer to the training level, the personality, the health status, the eventual use of drugs, etc. But it should be stated again that the same requests may produce fatigue symptoms differing in nature, time of appearence, and intensity in different individuals.

Sampling of population in these studies depends therefore on a thorough consideration of these points. The knowledge of these determinants and their role in the origin of fatigue is essential when considering road traffic accidents. Any attempt to reduce the influence of fatigue must consider the action on its determinants. Their identification and the evaluation of their influence constitute essential problems which cannot be avoided in the study of road traffic accidents.

III.- ROLE OF FATIGUE IN THE GENESIS OF DANGEROUS SITUATIONS

The link between fatigue and road safety is not a clear one; it has been considered because driving can be regulated differently. The same objectives can be reached using different methods and therefore producing different consequences. Two of these consequences are particularly important and should be kept in mind. They are that the same observable results can correspond to the involvment of different mechanisms, and that perturbation of one of these mechanism does not necessarily imply that the desired wish can be obtained. Thus it can be conceived that certain signs of fatigue are compensated and have no incidence on driving and road safety. The important problem however is to ascertain which are the regulation possibilities given to an individual to respond adequately to the requests of safety, and how they could be altered by tiredness. In other words is it possible to imagine that a driver can compensate certain deficiencies in his capacity to maintain constant his risk level? Speed and safety margins (distance between vehicles for example) are often quoted among the variables which may influence these compensations. Thus a slower speed of reaction could be compensated by acting on either parameters. One can see here a mechanism which could allow to establish links between fatigue and road safety in the presence of conditions blocking these regulation mechanisms. For instance a driver having to obey a strict time schedule will tend not to use the speed regulation possibility and become a higher risk factor.

These regulation mechanisms can act at various levels and lead the driver to chose the situations in which he accepts to be in.

It remains to be seen to what extent fatigue does not manifest itself also by alterations of regulation mechanisms, since the evaluation of risk levels and the knowledge of one's own possibilities are perturbed in the driver. It should be added that compensation mechanisms for fatigue can occur only within a certain set of conditions most commonly met, but would be quite inadequate in exceptional incident cases. Thus a decrease of vigilance on a monotonous strech of road can be compensated by the fact that the individual rests using automastisms calling for a minimum of concentration. These mechanisms sufficient under normal conditions may be quite inadequate in case of incidents.

IV.- METHODOLOGICAL PROBLEMS CREATED BY THE ESTABLISHMENT OF A LINK BETWEEN FATIGUE AND SAFETY.

The reasons invoked in matters of traffic safety relate to the role played by the factor considered and the prognosis that could be made of the efficiency of corrective measures. One may ascribe wrongly only to fatigue the responsability of certain accidents and thus block the research on other causes. Fatigue, let it be clear, can lead to accidents only through its interaction with other factors of a situation which it is imperative to study.

Any study of these problems to be fruitful should investigate the following points:

- safety and criteria which could characterize it: accidents and indicators deriving from them but also the "near-accident" (typical example being the traffic conflicts)
- driving as an observable behaviour
- mechanisms regulating driving, and their perturbation as influenced by fatigue
- the determinants of fatigue

This sequence indicates that the effects of fatigue on road safety can be considered from various approaches.

The direct proof of the relation between fatigue and road safety is very difficult to establish since it implies the use of means to measure fatigue and this is not possible for large samples. It is possible however to consider determinants of fatigue which are more easy to detect and to study their relation with criteria of safety. This statistical investigation method which supposes certain hypotheses on determinants has the further advantage of evidencing the relative importance of factors to be considered in road accident prevention. For example if it is shown that accident frequency increases after 7 hours driving, an immediate prevention measure will be to limit the driving periods below that value. It will be also possible to evaluate the role of a longer driving period and to estimate the advantages from the enforcement of the shorter period.

However the determination of such a relationship besides being difficult to establish could also be misleading since a correlation is not necessarily a cause-effect relation. It does not give any information either on the mechanisms which could explain it and it should therefore be completed by other studies to determine them. Two methods of investigation are available:

.- The clinical method which consists in analyzing the causes leading to the accident or the incident and thus allow to ascertain the mechanisms which could intervene, and

.- The experimental method which allows to test influences of these mechanisms by checking their manifestations and noting their consequences. Thus noting the values of certain electro-physiological parameters one can show links with certain types of behaviour related to road safety, e.g. low vigilance and absence of perception of signals or indications.

A combination of these two methods is to be prefered. When this it not possible, a certain number of pitfals must be avoided. These are generally inherent to the lack of information on a specific driving situation made up of the interaction between the driver and the driving conditions surrounding him. The lack of knowledge of the exact job description and work of a driver could lead to an unjustified extrapolation of laboratory results, or of generalizing results obtained in very specific conditions to a wide range of conditions wrongly considered similar. A good example is the non consideration of factors such as time constraints and technical training which could, other factors being equal, modify very greatly the onset and the consequences of fatigue in drivers and invalidate some generalizations.

CONCLUSIONS

To conclude this broad survey of the problem intended to point out matters for discussion it is worthwhile to consider again some analyses under a different form.

Man and the vehicle form a system of which the environment (infrastructure, signals) constitute the input and the modifications to this environment the output. The handling of these inputs has to obey definite rules. An accident is a sympton of ill-functioning of the system. This non-operation will manifest itself more under certain conditions, just as an anomaly of the organism will appear more critical depending on the requests made to that organism. Fatigue can be considered as a type of disfunctioning of the system. Its consequences will depend not only on modifications it will introduce in the mode of operation of the "conducting" element of the system, but also on characteristics of other elements of the system and of the environment, that is the driving conditions.

Thus a number of points should be considered in any study of fatigue involvment in road traffic accidents and these will serve to summarize the above considerations.

.- Fatigue per-se has no explicative value. Moreover, it can appear in different forms and the effects on driving will differ or may even be absent altogether.

.- Similarly it is not possible to speak of a general effect of fatigue on road safety. Requirements of a specific situation do not all call for the same ability from the driver and all will not be uniformly affected by fatigue.

.- It is only through the knowledge of the nature of fatigue, of the capacities of the drivers and requirements of the driving act, as well as on their interaction, that certain hypotheses can be formulated on the risk factors and the causes and prevention of accidents. This is why research on the influence of fatigue on accidents cannot do without the analysis of the system which covers the duty and the activity of the driver. It is in relation to this system that the various results of a study must be considered if they are to be useful and could guide and support a valid road safety policy.

WHAT IS THE EXTENT OF THE DRIVING FATIGUE PROBLEM ?

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ABSTRACT

A review of selected accident analyses and surveys of driver experience is presented to show that the problem of driver fatigue and sleep is extensive and serious.

INTRODUCTION

Several distinguished speakers at this symposium have offered the opinion that driving fatigue is a causal factor in only a small proportion of traffic accidents. This may be true in geographic areas where most driving is accomplished over short periods; in moderate to heavy traffic; in daylight; and, under circumstances which may readily be conceived as generally interesting or challenging to drivers. Unfortunately, much driving is accomplished at all hours on long, monotonous highways between urban centers. There, the problem of driving fatigue is both extensive and extremely serious.

RESULTS OF ACCIDENT ANALYSES

Large-scale but superficial analyses of ordinary accident records tend to underestimate the importance of the fatigue factor in the causation of traffic accidents. For example, as a prelude to a major effort to locate "black spots" where fatigue-related traffic accidents are unusually frequent, California investigators reviewed the entire state's accident records for the year 1969 (Tye, 1976). The data show that "driver asleep" or "driver fatigued" was cited by investigating officers as the primary causal factor in only 3,175 (14%) of 22,272 single-vehicle accidents. (No attempt was made to ascertain the cause of the 107,056 multiple-vehicle accidents that occurred during the same year in California.) Yet it is important to note that the relative frequency of sleep or fatigue was second only to alcohol (22%) among the identified causal factors. Moreover, 62% of all single-vehicle accidents were categorized as occurring with "no apparent reason". Many of these were probably the result of fatigue so the official estimate must be viewed as highly conservative.

After an accident, it is always difficult to determine whether the driver had been asleep at the time of its occurrence. The driver himself may have no memory of sleeping. Even when he does recall sleeping, he may be unwilling to admit the fact, because it can imply legal culpability. The investigating officer is often discouraged, or even prohibited (currently true in California), from reporting that the driver was asleep unless it is admitted by the driver himself or related by a witness. Finally, if the driver leaves or is taken from the accident scene before he can be interviewed, the accident report is completed and almost never amended to indicate that fatigue was a causal factor. The high percentage of accidents for "no apparent reason" in the California study suggests that many were caused by fatigue but were not reported as such for the reasons given. More comprehensive accident surveys, performed by researchers rather than investigating officers, seem to have a better opportunity for yielding valid estimated concerning the extent of the driving fatigue problem.

Baker's (1968) monograph yields perhaps the most systematic definition of the problem as pertains to the genesis of single-vehicle accidents occurring on rural American highways. For the year 1964, his data show that approximately 35% of all accidents involved only a single vehicle. Yet these accidents were the most severe, producing about 50% of total highway fatalities. Baker carefully analyzed a sample 850 such accidents to discover that the single most frequently cited causal factor was "driver asleep". That factor was cited, solely or in combination with other factors, as being responsible for 24.4% of the accident total. Generalizing from these results, one may estimate that at least 8% and 12% of all accidents and fatalities on rural American highways are attributable to driving fatigue. Those percentage estimates are again conservative, reflecting only single-vehicle accidents where fatigue was severe enough to produce sleep. Presumably lesser degrees of fatigue also contribute to both single- and multiple-vehicle accident causation, so the true percentages of fatigue-related highway accidents and fatalities are probably higher.

In fact, much higher estimates have been made of the percentages of fatigue-related accidents on particular American highways. Forbes et al. (1958) reported that between 13% and 20% of all accidents on the Pennsylvania Turnpike involved the driver falling asleep. While similarly caused accidents accounted for 22% and 48% of accidents and fatalities on the Oklahoma Turnpike, according to Case and Hulbert (1970).

The problem of fatigue in commercial truck and bus driving is likewise serious today in the United States. It is more definable, at least in the case of severe accidents (i.e. those involving injury death or property damage in excess of $ 2000) due to strict Federal reporting requirements. Each year more than 30,000 such accidents are reported to the U.S. Bureau of Motor Carrier Safety, and each year that agency summarizes its data in the document Analysis of Accident Investigations (Department of Transportation, Federal Highway Administration, Washington D.C.). Inspection of that annual report by the author over the years 1970 - 1975 revealed that the annual percentage of single vehicle accidents attributable to "driver asleep" remained relatively constant at between 7% and 9%. The number of multivehicle accidents attributable to the same factor was several percentage points less. Harris (1977) confirmed this finding in a survey of randomly selected but similarly severe truck accidents occurring throughout the U.S. during the month of January 1976. He reported that of 226 single-vehicle accidents and 116 multivehicle accidents where the truck overtook another vehicle, 7% and 5% accurred as the result of the driver falling asleep.

Harris went on to analyze those data, and separately, 406 severe truck accidents occurring during the year 1974 to determine the relationships between the accidents and both trip duration and time-of-day. He found that the actual accident rates exceeded the expected (on the basis of known exposure rates of truck drivers) beginning at about the fifth driving hour. Moreover, these accidents were most prevalent during hours between 2400 and 0800, reaching a maximum at about 0500 hours when actual rates of single-vehicle accidents exceeded expected rates by a factor of 6 for the 1974 data, and by a factor of 2.5 for the 1976 data.

RESULTS OF DRIVER SURVEYS

Harris et al (1972) interviewed 500 commercial intercity truck and bus drivers at company dispatching yards and highway rest stations. Among the questions posed to the drivers was that concerning the frequency of their experience of an accident, or near accident, as the direct result of fatigue leading to sleeping. Overall, 21% of the drivers recalled one or more episodes, and 4% actually ran off the road while asleep. It is noteworthy that 6% of all the drivers realized that they had been sleeping when suddenly confronted by impending collision with another vehicle. This suggests that sleeping is at least as important in the causality of multivehicle accidents, as it is in single-vehicle accidents where that factor is more identifiable. The authors further categorized their results by the type of driver. Those truck drivers (i.e. "common carriers") who operated according to more arduous (with respect to hours per work week) and less regular (with respect to daily working period) schedules had the greatest frequency of sleeping and of accidents due to sleeping (26% and 8%, respectively). Those who were employed to haul only one class of goods, according to generally more regular and less arduous schedules (i.e. private carriers) had fewer sleeping episodes and resulting accidents (19% and 2%). Bus drivers provided statistics comparable to the latter group (i.e. 19% and 4%, respectively).

When interpreting these results one should bear in mind that these professional drivers represent a population which is traditionally regarded as one of the most proficient and safety conscious in the world. The median sample age ranged between 34 and 39 years; and, professional driving experience between 10 and 13 years, for different driver categories. Moreover, the consequences of accidents for these drivers are even greater that for the driver population at large. Damage and cost are usually greater owing to vehicle size and contents. When those contents include passengers, as in the case for bus drivers, the anticipated result of a sleeping accident can be nothing short of catastophic. Even relatively minor accidents due to fatigue jeopardize the responsible driver's continued employment. A single sleeping accident is a blemish on a driver's record which persists in the mind of his employer for years. Two would almost certainly lead to his dismissal and permanent blacklisting. In spite of these drivers' unquestionable skill and desire to avoid such dire consequences, the results of this survey show that roughly one out of five occasionally sleep while driving, and one out of 20 will thereupon have an accident.

For the casual driver engaging in prolonged personal vehicle operation, the incidence of sleeping is apparently far greater. Prokop and Prokop (1955) interviewed 569 German drivers as they stopped at an autobahn rest station. Before the interview, the drivers had been enroute for between 1 and 20 hours (77% between 3 - 8 hours); and, had driven between 100 and 1000 km (79% between 200 - 500 km). Of these, 81 admitted to having experienced at least one brief sleeping episode, and 18 would or could not answer the question. Thus, 14,7% of the drivers who answered definitively admitted having fallen asleep while driving. Moreover, 58% of the latter reported that their sleeping episodes occurred during the hours between 2300 and 0500, or roughly with twice the frequency which one would expect on the basis of a random distribution of sleeping episodes over the day.

It may be argued that this particular driver sample was biased due to the administration of the questionnaire at a rest stop. Conceivably, the drivers who stopped tended to be more fatigued than those who passed by. Nonetheless, one conclusion seems inescapable and uncontroversial. Because none of the drivers who slept was actually involved in an accident, it must be assumed that the incidence of sleeping while driving is far greater than the incidence of accidents attributable to sleeping. Most drivers who briefly fall asleep may simply be fortunate enough to awaken before the road or traffic situation requires an immediate and precise reaction to avoid an accident.

CONCLUSIONS

1. Traffic accidents caused by driver fatigue and sleep are not rare events, although they may be difficult to identify as such from typical accident records, particularly in the case of multivehicle accidents.

2. Driving fatigue is responsible for between 14 % and 24 % of all single-vehicle accidents occurring on intercity (rural) highways. This estimate is conservative.

3. Driving fatigue is one of the two most frequently cited factors in describing the causality of such accidents (alcohol is the other).

4. About 7 - 9% of all serious commercial single-vehicle accidents are directly attributable to driver fatigue. The percentage of multivehicle commercial vehicle accidents is uncertain but may be as much as 5% for the case of the truck overtaking another vehicle (i.e. rear-end collisions).

5. Fatigue related commercial accidents increase as a function of the drivers' time on the road, exceeding expected values after the fifth hour.

6. Fatigue related commercial accidents are most prevalent during early morning hours, as are cases of reported sleep by private vehicle operators, presumably at the low point of human circadian arousal.

7. Approximately one out of five commercial vehicle operators

occasionally sleeps while driving and one out of twenty experiences an accident while so doing.

8. During prolonged vehicle operation on any given day, many (one estimate 14.7%) operators of private vehicles experience brief sleeping episodes. Nearly all recover and continue driving without incident, but it is likely that fatigue and sleep substantially increase the risk to these drivers and to highway users in general.

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FATIGUE IN DRIVING AND ACCIDENTS

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ABSTRACT

The research on the relationship between fatigue and accident risk has met great difficulties due to experimental problems and the theoretical construct of fatigue itself. Even the common view of an increase of accident risk with fatigue seems confused. Attention is brought in the present paper to the fact that fatigue may induce some compensatory changes in behavior of the driver which in turn are associated with decreased risk.

INTRODUCTION

The view that the fatigue of the driver is an important factor in the causation of many serious crashes is intuitively appealing indeed and deserves further exploration. However, we are here immediately confronted with serious conceptual problems. What is meant or should be meant by the concept of fatigue of the driver? It is generally accepted that there are many sources of fatigue and the use of the term fatigue in all these connections naturally implies that there is at least something in common in the change in the state of the organism when exposed to any source of fatigue. There are certain physiological changes, mainly deceleration of many physiological processes, and also some subjective changes such as feeling of sleepiness which might be regarded as composing the common core of the so called fatigue originating from various sources. We suggest the division of these diverse sources into the following five main groups:

(1) Driving itself i.e., driving with insufficient recovery periods;

(2) Lack of sleep and insufficiency of other kinds of

recovery periods (for example, after heavy physical effort or an examination);

(3) Certain phases of circadian rhythms;

(4) Certain medicines (sedatives, sleeping pills);

(5) Certain aspects of the stimulus condition (such as monotony of the stimulation during continuous highway driving).

It was already stated that the justification of using the term fatigue to denote the effect of any of these agents lies in the common (physiological, behavioral and subjective) changes these agents induce in the organism. However, it is to be emphasized that probably each of these agents also has specific effects on the organism. Another important justification for this broad use of the concept "fatigue" is the similarity of the manner of recovery in each of these cases: either sleep or other kind of rest or change of activity, hence passivity or other form of function of the whole organism or of the system stressed. This leads to the third kind of connecting link between these five sources: the undeniably increased probability of sleep onset associated with any of these sources. Finally, the effects of these agents seem to a large extent to be additive and they also appear to be compensable by preceeding sleep. To illustrate the last point, if we know that we have to drive through the whole next night we would manage much better by increased sleeping periods before the trip. (This beneficial effect is not only due simply to the compensation for the lack of sleep but also for the circadian-rhythm effect.)

ARE THERE DATA DEMONSTRATING THE DANGEROUSNESS OF FATIGUE?

After these efforts to define the concept "fatigue", the main trends of available evidence on the relationship between driver fatigue and traffic accidents will be shortly reviewed. The main conclusion made is very simple and perhaps depressing in the light of the amount of research effort invested into this question: research has not generally been able to show that driver fatigue increases the risk of an accident except by increasing the probability of falling asleep during driving. As already mentioned, there exists solid evidence in favor of an increased probability of sleep onset in the presence of any of the aforelisted sources of fatigue. On the other hand, there is negligible evidence to support the conception that the driver fatigue is associated with increased danger in traffic as long as the driver does not fall asleep (for a shorter or longer period of time). Here we would like to point to the embarrasment felt by many because of that main trend in research results according to which fatigue is dangerous mainly via the increased probability of sleep onset. It is felt that fatigue should be dangerous even well before the point of sleep onset is reached. Many people have strong subjective evidence in the light of which that result is to some degree inconceivable to them. And there are numerous studies which have shown a decrement in performance level in such tasks which are similar to (or closely resemble) component tasks of the total task of the driver. Additionally, many such findings come from the actual driving situation in which some aspects of driving such as wheel reversals or line following have been observed to change as a function of, for example, hours driven. In other studies carried out on the road, performance in some extra task given to the driver such as signal-detection or reaction-time task has been the target performance. However, in many cases in both kinds of studies no performance decrement in the presence of a source of fatigue has been observed.

THE PROBLEM OF THE VALIDITY OF THE MEASURES USED

In general, the great problem of these studies aimed at clarifying the effect of fatigue on safety by measuring performance is the common lack of validity of the performance measures used with respect to the probability of an accident. What does, say, a reduced frequency of wheel reversals signify from the safety point of view? Or an increased reaction time (RT) in a subsidiary task? This measure was reported to have been validated by Laurell and Lisper (1976) who used the detection distance of an object on the road during nighttime as a criterion measure and found out an inverse relationship between the two measures. Hence, as the driving time increased the RT became longer and the distance at which the object on the road was detected became shorter. But even such an attempt of validation is of questionable significance as it might be that the driver compensates deteriorations due to fatigue in his decision making in advance. Hence, it might be that a fatigued driver chooses a little slower speed and as a result his chances to avoid a disastrous collision with a sudden object on the road might even be increased. Another problem in such validation attempts is that they usually relate only to one kind of the various dangers of the road. To take an example, let us assume that no compensation in the form of reduced speed in the afore described situation exists so that the probability of colliding with a suddenly appearing object is indeed increased. But the compensation might also come in the form of a decreased probability of another kind of accident. It might, for example, be that the willingness of the driver to enter into overtaking situations on a two-lane road is decreased with fatigue as the Brown, Tickner and Simmonds (1970) study seems to predict(see note). Sometimes, however, the tendency of a fatigued driver to avoid effort may increase the danger. For example, he may be increasingly unwilling to reduce speed when approaching a blind corner.

More generally, it might be that under fatigue the driver deliberately increases his external margins of safety such as headways and drives slower because of feeling fatigue effects in his perceptual-motor systems and in his awareness and because of the feedback from his performance signalling deterioration. By driving slower and with larger margins of safety, he also can operate at a lower level of vigilance, readiness for action and of other forms of effort which might be of increased motivational significance to a fatigued driver. It is important that driving in contrast to many other perceptual-motor tasks is a submaximal task and that in driving continuous decisions are made with respect to what to try to do in each situation and to the allocation of effort (see Näätänen and Summala, 1976, 1977).

Several studies on driver fatigue have used the frequency and amplitude of lane drift as a measure of driver performance of apparent validity from the safety point of view. Drifts of a large amplitude have usually been considered undeniable signs of increased danger. It might, however, be that a fatigued driver - in order to avoid efforts - allows to himself drifts up to certain maximal amplitude. When this maximum is occasionally exceeded it presumably acts as a negative reinforcer or warning (see Taylor, 1964; Cownie and Calderwood, 1966; Näätänen and Summala, 1975); the driver becomes alerted for a while and his steering performance improves. He may also decide to take a rest period at that point of time.

But it might be said that at least such large drifts are dangerous. Even this is not certain as such large drifts might be far from being independent of the situation. For example, a drift on a two-lane road might rather take place over the midline than to the ditch side if the road shoulder is narrow and such a drift over midline might only occur when an oncoming car is not approaching. Hence, it is possible that even such performance decrements as large drifts are in fact under the driver's control to some extent. (Even the moment of sleep onset might favour safer traffic situations at the expense of more demanding ones. Unfortunately, the situation may change rather soon and an active contribution of the driver would be needed.)

An example of those few studies on the effect of fatigue on performance with probably a high validity with respect to safety is the early work by McFarland and Moseley (1954). In this study, a trained observer registered all near-accidents of truck drivers during a large number of their trips. This study showed that the number of near-accidents decreased with driving time.

It appears to be justified to suggest that the problem of the validity of the measures used should be given the priority position in future research on the effect of driver fatigue and safety. Already enough such data have been cumulated which show deceleration of certain physiological processes (e.g., slowening of the heart rate, increased amount of alpha in the EEG, etc.) and some performance changes neither of which has a known relationship to danger. Among others, the inverted U-shaped function between "activation" and performance level which is open to serious criticisms (see Lacey, 1967, and Näätänen, 1973) has frequently been uncritically referred to as a source of validity for the physiological measures used.

MISUNDERSTOOD DRIVER'S TASK AS THE BASIC PROBLEM

The basic problem of the research on fatigue in driving and safety appears to be a common misunderstanding of the driver's task (Näätänen and Summala, 1976, Ch.3): much effort has been invested in discovering changes caused by fatigue in separate perceptual-motor abilities and skills without due consideration of the whole driver-environment interaction with also situation-creating activities of the driver (for example, the before-after studies). It was suggested in the foregoing that fatigue effects as they show up in the driver's awareness, feeling of having control over situation, and in his performance have a compensatory effect on the driver's decision-making. It is suggested that it is the submaximal nature of the driver's task which mainly explains the fact that in many of these studies it has been difficult to obtain fatigue effects whereas in various maximal performances fatigue effects usually do not fail to show up soon.

It appears also that the presence of the observer and the conditions of the experimental situation decrease the degrees of freedom the driver otherwise would have in the direction of compensation for the fatigue effects. On the other hand, it is probable that because of the presence of the observer and of the exposure to a test situation the fatigue changes take place considerably later and perhaps in a different form than otherwise.

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NOTE

In Brown, Tickner and Simmonds' (1970) study, drivers at the end of a drive had a larger proportion of their total number of overtakings such that they were judged by the experimenters as unduly risky than in the beginning. This was compensated by the fatigued driver by reducing his number of overtakings to the extent that the number of "risky" overtakings was not increased.

THE INFLUENCE OF DRIVER FATIGUE ON TRAFFIC ACCIDENTS

Some Theories and Experimental Results

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ABSTRACT

Several multiple factor "ergonomic-and-systems" theories of traffic accident causation are noted. Fatigue may be one factor. Experimental studies described include a "near-accident" study and a study of sleep deprivation effects on driver behaviour. Trip planning, rest stops, vigilance in truck driving and monotony are discussed. Research is needed on methods of reducing fatigue on long trips and in city driving.
Multiple factor theories explain why it has been difficult to isolate individual factors such as fatigue.

INTRODUCTION

The different types of fatigue affecting human behaviour are well known to all of those working in this area of research and are well indicated in the outline of the Status of the Problem and the review of published research by Lecret and ONSER. The statement of the Object of the Workshop indicates that the interrelation of different research results and application of findings to the automobile traffic accident problem is the immediate concern.

TOPIC 1 -- INDICATORS OF FATIGUE

It is assumed that this topic refers to how one knows whether fatigue effects on driver behaviour are in part causes of certain types of automobile accidents. Many accident studies in the U.S. have reported and continue to report one car, off-the-road accidents under conditions suggesting fatigue and falling asleep at the wheel. How many other accidents also involve fatigue is another question. Two approaches seem necessary here. The first involves a theory of accident causation. The second involves experimental research procedures.

Theories of Accident Causation-Ergonomic Approach

A multiple factor Theory of Accident Causation was stated by Forbes in which the limits of ability and skill of the driver might be exceeded by the sudden occurrence of a critical situation. Foresight and skill of one driver might save others from an accident (Forbes, 1950). Others have also proposed such theories.

Multiple Factor Ergonomic Theories

Forbes (1954) again noted that limits of ability and skill of the driver may be exceeded by sudden increase of task difficulty from occurrence of an instantaneous critical situation. Prediction, planning and "appreciation of hazards" as well as various judgments and skills are needed for successful driving. Required is a continuous distribution of attention among vehicle, highway and other environmental factors including actions of other drivers. A sudden critical situation from unexpected combinations of these factors may result from lapses or judgmental errors by one or more drivers. Often several drivers may be involved, and, therefore, skill and good judgment by one driver may prevent an accident from an error or lapse by another driver.

This point of view leads to a search for combinations of hazards and physical, physiological and psychological conditions which may contribute to lapses and sudden critical situations. Many different combinations of physical and human factors may thus lead to exceeding the driver's ability and contribute to accident causation at different times. This fits in well with evidence of the importance of learning factors and of education and reeducation in improving driving safety (Forbes, 1954).

An ergonomic-and-systems approach theory was proposed more recently by Blumenthal (1968) in which short term variations of traffic conditions and hazards may increase the difficulty requirements of the task of the driver instantaneously beyond the limits of his ability to cope with it as illustrated in Figure 1.

The driver and the highway-and-driving environment were viewed as a whole. Variations often occur in the combinations of traffic conditions which present variations of hazard. As a result, the difficulty of the driving task for a particular driver may increase instantaneously beyond

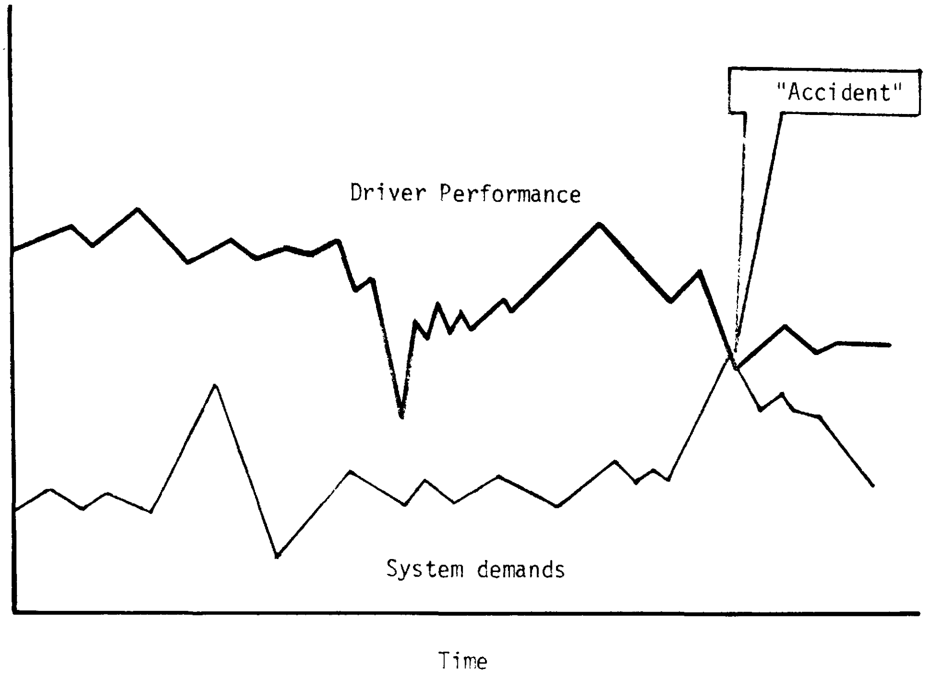


Figure 1: From Blumenthal 1968, Figure 4 -- Hypothetical Localized System Failure

his ability to respond successfully.

From the multiple factor ergonomic point of view, any factor increasing driving task requirement or decreasing the driver's alertness or ability to cope with the task momentarily is a potential accident factor. Fatigue may be such a factor.

Three Complementary Theories of Safety Psychology have been summarized by Kerr (1957) as: 1 - constitutional accident proneness, 2 - goals, freedom and alertness, and 3 - the adjustment-stress theory. From industrial accident studies and data, he estimates that they may represent as much as 15, 40 and 60 percent of accident variance respectively. These theories each center on different psychological areas and he rightly notes that they are complementary, i. e., factor combinations may overlap and vary.

From the Multiple-Factor Ergonomic-and-Systems point of view, any of the factors in the three theories may at times suddenly combine and thereby contribute to accident causation at a given instant by increasing task difficulty.

Two Experimental Research Approaches

An Analysis of Near-Accident Reports (1957) indicated that fatigue might be one of many factors in "near-accidents" and presumably in accident occurrences.

A total of 179 "near-accident" reports were obtained and analyzed. Report forms were distributed to drivers through the members of a Highway Research Board committee. The drivers, some interested in highway traffic and others not, were asked to report the next near-accident they observed and describe what happened. Next they were asked to give their opinion on factors of most importance in causing the incident and to check answers to four questions on hurry, attention and approximate data and time of occurrence. The reports were hand tabulated (no computer being available at that time) and combinations of factors were analyzed, including road condition; unexpected condition; inattention, sleep and intoxication; perceptual misjudgments; and attitudes, emotional behaviour and driving habits.

Results indicated that two to seven or more factors were probably involved in most incidents. The combination suggesting fatigue was "inattention, sleep, intoxication" in which 74 driving incidents were classed. Of these, 40 were classed as "not alert", "probably inattentive", "asleep, fatigued, drowsy", "probably drowsy or intoxicated" (Committee on Road User Characteristics, 1957, see Table 16). Categories, of course, overlapped but it appears that at least some of the near-accidents probably involved fatigue as a factor.

The largest number of cases fell under "driver in a hurry". This group overlapped the other categories but did not show any statistically significant relation to the other specific factors. All that can be said is that sleep and possible fatigue conditions were among the factors reported.

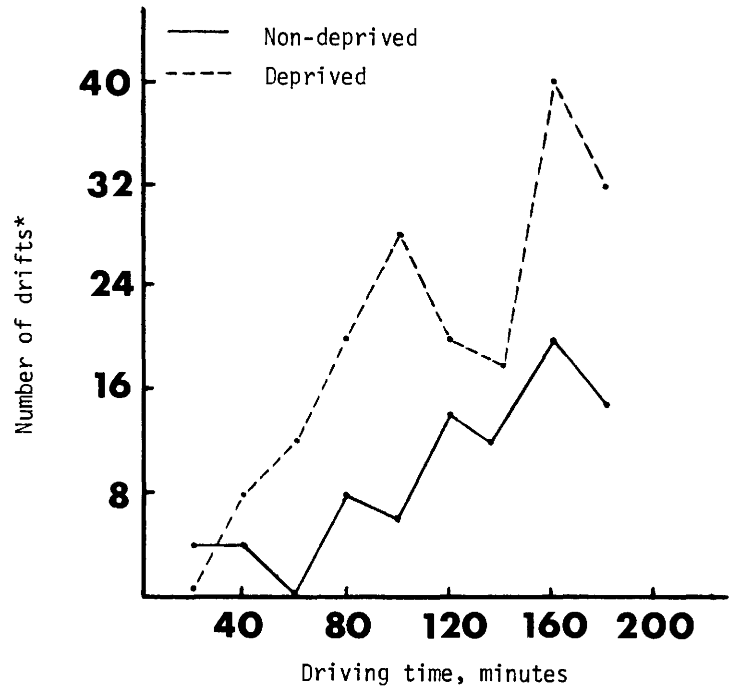
The method of "near-accident" reports has the advantage that those reporting were at the scene and could report conditions but were not involved in an accident and therefore were more likely to give a frank report. It has the disadvantage of being very subjective and lacking in precision.

A study of Sleep Deprivation Effects (Forbes, et al., 1958) which observed driving behaviour on the open highway showed gradual decrease of alertness and finally actual dozing at the wheel. This study was undertaken because analysis of accidents on a freeway (the Pennsylvania Turnpike) showed that from 13 to 20 or more percent of the accidents and 35 percent of fatal accidents probably involved drowsiness or sleep. A car with dual controls (both steering wheel and pedals) was used. Two observers using a time sampling procedure (observations during five minute periods with five minutes of rest between) recorded drifting in the lane, unnecessary speed decreases, quick eyeblinks, longer definite eye closures, and six other behaviours. The subject driver was asked to report possible hazards and reasons for any speed decrease.

Not only did drifts (gradual drifting to the right or left edge of the lane) increase in sleep deprived as compared to non-deprived runs but also they increased with driving time as shown in Figure 2. Figure 3 shows a similar pattern in frequency of eyeblinks.
Also, four out of five of the extreme sleep deprivation group actually dozed at the wheel within the approximately 2 1/2 hour run (total run of five hours with a rest break at the halfway point).

Subjects were four graduate students in a pilot experiment, five for the extreme sleep deprived experiment (24 to 36 hours without sleep) and another five for a less severe deprivation (no more than four hours sleep for each of the previous three nights). Results were less dramatic with the second group, showing less difference between deprived and normal runs. At least one of the subjects, however, was found to be carrying on a schedule with no more sleep on "normal" than on "deprived" days.

The study demonstrated that under sleep deprived fatigue conditions, drivers may doze at the wheel in runs of slightly over two hours (half of a five hour run) while holding uniform speed and reporting from time to time on features of the route. Also that both blink frequency and drifting increased consistenly with increased driving time (probably indicating fatigue).



*Total - 5 subjects

Figure 2. Comparison of deprived and non-deprived groups on drifting. (From Forbes, et al. 1958, Figure 1)

NOTE: Divide frequencies on the left of the charts by 30 to give average frequency occurrence per man per minute.

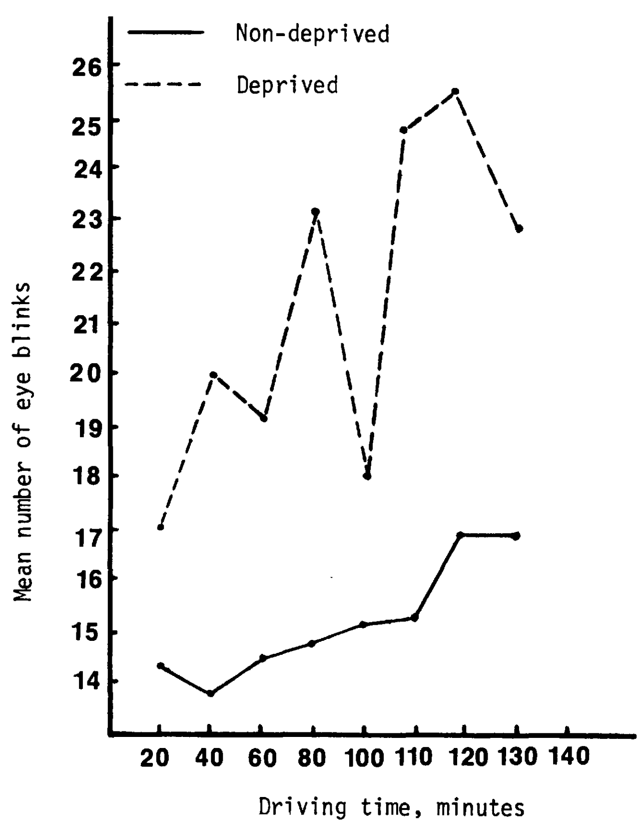


Figure 3. Comparison of deprived and non-deprived groups on eye blinks (From Forbes et al. 1958, Figure 5)

These and other studies of both simulated and actual on-the-road driving, especially where multiple tasks load the driver to near his ability limits, provide one type of evidence of stress effects from fatigue which may affect or limit driving ability.

TOPIC 2 -- DETERMINANTS OF FATIGUE

The above studies indicate that fatigue may indeed be responsible for accidents due to sleep at the wheel. In the last study, it was the result of previous sleep deprivation.

Inadequate planning for rest stops and also possibly greater susceptibility to sleepiness in some subjects have been reported by Hulbert (1972) as possible factors. With Case and others, he investigated rest stops as a countermeasure. A previous study of long trip driving in the western U.S. indicated a need for trip planning to avoid starting when fatigued and to include rest stops at moderate intervals, for example, every hour.

In his review chapter, Hulbert notes that several experimenters who measured steering, speed control, and similar behaviour found effects of long continued driving. The changes of behaviour differed among individuals but were consistent in showing reduced ability to divide effort and attention equally between two simultaneous parts of the task.

A vigilance task carried out by truck drivers in large scale road tests under the Highway Research Board and the U.S. Army psychological research laboratory showed gradually increasing loss of response with time of continuous driving by some drivers.

Monotony and "highway hypnosis" were found to be related to familiarity with the road (Forbes, 1954). Drivers living near the Pennsylvania Turnpike and who drove it often complained that it was monotonous. On the contrary, drivers from flat western areas of the U.S. reported that the road through the Pennsylvania mountains was interesting and not monotonous because of variations of scenery. Here again, however, fatigue also may be an important factor.

TOPIC 3 -- CHOICES OF RESEARCH DIRECTION

The previous research results indicate that driver fatigue may be one of the contributing factors in traffic accident causation. If so, it would seem that research should include studies of effective methods of preventing driving fatigue, making drivers aware of the problem, persuading them (and sometimes their supervisors in the case of commercial drivers) to schedule driving and rest properly. Finally, they must be influenced to realize the importance of stopping when sleepy and to actually do this.

Where trips of 600 miles or more per day and driving continuously for 10 hours and more are undertaken (as in the western United States), awareness of the problem by drivers is of special importance. But very heavy, close schedules for truck and other commercial drivers within cities may also present similar problems.

LATER COMMENT

From Dr. O'Hanlon's presentation, it is noteworthy that he also found drivers showing increased frequency of "drifting in the lane" with increasing driving time (and probably fatigue). Thus his measured records of drifting confirm the observations in our previous smaller study and show this index to be useful in studying driver, vehicle and highway factors in fatigue on the road.

DISCUSSION

A multi-factor ergonomic study of accident causation explains why it has been difficult to determine precisely how much the factor of fatigue contributes to traffic accidents. Research on effects of rest stops, motivation and similar factors suggest possible countermeasures.

Neither of these approaches, of course, answers the very complex questions of what physiological and psychological factors are involved in development of and susceptibility to fatigue. That is another entire field of research to which many have contributed but which will require many more years of research.

However, for practical more immediate purposes, some of the research results reported above suggest approaches which can be helpful.

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A PSYCHOLOGIST'S VIEW OF DRIVING FATIGUE, ITS MEASUREMENT, AND POSSIBLE COUNTERMEASURES

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ABSTRACT

The approach adopted in this presentation follows Cameron's (1974) view that driving fatigue is readily explicable in terms of three well-known psychological phenomena: effects of sleep disruption, effects of emotional disturbance, and reactive inhibition. Thus, fatigue is "a generalised response to stress maintained over a period of time".

Sleep-loss and emotional effects are not dealt with here. Instead, Cameron's 'reactive inhibition' category of fatigue effects is extended to include a set of cognitive processes by which the human brain deals with overload and stress.

Selective attention is seen to be particularly vulnerable to prolonged driving. Research by Kahneman et al. (1973) and by Mihal and Barrett (1976) is described, showing that individuals scoring poorly in laboratory tests of attentional selectivity are overrepresented among accident-involved groups of 'bus and truck drivers, respectively. Discussion also centres on Goodenough's (1976) review of 'field-dependence' effects, showing that individuals who are less able to extract the salient cues from displayed information are also more accident-involved and drive less 'defensively'. It is proposed that both these individual differences will interact with time-on-task, therefore future research on driving fatigue may be sensitised by concentrating on field dependent individuals and those with poor attentional selectivity.

From a methodological and a practical point of view, it is seen to be important to study independently changes observed in performance related to time-of-day and to time-on-task. A field study is described which attempts to achieve this objective.

Some suggestions for environmental design to offset performance decrements caused by fatigue are briefly discussed.

INTRODUCTION

I have chosen to develop a rather narrow, speculative theme, which I will attempt to link to some of the findings reported by earlier contributors to this Symposium.

I can identify my theme by attempting to answer some of the questions which occur time and again in the literature on fatigue and which were specifically posed for us by the organisers of this Symposium.

One such question concerns the determinants of fatigue. Here, I find myself in agreement with Cameron (1974), who asserts that fatigue can be explained completely using the following three accepted psychological phenomena:

1. Reactive Inhibition. The tendency of an organism to discontinue responding to repeated stimulation.

2. Emotional Responses. Such as anxiety, aggression and so on.

3. Effects of Sleep Loss.

Once one has explained away effects related to these three phenomena, there is nothing left of fatigue, in Cameron's view, except to describe it as a generalised response to stress maintained over a period of time.

Now we have heard about the limited amount of sleep taken by professional truck drivers in Mr. Sandover's study. We have also heard from M. Hamelin and Mme. Lille of some socio-economic and psycho-social problems among drivers, which may predispose them to take sleep of poor quality and insufficient quantity. We have evidence that time-of-day, as well as time-on-task, are important factors in determining the effects of fatigue on driving performance. Clearly, both these factors are important for future research on fatigue and also for the design of accident countermeasures against fatigue. For example: any legislation on truck drivers' hours of work must take into account the distribution of their work-periods over the 24 hours of each day, as well as the total time spent working each day, in order to ensure that drivers have sufficient continuous sleep.

Regarding the second factor, the emotional component in fatigue effects: we have heard Professor Cullen describe some exciting developments in knowledge and methodology associated with psychoendocrine responses to stress. Personally, I regard these as the most promising development for fatigue research in recent years. There may, of course, be some aversion among potential subjects to the frequent blood-sampling currently required by the methodology. However, we must trust that the research reported by Professor Cullen will not all be in vein! If we could get these techniques accepted in field studies on the road, I believe we could begin to understand what coping with driving fatigue really entails, in terms of its physiological cost to the driver.

Turning quickly from these two areas of sleep deprivation and psychoendocrine responses, which are largely outside my field of interest, let me present as my theme, then, the third of Cameron's determinants of fatigue - reactive inhibition. But let us interpret this factor fairly liberally, and extend it to include a whole set of processes by which the human brain deals with overload and stress.

What happens when the driver is exposed to repeated, relatively unchanging demands? There is evidence (e.g. Hockey, 1970) that exposure of this kind lowers arousal and reduces the selectivity of attention.

This impairment of selectivity may show up in two ways:

1. The driver may cease to distribute his attention among various events in accordance with the objective probabilities that they will present information. Events of central importance may be given no more attention than peripheral events. On this effect alone, one could explain those single-vehicle accidents in which the driver ran off the road. The implication is that the fatigued driver is giving insufficient attention to the processing of steering cues.

2. The driver may demonstrate an increase in time taken to switch attention between events. Again, many accidents could obviously be explained on this effect alone.

However, it is one thing to have a plausible explanation of fatigue effects and quite another to show that they really are a source of road accidents, as Dr. Näätänän points out in his paper. Fortunately there is some evidence that selective attention may be implicated in road accidents. This evidence is provided by Kahneman and his colleagues (see Gopher and Kahneman, 1971, Kahneman et al., 1973), who showed that a poor inability to switch attention between sources of auditory information was correlated with flight proficiency among pilots and with a higher level of accident involvement among 'bus drivers. This latter finding has recently been replicated by Mihal and Barrett (1976) using a sample of 75 commercial drivers. (Incidentally, the latter authors also showed that this correlation was not just a function of individual differences in simple or choice R.T.).

I am therefore prepared to believe that prolonged driving can impair selectivity of attention via reduced arousal, and that this may result in a higher accident involvement. I will go further, and speculate that this is <u>the</u> important effect of psychological fatigue.

INDICES OF FATIGUE

It follows that I can now comment on another question posed for us by the Symposium organisers, regarding <u>indicators</u> of fatigue.

<u>Reduced attentional selectivity</u> is a meaningful and apparently important index of the fatigued state. How to measure it, unobtrusively, in the field is the next obvious question and we might talk about that in the discussion. Some of the techniques reported in Dr. Hieatt's paper may be useful

for the measurement of this index.

FUTURE RESEARCH DIRECTIONS

At this point I think I am ready to answer the third question posed for this Symposium, on the directions in which future research might be developed. My answer is, of course, restricted to suggestions for further research within the general area of attention and perception. I am not suggesting that there are no other potentially profitable lines of enquiry. I am simply restricting my suggestions to the theme I have selected for discussion today.

Given that reservation, I would suggest:

(a) That we give some thought to the problem of measuring breakdown in attentional selectivity, under real-life driving conditions on the road.

(b) That we research this topic in the context of a whole set of cognitive processes by which the human brain deals with overload and stress (for example: see Broadbent, 1977).

(c) That we look at the time-course of this breakdown and the way in which it may be determined by the structure of the driving task (see Robinson, 1975) and the environment.

(d) That we might also explore the many possibilities of restructuring the task and the environment in order to maintain appropriate levels of arousal and attentional selectivity among drivers. A start has already been made here, in relation to environmented design, by early work on devices such as 'rumble strips', which are supposed to maintain the driver's lane-tracking performance. Dr. O'Hanlon has described to this Symposium some of his own studies on alternative designs of 'rumble strips'. A more recent environmental device is the yellow bar pattern laid down on the road surface at the approach to some traffic islands in the UK and which is supposed to offset adaptation to sustained speed (see Denton, 1971, Rutley, 1975).

Within the driving task itself, there are possibilities for maintaining attentional levels by, say, converting some of the driver's visual demands (e.g. from dashboard instruments) to an auditory form. Or by requiring him to cancel a carefully graded set of 'artificial signals', displayed as changes in vehicle state on his dashboard instruments and indicator lights.

(e) That we need better evidence on the independent and combined effects of time-on-task and time-of-day on performance, before we are able to comment on driving fatigue and its possible countermeasures with any certainty. Here, I should mention a recent study by Folkard et al. (1976), in which they found that the function relating performance efficiency to time-of-day depended largely on the short-term memory load imposed by the task being performed. Only with a low memory load was there the usual positive correlation between performance and physiological activation. With a higher memory load the correlation was, in fact, negative, with performance being best for the night shift. This result suggests that time-on-task and time-of-day effects act synergistically to produce fatigue only if the driving task imposes little load on short-term memory. It also suggests that we could perhaps manipulate the driver's memory load (e.g. by the 'artificial signal' device mentioned in (d) above), to offset time-of-day effects on prolonged driving. A further, methodological, point made by the authors, is that the finding casts doubt on earlier suggestions (e.g. by Kleitman and Jackson, 1950) that performance efficiency may be inferred from changes in physiological indices. A final conclusion is that individual differences seem less important than task demands in determining the relationship between performance and time-of-day; contrary to Kleitman's (1963) suggestion.

Now let me turn to another potential index of fatigue, which is related to selective attention, and which requires to be studied further in my opinion. I am referring to the role of cognitive style in driver behaviour and accidents.

The best known dimension of cognitive style is probably field dependence. For the field dependent individual, perception is determined by the immediately given organisation of the stimulus field. The field independent individual is able to disembed the salient features from the display and his perception is thus less determined by the total field. This dimension of cognitive style is usually measured using the rod and frame test, the body adjustment test, or the embedded figures test. Goodenough (1976) has discussed some methodological problems associated with these tests and has developed some hypotheses concerning the differing responses of field dependent and independent drivers to developing emergencies. Clearly, if the field dependent driver cannot break down the component parts of a given road scene, he will be at a disadvantage when a change in one component constitutes a hazard, especially if the change occurs insidiously.

This idea has been tested out by Mihal and Barrett (1976), using their 75 commercial drivers mentioned earlier. As predicted, all three measures of field dependence they used correlated well with accident records obtained from the subjects' employers for the previous 5 year period.

Now, to my knowledge, field dependence has not yet been tested as an index of fatigue. However, there was a correlation between field dependence and selective attention among Mihal and Barrett's subjects, suggesting that field dependence might provide an index of susceptibility to driving fatigue, which would be extremely useful in identifying individuals at risk. It is interesting that field dependence was more strongly correlated with accident records for the drivers over 45 years old in Mihal and Barrett's study. I am tempted to connect this with the Harris and Mackie (1972) finding of a greater fatigue effect among their over-45 year old group. But that is speculation. Clearly we would need a specific study of field dependence and its implication in impaired performance under prolonged driving, before commenting further.

If I could just summarise my main points so far:

1. I think psychological fatigue is determined by sleep loss (or sleep disturbance), reactive inhibition and emotional factors; ranked in that order of importance for professional drivers.

2. I think we have selectivity of attention as a plausible index of fatigue, which has been shown to be associated with individual differences in road accident involvement. But further work is needed on the relevant methodology, to verify its validity and importance. The work reported here by Professor Michon on changes from 'attentive' to 'intentive' ocular-motor control among fatigued subjects seems to offer a promising line of research.

3. We have cognitive style as a possible index of individual susceptibility to fatigue. With the advantage that the relevant methodology is fairly well developed.

4. I would like to see some effort devoted to further validation of these indices, in the field.

5. I think we need to explore the relationship between selectivity of attention and specific task and environmental demands - with a view to the design of fatigue countermeasures involving manipulation of both the driving task and the environment.

6. I think we need to identify the independent effects of time-on-task and time-of-day on performance impairment among drivers. I also think we need to be extremely careful in our choice of research design in this complex area.

Finally, let me describe very briefly an experiment run by my colleagues Dr. Hunt and Mr. Copeman, which attempted to explore these independent contributions of time of day and time on task, to fatigue. I introduce this, not as an example of the ideal experimental paradigm, but to demonstrate the difficulty of running field studies on effects of prolonged driving and circadian rhythms, and to stimulate discussion of alternative paradigms.

The major difficulty in studies of these interacting variables is that one would like to compare the effects of prolonged driving during circadian increases in arousal with those during decreases in arousal. In real time, this usually implies a day-time versus night-time comparison which, on the road, confounds circadian variations in physiology with attendant variations in traffic load and ambient illumination, and hence in task demands. It would be possible to surmount this difficulty by inverting the circadian rhythm of one experimental group of drivers, to control for effects of traffic load and ambient illumination. However, this would be a costly exercise in the field, given the time required for acceptable inversion of circadian rhythms.

As an alternative, we designed an experiment to be run in daylight only. It required subjects in the experimental condition to drive a car for 10 hours in 4 x 2½ hour spells, with 30 minutes for a mid-day lunch break and with the morning and afternoon spells interrupted by a 10 minute break. This procedure was continued on two consecutive days, to explore any cumulative effects of fatigue. A control group of subjects travelled initially as a passenger in the car, which was driven by the experimenter for the first three 2½ hour spells of each day. The subject took over as driver only during the final 2½ hour spell. We were, of course, careful to run each subject as his own control on the same day of the week in either condition, to minimise effects of traffic load changes with day-of-week. We also ensured that the final 2½ hour spell involved driving over the same stretch of road, in the same direction, under both conditions. Environmental measures of vehicle internal temperature and humidity were recorded at 10 minute intervals. Physiological indices measured included body temperature and heart rate; the former sampled every 15 minutes, the latter every 5 minutes. Urine specimens were also collected during each break and later analyzed for corticosteroid excretion. Vigilance was sampled by presenting a signal-detection task at random intervals. The target was a star-shaped light signal, presented by a head-up display, to appear at eye level some 300 m. ahead and slightly to the left of centre. (It simulated the position which might be occupied by a road sign, but its shape was designed to be non-confusing with symbolic road signs.) The subject responded by depressing a level switch close to his left hand.

This paradigm should allow us to establish a circadian rhythm of physiological arousal for each individual, under conditions of prolonged and short-term driving. Correlations between these rhythms and time-of-day effects on performance can then be explored, across the subject group. Intra-subject comparisons between the final 2½ hour spells in the two conditions should allow us to identify any additional effect of time-on-task. Since subjects were exposed to the same levels of noise and vibration in both experimental and control conditions, effects of time-on-task will clearly be a function only of performing the task. Any findings here will thus be pertinent to questions on the relative merits of 'relay' and 'sleeper' operations among long-distance truck drivers (see Harris and Mackie, 1972).

In view of the post-lunch depression in vigilance noted by some earlier investigators of prolonged watch-keeping, I should mention that we attempted to explore possible causal factors here, related to digestion, by giving half the subject group a high-protein lunch and half a high-carbohydrate lunch. Soft drinks were provided throughout each condition of driving. Thus there was total control of the subjects' diet during the test periods.

It is premature to comment on the findings of this study. As I said earlier, I mention it now to indicate the variety of possibly interacting and confounding factors which researchers on fatigue must control systematically, if interpretations of their data are to be made with any degree of validity. In determining future directions of research on fatigue, I think we have to accept that most of our studies will be compromises between the rigorous demands of scientific experimentation and the need to maintain face-validity by unobtrusive testing of relevant subject populations under realistic task and environmental conditions. Each of us will have his own priorities when attempting this compromise, but I hope that by airing these differences of opinion in our past and future discussions we will at least have provided some kind of decision structure, within which our various methods and findings may be evaluated.

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PSYCHO-BIOLOGICAL ASPECTS OF FATIGUE

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ABSTRACT

"Fatigue", in common with many very real and important phenomena of human life, is at the scientific level of discourse an ill-defined and complex theoretical construct without internationally agreed parameters. Psychosocial components might include the following:-

Subjective states.

Performance measures.

Motivation levels.

Learning factors and stereotyping of response patterns.

Skills and experience.

Personality factors.

Insight and compensatory strategies.

Mood fluctuations and clinical or sub-clinical psychopathology.

Life-style, life-events and stress in living or working conditions.

The list is by no means exhaustive. The variety of theoretical approaches in psychological thinking would embrace old and new ideas from both experimental and clinical fields. New theoretical constructs becoming popular with workers in the psychobiological area, for example, the concept of "coping strategies" and "learned helplessness" may have value in approaching a reconciliation of psychological and biological data.

The physiological components in fatigue are many and varied. They include accumulation of metabolites, changes in metabolism, dietary factors, fluctuations in physiological response thresholds, psycho-endocrine factors and intercurrent

pathology. The contribution of sleep to the offsetting of fatigue and its effects on stress loadings may be a promising area for study using new techniques just recently becoming readily available and convenient to use.

INTRODUCTION

"Fatigue", in common with many other very real and important phenomena of human life, is at the scientific level of discourse an ill-defined and complex theoretical construct without internationally agreed parameters. Perhaps its very familiarity and immediacy to us all in our every day life helps to blind us to the very real need we have here for semantic surgery. Similar problems beset terms like "Stress", "Arousal", "Anxiety" or "Aggression". The variables we try to control and manipulate in studying fatigue are common to all of these constructs. The problem is that human behaviour even at its worst is extraordinarily unitary, with an interaction of functions that provides for exquisite adaptability and many alternative options for adequate responding. I think Dr. Naatanen, who is to follow me, will emphasise this point.

In my pre-circulated summary I tried to itemize some of the classes of variables that would have to be taken into account and I will try now to give some comments on them.

(1) Subjective States

The obvious phenomena here are the altered states of consciousness associated with perceptually and sensorily monotonous driving tasks. These have been adverted to as long ago as the 1950's or earlier by Moseley and other workers. There are less obvious phenomena associated with the presence or absence of subjective awareness of levels of performance or deterioration in skill or responsiveness. This whole area has relevance for psychobiological factors, as well as for cognitive function, because coping ability may depend on reading bodily cues appropriately. In psychosomatic research ways are sought through "biofeedback" techniques to improve this kind of awareness. Perhaps a sharing of techniques here might help towards the development of some kind of early warning device for drivers. The problem is, of course, to select appropriate biological transducible indicators of fatigue. I do not think we can select these yet, but fast progress is being made. A further problem is that generally applicable physiological tolerance levels would not be possible to specify and personalized calibration might be required.

(2) Performance Measures.

Similar problems in selecting appropriate indicators for "feed-back" to drivers exist here. Partly this arises from the difficulty of validating the extrapolation of laboratory measures of psychomotor skills to real-life driving situations. Even more important is the difficulty in weighting the contribution which personal coping styles, or the level and quality of motivation, may give to a particular driver's ability to offset the bad effects of potential losses in performance factors. And, of course, in real life these may be available to him in different degrees at different times.

(3) Motivation levels are profoundly influenced by mood, and mood and affect are subject to endogenous metabolic changes as well as environmental factors. The mood changes may be clinical or sub-clinical. How do we screen for these or even manage the medico-legal or trades-union aspects of early detection. Education of the driver in self-monitoring and in awareness of the effects of inter-current life-events may make an important contribution here.

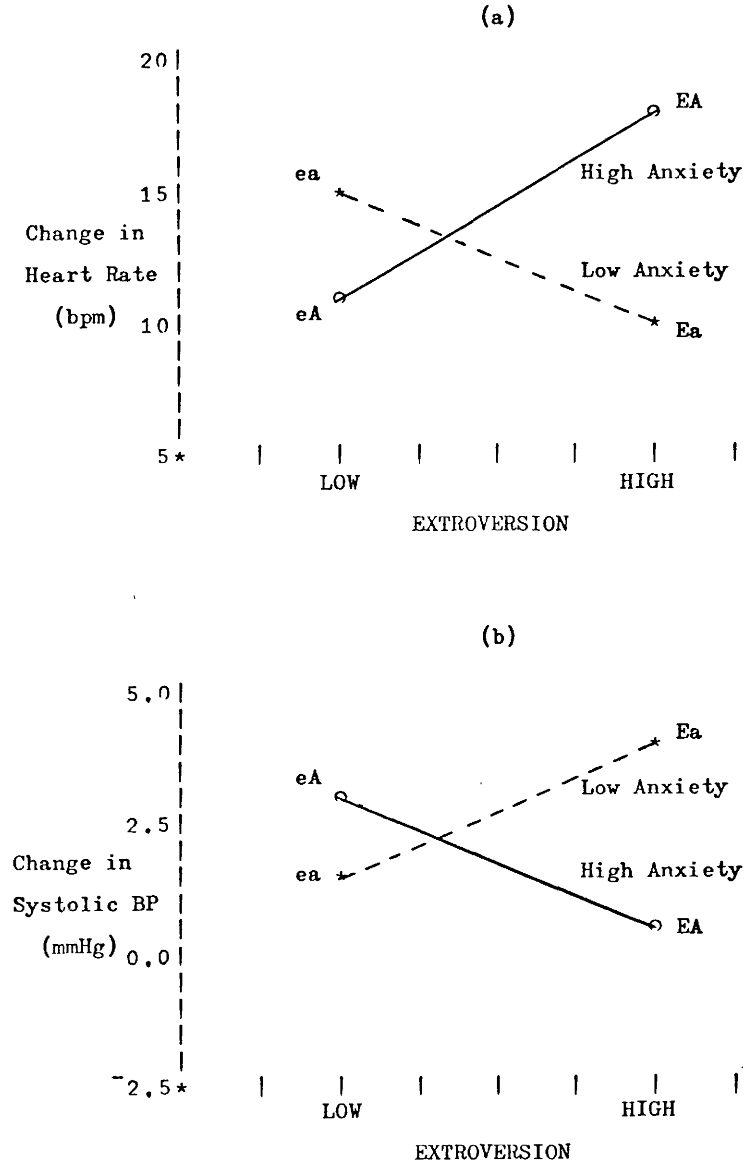
(4) Learning factors and stereotyping of response patterns.

Stereotyping and perseveration of inappropriate patterns, as performance breaks down under stress or fatigue, has been reported as long ago, at least, as the 'Pilot Error' experiments of Russell Davis in the Cambridge Cockpit. More recent psychobiological evidence points to the involvement of a stress hormone, ACTH, in this kind of phenomenon. Short chain polypeptide fragments of ACTH (e.g. ACTH 4-10) have been shown by workers like De Wied and Rigter in Holland to enhance the acquisition and permanence of learned avoidance responses. Avoidance learning in stress psychopathology is usually specified by context, but it is clearly a more generic type of learning in the adaptive repertoire and frequently leads to stereotyping of responses or a marked decline in coping responses (e.g. "freezing"). This type of outcome is obviously a potential contributor to failure in a difficult psycho-motor situation e.g. in driving, where high levels of ACTH may be evoked in a prolonged and stressful task.

(5) Skills and experience may have offsetting advantages if there is a risk of some of the factors I have been discussing tending to arise together. Our experimental evidence in this area could be much enhanced by better hypotheses taking more cognisance of the habitual coping response patterns of different types of driver.

(6) Personality factors obviously contribute both to motivation and to mood changes. Some work by M.H. Parry suggested that the concomitance of anxiety and agression lead to markedly increased accident risk in the driving situation. This work has not been followed up by him. However, the personality factors elicited in the test instruments usually used have a marked bias towards interpersonal skills and behaviour patterns. They do not give much information on psychomotor or similar adaptive potential under extreme conditions such as stress or fatigue. More recently however, some data from my own laboratory presented a few weeks ago at the Eleventh European Conference on Psychosomatic Research in Heidelberg seemed to show quite profound differences in physiological responses for different personality types on the 16PF. Anxious extroverts showed a preference for heart rate rather than blood pressure responses to rapid forward tilting as a postural change. (See Figure 1.) How these habitual biological coping patterns relate to physiological competence in fatigue or to conditions of acceleration or deceleration in the driving situation remains to be explored. We have found however, that training e.g. in athletes may override personality factors. A useful review of some of these problems has been published by Obrist earlier this year. (Figure 2.)

Figure 1.



	PASSIVE COPING	ACTIVE COPING
HEART	VAGAL	SYMPATHETIC
BLOOD PRESSURE	VASCULAR (Diastolic)	CARDIAC (Systolic)

(After OBRIST 1976)

Figure 2.

(7) Insight and compensatory strategies will be discussed by the next speaker, but perhaps in a different language frame. I have referred earlier to subjective states which may be a component of insight. These may help to elicit compensatory strategies in psycho-motor performance under fatigue. My clinical experience tells me, however, that insight has a very vulnerable and vicarious presence. Fatigue may contribute to the loss of insight.

(8) Mood fluctuations and clinical or sub-clinical psychopathology is perhaps best discussed using depression as a paradigm. Recent work by Seligman looks on depression as a kind of "learned helplessness". It can occur in situations where stress is continuous and unavoidable or more precisely, outside the control of the subject. For example, there is distortion of the perception of control and difficulty in learning that a response has succeeded even when it is actually successful. Human subjects exposed to inescapable noise developed a negative cognitive set in which "they treated their successes and failures in a task of skill just as if it had been a task of chance in which their responses didn't matter". This kind of outcome occurs in more or less the same type of stressful environmental context in which we experience fatigue although the time scales may be different. These profound distortions in evaluating a situation may make for serious miscalculations in "risk-taking" by drivers.

(9) Life-style, life-events and stress in living or working conditions have all been explored in recent times in a more scientific way. The work of Richard Rahe and others using life-events inventory ratings has shown how these exogenous factors may contribute to breakdown of psychobiological coping in almost every way we can describe including accident risk and incidence. It may be that some of these approaches can contribute to a better understanding of psychosocial factors outside the immediate driving situation.

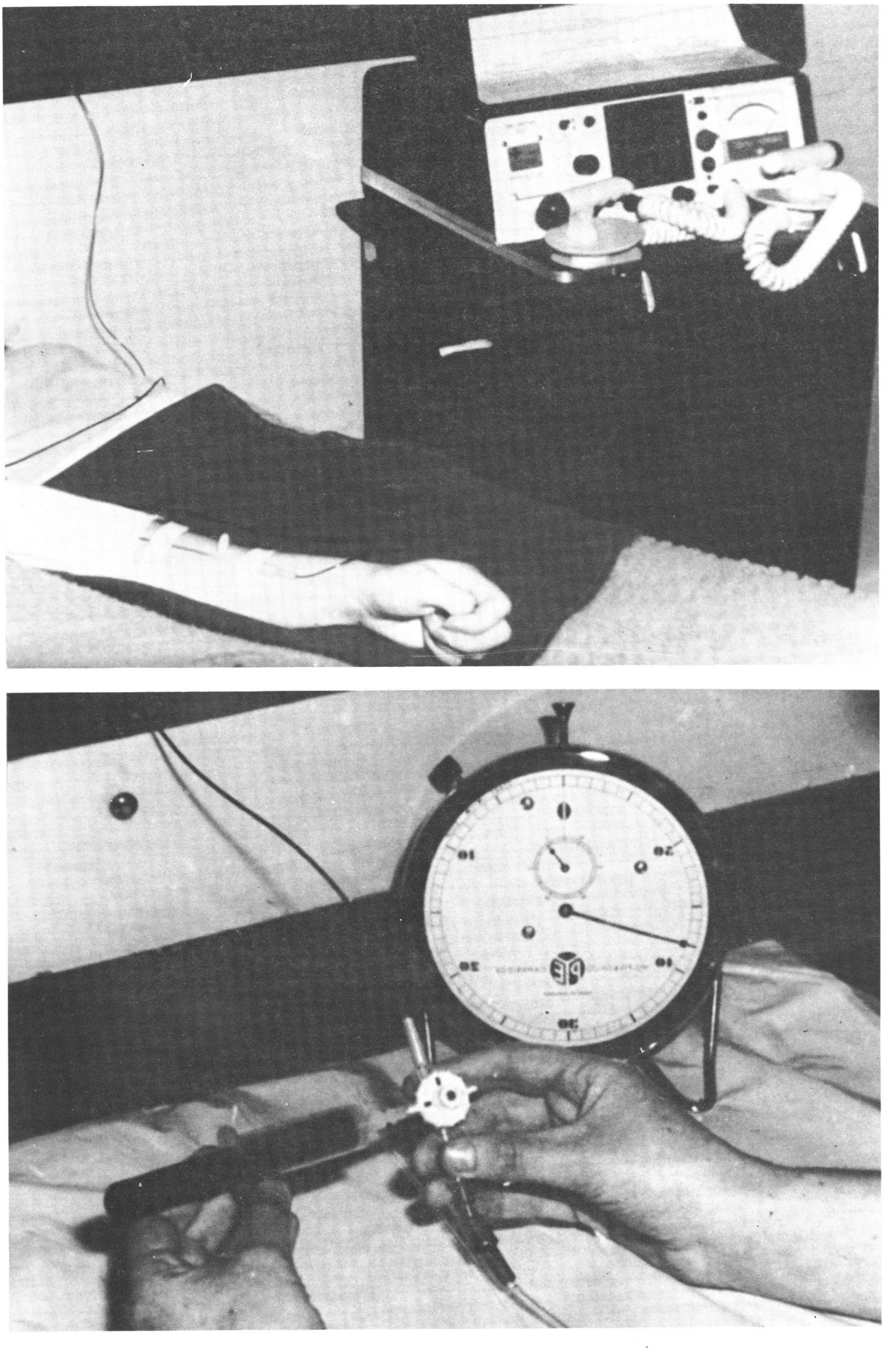
There are so many possible psychobiological factors in the stress-fatigue syndrome that it is not possible to review them here. The summary report of the E.E.C. Workshop on

Psychobiological Factors in the Breakdown of Driving Skills, gives an account of some of these.

I would like to describe briefly some recent work going on at our Psycho-endocrine Unit, in a research programme on sleep and changes in hormone profiles. Dr. Austin Darragh, who is directing this work has developed a new blood sampling procedure in collaboration with the biomedical company of Braun. (Figure 3). It is essentially a much improved intravenous cannulation technique for continuous sampling of blood for hormone assays. It has proved so well tolerated by human subjects that we have conducted many twenty-four hour sampling schedules at half-hourly intervals and the subjects have slept well during the night hours. Recently we have added EEG monitoring for correlation of the well-known phases of sleep with the hormone assays. A useful review of sleep endocrine and EEG studies in man has been published by Rubin and Poland this year. Dr. Darragh's findings explore many of the complex relationships between hormone levels and the different phases of sleep. The effects of various commonly used pharmacological agents, for example, the minor tranquillizers on these patterns have been studied. Some of these substances have a profound effect on endocrine parameters which enter into processes of learning, memory and the setting of arousal levels.

Now, if we consider sleep as in some ways a contributor to lowering pre-sleep stress and fatigue levels, or at least to contribute e.g. through the diurnal cortisol rise to arousal levels which enhance performance (cf. Pearlman, 1976), then the quality of sleep in hormonal terms will have to be scrutinized more carefully. Perhaps in this way we may understand how fatigue and arousal are counterpoints in our daily lives. Dr. Ray Fuller and I have commenced in Dublin a collaborative study on the effects of hours and schedules of work on HGV driving performance and we have introduced blood sampling from the drivers for hormone assays in our laboratory. The first phase of this work has now been completed, and interesting hormonal findings have been made. They show that older drivers on late shifts incur a greater endocrine cost in

Figure 3.



the driving task. They may fare better than younger drivers during the day.

I have only been able, briefly, to attempt to give you the flavour of the more dynamic thinking nowadays in the psychobiological field. I think it is a real advance on the older static rank correlations of biological and psychological phenomena and is full of potential for experimental elucidation of some of the problems in the stress-fatigue syndrome.

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DROWSINESS IN DRIVING

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1. THE PHENOMENON

This study is part of the story of fatigue as a factor in road safety. You may consider it as a study on micro-fatigue: it deals essentially with the phenomenon of drowsiness which may take possession of a driver, suddenly and unexpectedly. This brief shift in alertness -- ranging from a few seconds to a few minutes appears to be quite common. Between 80 and 90 percent of the normal driving population has the experience more or less regularly.

Drowsiness is characterized by its fairly sudden onset. It entails a loss of attention which is often subjectively conspicuous, and it is extremely difficult to suppress. While being drowsy, however, the driver can still perform rather coherently; he is not at a complete loss, and most of the time he will stay sufficiently awake to perform the relatively automatic aspects of the driving task quite adequately.

The phenomenon has been given various names that describe it more or less adequately and at the same time seem to suggest an explanation: highway hypnosis, Sekundenschlaf, polder-blindness. It appears safer, however, to stick to the more neutral descriptive term drowsiness.

Since the experience is judged by most drivers, to be potentially hazardous, we may ask if, indeed, drowsiness is a factor in accident causation. Dr. Forbes, in his contribution to this Symposium has quoted some interesting figures which suggest that in at least 13 percent, and maybe even in as much as 20 percent, of the single vehicle car accidents drowsiness or dozing is a determining factor. Some authors (e.g. Roberts, 1971) go even as high as 30 percent.

2. EXPLANATIONS?

2.1. Fatigue

The drowsiness phenomenon has been studied in several investigators and a number of explanations has been proposed. McFarland (1954), for instance, attributed the phenomenon simply to fatigue. There is little doubt that fatigue may cause the driver to fall asleep at the wheel, but it cannot be the only, or even the most important determining factor since drowsiness may also occur when the subject is well-rested and when he has not performed any exhausting activities in the preceding period. It may also occur when the driver has not suffered from loss of sleep at all.

2.2. Hypnosis

A second type of explanation, put forward originally by Williams (1963) is that monotonous driving situations will induce a hypnotic trance in the driver. This explanation raises two objections. First, monotony can not be a prominent factor since drowsiness may be observed when driving in a highly variable situation or even in dense traffic. Secondly, the explanatory value of the concept hypnosis is low: we still do not quite know what hypnosis is in terms of information processing and motivation. Some recent research suggests, for example, that hypnosis may be likened to a "social contract": the subject voluntarily agrees not to process certain stimuli. Possibly, therefore, the hypnosis theory of drowsiness would not survive the application of Occam's razor.

On the other hand, it has been demonstrated by Williams (1963) that if one takes hypotized subjects on the road, they will be quite well able to perform in an "appropriate" way. It is unknown, unfortunately, how far Williams went in confronting his subjects with difficult traffic situations.

2.3. Narcolepsia

One rather interesting explanation has been proposed by Roberts in his book on traffic safety (Roberts, 1971). He suggested that the drowsiness phenomenon derives from a narcoleptic disposition, comparable to the lapses of consciousness diabetics may suffer. Roberts even proposes the highly suggestive name: hyperinsulinism.

As is said this is an interesting suggestion but unfortunately (or rather: fortunately) narcolepsy is a very rare psychiatric condition, occurring mostly in stressful situations. What Roberts hypothesis actually implies is that some 90 percent of the driving population is essentially narcoleptic, which seems a bit far fetched. Also, drowsiness is not likely to occur in really stressful situations on the road, which practically rules out the narcolepsy theory altogether.

2.4. Information processing

In the studies about fatigue and mental load carried out at the Traffic Research Center of the University of Groningen, we have found it necessary to take an entirely different look at the drowsiness phenomenon, by considering it as a rather straightforward and normal consequence of the information processing task that must be performed by drivers.

Before going into more detail, however, I wish to summarize the arguments that have led us in the direction of information processing as an explanatory concept.

1. Drowsiness may occur in situations where no sleep shortage or other detrimental organismic dispositions can be traced.
2. Drowsiness may occur without any adverse environmental condition such as heat, or loud noise, or a stuffy atmosphere in the vehicle.
3. When drowsiness sets in, it is not easy to overcome by conscious effort. Neither will advance warning, or instruction, suppress the effect.

Although each of these factors may contribute to the onset of drowsiness, they do not constitute a sufficient reason for the phenomenon to occur. This effectively rules out three of the four types of variables that may influence human task performance: organismic, environmental and instructional variables. And it leaves us with the fourth type of variable: task variables that specify the structure of the task at hand (see e.g. Mulder, Michon and Moraal, 1978). In short, we feel that, perhaps, drowsiness is something that has to do with the nature of the driving task and the type of information processing that is required of the driver.

The theory and the experimental work which underlie the following three points have been the work of Alexander H. Wertheim (now at the Institute for Perception TNO, Soesterberg, The Netherlands) at the Traffic Research Center. His findings will shortly be published as his Ph.D. thesis. A somewhat detailed report of some of the experiments may also be found in Wertheim (1978, in press). The study was made possible by a grant of the "Preventiefonds" to the author.

3. ATTENTIVE AND AUTOMATIC OCULOMOTOR CONTROL

The first distinction that should be made in the information processing apprach to the drowsiness problem is between what we now call attentive oculomotor control and automatic oculomotor control. The basic proposition is that drowsiness has to do with the attention drivers pay to the proces of steering or regulating their eye movements. The two types of oculomotor control are schematically illustrated in Figure 1. The diagram shows the eye with its afferent pathways leading up to the visual centers. These in turn process the information and, if necessary, activate the motor units that will trigger the eye muscles through efferent pathways and thus generate observable eye movements, orienting the eye relative to the source of information. This information loop will remain closed as long as the eye movements are indiced directly by the information requirements of the task and this closed loop processing mode is what we call attentive control.

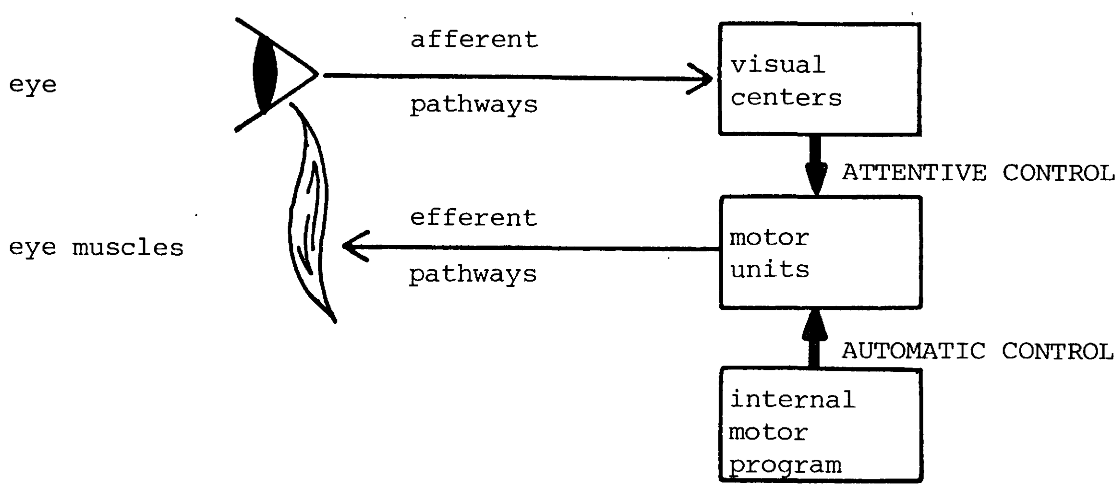

Figure 1

Attentive oculomotor control is, in fact, one observable consequence of what is called the controlled mode of information processing (e.g. Shiffrin and Schneider, 1977; Schneider and Shiffrin, 1977). This mode is relatively slow, serially organized and it is capacity limited. It will be in operation if the visual input is either unpredictable or unfamiliar, i.e. if the person has no innate or learned strategies or "schemata" avaiblale -- perceptual or cognitive -- to cope efficiently with the situation (Neisser, 1976; Turvey, 1977).

When, on the other hand, the subject has, genetically or by learning, the appropriate schemata for understanding and responding to a situation -- in other words: when he has to cope with a situation that we call predictable-- then the necessary degree of attentive oculomotor control may become less, and the control of eye movements is transferred to some internal, automatic oculomotor control mechanism.

4. LABORATORY EXPERIMENTS

The studies that have been carried out thus far are essentially laboratory experiments, and still the necessary final step must be made, i.e. taking our subjects out on the highway. Right now and here, therefore, the experimental results should not be generalized to the actual traffic situation without acknowledging that such a generalization is highly speculative.

In the experiments subjects were seated in front of a screen on which a small circular spot of light was projected, approximately 1 deg in diameter. This spot would move along either of two trajectories and the subject was required to keep his eyes focussed on the spot as it moved. In the first condition the spot would describe a simple circular path, continuously repeating the same trajectory at a constant rate. In the other condition the spot would describe a quasi-random pattern of connected circular arcs, also at a constant rate. This constituted a highly unpredictable trajectory which is difficult to follow with the eye.

By means of these two patterns of target movement it is possible to evoke automatic vs. attentive eye movement control in the subject. Of course the two conditions do not necessarily each evoke one of the control modes in its pure form; they only create a situation that is favorable for the occurrence of one mode rather than the other.

5. THREE FACTORS IN DROWSINESS

From the results of a series of experiments using the procedure described in the preceding section, three factors may be derived that appear to be relevant for an explanation of the drowsiness phenomenon.

5.1. Allocation of Attention

It is commonly assumed that attentive information processing requires effort and absorbs some of the (limited) processing capacity of the subject, whereas processing capacity under automatic control conditions is practically unlimited as no effort is required. By the same token attentive oculomotor control will require effort, whereas automatic oculomotor control will not.

The information required for eye movement control is intrinsically visual since the eye muscles do not provide the appropriate feedback information. Therefore the theories that have been advanced to account for the fact that the world around us remains stable when we move our eyes, have been based on the assumption that the brain will somehow set up a prediction about the way the visual field should look after the eyes have moved to their new position. This predicted state -- variously called efference copy, reafference copy or corollary discharge -- is then matched with the actual position of the visual environment on the retina and any mismatch will then lead to a further correction of eye positioning (e.g. Holst and Mittelstaedt, 1950; Sperry, 1950). In our opinion it is this matching operation which is requiring attentional effort, and this implies that this effort is spent on the processing of positional or orienting information.

In view of the commonly accepted idea that the amount of attentional effort that may be spent is limited, the upshot of the preceding argument is that in the condition of attentive oculomotor control there will be less effort available for the processing of other, i.e. non-spatial, visual information. This latter type of information we shall call categorical; in actual traffic it would include, among other things, road signs, traffic lights and other vehicles. In the present series of experiments it is restricted, however, to alphanumeric symbols displayed in the moving circular target.

While the target disc described its circular or random path, and while the subject was tracking the target visually, a symbol would appear suddenly at irregular times in the center of the target. The subject's task was to identify the symbol as quickly as possible and to react immediately. When the subject was tracking the irregular target movement and when he had his eyes well on target, the observed reaction times turned out to be much longer than when the task was to track the predictable target movement, or even when the symbol was presented in a stationary target.

These long reaction times -- see Figure 2 -- are not attributable to a greater difficulty of discriminating the symbols in the unpredictable condition: the symbols were shown only at moments when the subjects' eyes were indeed on target. The only factor to which the observed difference in reaction time can be ascribed is the difference in attentive effort spent in the predictable and unpredictable target movement conditions.

Here we may have a first important factor related to the drowsiness phenomenon. If drivers have entered into the state of automatic oculomotor control, they may still react faster to relevant categorical information (objects, signs) in their visual field, if only when they happen to notice them, which may be less likely than in the attentive control state. This may be the cause of the frequently observed panic, or startle reactions, such as hard braking or exaggerated evasive manoeuvres. Moreover, his abili-

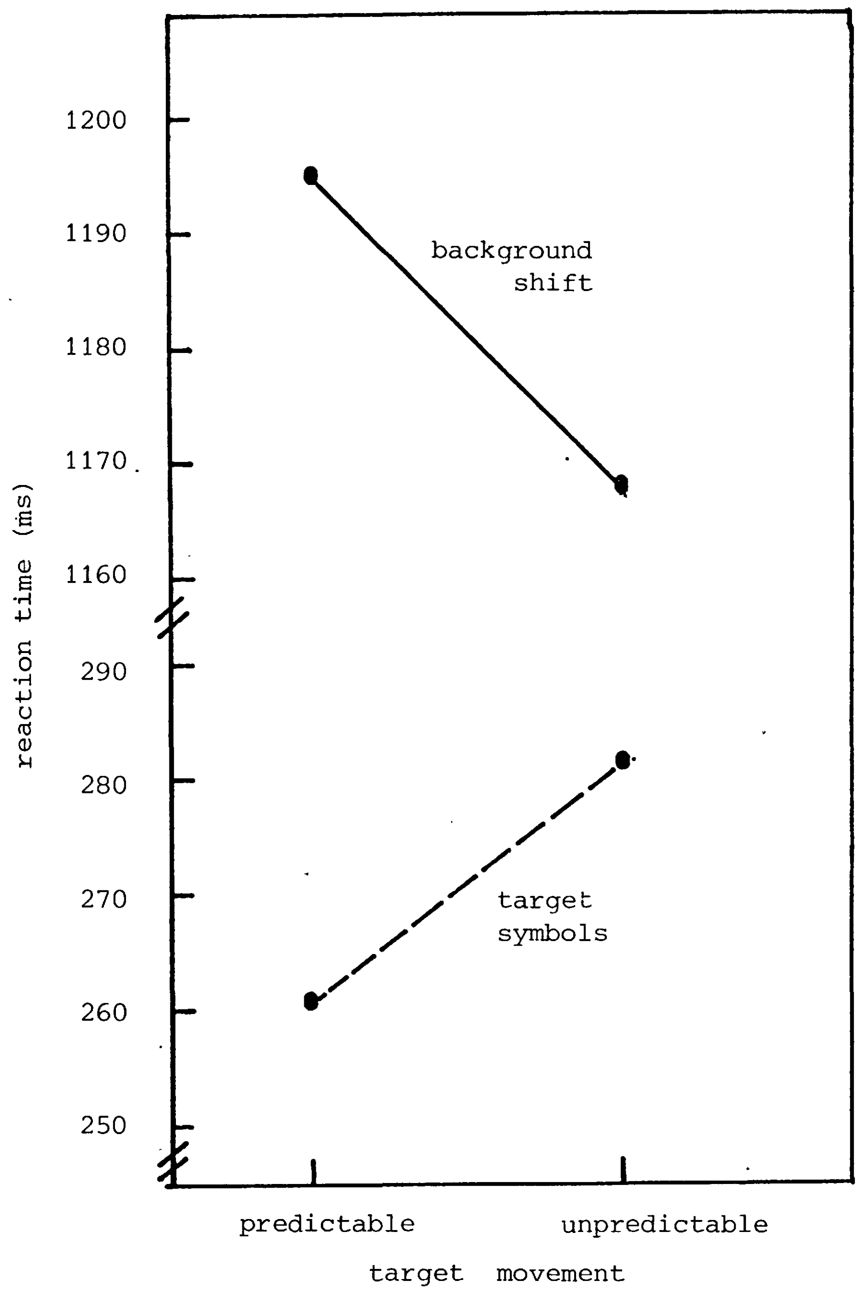

Figure 2

ty to react fast may give the driver a false feeling of being alert and capable of adequate performance.

5.2. Lowered Arousal

The occurrence of relatively fast reaction times may be explained by the extra attentional capacity that becomes available under automatic oculomotor control. At the same time however, the drop in spatial information processing which characterizes this automatic control condition may in itself cause a considerable reduction in arousal. In fact this arousal decrement is supposed to be the principal determinant of the drowsiness phenomenon.

We have obtained a psychophysiological estimate of the arousal level of our subjects by measuring the occipital alpha rhythm in their brains. During the visual target tracking experiments the amount of alpha-energy was measured, and a considerable effect of the predictability of the target movement on this measure was observed. In the predictable target condition alpha deblocking is very likely to occur. As a result, the subject in such a situation is running an increased risk of entering into a state where he will start producing even slower EEG-waves, which would be indicative of drowsiness, or sleep.

This result, in connection with the relatively fast reactions in response to the information in the target disc, suggests that the loss of arousal and the onset of drowsiness are indeed more related to the processing of the information that is necessary for oculomotor control than to categorical information processing, such as reading symbols or perceiving road signs.

5.3. Corollary Matching

A third aspect of the experimental situation in which the subjects were put, brings us back to the visual feedback of positional information. A mismatch between the momentary input and the predicted input (the efference copy or corollary discharge) will normally, i.e. under attentive control, lead immediately to a corrective eye movement. When, however, the subject is in the automatic control state even relatively large mismatches might go unnoticed.

This condition was created experimentally by introducing a dim dotted background behind the moving target disc. At random moments this projected background would start moving away from its original position, slowly but steadily. This artificially creates a mismatch between predicted and actual retinal location and should therefore lead to immediate detection.
As a matter of fact this did indeed occur in the unpredictable target condition, but not in the predictable condition -- see Figure 2. In the latter case reaction times were considerably longer, even though in this case the background shift should be much more easily detectable, as this shift is superimposed on a much less complicated target movement pattern than in the

unpredictable target condition.

This effect is, in our opinion, the third contributing factor to the drowsiness phenomenon. In terms of vehicle control this effect may cause the driver to deviate very gradually from his intended course, without noticing, and even swerve off the road. Under automatic oculomotor control he may be late in detecting the growing mismatch between his intended and his actual path.

6. CONCLUSION

I have discussed three factors which, in our opinion, are crucial constituents of the drowsiness phenomenon. Experimental conditions which bring out the distinction between attentive and automatic oculomotor control are likely to create the following effects:

- -- a difference in reaction speed which favors fast reactions in a state of lowered attention. This effect occurs when the subject is responding to categorical information but not when he is responding to positional information. The effect may contribute to panic reactions and false judgments about the driver's momentary state of alertness.
- -- a difference in arousal. Lowered arousal will occur particularly under highly predictable visual input which is facorable to the onset of automatic oculomotor control and may induce sleep symptoms in the electroencephalogram, as well as in behavior.
- -- a difference in the speed at which a mismatch between intended and actual visual orientation is detected. The result may be a marked loss of lane keeping behavior.

Each of these three effect may considerably enhance the potential hazard of driving under highly predictable circumstances.

Further experiments, particularly on the road in actual traffic conditions need to be carried out. Moreover it is not yet clear what measures can be taken to overcome the drowsiness phenomenon. If the external visual information can not be modified sufficiently, the only suitable strategy is to stop along the roadside to re-establish attentive control. The findings reviewed in this paper also suggest, however, that the popular policy of traffic engineers to increase the homogeneity -- i.e. the predictabiliy -- of traffic flow and traffic environment will have its limits of usefulness, and may be altogether without hazard.

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ON THE EFFECTS OF PROLONGED NIGHT DRIVING*

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ABSTRACT

The experiment to be reported was aimed at clarifying the effects of prolonged night driving. Subjects in one condition carried out a continuous driving task during the night which was preceded and followed by a short drive, while in another condition subjects only carried out the pre- and post tests and slept in-between. The results showed considerable decrement in driving performance (a.o. increase in lane drifting) and performance on two subsidiary tasks, while heart rate, although decreasing during the drive, could not be directly related to fatigue, but was also influenced by adaptational effects.

INTRODUCTION

This experiment was specifically aimed at isolating the internal process of fatiguing of the driver during very long driving. This objective of the experiment necessitates that the influence of the environment is constant during the task and this was reached by driving at night on a motorway. Demonstrating effects of fatigue on performance has been a challenge to many authors, but in spite of all the effort invested in research, generally the results have been inconclusive. This state of affairs may be partly due to the considerable variety in approaches to the problem. A large distinction can be made between studies with before and after tests and experiments with continuous (performance) measurements during the task itself. Phenomena as short-term mobilization of effort, adaptation and inadequate matching of the before and after tests with the fatiguing task often render results of before- and after studies obsolete.

In studies with measurements during the task itself, a further distinc-

*A much more complete discussion of this experiment can be found in: "Vigilance: Theory, Operational Performance and Physiological Correlates". Robert R. Mackie (Ed), London: Plenum Publishing Company Ltd., 1977. This text is an earlier condensation, forming part of: Fatigue and Stress Due to Prolonged Driving and Changing Task Demands, J.B.J. Riemersma, P.W. Biesta, C. Wildervanck, SAE paper 770134, 1977.

tion can be made concerning the type of measurements. At least three types have been reported:

1 Continuous measurement of performance and/or physiological variables. Results have not been encouraging in demonstrating specific fatigue effects or declining arousal. For example, Harris and Mackie (1972), in a laborious field experiment regarding bus and truck drivers could not demonstrate significant effects of prolonged driving on behavioral indices (steering wheel reversal state, lane drifting), while on the other hand mean heart rate consistently declined with prolonged driving.

According to common sense, if there is such a thing as performance decrement due to fatigue, or decline of arousal, it should not be limited to the initial phase of the work period as was the case in many laboratory studies (Teichner, 1974; Sanders et al., 1970). In driving studies such initial effects have been found a.o. by Ellingstad and Heimstra (1970) in a simulated driving task.

2 Subsidiary tasks. Other authors (Risper et al., 1971) have tried to evaluate fatigue by means of a subsidiary task used as a secondary task. The logic behind the use of a secondary task is the "spare mental capacity" concept. In studies of fatigue it is assumed that during prolonged driving, drivers will increase effort to maintain constant performance and hence their spare capacity will be reduced, causing a degradation of performance on the secondary task. One of the difficulties with this type of measurement is, that in the experiment there should be a control, if the secondary task is not used contrary to instructions as a primary or loading task. In that case reduced total capacity will be reflected in performance decrement, not in the subsidiary task but in the main task. So, concurrent measurement of both task performances seems necessary.

3 'Critical incident' studies. These studies, as opposed to the aforementioned studies, are concerned with the more complex decisions drivers have to make, such as to overtake. Laboratory studies, a.o. on the effects of lack of sleep, show that it is difficult to find clear-cut fatigue effects on complex decisions. Brown et al. (1970) however, did find that the frequency of risky overtaking, as assessed by on-board raters, increased during 12 hours of driving.

A further reason why many of the studies on fatigue have been so disappointing is the existence of factors which can counteract effects of time-on-task, and which should be, but have not always been taken into consideration (Brown, 1967). Our first experiment is designed such that the effects of time-on-task and the possible interaction of other factors (monotony, diurnal rhythm, and sleep loss) are all converging in the same direction. Furthermore, measurements were taken during the long night driving, as well as during before- and after tests. Critical incidents were taken into account, but the experiment was not aimed at them specifically. Two subsidiary tasks were used. They were however not used as a secondary task, but had more a vigilant-type character.

APPARATUS

In this experiment an instrumented car was used (a Volvo 145 Express). This car enables continuous measurement of heart rate, lane positioning, steering wheel reversals, velocity and longitudinal acceleration. The lane position can be measured by a special device, which scans for brightness differences on the road surface (Burry et al., 1972). In both experiments heart rate was measured by fitting chest-electrodes and digitally stored as beat-to-beat intervals in milliseconds. All data are recorded on magnetic tape.

Besides, the instrumentation enables the synchronous recording of special events like overtaking, being overtaken and the like, through a portable keyboard. These recordings can be used to exclude invalid data from analysis, or as trigger points for special event-related analyses. In general, two experimenters (E) are present during experiments. One E is responsible for the measurements. The other E, sitting next to the driver, operates the keyboard and is also able to stop the car in case of emergencies.

These hardware facilities are complemented with a large package of programs for analyzing the analog and digital data. The main types of analysis are frequency-analysis and analysis of variance procedures.

Method

All night driving tests consisted of driving a triangle of four-lane motorways with divided traffic lanes, comprising a total distance of about 56 kms. The drivers were instructed to maintain a speed of 90 km/h. In this experiment continuous measurements were taken of lane positioning, speed, steering wheel deflections and longitudinal acceleration. As physiological indicators heart rate frequency and heart rate variability were measured.

Subsidiary tasks

Concurrently with driving, subjects (Ss) carried out two subsidiary tasks. In the first, Ss had to keep track of the kilometrage, reporting each occasion the counter reached a multiple of 20. In the other task Ss reacted to changes in color of a light mounted on top of the dashboard, occurring at intervals varying randomly between 0.5 and 4 minutes, by pressing the button normally used for the horn.

Procedure

Always, two subjects were involved in each experimental day. In the afternoon each S had practice runs of about two hours, after which, in the evening between 20.00 and 21.30 p.m., both carried out a pre-test, namely driving the experimental route (56 kms) once. Then, one S went to sleep in a caravan, while the other drove the route 10 times between 22.00 p.m. and 6.00 a.m., interrupted at about 2.00 a.m. for fuel intake and shift of E's. At 6.00 a.m. both Ss had breakfast, whereafter each of them carried out a post-test, again driving the experimental route once.

After minimally one week both Ss returned to complete another experimental day, on which the S who had slept first, now did the driving and vice versa.

Subjects

12 Students from the University of Utrecht, about 20 years of age and having a driving licence for 2 years, served as Ss. They were paid for their services.

RESULTS

The results were analysed separately for the pre- and post tests and for the night drives.

The values of the pre-tests are depicted in all figures as "C_b" (sleep condition) and "E_b" (driving condition), while the results of the post-tests are depicted as "E_a" (driving condition) and "C_a" (sleep condition) respectively. In between, the results of the night driving runs are presented, each run equalling driving the experimental route once. The two segments (1-5 and 6-10) are separated by the fuel stop.

(1) SUBSIDIARY TASKS.

a. Reporting kilometrage: The percentages of incorrect (including missed) reports are presented in Fig. 1.

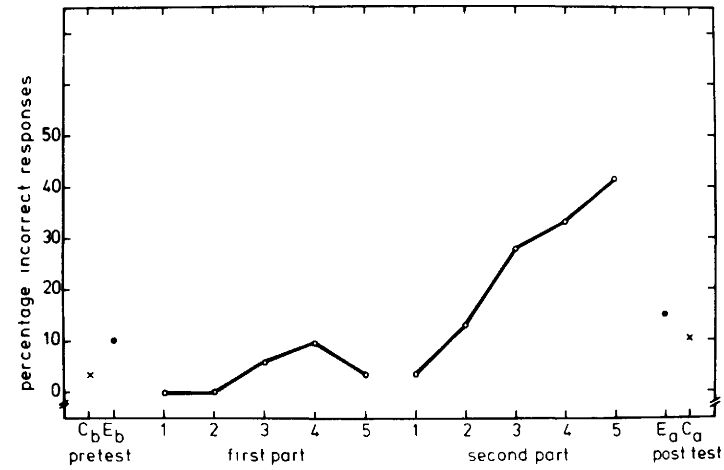

Fig. 1 - Percentage incorrect reports in the kilometrage task as a function of driving time

Significant differences were found during night driving, especially the rise of the percentage incorrect responses (χ^2=34,67, p<.01) in the second part of the experiment indicated a progressive decline of accuracy.

b. Detection of change of color: With regard to correct reaction times, the individual means, medians, third quartiles (Q75), standard deviations and number of mental blocks (defined as a reaction time exceeding twice the median) were calculated. Fig. 2 shows the percentages of mental blocks, missed signals and false responses.

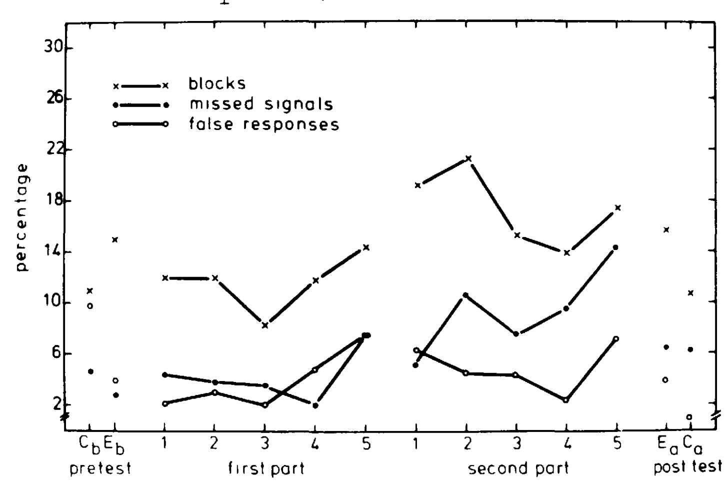

Fig. 2 - Percentage blocks, missed signals, and false responses in the reaction time task as a function of driving time

Missed signals and mental blocks showed a significant increase from the first to the second part of the drive ($F_{(1,10)}$=4.63, p<.05; $F_{(1,10)}$=6.9, p<.05) most of the reaction time measures also showed an increase from part I to part II, a.o. Q75 ($F_{(1,10)}$=6.08, p<.05).

(2) DRIVING PERFORMANCE MEASURES.
From the four continuously measured variables (lane position, steering wheel deflection, speed and longitudinal acceleration), the variables considered as most relevant, namely variation in lane position and speed, will be presented here.

Fig. 3 shows the standard deviation of lane position. During the night drive an increasing trend is clearly visible: from 20 cm (pre-test) to 27 cm (post-test) ($F_{(1,10)}$=10.2, p<.01). Lane position itself cannot explain this result, since it did not change significantly as a function of driving time, although there was a trend in position towards the right side, which is known to facilitate rather than disturb course maintenance (Riemersma, 1976). From the indices of the frequency of lane drifts (number or reversals) it was concluded that there were no systematic changes over time. Also, indices describing the steering behavior did not show any systematic changes. So, the result of Fig. 3 cannot be explained by an increasing trend to drift slowly away because there was less steering activity. From the pre- and post tests it can be concluded that lane position maintenance was significantly better for subjects who slept in between ($F_{(1,10)}$=12.3, p<.01).

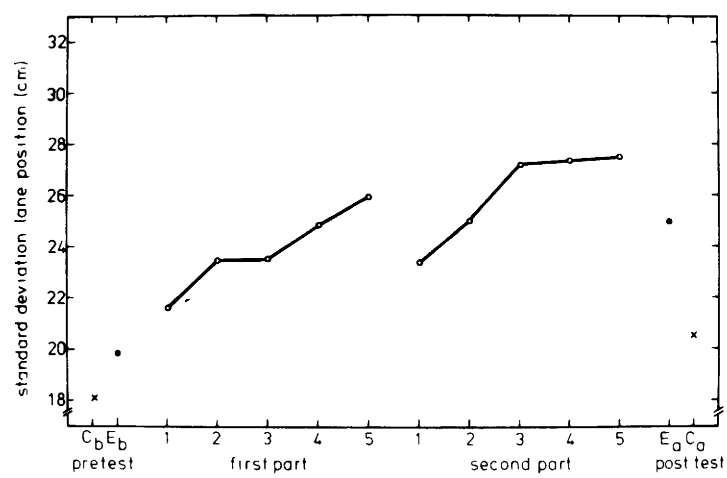

Fig. 3 - The standard deviation of lane position
as a function of driving time

Mainenance of speed (Fig. 4) tended to be less consistent after the interruption for fuel intake ($F_{(1,10)}$=3.46, p<.10). This is quite the opposite of what one would expect on the basis of the very low traffic density at that time.

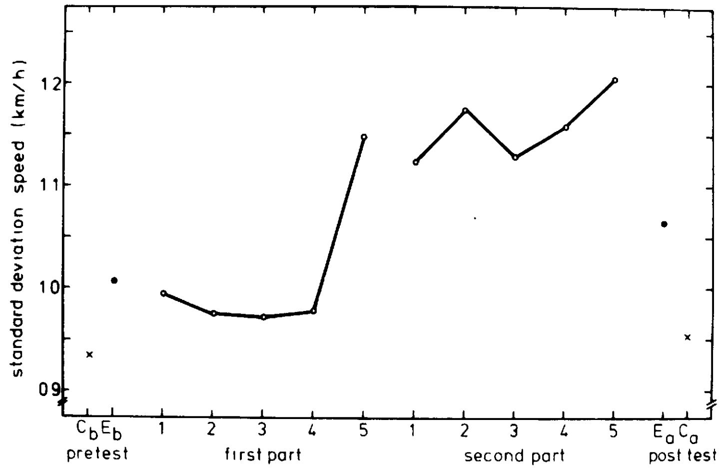

Fig. 4 - The standard deviation of speed as a function of driving time

(3) HEART RATE.

Both mean interbeat interval times (IBI) and standard deviations (SD) showed a monotone increase during the night driving task (Figures 5 and 6), except for a decrease directly following the fuel break. Besides significant effects of runs (IBI: $F_{(4,36)}=38.2$, $p<.01$; SD: $F_{(4,36)}=14.2$, $p<.01$) an interaction between parts and runs was observed (IBI: $F_{(4,36)}=3.95$, $p<.01$): the increase in IBI was larger during part I than during part II. Trend effects within a run proved to be stronger for the first run than for the fifth ($F_{(72,648)}=1.54$, $p<.01$). The results of pre- and post tests were similar to those of the night drive: both IBI and SD were higher during the post-test than during the pre-test.

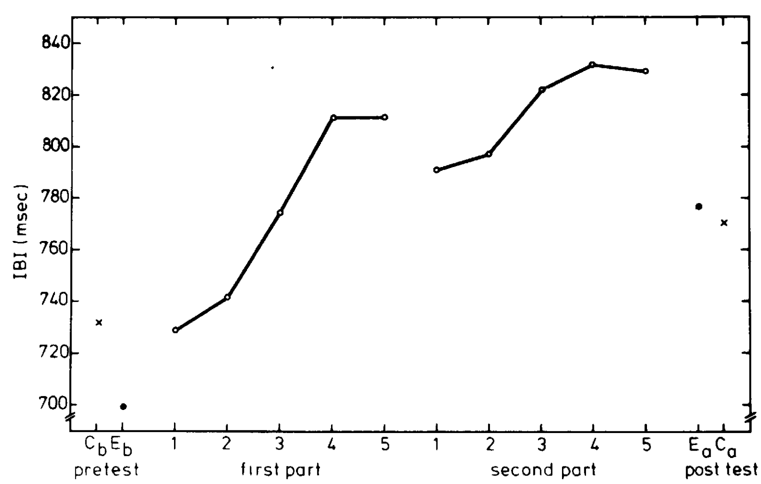

Fig. 5 - The mean interval time between successive R-waves (IBI) as a function of driving time

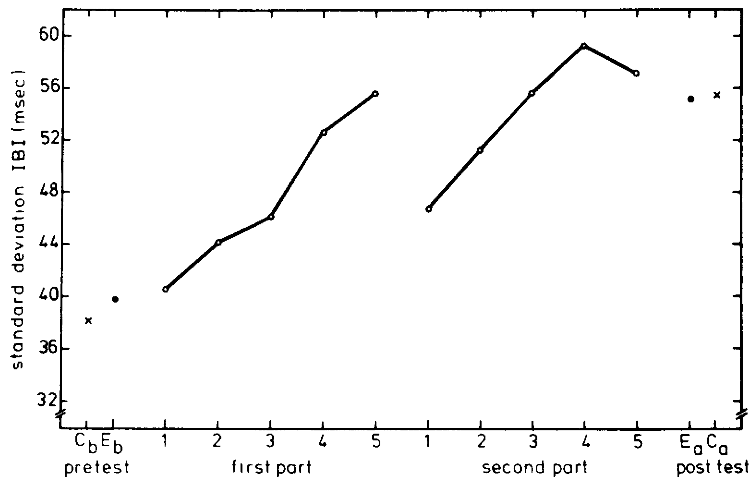

Fig. 6 - The standard deviation of R-R intervals as a function of driving time

DISCUSSION

Subsidiary Tasks: The results of the subsidiary tasks clearly showed an impairment during the night drive, especially during the second part. The increasingly inaccurate reporting of kilometrage during the second part confirms a suggestion by Bartlett (1953) that a clear sign of fatigue is found in Ss starting to forget incidental aspects of their tasks. The present observation could well be explained as a shift from anticipating to reacting to such an event; if this is found to be a more general phenomenon such a shift would certainly be dangerous.

The second subsidiary task, reacting to changes in color of a light, also showed that the reaction time (Q75) and the number of mental blocks and missed signals, hardly increased during the first part, but increased considerably during the second part.

Driving performance measures: Standard deviations of lane positions and speed maintenance both increased during driving at night. While the variability of speed maintenance increased mostly during the second part, lane drifting increased in the first as well as in the second part, but also showed a considerable recovery after the fuel break. The size of the increase is certainly noteworthy: with a standard deviation of 26 cm, lane positions can vary 1.6 m (6 times the standard deviation). It should be realized that any further increase would undoubtedly imply running off the road or drifting into the adjacent lane, which indeed sometimes occurred. Since the observed increase in lane drifting was apparently not related to steering wheel activity, it might be tentatively concluded that during longer driving spells steering wheel activity and lane positioning become dissociated in a way.

However, this observation certainly needs replication. Regarding the results on pre- and post tests, both driving performance measures more clearly reflect the effects of lack of sleep and night driving than the two subsidiary tasks. This finding confirms a statement of Harris and Mackie (1972) who, based on an extensive survey of the literature, also concluded that direct performance measures are possibly more sensitive to these effects.

Heart rate and heart rate variability: During night driving, heart rate decreased by about 10 beats/min. This decrement, which is not large compared with decrements found in much shorter laboratory experiments, was for the larger part already reached in the first hours of the driving spell. Such a trend is somewhat at odds with the trends found in the driving performance measures and the subsidiary tasks, which more clearly can be ascribed to a progressive degradation. Thus it is possible that the decrease in heart rate during the first runs of the long night driving, for a larger part must be ascribed, not to fatigue, or a change from normal to hypoarousal, but to adaptational effects, or a change from hyperarousal to normal arousal.

Although no criterion for the "normal" level of arousal for this situation is known, some aspects of the data do substantiate such a view. The decrease in heart rate was high in the first part of the night driving, and much lower in the second part. This decelerating trend not only was found over the ten runs, but also within the runs: the decrease during the first run was highest and it was almost non-existant in the last few runs of the second part. Although a straightforward comparison of pre- and post tests is difficult, due to phenomena like short-term mobilization of effort, also these results are in line with this interpretation. In the pre-test SS facing a night drive not only have a higher heart rate, but also have higher standard deviations of lane positioning compared to the control group, which is an argument of hyperarousal. In summary, it seems most suitable to ascribe the decrease of heart rate during the pre-test and the early runs of night driving to adaptation - decreasing stress, habituation to sensory stimulation etc. - rather than fatigue. Probably, there is also an effect of diurnal rhythm, as time goes on, since in the sleep condition the heart rate was higher in the evening than in the morning. This interpretation does not exclude an interpretation in terms of fatigue effects of the decrease in the later runs, but such an effect certainly is obscured by the more prominent effects discussed.

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VISUAL INPUT AND DRIVER'S FATIGUE

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ABSTRACT

Field and laboratory experiments provide good evidence that luminous conditions on the road may modify the visual performance of the driver and his ocular strategy. It can be suggested that part of the driver's central fatigue is in fact of peripheral origin and derives from the necessity to overcome visual strain. It is the reason why research workers should not forget visual afferences (input) in their studies on fatigue on the road. This paper points out arguments for discussion.

VISUAL REQUIREMENTS ON THE ROAD

Luminous conditions on the road do not usually optimize the visual performance in emmetrops who are in good physical and psychophysiological health. The driver is indeed required:

.- to be able to see during the day or at night, in other words, to have a good photopic and scotopic adaptation;

.- to be able to resist to excessive illumination and glare, either during the day or at night;

.- to be able to adapt to very abrupt changes from light to dark or vice-versa when going from sunshine to shadow for example;

.- to be able to perceive objects which are poorly illuminated;

.- to be able to accomodate very rapidly on distant or near objects;

.- to perceive moving objects in any location of the visual field, to appreciate their speed and to detect the direction of movement;

.- to resist to the adverse effects of external or internal origin such as vibrations and noise on one hand and fatigue, alcohol and drugs on the other;

.- to distinguish between colors, e.g. colors of the rear lights, even when distorted by sun, mud, etc. ;

.- to recognise shapes in weak photopic adaptation when necessary, and to be able to distinguish different vehicles or to read numbers and letters;

.- to resist to disturbing luminous signals, e.g. to perceive steady lights in the presence of flickering stimuli.

EXTERNAL AND INTERNAL FACTORS

External as well as internal factors are able to affect adversely the capability of the eye to fulfill such a complex task. Some of them will be considered below.

When luminances are not appropriately scattered in the visual field and are not in the correct proportion with central illumination, a decrease in visual acuity can be observed. This effect appears when watching a low-contrasted object surrounded by a highly illuminated background (Gramoni et al., 1973).

The disturbance of central vision can be enhanced by intermittent flashes stimulating the visual field. Flicker sensitivity can be depressed in similar circumstances. Laboratory experiments showed that these negative effects are dependent upon the frequency and the modulation amplitude of the intermittent signals. They disappear quickly after the stimulation has ceased according to an exponential time course (Rey P. & Rey J.P., 1965).

Glare is a well known phenomenon which does not require comments. Let us recall that rain drops on the windshield act like magnifying glasses and that multiple small light sources can induce glare sensations.

Alcohol and drugs which are considered as important factors in road safety are known to alter visual perception. Some kind of synergistic effect can be observed when alcohol and drugs are combined even at low concentration (Gramoni et al., 1972).

In nuclear research, a situation exists which displays similar characteristics to night driving. In that research, pictures are projected on large reflecting tables to scan traces of particles and "events" looked for are transferred in digital form to the computer. Communications between operator and computer are secured by video screens and printing machines. Visual requirements in this task can be summarised as followed: the recognition of shapes has to be performed in mesopic or weak adaptation, abrupt changes in illumination occur randomly in such a way that the eye adaptation needs to be constantly readjusted, numerous luminous signals either steady or flickering stimulate anarchically the visual field, the eye is required to accomodate successively on near or distant objects. Even though the final content of the task is different the conditions in which the eye has to function is comparable to those which can be encountered in driving at night (Meyer J.J. & Gramoni R. 1976).

Our study on scanning is worthwhile mentionning here since it showed that in such circumstances which can be rather easily faced by emmetrops, operators with slight visual defects could experience fatigue. This is particularly true of people with hyperopia.

VISUAL FATIGUE IN DRIVING

The question has to be raised whether visual fatigue, in a clinical sense, can be experienced in driving?

Clinically, visual fatigue is usually described as a syndrome consisting of redness and tiredness of the eye, tears, ocular pain and frontal headache. Visual fatigue reflects thus a strain of the accomodative system. Accomodative fatigue is enhanced when fixation points are close to the eye. Changes in distance are opportunities for accomodative relaxation. However, coming back to our previous example, hyperopia is a condition in which, specially in uncorrected people, accomodative relaxation is impaired, and it can be expected therefore that such drivers suffer of some kind of visual fatigue which could be easily overcome by emmetrops.

From the point of view of visual performance, the reverse situation should be carefully studied: how does central tiredness influence the visual performance?

Changes in ocular strategy could be wrongly attributed to fatigue while related to changes in luminous adaptation. It seems that more attention should be paid to such changes in research on fatigue in driving.
In photopic adaptation, the peripheral stimulation of the visual field is used to adjust eyeballs and head balance to the road center. Ocular movements are scarce and short.

In scotopic adaptation, the eye seems to be attracted by any peripheral luminous signal along the road and move towards these lights in such a way that ocular movements are numerous and anarchic. Rockwell tests using a laboratory car in which road events and eye movements are simultaneously recorded, are, in this respect, quite clear (Rey P., 1977).

CONCLUSION

Of course, many more data should be given on visual requirements in driving. Our purpose however, was not to bring more information but to produce a few arguments to stress the importance of visual afferences in driving.

Adverse effects on visual perception may indeed alter the way in which visual information is captured, and secondarily modify the integration of signals and the motor response of the driver. It may be suggested that to overcome the visual strain introduced by these adverse conditions, the driver is requested to make an extra-effort which induces, later on, a feeling of fatigue and a lack of adjustment to road dangers.

The reduction of vigilance, fatigue and sleepiness are widely studied and publications in this field of research are abundant. These parameters seem however to characterize better the situation of the driver lost in the middle of the desert, on an endless turnpike, than the situation of the driver in heavy urban traffic. Heavy urban traffic is nevertheless the rule in many European countries; and particularly at night, it is not so much the lack of sensorial stimuli which has to be emphasized but, on the contrary, the excess of visual afferences. At least, in the absence of more data on this particular problem, it can be hypothetized that part of central fatigue could be related in heavy traffic to the selective processes necessary to choose from the multiple luminous signals those which are relevant to the road situation.

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ELECTROPHYSIOLOGICAL INDICATORS OF AROUSAL IN LORRY DRIVERS

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ABSTRACT

A study of psychophysiological changes of lorry drivers including monitoring of EEG, EKG and EDG as well as postural angles is reported. A comparison is made of drivers working regular daily hours with others working an 18 hours day schedule.

INTRODUCTION

As lorry driver's fatigue is an important factor in accident rates, the French Organisation for Road Safety (ONSER) was approached by the Department of Social Insurances to determine objective indicators of this particular fatigue. Information based on bibliography and a short series of interviews showed some of the important disturbing problems in the life of these workers, and it was hypothesized that these particularities could be related to certain physiological deteriorations, especially in terms of nervous arousal.

MATERIAL AND METHODS

Following series of "on road" vigilance studies which gave a methodological background, a lorry was specially equiped to record electrophysiological parameters.

The following indicators: alpha waves of the electro-encephalogram (EEG), cardiac frequency (EKG) and eye blink rate frequency (EOG) were used to show, in their coincidence, variations of drivers alertness. Concurrently, the drivers were filmed all along the trip. Some indicators of different postural angles were analysed afterwards.

Two groups of lorry drivers were studied. The first group worked regular usual daily hours, while the second worked "normally", as it is said in France, which means about 18 hours a day depending on different factors (load, length of trip, etc...), the purpose of this experiment was to ascertain the evidence of the problem of fatigue for lorry drivers. After compilation of data from a short series of questionnaires answered by workers, unions and persons in the transport administration, it was decided to study a category of long distance lorry drivers who do not return home each evening and who travel also accross national borders. It was evident that they drive for very long periods with an anarchistic way of life, sleeping and getting their meals at irregular hours so that, it was hypothesized, their general degree of fatigue or arousal must be different from that of workers with a regular daily activity of eight hours.

A previous series of experiments on ordinary drivers tested electrophysiological parameters related to two hours of driving, the concurrent deterioration of which can be used as alertness indicators.

Secondly, an attempt was made to get information on behavioural signals during these long periods of time, and it was hypothesized that some postural angles could be modified.

The equipment for the electrophysiological part of this study consists of a telemetrical apparatus.

The EEG electrodes of the subjects were attached to small amplifiers placed directly on the head. The signals were transmitted to the receptor in the back of the experimental truck. They were controlled on an oscilloscope and recorded The data was evaluated in the laboratory after the experiment was over. The lorry chosen (19 tons) was an average weight one for France at this time.

Postural angles were recorded with the help of indicators attached to the drivers clothes. At regular intervals (of 5 sec.), pictures were taken and because of the darkness infra red films and infra red filters for the flash were used.

The test drivers groups were chosen as follows: the first from workers with particularly heavy workloads (80 hours working week), the second from a group of lorry drivers with "normal" schedules who work during the day.

The drivers were supposed to make trips of about 300 kilometers, which were rarely accomplished in the case of workers with a heavy workload. The trip took place on a particularly monotonous stretch of a french motorway.

They were asked to drive normally without stopping on the highway after having been equiped. They all worked at night between 9 pm and 1 am, some after a normal days work for the reference group, and the rest immediatly after coming back from long distance trips.

Unfortunately because of various reasons a large long term statistical study was not possible, and found results were applicable only to a very small group of subjects. In fact, out of 30 drivers tested, only six were taken into account, but despite the very small groups considered, great differences were found.

RESULTS

Difference between the two groups appears for all the parameters, EEG of "fatigued" drivers were rich in alpha and even showed some slow waves.

In general, it was rare that the "fatigued" subjects accomplished the experimental trip and we sometimes observed slow waves (theta) on their EEG, which can probably be related to the diminution of alpha waves, observed on the curves (fig. 1).

The cardiac frequency diminishes for all subjects, but the reference group has a higher frequency than the experimental group (fig. 2).

The variations of the eye blink rate do not seem to differ between the two groups.

As far as postural angles are concerned, the angle between the upper part of the seat and the shoulder and the hip of the subject were studied. General variations of this angle can be obviously observed when projecting the five seconds pictures as a normal film.

Figure 3 shows variations of the angle on two subjects, one from the reference group which had driven for a long time and whose angle varied very little, and the other from the heavy work load group whose angle showed short and wide variations probably corresponding to a drowsy reaction which was also observed while driving. Sometimes, the men actually fell asleep, and this corresponded to the observed increase in very slow electrophysiological rythms.

CONCLUSIONS

It was clearly demonstrated that truck drivers submitted to heavy schedules, corresponding to some "average" of this professional group in France, are strongly affected by fatigue which can be observed through behavioural indicators and changes in physiological parameters. This indicates an immediate deterioration the consequence of which can be obviously interpreted in terms of safety on the road.

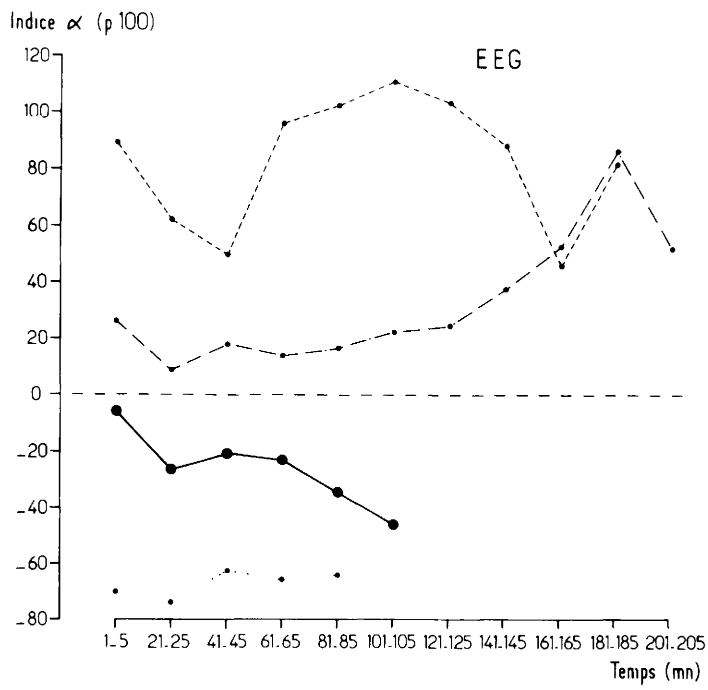


Fig. 1: Variation around their mean value of the alpha index of the EEG along the experimental trip for three "normal" drivers and one "fatigued" driver( ). A regular diminution in alpha density is noticed for the fatigued driver. The diagram shows concurrently an increase in slow waves.

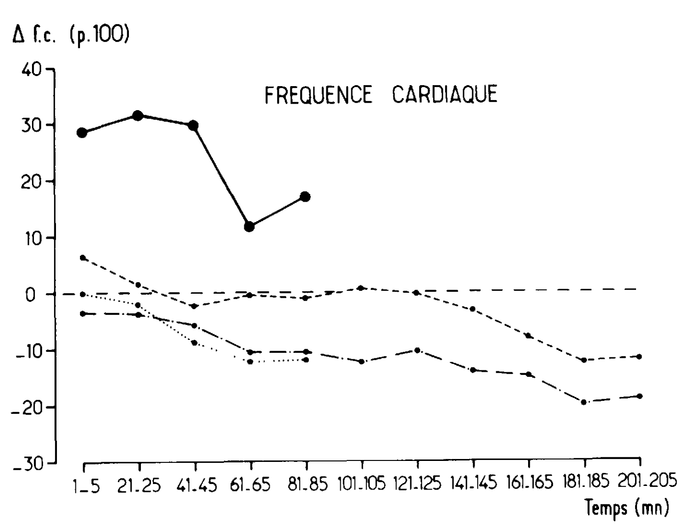
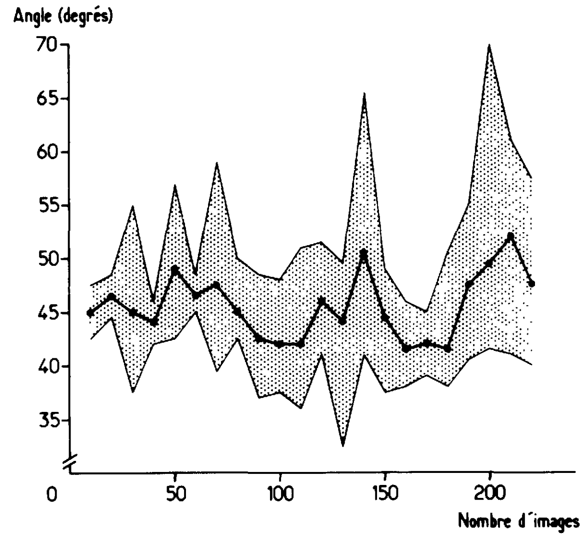


Fig. 2 : Variation of the cardiac frequency along the experimental trip for three "normal and one fatigued ( ) drivers.



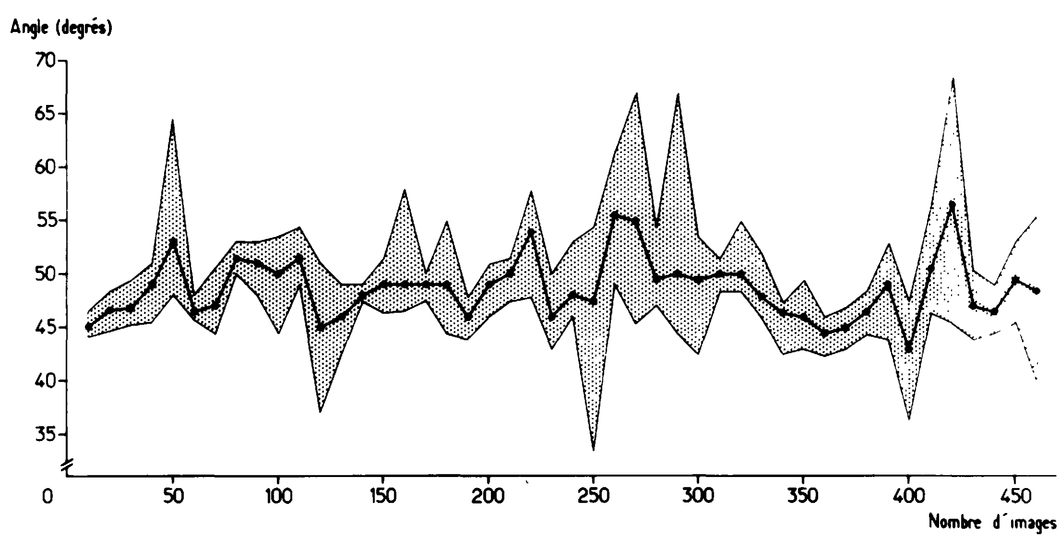


Fig. 3 : Variations of postural angles for a "fatigued" driver (a) and for a driver with a "normal schedule (b).

IS BRAKING NECESSARY? USE OF ELECTRODERMAL RESPONSE FOR EVALUATION OF HIGHWAY DESIGN FEATURES

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ABSTRACT

An instrumented vehicle was used to record drivers' electrodermal response (EDR, GSR), heart rate, and electromyograms (EMG) from muscles in the right leg. Simultaneous recordings of vehicle behavior was obtained--speed, distance traveled, triaxial accelerations, brake pressure, and steering wheel angle. Sixty test persons were used and 7 million measurement values collected.

EDR is indicative of the mental effort in driving rather than the physical effort, and it is a relevant variable to use for assessing relative changes in task demand. Traffic and road situations involving the use of the brake evoke EDR and are perceived as stressful. Roads should therefore be designed so that the use of the brake is minimized. This is a new criterion for use in highway design.

INTRODUCTION

The most important ergonomic rules in road design are the use of transition curves (clothoids) and the implication of drivers' reaction time for the choice of road curve radii. These rules have long been questioned, and it has been recognized that driver behavior is complex, demanding the use of comprehensive theories. Such theories should most likely take into account both general factors of information evaluation (e.g., perceptual load, attention, arousal level) and modulating factors (e.g., time of day, time at driving task, driving experience).

It has been proposed that driver mental capacity and arousal level vary in a moment-to-moment fashion depending on fluctuations in task demand (Kahneman, 1973). Electrodermal response (EDR) is held to be the most useful indicator to assess such fluctuations. EDR may however also be affected by muscular activity (Duffy, 1962). Although no traffic studies have investigated the influence on EDR of muscular activation, some research has been done using heart rate (HR). Wyss (1971) showed that increases in HR during driving depend more on emotional factors than physical workload. A comparison of HR levels obtained from drivers using automatic and manual gearshifts showed no differences, indicating that physical effort is of little

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importance (Seydel, 1972). Simonson et al. (1968) found no differences when comparing drivers' and passengers' heart rates.

The present study has an exploratory design. Full details are given in Helander (1976) and this paper will mainly investigate the validity of EDR as an indicator of mental load.

METHOD

During runs along a particular test road, drivers' psychophysiological variables (PPVs) were recorded together with variables describing the dynamic behavior of the vehicle and a description of traffic events. All data were stored on a digital tape recorder. After each test drive, the information collected was processed by computer.

The PPVs chosen were EDR and HR. In addition to these, electromyograms (EMGs) were obtained from two muscles in the drivers' right leg. Recordings from the m. tibialis anterior (EMGTA) indicated release of pressure on the accelerator; recordings from the anterior hip muscle (EMGAS) indicated lifting of the right leg in anticipation of brake pedal activation.

Two EDR measures were obtained. The conventional response, EDRC, evaluates relative changes in conductivity and was produced by high-pass filtering of the EDR signal using a time constant of $\tau \simeq 10$ sec.

$$\mathrm{EDRC} = 10 \cdot \log \frac{G}{G_m} \ \mathrm{dB}$$

where G = momentary conductivity in μmho

and G_m = mean conductivity in μmho

A special function, EDRT, was calculated to evaluate the relative magnitude of each EDR amplitude. EDRT returns to zero when the maximum amplitude has been reached.

$$\mathrm{EDRT} = K \cdot \log \frac{G}{G_o} \ \mathrm{dB}$$

where K = amplification (K was varied for each subject to produce an amplitude of specific magnitude for a standard startle stimulus)

and G_o = conductivity in μmho just before the start of a response.

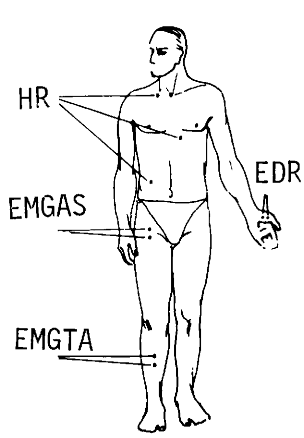

Figure 1. Electrode Placement.

Vehicle Variables

The test vehicle was a Volvo 145 with manual gearshift. The velocity of the car and distance traveled were measured by means of a digital counter connected to the left rear wheel. Three accelerometers positioned behind the driver's seat gave information concerning longitudinal, lateral, and vertical accelerations. The steering wheel angle was obtained through two gear wheels and a potentiometer attached to the steering wheel. A transducer of strain-gauge type was connected to the hydraulic brake system to measure the brake pressure. Traffic events were recorded on a keyboard. Details of the equipment used are given in Helander and Hagvall (1976).

Test Road

The test drives were performed on a 23.7-km stretch of rural road, representing four different road standards. The first segment (5.8 km) was of low geometric standard and moderate traffic density; the second segment (8.5 km) had a slightly better geometric standard than the first and low traffic density; the third (3.2 km) had a high geometric standard and moderate traffic density; the fourth segment (5.7 km) was a motorway with dual carriageway and grade separations and moderate traffic density. All test drives were performed during off-peak hours, in daylight and dry road conditions. Sixty test drivers (paid for participating) were selected randomly from Volvo owners in Gothenburg.

Processing and Reduction of Data

During the test runs, 14 variables were registered 5 times per second on a digital tape recorder. A total of 7 million measurement values, corresponding to 120,000 per test, were recorded. Data were then processed in a computer (Helander, 1976). Abbreviations of the variables used are given in Table 1. For each driver, all measurement values were ordered according to road length. Measurement values were then interpolated for each 10-meter road segment.

RESULTS

Response Profiles

In order to visualize the collected data, average responses ± 1 S.D. for the 60 drivers were plotted. Figure 2 shows this for the first test segment. The hypothesis that there is a correlation between average response and 1 S.D. was tested. Results are shown in Table 2.

Statistical Analyses of Response Activities

In order to rank the influence of vehicle variables on PPVs, several stepwise multiple regression analyses were performed. Each analysis was

Table 1

Variable Abbreviations

EDRC	Conventional EDR amplitude
EDRT	Normalized EDR amplitude
HR	Heart rate, beats per minute
EMGAS	EMG, anterior hip muscle, normalized
EMGTA	EMG, m. tibialis anterior, normalized
VEL	Velocity, km/h
ACCX*	Longitudinal acceleration
ACCY*	Lateral acceleration
ACCZ*	Vertical acceleration
STWA*	Steering wheel angle
BRAKE	Brake pressure
KEYB	Traffic event density

*An extra "A" in front of the symbol indicates absolute value of the variable.

Table 2

Correlation coefficients for average and 1 S.D. in response (entire test road, 10-meter increments; N=2 350; $p < .01$ for all variables except AACCZ)

Variable	Correlation Coefficient	Variable	Correlation Coefficient
VEL	0.68	EDRC	0.89
AACCX	0.57	EDRT	0.63
AACCY	0.77	HR	0.40
AACCZ	-0.01	EMGAS	0.87
ASTWA	0.72		

terminated when the F-value for the last variable was lower than 2.0. The calculations were first performed using average responses for 100-meter road increments. They were then repeated for the least experienced drivers in the group and for the most experienced. There were a total of 17 inexperienced drivers with less than 30 000 kms driven during the previous 5 years and 16 experienced drivers with more than 175 000 kms driven. Table 3 shows results for the entire road. Only the first three independent variables included in the stepwise process are given with a number indicating the order of inclusion. The sign of the correlation coefficient is also shown.

From Table 3 it was concluded that road conditions involving the use of the brake evoke EDR activity. To substantiate this finding, values of EDR and simultaneous brake activity were obtained for different traffic events. Table 4 shows the ranking of traffic events according to average magnitude in EDRC and brake pressure. It can be observed that the event "Own Car Passes Other Car" adds most to the differences between the rankings. Indeed, it was not expected that the driver would apply the brake when passing, and

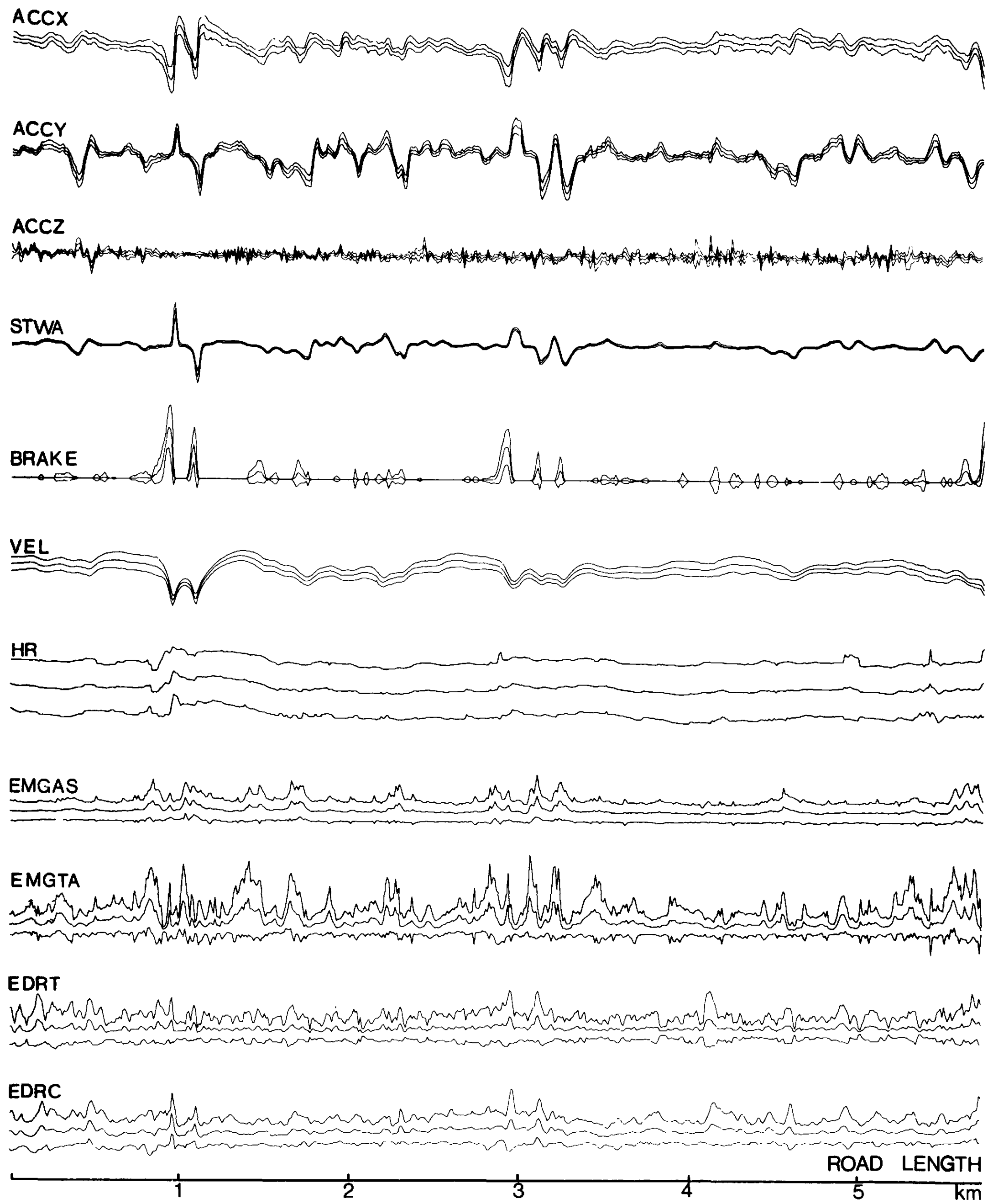

Figure 2. Average responses ± 1 S.D. obtained for the first test road segment (road length = 5.7 km; 60 drivers).

if this particular event is excluded, the rank correlation coefficient increases from $R_s = .66$ to $R_s = .86$.

EDR as Indicator of Mental Load

From Tables 3 and 4 it is concluded that events which necessitate the use of the brake are perceived as stressful. However, since muscular activity can also affect EDR, it was of interest to analyze the time lags for EDR following muscular activity in the right leg. It takes 3 seconds or more following a stimulus situation for EDR to reach maximum amplitude

Table 3

Multiple regression analyses for experienced, inexperienced, and all test drivers (entire test road; N=236; all Rs significant, with $p < .01$)

Independent Variables	Dependent Variables														
	Exp. Drivers					Inexp. Drivers					All Drivers				
	EDRT	EDRC	HR	EMGAS	EMGTA	EDRT	EDRC	HR	EMGAS	EMGTA	EDRT	EDRC	HR	EMGAS	EMGTA
VEL			3-	3-	2-			1-	1-	2-			1-	3-	2-
KEYB	2+		2+			3+	2+	2+							
ACCX	3-	2-		2-	1-			3+*	2-	1-			2+*	2-	1-
AACCY						2+					2+	2+			
AACCZ		3-*									3+	3+			
ASTWA	1+	1+	1+	1+					3+					1+	
BRAKE					3-*	1+	1+			3-*	1+	1+	3+		3-*
R	.38	.38	.54	.71	.81	.43	.41	.53	.74	.75	.53	.45	.66	.74	.84

*The sign of the correlation coefficient is not in the expected direction.

Table 4

Rank ordering of traffic events by magnitude of EDRC BRAKE ($R_s = 0.66$; $p < .01$)

Traffic Event	N*	Rank Order by EDRC	Rank Order by BRAKE
Cyclist or Pedestrian + Meeting Other Car	28	1	1
Other Car Merges in Front of Own Car	47	2	2
Multiple Events	163	3	3
Own Car Passes Other Car	3,590	4	15
Leading Car Diverges	207	5	4
Own Car Passes Other Car + Car Following	126	6	6
Cyclist or Pedestrian	839	7	5
Other Car Passes Own Car	157	8	13
Meeting Other Car	1,535	9	9
Cyclist or Pedestrian + Car Following	65	10	7
Car Following	13,049	11	10
Car Following + Meeting Other Car	353	12	8
No Event	112,630	13	12
Parked Car + Car Following	64	14	14
Parked Car	742	15	11

*N = Number of 10-meter strips during which the event code button was pressed.

(Lockhart, 1972). To compensate, the EDR signal was moved 3.0 sec earlier. Cross-correlation coefficients were calculated between EDR, EMG, and BRAKE (Figure 3). It is inferred from Figure 3 that EDR leads EMGAS by 1.0 sec, EMGTA by 1.4 sec, and BRAKE by 2.0 sec. Similar results were obtained for the other road segments.

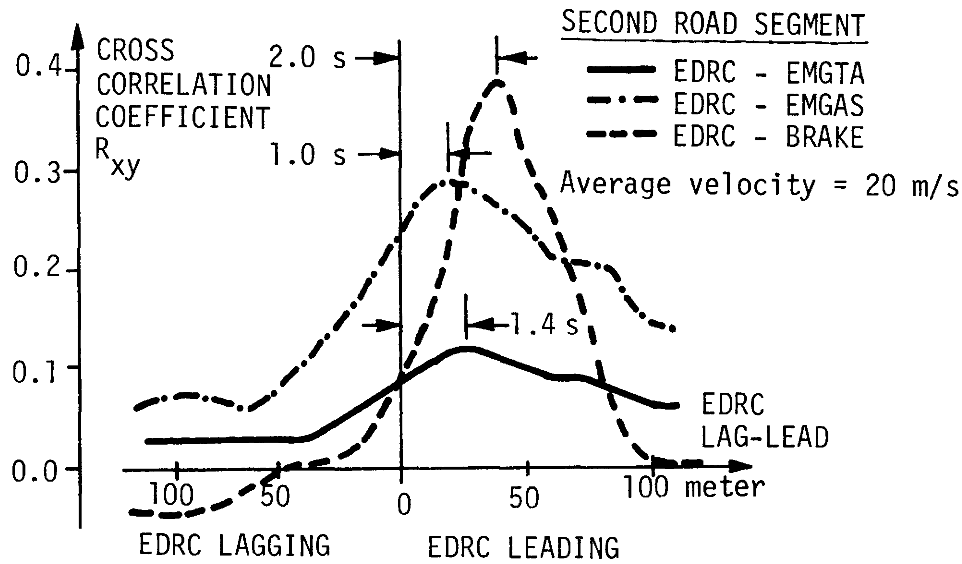

Figure 3. Cross-correlation coefficients obtained from EDRC and respectively EMGTA, EMGAS, and BRAKE (2nd road segment; 10-meter increments; N=840).

Steering activity during the traffic event "Own Car Passes Other Car" was compared to simultâneous readings of EDRC and HR. This traffic event was chosen since it involved, in average, the largest steering wheel movement and hence the greatest muscular effort in the arms. Figure 4 shows average responses for 315 passing maneuvers from 10 sec before until 10 sec after the event.

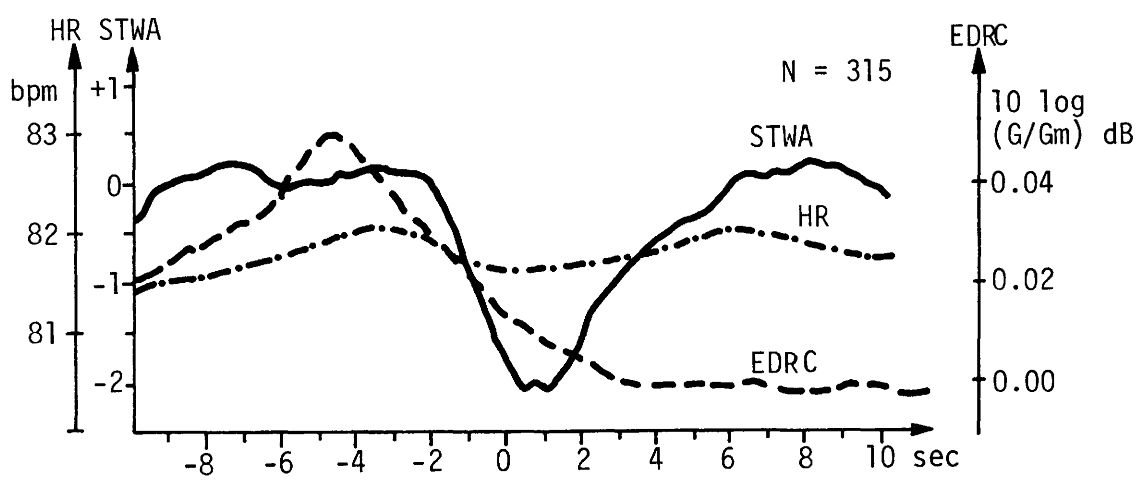

Figure 4. Average HR, EDRC, and STWA during the traffic event "Own Car Passes Other Car" (N=315).

DISCUSSION

Response Profiles

EDR is a more dynamic (and sensitive) measure than HR. Whereas the variability in control behavior parameters is only slight, there is a large variability in the physiological variables. For investigations of drivers' physiological responses, a large number of subjects must therefore be used.

Statistical Analyses of Response Activities

Intercorrelations between the independent variables make the correlation patterns in Table 4 difficult to interpret. However, the signs of the correlation coefficients were, with few exceptions, in the expected direction.

The most important variables for the experienced drivers were those employed for the lateral control (ASTWA) of the car and, for the inexperienced drivers, those involving longitudinal control (BRAKE, ACCX, and VEL). Thus the road-traffic environment is interpreted differently depending on experience. Inexperienced drivers, however, constitute a targer group in accident prevention. For road design purposes it might therefore be suggested that road elements involving the use of the brake be avoided.

The rank correlation $R_s = .86$ obtained for brake pressure and EDRC is in agreement with the other results. The rankings of the traffic events in Table 4 also have a high face validity, since the apparent difficulty of each event is reflected in the ranking of both BRAKE and EDR.

EDR as Indicator of Mental Load

Figure 3 shows that EDT is obtained in advance of EMG and BRAKE responses. Should EMG activity affect EDR, we would have expected the reversed order since the muscles are actually activated before the brake is applied. It is also obvious that the rate of increase and decrease in EDR-EMG curves is comparatively low. Therefore, EMG can only explain relatively slow drifts in EDR (base level). From Figure 4 it can also be seen that the peak value of EDR is obtained in advance of the muscular effort necessary to steer the car. It appears that muscular activity in the driving situation could only have a slight and probably negligible effect on EDR. An EDR is therefore interpreted as indicative of mental activities rather than anything else.

A Theoretical Frame of Reference

During the process of driving, the driver adopts a certain average arousal level or a mental adaptation level (Helson, 1947). This level will fluctuate with the quality (demand) of the road (Kahneman, 1973). However, if the driver drives for long periods of time there will be decrements in vigilance which will decrease the arousal level. This is counteracted by built-in desires to perform at an optimal level (Berlyne, 1966; Hebb, 1955). These principles and their consequences for driver performance are illustrated in Figure 5. It is difficult to obtain a valid measure of the mental adaptation level so that the effects of transient increases in arousal, as indicated by EDR, can be predicted. From Table 2, however, it is clear that

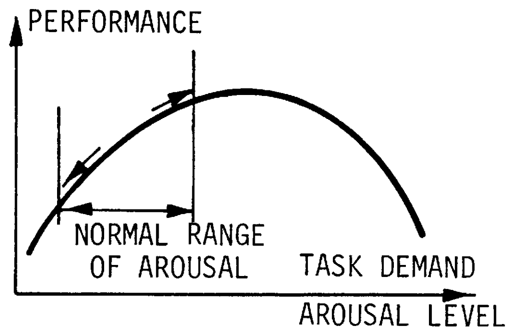

Figure 5. Illustration of the Yerkes-Dodson law.

there is a positive correlation between average EDR and variance in response. We might, therefore, on probabilistic grounds, argue that road sections associated with high average EDR values are dangerous, since there is an increased chance that some individuals' arousal will increase to a level where performance deteriorates.

Depending on the time of day and the state of the driver, performance and response profiles along a road will vary. It is therefore difficult to suggest traffic safety modifications of the road environment which are equally valid during, say, night and day. However, crude evaluations of factors such as drivers' average arousal level, accidents reported (due to vigilance phenomena or not), and the average traveling time for drivers using the road would provide useful information for the design engineer. For example, rumble strips, a device used to raise drivers' arousal level, are not relevant in town areas, where the average arousal level is already high.

Engineering Implications

This study has shown that situations which necessitate the use of the brake, whether due to the traffic or the road environment, are perceived as stressful. Therefore, it seems important to design roads so that the use of the brake is minimized. It is hoped that the findings of this study extend the ergonomic basis upon which new and improved road design principles can be established.

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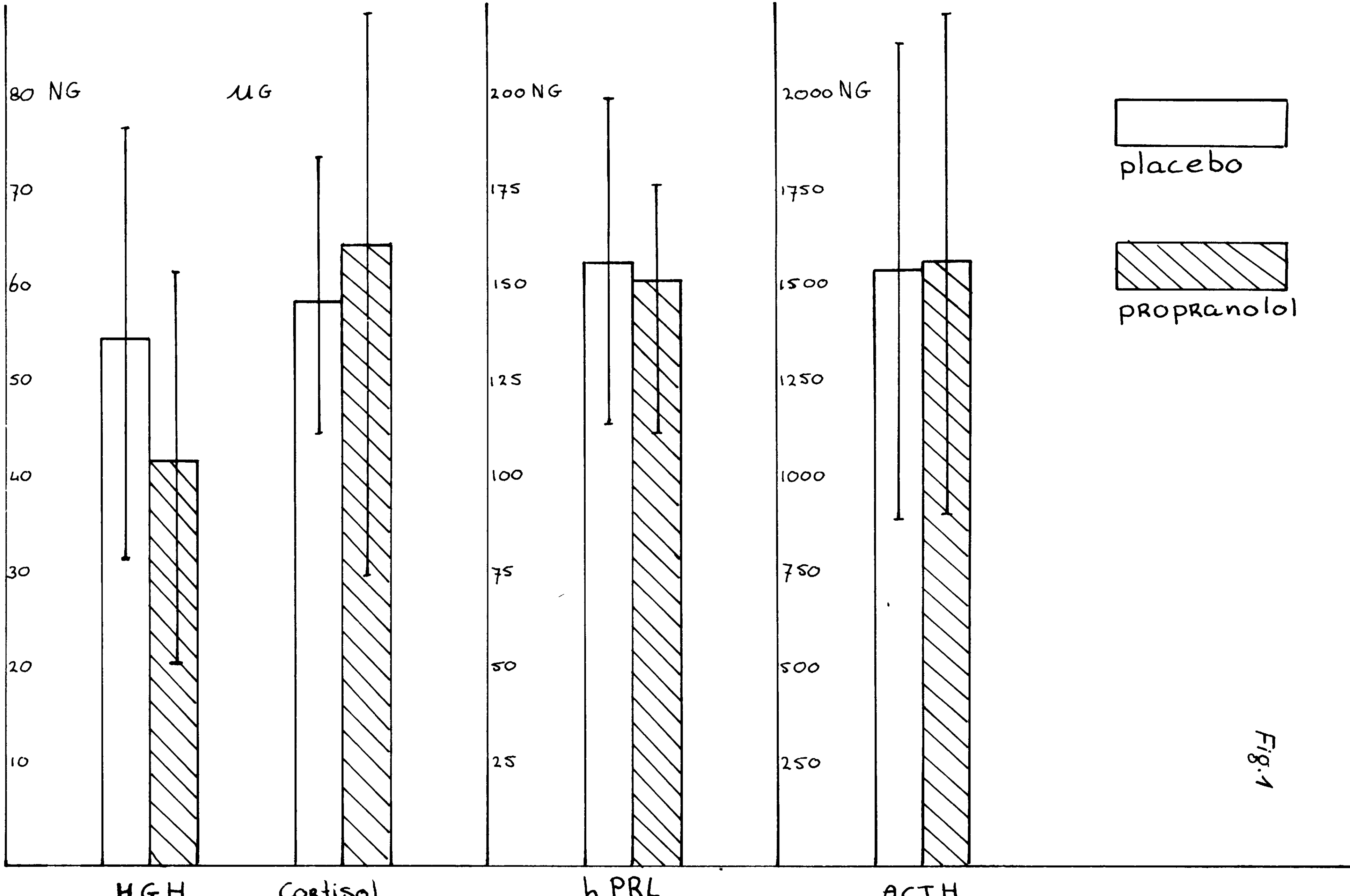
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Fig. 1

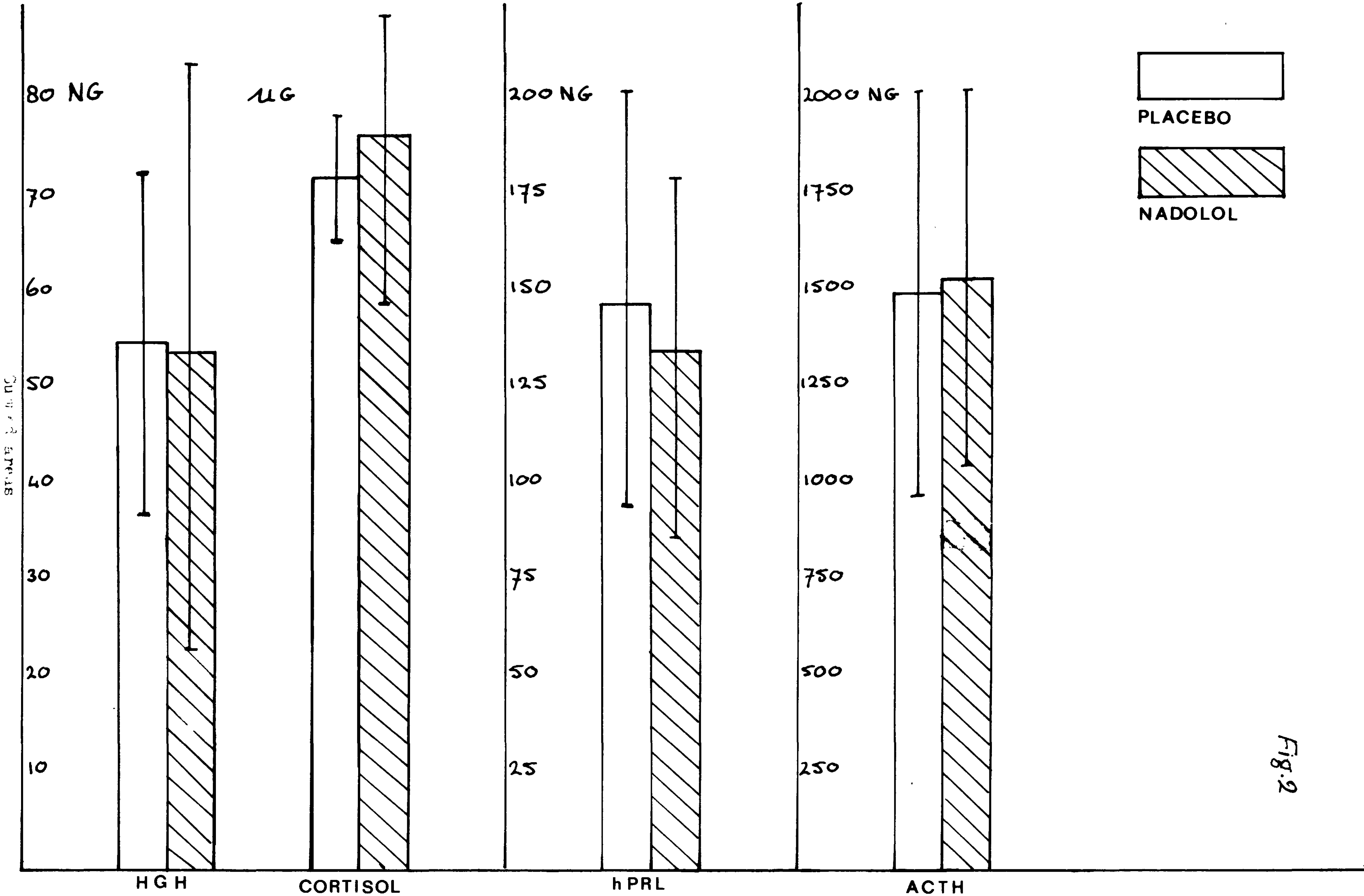
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Fig.2

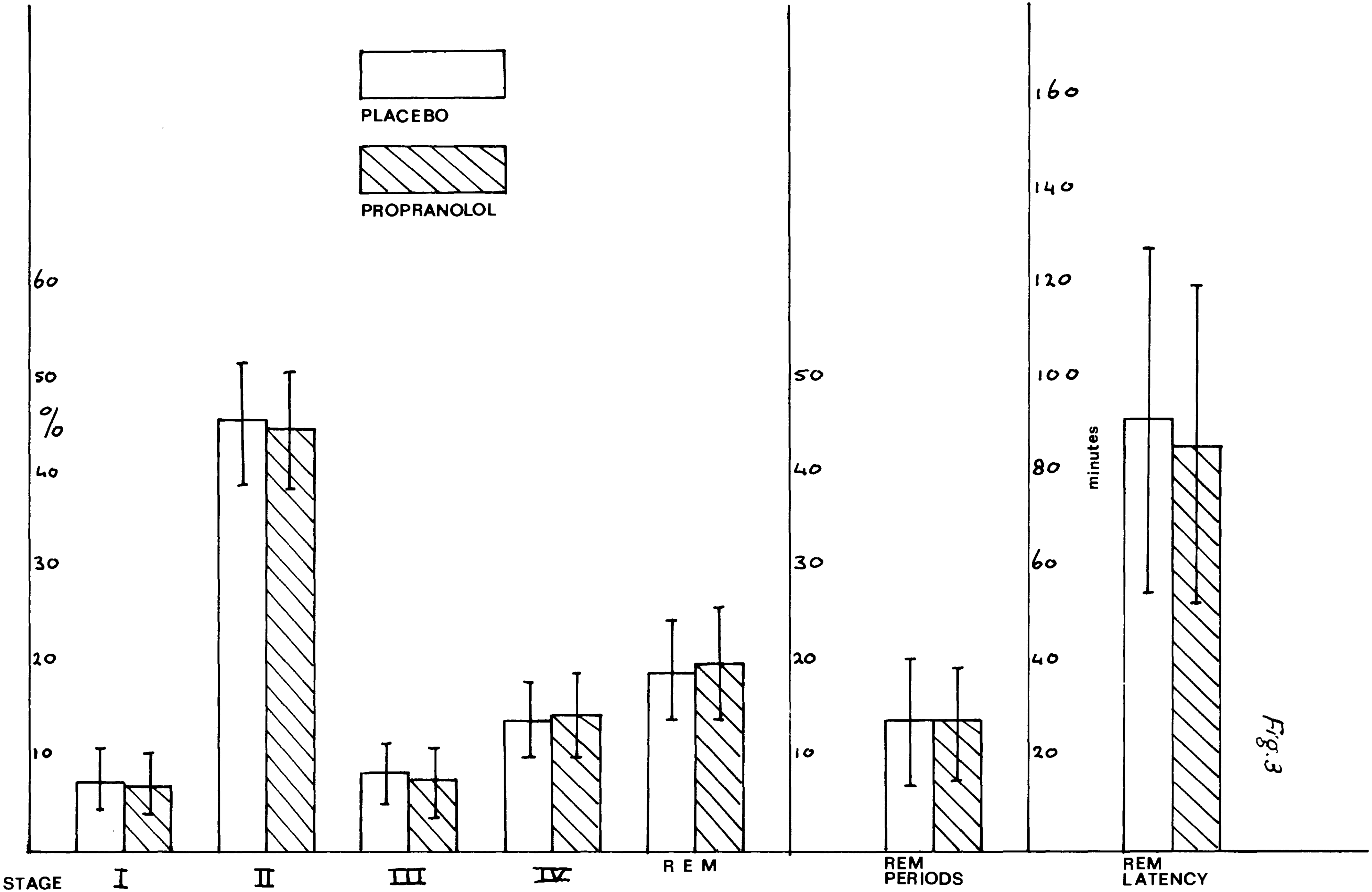
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Fig. 3

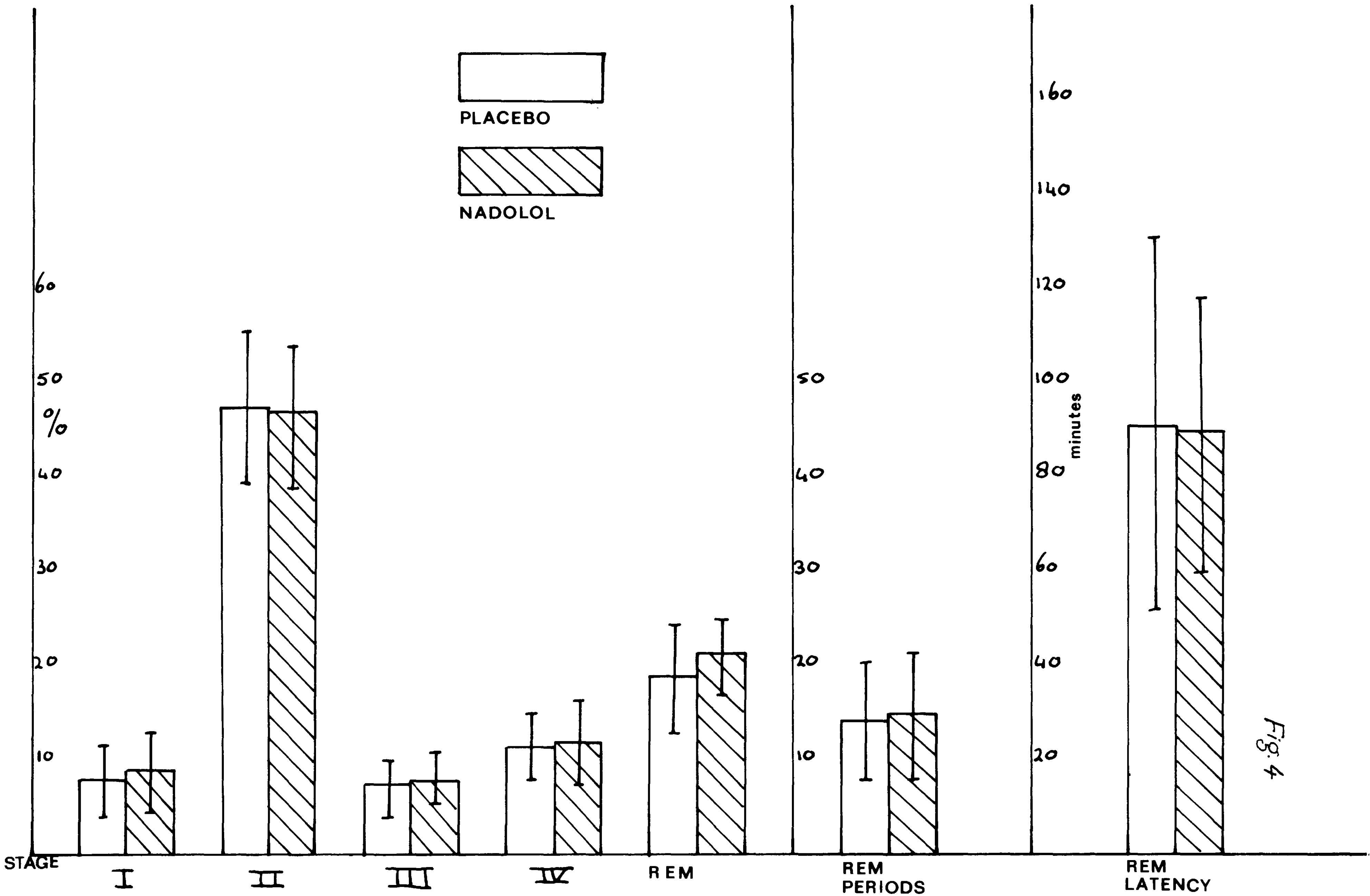
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Fig. 4

ENDOCRINE FACTORS AND BEHAVIOUR

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The important characteristic which distinguishes machines from man is that the former tend to exhibit steady state performance whereas man is subject to fluctuations in performance efficiency as a consequence of physiological bio-rhythms. Such variations in competence may be entrained to both internal and external factors outside of the individuals voluntary control. In certain instances however volition may be a determinant e.g. regulating drug ingestion or variations in sleep/wake cycles.

Endogenous rhythmical activity is evident from the early stages of embryonic development expressing in observable ways responsiveness to the dictates of the genetically controlled biological clock. Internal and external factors or cues may modify the frequency amplitude and pattern of fundamental rhythms. For example, the obvious coincidence of such phenomena as night and sleep seem to be fully answered by explanations based solely on light perception. Without doubt light and other external cues reaching the brain through the various sensory tracts exerts influences on the ultimate expression of physiological rhythms. Nevertheless the organism isolated fully from sources of these external cues will continue its activities in a rhythmical fashion. When no longer entrained to external stimuli the cyclical rhythms now "free running", tend to escape from the hands of the temporal clock and to establish their own constant biological time cycle periodicity. This periodicity may be greater or less than 24 hours.

The cyclical ebb and flow of adrenal hormone secretion into the peripheral blood stream offers a suitable first example of cyclical activity. Between mid-night and 02.00 hours the nadir or low point of activity of the adrenal gland occurs. At this time the hypothalamus elaborates corticotrophin releasing hormone which passing to the adenopituitary effects the release and additional secretion of ACTH into the peripheral circulation. As a consequence in the zona fasciculata of the adrenal cortex enzymatic and mitrochondrial activity is stimulated and cortisol is synthesized and released to achieve highest plasma concentrations immediately prior to the expected hour of arousal from the sleeping phase of the organisms day.

The inverse reciprocal relationship between plasma cortisol concentrations and plasma tryptophan concentration is noteworthy in the view of the demonstrated role of this aminoacid as a naturally occurring hypnotoxin.

Under normal circumstances the motor activity related night/day entrained periodicity of cortisol secretion is relatively slow to adapt to the changes in sleep time shifts.

Deprived of visual perception as an external cue the character of the adrenal response is altered with less marked episodic bursts of activity during the day but with the sleep related pattern preserved to a greater extent.

Not only hypothalamic pituitary adrenal function is found to exhibit a circadian pattern of activity. The study of other hypothalamic pituitary peripheral gland axes show similarities of phasic secretory activity and also some interesting differences.

Prolactin a hormone of greatphylogenetic antiquity exhibits a far more wide spectrum of action than its name implies. This hormone shows special secretory controlled characteristics. Alone of the "big six" anterior pituitary hormones in the human its rate of secretion is determined not by a hypothalamic releasing hormone its secretion rate being primarily regulated by an inhibitory factor operating through the agency of dopaminergic neurons.

The release of prolactin from the pituitary differs from that of ACTH in being more independent of the temporal clock or light perception and being governed more by the arousal level of the subject.

Hypothalamic pituitary gonadal secretions also demonstrate cyclical activity. While a circadian rhythmicity is evident in LH and testosterone secretion in males, it is the longer menstrual periodicity which is physiologically of greater importance in the female. The complex interrelationships of FSH, LH, oestradiol and progesterone in the normal menstrual cycle are now well defined.

Even in non-ovulatory cycles the ebb and flow of a pulsitile secretion of FSH and LH is clearly seen. Evidently more than the mere presence of all of the endocrine ingredients is necessary to produce the normal physiological effect. The action of many hormones depend upon the presence of absence of others which have facilitative or antagonistic actions. For example, cortisol facilitates the action of adrenalin in lipolysis and antagonizes the anabolic action of growth hormone. A point of considerable importance when one considers the potential role of growth hormone in mentation.

Growth hormone's peak secretion is related to the early phase Stage IV sleep. The amplitude of growth hormone secretion reaches maximal levels in puberty and early adult life. Waning growth hormone response to sleep and other stimuli such as fasting, stress, glucagon and aminoacid administration are features of senescence.

Behaviour and performance data supported by comparative studies of catecholamine excretion indicate the existence of two distinct arousal patterns in normal subjects. One group classified as "morning workers" and the other as "evening workers" on the basis of a questionnaire which established the time of day preferred by the individual for undertaking maximal work. Both biochemical and behaviour/performance data supported the premise that either constitutionally or by other factors the two groups could be identified. Furthermore a relationship to personality type could also be demonstrated morning workers being more frequently introvert types and evening workers demonstrated more extrovert characteristics.

Our group is endeavouring to assess the effect of drugs on the efficiency of the hypothalamic pituitary unit as a functioning entity in the normal subject during either a standard comprehensive challenge or during sleep with or without drug administration. e.g. LHRH, TRH plus insulin hypoglycaemia. The data obtained from such studies can only be of value if the drug induced changes are unequivocally different to changes which can occur either spontaneously or as a part of an inherent biological phenomenon.

Behaviour is the final common pathway of a number of factors including physiological, neurological and endocrinological ones. With the development of radioimmunoassay techniques the assay of hormones is now possible using micro-samples of blood. It is now possible to define the endocrine profile at given points of time. This will facilitate the elucidation of the complex interactions between the psychoneuroendocrine components of the individual. The composite effects of which are reflected in the efficiency of both mentation and motor performance.

In the context of this workshop, then, it should be clear that driver competence or judgement as reflected for example in risk taking is a behavioural final common pathway of all these interacting mechanisms.

The following is an example of a study carried out by the group illustrating the techniques used:

"Comparison of low pharmacologically effective doses of Propranolol and Nadolol on sleep neuroendocrine parameters":

Recently improved techniques for obtaining electrophysiological and biochemical data under physiological conditions during sleep offer new opportunities to re-examine questions concerning the effect of drugs on EEG monitored normal sleep endocrine profiles. The literature is at present confusing with inconsistent and often contradictory results recorded.

Catecholamines are important transmitters of the psychoneuro-endocrine system. Adrenergic mechanisms have complex effects on the phenomenon of arousal. They determine the percentage of total sleep time spent in the desynchronized (D) or REM stage of sleep. Their involvement in psychological processes controlling mentation is also evident. The pharmacological manipulation of brain catecholamine content has been beneficial in treating depression, anxiety and more recently schizophrenia, reviving interest in older theories concerning the aetiology of this psychiatric disorder. Monoamines are important regulators of the hypothalamic-pituitary-endocrine axis and of peripheral hormonal responses.

The following is an example of a protocol employed now by our group to investigate potential behavioural modification by drugs. In this instance sleep and its concomitant hormone activity is subjected to a pharmacological challenge.

Beta-blockers are widely used both as therapeutic agents and now also as investigative drugs. Propranolol is at present the standard beta-blocker because of its acceptable therapeutic index.

Propranolol and Nadolol (SQ 11,725) cross the blood brain barrier and are therefore important tools in psychoneuroendocrine pharmacology

Nadolol (SQ 11,725) is a new beta-blocker and is an effective agent which has reportedly some advantages over other presently available beta-blockers in treating patients with cardiovascular disease.

The objective of these studies, of which this is the first, is to compare the pharmacologic effects of Propranolol and Nadolol on sleep neuroendocrine parameters and to attempt to uncouple endocrine activity from the sleep phase to which it is normally entrained physiologically.

In this first study low pharmacologically effective doses of Propranolol and Nadolol are compared.

SUBJECT AND METHODOLOGY

The protocol for this investigation was approved by the National Drugs Advisory Board and the Ethics Committee. Six normal male volunteers aged 19 - 25 years were selected. Each had EEG sleep laboratory verification of normal sleep patterns. Prior to the study each had a complete medical and biochemical evaluation. Written informed consent was obtained. On completion of the study, the complete medical and biochemical evaluation was repeated. No subject had a history of a) psychiatric disease; b) drug use within 30 days of the study; c) history of alcoholism or narcotic abuse.

For the duration of the study all medication other than the test substances as prescribed were prohibited. The use of alcohol or marijuana was prohibited throughout the course of the study. Subjects were instructed not to nap at any time during the study from wake-up time to lights out each day.

METHODS AND STUDY DESIGN

Sleep Laboratory Facility

Subjects were accommodated in the sound attenuated sleep rooms which permitted monitoring of electrophysiological parameters and remote sampling of venous blood "trans-murally" in a room adjoining the sleep room.

Protocol

The study design was for a single blind cross-over sleep laboratory study with EEG sleep records scored on a double-blind basis. Results were evaluated on the basis of the standard accepted criteria for scoring of sleep stages and efficacy parameters established by the Association for the Psychophysiological Study of Sleep.

In addition the sleep endocrine profile in terms of growth hormone (HGH), prolactin (hPRL), adrenocorticotrophin (ACTH) and cortisol plasma concentrations was determined at the end of the base-line phase, at steady state during each drug administration phase, and at the end of the placebo withdrawal phase.

Drug Treatment Plan

There were two phases separated by one week's interval. Each phase was divided into four unequal periods totalling 14 nights, during which each subject was admitted to the sleep laboratory facility and dosed orally with drug according to the schedule in Table I.

Identical tablets containing placebo or 40 mg Nadolol or 40 mg Propranolol were used.

Each subject was confined to bed for a minimum of 8 hours per night. The amount of time spent in bed per night per subject was held constant throughout the study. Placebo or active medication was given orally at 22.00 hrs. Lights out and the beginning of EEG recording was 23.59 hrs. throughout the study.

Blood Sampling Technique

An intravenous siliconized polyethylene catheter was inserted via a cannula into an anti cubital vein at 22.00 hrs. during each night on which the endocrine profile was studied. (Study nights 4, 9 and 14). The catheter was advanced proximally until it reached the subclavian vein. The system was primed with heparinized saline, 2.5 units/ml administered at a flow rate regulated to 1 ml/minute. The overall capacity of the catheter system was 3.8 ml. Complete evacuation of the system before blood sampling was proven by microhaematocrit determinations before each sample was accepted. 10 ml samples of blood were drawn at 21.55 hrs. (control), 23.00 hrs., 23.59 hrs., and half-hourly through the night up to and including 07.00 hrs. All samples were collected into heparinized tubes, spun and the plasma transferred to a plain tube and refrigerated immediately. Analyses of HGH, hPRL and ACTH were performed by standard radioimmunoassay techniques. Plasma cortisol concentrations were determined by a competitive protein binding method similar to that described for progesterone.

Electrophysiological Mensuration

On nights 2, 3, 4, 8, 9, 10, 13 and 14 of each phase of the study sleep physiological data was recorded continuously from 23.59 to 08.00 hrs. on a Washington 400 MD 4 polygraph. Chart speed was 10 mm/sec.

Parameters Measured

a) Two channels of EOG from the outer canthus of both eyes with reference to the mastoid.

b) One channel of EEG C4 position with reference to A1.

c) Chin EMG electrodes 3 cm apart under the jaw.

For scoring purposes the polygraph record was divided into 30 sec. epochs. It was scored according to the method of Rechtschaffen and Kales with the exception that no attempt was made to distinguish K complexes from delta waves when scoring Stage III.

The record was completely scored by one person and any difficult areas re-scored by a second person. In addition random samples were completely rescored to maintain reliability.

Presentation of Sleep Data

When a score had been assigned to each epoch in the sleep record, the epoch scores were entered into an IBM 360/50 computer. The computer calculated 20 sleep parameters for each night (Table II). A graph was also plotted for each night using a Calcomp plotter attached to the IBM computer.

RESULTS

Endocrine Parameters

Figures 1 and 2 illustrate the results of the hormone analyses. They represent the integrated through the night half-hourly plasma concentrations of HGH, cortisol, hPRL and ACTH. Statistical analysis by Student's t test showed no significant differences in any of the parameters measured when sleep following the ingestion of placebo, Nadolol or Propranolol.

Electrophysiological Parameters

Figures 3 and 4 summarise the scoring of 7 standard variables recorded in the group of subjects in the study. Sleep patterns within normal limits were recorded during the control (placebo) phases. No statistically significant differences were observed in any of the full range

(20) of standard variables observed during sleep following the ingestion of either placebo, Nadolol or Propranolol.

CONCLUSION

The dosage of Nadolol and Propranolol selected for this first-step study will produce pharmacological effects in normal subjects. No statistically significant deviation from base-line values of electro-physiological or endocrine parameters was observed during sleep following the ingestion of 80 mg of either Propranolol or Nadolol.

Further studies in this series utilizing ascending dosage regimes and also chronic administration will be pursued. The objective is to determine whether or not at normally employed dosage levels any facet of endocrine activity can be uncoupled from the sleep phase to which it is normally entrained.

Table I

	Oral Drug Administration	Study Nights
I (Adaptation)	Placebo	1
II (Baseline)	Placebo	2 to 4
III (Treatment)	Nadolol or Propranolol (80 mg q.h.s.)	5 to 10
IV (Withdrawal)	Placebo	11 to 14

Table II

Name	Description
1) Sleep latency	Min. from"lights out" to sleep.
2)-4) Wake time thirds	Wake time after sleep onset in each third of the night.
5) Wake time	Sum of 2) to 4)
6) Number of awakenings	Total number including final wakening.
7) Total sleep time	Total time spent asleep during "lights out."
8) % sleep time	8) as a % of total "lights out" time.
9) - 12) Sleep stage time	Time in mins. spent in each of stages 1 to 4.
13) - 16) Sleep stage %	Stage 1 - 4 as a % of sleep onset to final awakening.
17) REM time	Time in min. spent in stage REM.
18) % REM	REM as a % same as 13) to 16).
19) REM latency	Time from first sleep to REM.
20) Number of REM periods	Number of times REM was entered and left.

POSSIBLE PITUITARY-ADRENAL FACTORS IN ATTENTIVE BEHAVIOUR

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ABSTRACT

Pituitary-adrenal factors influence attentive behaviour. The ACTH-fragment, ACTH 4-10, improves vigilance and alertness in the first few studies in man. The relevance of this finding for driving performance is discussed.

The endocrine system as an integrated whole is vitally important in the regulation of normal metabolic function, sexual and reproductive behavior, and growth and differentiation processes. Of greatest relevance in the present context is the intimate involvement of hormonal factors in many aspects of the adaptation of organisms to changes in their environment, especially those of a threatening nature.

Over 40 years ago, Selye called attention to the fact that a wide variety of stressful stimuli produced in rats a rather stereotyped response. Selye termed this syndrome the "General Adaptation Syndrome" and its initial stage the "alarm reaction". The involvement of many physiological systems in the "alarm reaction" as well as its non-specificity with regard to the precise stressor suggested that hormonal mechanisms were involved (Tepperman, 1973). Indeed, a large body of subsequent research revealed that the pituitary-adrenal axis hormones in particular played a crucial role in adaptive readjustment of the organism's physiology (Selye, 1971).

An example may help to clarify this point. In response to stress, neural impulses promote the release of a substance by the hypothalamus, an important regulatory center in the brain. This substance, corticotrophin releasing factor (CRF), acts upon an adjacent structure, the pituitary, frequently characterized as the "master gland". Specifically, CRF elicits the secretion by the pituitary of adrenocorticotrophic hormone (ACTH). ACTH then travels via the bloodstream to the adrenal gland, an organ located peripherally in the peritoneal cavity. Here it causes the secretion by the adrenal gland of certain types of hormones, corticosteroids. A variety of peptides and hormones are similarly elicited by stressful stimuli, including prolactin, vasopressin and endorphins. Once they are released, these substances exert their "normal" peripheral effects. Such peripheral effects may be seen as part of the adaptive response to the stressful situation. Hormonal influences are, therefore, vitally linked to the normal regulatory and adaptive control mechanisms of the organism and serve to protect it from environmental insult.

Recently it has become clear that hormones, in addition to their peripheral effects, influence behavior by a direct action on the brain. Pioneering work in this area was performed by De Wied and associates (Utrecht) who systematically studied the role of pituitary-adrenal hormones in maintaining certain types of adaptive behavior in rats. Specifically, it had been noticed that hypophysectomy (surgical removal of the pituitary gland) produced a severe deficit in the learning and retention of a particular response in rats. Administration of either ACTH or vasopressin, two of the pituitary's products, was able to reverse this deficit (De Wied, 1969). Further, they demonstrated that the facilitatory properties of such hormones were not confined to debilitated subjects, for ACTH or vasopressin could also improve behavioural performance in normal rats (De Wied, 1971; De Wied et al., 1972; King and De Wied, 1974).

Several lines of reasoning demonstrate that these effects on behavioural adaptation are mediated by direct action on the brain rather than through the peripheral sites of action of these hormones. First, microquantities of these compounds have been implanted directly into discrete locations in the brain and have been found to exert their characteristic effects (Van Wimersma Greidanus et al., 1974; Van Wimersma Greidanus and De Wied, 1978). Second, fractions of the ACTH molecule, e.g. ACTH 4-10, have been synthesized that have no peripheral adrenocorticotrophic activity; similarly, analogues of vasopr essin virtually without peripheral potency are available. These compounds also exert the effects on learning and retention seen by the parent hormones (Greven and De Wied, 1973; Rigter and Van Riezen, 1978). Third, inferential evidence for central effects of these peptides is provided by the fact that both central neurochemical changes and alteration of specific electrical activity in the brain may be induced by their administration (Dunn and Gispen, 1977; Urban and De Wied, 1974; Van Wimersma Greidanus and De Wied, 1978).

Although it is clear from the studies in animals that ACTH-like and vasopressin-like peptides may affect behavioural adaptation through direct central nervous system effects, the precise mechanism of these actions is not yet understood. Although learning is enhanced in some studies, in others it is unaffected. Memory retrieval processes are more reliably facilitated in the animal studies. The most consistently supported hypothesis is that these peptides enhance attention, perhaps through an influence on arousal or motivational systems. Fortunately, there are now available a few studies with human subjects in whom such distinctions may be more easily drawn. We shall consider a representative few of these studies in some detail.

Most studies have employed normal human subjects and have administered a variety of psychological and physiological tests following peptide treatment. Miller at al. (1976), for example, studied the effects of ACTH 4-10 in 20 male subjects in two testing sessions. In one session the peptide was given (30 mg subcutaneously) and in the other a placebo injection. This fragment of the ACTH molecure has no peripheral adrenocorticotrophic activity, but it is nonetheless active in behavioural tests in animals. In each testing session, subjects were administered a variety of memory tests, questionnaires designed to assess anxiety level, and a test of perceptual flexibility. In addition, a sophisticated assessment of continuous performance in a vigilance task was obtained. This task required subjects to view an oscilloscope screen on which letters appeared briefly and press a button whenever the letter X appeared. Task difficulty was varied by decreasing the relative frequency of occurence of the letter X from 1:2 to 1:13. Throughout both testing sessions, electroencephalographic measures were recorded.

Treatment with the ACTH fragment improved performance on some but not all of the memory tests. It had no effect on perceptual flexibility or anxiety measures. This pattern of results is typical of most such studies, in which a mildly enhancing effect on cognitive ability is only rarely seen. On the vigilance task, however, improvement was seen on the first occasion that the difficulty level of the task was changed. Subjects at this time detected significantly more Xs and responded incorrectly to other letters less frequently. Thus, the peptide-induced facilitation could not be due simply to increased response rate. The electroencephalographic measure, average visual evoked potential, showed changes consistent with the enhanced attentional properties. Specifically, there was an increase in the latency and a decrease in the amplitude of the negative component appearing 200 msec after stimulus presentation. In sum, the suggestion is of a quite specific effect on attention and alertness. While general arousal was not elevated, the enhanced attention most probably enabled improved memory in some conditions.

Another study of the same peptide reinforces the attentional hypothesis. Gaillard and Sanders (1975) gave two groups of subjects either placebo or 30 mg subcutaneous injections or ACTH 4-10. The subjects were then tested for reaction time in a continuous session. In this task, a subject had to respond to one of six lights by pressing the appropriate key as quickly as possible. Shortly after a response, a new light appeared; the subject, therefore, had to monitor the light panel continuously. Performance was measured by response accuracy (i.e., whether the correct key was pressed) and reaction time (i.e., latency to press the key). As training progressed on this task, the average reaction time remained stable. This is misleading, for in reality two tendencies appeared. First, there was a gradual shortening of reaction time due to learning. On the other hand, there were increasing numbers of long reaction times, due to mental fatigue. These two counterbalancing trends resulted in stable average performance. Further, the number of errors increased as training progressed. Gaillard and Sanders found that ACTH 4-10 prevented the increase in the number of long reaction time trials seen in the placebo condition. In addition, it prevented the elevation in error rate normally seen. These results suggest that the peptide served to maintain an optimal level of vigilance, perhaps by counteracting a corticosteroid-dependent development of fatigue.

It seems clear that these findings are relevant to the ability of individuals to drive, especially in the case of long-distance driving where vigilance must be maintained. If we consider the problem of safely negotiating a busy highway, we can see that a discriminated continuous performance problem of the sort employed in the studies of Miller, et al. and Gaillard and Sanders provides a reasonable model for the task. Certainly, an increase in reaction time in an automobile is a highly dangerous situation. On the other hand, vigilance must retain some degree of selectivity. It can be as dangerous to respond quickly to irrelevant events in the roadway as it is to fail to respond to real threats. Individuals faced with long-distance driving fatique typically attempt to cope with one of two strategies. The first is to do nothing other than to continue driving, presumably with the hope of arriving before the accident. This strategy increases the likelihood of missing a relevant stimulus. The other strategy is selfadministration of stimulants such as amphetamines or caffeine. These compounds tend nonspecifically to increase arousal; consequently, the likelihood of responding drastically to an irrelevant event is increased. Clearly neither of these coping strategies is optimal.

Stress, whether it results from injury or the fatigue and tension accompanying the continuous vigilance required by driving, has clear effects on the pituitary adrenal axis. Conversely, the endocrine system is intimately involved in the organism's adaptive response to stressors. The research surveyed here suggests that, in particular, attentional processes are influenced by endocrine factors. We may expect, then, that any behavior so dependent upon continuous vigilance as driving would interact with the endocrine system. In other words, normal functioning of the adaptive hormonal mechanisms would be expected to be a necessary condition for the adequate performance of driving skill. We have presented evidence that this statement may be true for hormones of the pituitary-adrenal axis. It remains to be seen whether other hormones are involved.

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RATING BIOLOGICAL AGE

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ABSTRACT

Advantages and disadvantages of methods used for rating biological age are recalled. Stress is put upon particularities of the ageing of the nervous system, for instance, on difficulties in identification of information and on tardiness in decision making which can be masked or compensated by an adapted behaviour of the individual. By no means biological age should be used to decide someones fitness for driving; too many factors interfere, environmental conditions being not among the least.

INTRODUCTION

Ageing is a reality, but its process differs from one individual to another. The variability which is shown already during growth is more marked in ageing because of the long history of each subject, his heredity, his psychological, physical and social health. Nevertheless, even if it is possible to follow the life of an individual, it is uneasy to tell when impairment of functions and decline of performances start, and hard to estimate if this is normal for his age due to lack of references. Longitudinal studies have show their first results in specific groups but are not always adequate to be generalized to others living or having lived in different conditions. Ageing is due to tissues and organs involution, but the rate of this mechanism is particular to each of them. Taking the extremes, some begin to alter long before the end of growth (lens), others keep their functional capacities until late in life. (secretion of gonadostimulines, ante-pituitary growth, insulin).

METHODS OF RATING

Physiological ageing :

Bourlière assesses three ways of estimating body involution :

1° Global tests for ageing are measuring the entire active protoplasmic mass. Radioactivity of K_{40} must be mentioned. This isotope is present in every natural potassium. 98% of body potassium is located in living cells, of which 60% in muscle. Unfortunately, this method can only be used in highly equiped laboratories and therefore is an expensive one. Among more simple methods, the basal metabolism seems to correlate rather well with the K_{40} results and therefore with the active protoplasmic mass. Other methods are too much under influence of external causes (activity, food intake) to be of overt value (urinary excretion of creatinin being correlated with muscular mass) fiability of such methods seems all the more, less certain after sixty.

2° Functional capacity :

Seeing that global tests are sometimes complicated and probably inappropriate to the purpose of finding out if someones has its driving skill diminished, the investigation of functional capacity of particular organs will help to solve the problem. The results of these tests might permit to build up an ideal profile of the average individual at different ages in the manner R.HUGONOT (1973) has established the individual profile by rating between 0 and 10 the degrees of autonomy in motor, sensorial and cerebral fields. But its components (muscular, locomotor, cardiac, respiratory capacities; sight and hearing perception and discrimination) will have to be weighted. Between all the static tests used in clinical medicine and in investigation of ageing, the followings are also appropriate for the study of driving skill : Blood pressure - Vital capacity - Blood sugar - Muscular strenght - Visual field - Visual acuity - Transparency of the refracting medias - Time of recuperation after dazzling - Audiometry.

Urinary excretion of 17-ketosteroids, lens accommodation (before 55years) have not the same signification as routine tests or skill evaluation. But the dipersion of the values found is getting wider and wider in the older age groups, so appraising "normal" ageing is less accurate. Nevertheless, it can be said that ageing increases the biological differences amongst human beings and therefore the limits of normality become blurred.

Moreover, all the deficiences encountered have not the same burden; as a matter of fact some are easily overcome by technical aids while others constitute severe unimprovable impairments or are the sources of secondary impairment (miotics, etc...).

3° Dynamic tests seems more favourable to find out the real capacities with which the organism has to react to effort or stress; adaptability is thus more objectively measured. Differences which are known as existing between adults and aged are more strongly marked by these dynamic investigations. Though, while ageing, the individual is still able to react to a stimulus coming back to the starting point is more and more difficult.

Stress or loading metabolic tests are rather numerous : induced hyperglycemia, Clement muscular fatigue tests, and in the cardiovascular field: step tests, tread mill, bicycle ergometer etc...

But adaptability must also be viewed on the environment standpoint; heat, noise, light must be taken into consideration for example. It has been demonstrated that the elderly do not stand overheated atmosphere as young adults do. Paradoxically intense light, which help the old people to discern precisely, is tiring after a while (Lehman) and in the same way those suffering from hearing loss are still sensitive to noise.

Psychological ageing :

It is perhaps in this field that ageing has been investigated to a larger extent. Here again variability in the population is important, as well as the variability in the way each psychological function regresses.

Anything which recalls acquired knowledge or experience and knowledge do not interfere are less and less successful with the ageing proces.

Determinations of intellectual ageing may be classified into two categories:

1° Non specific tests :

These are supposed to measure a factor common to every mental process : the capacity of abstraction and synthesis. As long as these tests are not verbal they are influenced by ageing : Kohs cubes and Raven progressive matrices are examples of non specific tests. Wechsler Intelligence Scale, though evaluating the global intelligence of adults, takes also into consideration acquired knowledge and experience. This last test is less susceptible to be modified by physiological damage than the two first ones.

2° Specific tests :

Such ones are focused on learning as is the code test which associates symbols and is the test which explores short term memory. As for investigating perception, the test generally used is Benton's visual retention test. Though influenced by the degree of memory, it has the capacity of evaluate cerebral integrity. In a review of ageing one must not omit evaluating tests measuring reaction time. They are physiological and psychological tests. The reaction time increases with age especially after 80 years old.

More essential still is the determination of the amount of coordination that the central nervous system can handle, amounts which decreases with ageing and is greatly responsible for the slowness in performance. Slowness of elderly in accomplishing tasks is due to the tardiness in decision making and in identification of information rather than to the decreasing speed of motor reaction.

Personality tests are of very little value in the study of psychological involution. Again because variability is large in the affective and characterial field. However, the personality tests such as Minnesota Multiphasic Personality Inventory and the Rorschach have demonstrated a slight tendency of introversion and depression which occur with age, but also perhaps with social status changes.

State of health

It is not possible to consider the rating of biological age without taking notice of the individual state of health and the influence that the latter exerts on the first. Family and personal history can too, impress ageing process. Besides genetics, environment since childhood may have consequences on capacities of adaptation and intellectual or physical faculties.

Paraclinical examinations (cholesterol, lipids, blood counts, uremia, creatinemia, etc...) may be of prognosis value and must be examined when a biological age is attempted to be given to an individual.

CONCLUSION

In spite of these alternative ways of conceptualising and measuring the effects of ageing, it has not yet been demonstrated that biological age can replace chronological age as a more effective predictor of impaired performance. However, the problem is an important one because legislation regarding fitness to drive, which uses chronological age as a criterion, may be arbitrary. Moreover it has been proved that a large number of handicaps are perfectly compensated.

There is a dearth of knowledge about the circumstances in which the aged are involved in accidents and this makes it particularly difficult for medical practitioners to administer certificates of fitness for driving licence authorities.

It must also not be forgotten that experience and awareness are in favor of most of the elderly but also that an environment which allows them a better perception reduces reaction time and improves discriminations, and anything which reduces belittlement of elderly in front of younger adults.

Taking note of this, anything which is in favor of the aged can be propitious to the rest of the population when security, comfort and enjoyment are in mind.

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THE WORKING CONDITIONS OF ROAD TRANSPORT DRIVERS

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ABSTRACT

The working conditions of lorry drivers travelling regular or irregular, short or long term trips in France have been studied. The influence of such conditions on the drivers vigilance and ability are analyzed.

INTRODUCTION

The research work related to driver's fatigue is motivated by the operational concern to reduce road insecurity. Nevertheless, it can be stated that the study of this problem can be envisaged in different ways and that often many disciplines are involved depending on whether this or that aspect of the phenomenon of insecurity linked to the circulation of individual vehicles is studied. It seems that the different disciplines involved come under two distinct modalities. They may be called upon, externally so to speak, by the various solicitations which contribute to the organization and regulation of road traffic so as to define through the generality of the phenomenon of fatigue, all the existing problems of road security. They may also be called upon, internally, since the criteria they use are only, in an induced manner, the reflection of the phenomena they study, and in such a way that the pertinence of the results they give imply an interrogation of their own theoretical and methodological schemes.

In other words, whether it concerns socio-economics, statistics, physiology, ergonomics or any other discipline, two questions concerning their intervention in the analysis of the phenomena face the research worker called upon to investigate a problem before submitting conclusions to the man in the field:

.- How do results produced in a given perspective concern the practical problems to be solved?, and

.- How and in what way do the theoretical and methodological modalities of the research done in each discipline take into consideration the phenomenon of fatigue?

If, in the studies on drivers fatigue carried out by psycho-physiologists, the level of vigilance constitutes the criterion to measure the state of fatigue, and, if this depends on driving time, then the point remains all the same to find out if the indices which permit the measurement of the level of vigilance are unequivocal, and even if they are the best criteria to measure fatigue... Thus, many questions are raised in the researcher's mind and on their answer depends the quality of the replies given to the man in the field.

Results of investigations carried out by physiologists, confirm so far their hypothesis that there is a deterioration of the drivers' sensory-motor capacities and vigilance under the influence of fatigue measured in terms of the accumulation of efforts and depending on the duration of the task to be accomplished.

The purpose of the socio-economic studies carried out by ONSER, after having studied the drop in vigilance in relation to working hours, was to describe the different work situations to establish a system of differences allowing a distinction to be made between these situations on the basis of the amount of efforts they require from the drivers, by the measurement of the time they devote to the work and the various activities making up their job. In other words, if the physiologists have established that the drop in vigilance and therefore the risk of errors or sleep can be related to the time spent in performing a task, the enquiries made and reported here aimed at ascertaining which global conjuncture or which work post required most time and were most probably linked to risk taking, due to a drop in vigilance.

MATERIAL AND METHOD

It is therefore necessary to define different work situations in their concrete structuration (usual type of journey, global amplitude of time (week, day, group of days) necessary for the transports, tasks to be done..) and to see how they induce different profiles of expenditure and the usage of time by the drivers.

A sample of 139 drivers doing different assignments have during two consecutive weeks filled a note-book, where they uninterruptedly rated the durations of different activities of work, pause, rest and sleep.

The facts established on the basis of this sample verify the tendencies that can be uncovered by a knowledge of the milieu it does not measure them with the statistical precision that would have been possible with an aleatory sample, but the subject itself of the enquiry, viz "working hours", constitute a theme which spontaneously provoke the distrust of drivers. This is easy to understand when it is realized that working hours are often the subject of rules and that the sanctions apply to the drivers themselves. To avoid this difficulty, personal contact with 500 drivers was established in order to convince them to collaborate in the study. Less than half (about 200) accepted, but only 139 gave data that could be used.

The results obtained corroborate a fact testified by the discussions with the majority of people who know the professional sector, and by administrative enquiries.

The working hours are very long (62.5 hrs. a week. 11.5 hrs. a day on an average in our sample); for most of the drivers (80 % in our sample, 75 % in the administrative enquires) the prescribed duration of 50 hrs. of work a week is largely exceeded. This indicates that rules do not constitute the reference on which behaviour depends, but that behaviour depends on restrictions particular to the different work situations of the drivers. Besides, a hypothesis can be made that the generality of the deviation from the regulations is probably the result of structural phenomena in the economic and sociological sense. The study of these structural phenomena would permit (if it were developped) to explain the specificity of a profession which is largely an exception to the general tendency to reduce working hours.

If this general result underlines that the practical imperatives of the different types of road transports are, at least at behaviour level incompatible with respecting the regulations of working hours, more detailed results indicate that this incompatibility is not fatal as it is a relative fact about which strong hypotheses can be formulated.

Differential structuration of work situations:

In the analyses undertaken, taking into account the knowledge acquired from interviews with drivers and company managers, it was possible to distinguish between five big groups of work situations, which differ according to two dimensions :

- radius of the usual journeys:

territories of several countries, the whole of the country, several provinces adjacent to the depot, urban or peri-urban zones surrounding the depot.

- the temporal periodicity defining the work:
  - Work that allows the driver to return home every evening.
  - Work necessitating the drivers absence during periods of two to three consecutive days.
  - Work necessitating the drivers absence for a whole week or more.

Possible categories permitting the regroupment of drivers according to the two dimensions of temporal and spatial definition of transports:

	Territorial zone of transports			
	International	National territory	Limitrophe province	Urban or peri-urban. Zones close to the depot
			(M.D.)	(S.D)
The Day			Médium distance	short distance driver cum delivery man
2 to 3 consecutive days		Long distance on tour LDRM 2	Rare (M.D.)	
The week	International (I)	long distance absent for the whole week LDRM 1		

If the scale thus defined is realistic and precise for international and long distance drivers, it absolutely does not take into consideration the existing differences in the category of medium distances which can in turn be divided into two sub-groups:

- the medium distance drivers who make many deliveries in one day and are responsible for their rounds of clients and who assume the function of driver cum delivery-man on a territory slightly larger than the town and its suburbs.

- the medium distance drivers who make one or several rounds the same day, whose work is not organized according to one round of clients to be delivered, but rhythmed by a series of rotations in quasi complete loading or with very few loading breaks.

Unfortunately, it has not been possible to make this distinction for reasons linked with the relative imprecision of both the categories, the difficulty in finding combinations of unequivocal criteria, and the limited number of enquiries available. Inspite of this lack of precisions for which new investigations are necessary, the hypothesis according to which the different structurations of work posts are correlative to different ways of spending and using working hours is verified.

Indeed, it can be stated that the tendency to work much and to rest (sleep) in precarious conditions is much more frequent in the case where the radius of habitual transport and the temporal amplitude defining the work to be done are wider (see tables 1 and 2).

RESULTS

National and international drivers (I and LDRM 1) who are absent from home, or from the company's depot, for one whole week work more than 60 hrs. a week in most cases, whereas among transport drivers on tour who make several rotations with one or several returns home, or to the company, and among medium distance drivers the number who work more than 60 hrs. is about the same as the number who work less (LDRM 2 and MD). The majority of short distance drivers (SD) work less than 60 hrs.

The analysis of the composition of time spent on different work activities allows to conclude that there are connections between the global work duration and the relation between driving time and time of loading breaks. Allowing for different work structurations, depending on the groups, there are different relations in the same group between the relative part of time devoted to driving and that devoted to loading breaks. This is shown in terms of the global of working hours and leads to the idea that if the differences which appear in the same group depend on this relation between the relative part of driving time and the relative part of loading breaks, some hypothesis should be formulated about the tendencies produced by this relation. A detour is necessary to formulate this hypothesis.

Differential role of the duration of loading-breaks and of driving in the structuration of work situations.

a) - Loading breaks : the lengths of the loading-breaks represent a relative part of working time more important for medium and short distance drivers.

These are also composed more of administration than of waiting when compared to the loading-breaks of long distance drivers. This result shows the specific elements of the differential structuration of work situations. Medium and short distance drivers have in theory more deliveries to make, thus more points of loading-breaks, handling being statutarily part of their work. While, theoretically, long distance drivers do not have to handle anything, they actually do so during half the time allotted for loading-breaks (8 to 12 % of their entire working time - 1 to 5 % of the global time) probably in order to reduce the latter as much as possible.

All tend to confirm what the drivers and the company bosses say about the importance of the time spent at the place of loading-breaks in the arrangement of the chronology of work activities and in their effects on the possibilities of rest. The long distance drivers in particular organize their work according to the loading-breaks. The hours during the day when industrial and commercial establishments are closed, or the unloading or loading quays are crowded, or when the quay staff is available or not, are so many elements which the drivers have to take into consideration to choose the best arrival time in order to reduce halting time at the loading break points. Indeed, if at any one loading-break point, a driver wastes too much time, it is the economy of his work / rest rhythm which is affected.

This point is fundamental in understanding the logic of important differences that one notices between the different categories of drivers and between groups of drivers belonging to the same category.

b) - Driving of the vehicle: a very narrow relation exists between the tendancy to drive a lot and the structural definition of the work situation in terms of the stretch of territory on which the habitual journeys are made (see table 1). In addition, for the group of long distance drivers the frequency of working days having more than 8 hours driving time is greater when the temporal definition of the transports is wider (difference between LDRM1 and LDRM2) (see table 2).

These two results illustrate the different effects of the dimensions defining the groups of drivers. The stretch of territory covered by the usual transports determines and influences the quantity of work and of driving; similarly, a smaller or greater periodicity of rotations (returns to the depot), defining the more or less loose structuration of working hours, also has effects on the quantity of the entire working and driving periods.

These two dimensions have important effects which can be expressed in the following statement: the greater the reduction of territory on which the transports are made and the greater reduction of the period of time necessary for these transports, the greater will be the reduction of the proportion of drivers who work more than 60 hrs a week.

Such a formulation seems quite insufficient. If, in fact, the usual distance of the journeys can discriminate relatively well between the different groups of work situations, the longer or shorter period of time necessary for the work is only a discriminating factor inside the group of work situations of long distance drivers. A certain number of questions arise about the real contents connected to this last dimension. Does returning to the depot one or several times a week create a certain regularity in the work done? We can make the hypothesis that this element of regularity is connected to the company's capacity to control its relations with the client or the market. It is also part of forms of organization of the transport processes, particularly that which concerns the organization and the division of work between transporters and clients at the loading-break points. The regular periodicity of rotations into shorter amplitudes (time required for the transport) seems to be the fundamental element determining the improvement of the drivers' work productivity and the conditions under which the transport is done.

Without believing, against the most manifest facts, that there is a necessary correlation between the increase in productivity and the reduction of working hours, the results of the enquiry show that the working hours have a greater chance of being reduced if the periodicity of rotations and the temporal limitation of amplitudes are insured (see the differences between LDRM1 and LDRM2) or according to the terms of our hypothesis that the work post is more organized.

It can be considered that the rate of time per day spent in stop loading (rate of stop loading = $\frac{\text{time of loading stops}}{\text{work time}}$) and, a contrario the rate of time per day spent in driving (rate of driving = $\frac{\text{driving time}}{\text{work time}}$) constitute the two indices which give an approximate idea of the degree of organization of the work post.

It can be stated that for a same group of long distance drivers (LDRM1 and LDRM2) (see tables 3 and 4) defined on the level of the geographical area of activity, the frequency of days of a high driving rate ($\geqslant$ 80 % of time spent in driving) is <u>greater</u> when the drivers have lesser weekly working hours ($<$ 60 hrs.). A contrario the frequency of days of a high rate of loading-breaks ($\geqslant$ 40 %) is <u>lesser</u> when the drivers have shorter weekly working hours ($<$ 60 hrs.). The latter is particularly true for LDRM1.

If, at the same time it is remembered that the chances of working less than 60 hrs. a week are greater when the definition of the temporal rhythm of work is less loose (difference between the groups LDRM1 and LDRM2), then one could to ask whether the work specification (a priori definition of the number of rotations, the places and the conditions of loading-breaks) at the level of the company rather than at that of the driver (the latter not having to look after the following up of the transports) does not constitute the main element which would permit a reasonable diminution of the general working hours.

Evidently, our results help more to make this question a hypothesis than to reply precisely to it.

In fact, if it is admitted that this question could be a conclusion, then one has to explain nevertheless why and under which forms half of the long distance tour (LDRM2) drivers work for more than 60 hrs. a week. Two interpretations are possible:

.- The hypothesis does not hold: the definition of work in short and repetitive amplitudes does not induce any form of specification of the task resulting in the least amount of time spent, but is in effect aleatory, or

.- the first hypothesis holds good and the long weekly working hours are due to two different phenomena: for some, the work posts have long durations of loading breaks, and, for others the driving work is intensified.

With our present knowledge we lean towards the second interpretation even though it deserves verification that would be possible only with a systematic budget time enquiry concerning drivers living in differentiated work situations and belonging to enterprises whose modes of organization could be analysed.

Apart from the study on the specification of working conditions as such, which remains to be done, we would like to repeat that the tendencies brought out about the spending of time and its structuration follow the same logic for driver's rest and more specifically for their sleep.

Globally, 31 and 11 % of the series of 24 hrs. analysed consists of less than 6 and 4 hrs. of sleep respectively . The conditions of sleep are clearly more precarious for long distance drivers than for the others. Thus,for national and international long distance drivers 66 % (and more depending on the categories) of the series of 24 hrs. of work analysed had less than 6 hrs. of sleep and 13 to 19 % (depending on the categories) less than 4 hours of sleep. Besides, we know that half the resting time is spent in bunks. For medium and short distance drivers, in one fourth of the analysed days for the first case, and 1/10 th for the second, the duration of sleep was less than 6 hrs. It is rarely less than four hours. Besides,they rarely rest in bunks.

CONCLUSIONS

All the elements noted here, compared to those of an american study (Harris et al, 1972) and of another study now in progress at ONSER, which shows the existence of a major risk of accident linked to the work duration allow to give some elements of reply to the question as to whether the working conditions of the sample considered here were dangerous for road security.

Comparing, with due caution, the results obtained here with those of the american study, and allowing for the fact that driving conditions differ in the USA and France (the average accident rate per km run is almost three times lower in the USA) one can still underline a number of facts:

.- A significant increase in the frequency of accidents was noted in the USA after 7 hours of driving; the same number of hours happens to be the average daily driving hours of our sample;

.- In the american study an increase of 300 % of the average risk after 10 hours driving was found; in our sample 16 % of the analyzed days included at least 10 hrs of driving, and even at least 12 hours in 7 % of the cases.

The influence of many other facts remain to be shown, such as the cumulative effects of weekly working hours, the pauses sometimes not long enough to allow an adequate recuperation, the nychtemeral effects rendered more dangerous by the not exceptional practice of long night driving, the frequency of uninterrupted driving sequences of more than four hours, etc.

Despite these reserves, it is a global affirmative reply which can be given to the question originally asked. Indeed, the working conditions stated and analyzed by us are effectively dangerous in terms of road safety. Fortunately, of course road safety relative to the traffic of trucks does not depend only or even mostly on the working conditions of professional drivers. Although effective action in the field of road safety is always pluridimensional and general measures concerning speed limits, improvement of the infrastructure, checks on alcohol consumption or wearing of safety belts which have been or will be soon applied should help reduce road traffic accidents, it is of particular importance to recognize that working conditions are one of the specific factors of lorry traffic safety.

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TABLE 1 . PRESENTATION OF THE CHARACTERISTICS OF THE USAGE OF TIME PECULIAR TO EACH GROUP OF DRIVERS.

	W O R K	D R I V I N G	LOADING - BREAKS	S L E E P
I	9/10 th of the drivers work more than 60 hrs a week 37 % of the work amplitudes are greater than 15 hrs.	9/10ths drive more than 35 hrs a week Globally 62 % of their working time is spent in driving 42 % of the days of W km > 450. 11 % of the driving sequences > 4hrs	24 % of the time is devoted to stops for loading and unloading (1/2 in handling 1/2 in waiting) 10 % of the time is spent in waiting for custom clearance	33 % of the days, hrs of sleep are less than 6 hrs. 38 % of the sleep sequences are < 6hrs 30 % of those spent in bunks < 5hrs.
LDRM1	8/10ths of drivers work more than 60 hrs/week 25 % of the amplitudes are greater than 15hrs	6/10th drive more than 35hrs/week Globally 64 % of their working time is spent in driving. 42 % of the days of km > 450. 15 % of the driving sequences > 4hrs	30 % of the global time in loading - halt, 6/10ths of which is for handling.	38 % of working days when they sleep less than 6 hrs. 43 % of consecutive sleep sequences are < 6 hrs.
LDRM2	5/10ths of drivers work more than 60 hrs/week 38 % of the amplitudes are more than 15 hrs.	6/10th drive more than 35 hrs/week Globally 66 % of their working hours is spent in driving. 42 % of the days of km > 450. 12 % of the driving sequence > 4hrs	26 % of the global time in loading halts, 6/10 th in handling.	38% of the days, hrs. of sleep are less than 6 hrs. 37% of the continuous sleep sequences are < 6 hrs.
MD	5/10th of the drivers work more than 60 hrs / week 14% of the amplitudes are greater than 15 hrs	4,5/10ths drive, 35hrs/week. Globally 60% of their working hrs is spent in driving 22% of the days of km > 450. 1,5%of the driving sequences > 4hrs	33%of the global time in loading halts 3/4ths of which in handling The loading breaks are more or less numerous depending on the cases.	25% of the days the time of sleep is < 6hrs 20% of the continual sleep sequences < 6hrs
SD	2/10th of drivers work more than 60 hrs/week 5% fo the amplitudes are greater than 15 hrs	1,5/10ths drive 35 hrs a week. Globally 48% of their working time is spent in driving. 9 % of days of km > 450 . time of driving sequences > 4hrs.	47% of their time, 8/10ths of which consists of handling. the loading breaks are numerous.	Very few days when the global sleeping time is less than 6hrs. 19% of the sleep sequences are less than 6 hours.

TABLE 2. DAILY DURATIONS OF DIVERSE ACTIVITIES DEPENDING ON THE GROUPS AND WEEKLY DURATIONS OF WORK. *

	Work ≥ 12hrs %	Driving ≥ 8hrs %	Loading-break ≥ 2hrs %	Sleep < 6hrs %	< 4	(1)
I ≤ 60						8
I > 60	56	42	44	34	13	92
I E	51	40	47 (A=M)	33	12	100 (258)
≤ 60	31	23	36	20	8	20
> 60	51	46	61	42	17	80
E.LDRM1	47	45	56 (A=M)	38	15	100 (308)
≤ 60	22	29	51	27	11	49
> 60	47	45	70	49	28	51
E.LDRM2	34	37	61 (A=M)	38	19	100 (287)
≤ 60	11	10	66	15	2	50
> 60	39	39	57	36	6	50
E.MD	25	25	61 (M>A)	25	4	100 (471)
≤ 60	5		93	16	1	78
> 60						22
E. SD	11		91 (M>A)	12	1	100 (132)
E / groups E / 1456 days	35	32	60	31	11	

(1) Proportions of driving/days of drivers working less than 60 h/week and of those who work more than 60 hrs/week.

In each group of drivers, proportion of days for which the work is ≥ 12 hours, the driving ≥ 8 hrs ; the loading-breaks ≥ 2 hrs (A> M or M >A means that the durations of loading-breaks are made up of a greater amount of waiting-time than handling time and vice-versa) sleeping time < 6 hours.

* Each group of work situation is subdivided in 2 subgroups depending on whether they require more or less than 60 hrs of work/week.

TABLE 3. DAILY DRIVING RATE.*

% driving	< 60	< 80	≥ 80	%	E
International	37.98	43.49	27.51	100 %	(258)
LDRM1	33.31	37.66	29.33	100 %	(308)
> 60hrs ≥ 481	33.60	40.48	25.91	100 %	(247)
≤ 60hrs < 481	16.34	26.13	42.62	100 %	(61)
LDRM2	35.54	39.37	25.09	100 %	(287)
> 60hrs ≥ 481	31.03	44.14	19.31	100 %	(145)
≤ 60hrs < 481	33.51	34.24	30.99	100 %	(142)

TABLE 4. RATE OF LOADING HALTS.*

% loading-halts	< 20	≥20 <30	≥30 <40	≥40 <50	≥50	%	E
International	49.23	18.22	16.28	6.98	9.30	100 %	(258)
L D R M 1	36.31	23.70	15.26	10.71	13.96	100 %	(308)
≥ 481 > 60 hrs	32.79	24.29	16.60	10.93	20.19	100 %	(247)
< 481 ≤ 60 hrs	50.82	21.31	9;84	9;84	8.20	100 %	(61)
L D R M 2	28.92	18.47	21.60	13.59	17.46	100 %	(287)
≥481 > 60 hrs	25.53	18.62	20.69	17.24	17.94	100 %	(145)
<481 ≤ 60 hrs	32.40	18.31	22.53	9.85	16.89	100 %	(142)

* Each group of work situation is subdivided in 2 subgroups depending on whether they require more or less than 60 hrs of work/week.

THE MEDICAL RESEARCH COUNCIL/TRANSPORT AND ROAD RESEARCH LABORATORY STUDY OF THE WORKING CONDITIONS OF HEAVY GOODS VEHICLE DRIVERS

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ABSTRACT

A field study of the working conditions of heavy goods vehicle drivers is described. The work relates to the deterioration in driving skills that may arise in operating conditions, especially where the driver is close to falling asleep. The paper describes the measurements being attempted, the equipment used, and the practical problems that arise.

INTRODUCTION

The Transport and Road Research Laboratory, and the Medical Research Council Environmental Physiology Unit are operating a joint research study of the working conditions of heavy goods vehicle drivers. This note refers to the approach taken, and gives some information on the lessons we have learnt from our first two months field study. We are not following a closely defined area in detail as one might do for a planned experiment. On the contrary, we are taking an overall view, gathering information on the situation facing heavy goods vehicle drivers under real working conditions. This approach leads to numerous difficulties and many restrictions on observations and equipment, as our study is (of necessity) of secondary importance compared with the job of transporting goods. However, there is such a wide range of factors which may influence the situation, that we consider that a broad approach is necessary at this stage. The aim of the study is primarily to consider the possibility of extreme driver fatigue leading to accidents and to attempt to isolate the important causes of fatigue. However, the work should offer useful information on other factors such as the health of the driver.

DESIGN OF FIELD STUDY

The aim of the work is to investigate conditions of extreme fatigue in H.G.V. driving (where the driver is close to falling asleep), and the situations leading to those conditions. We believe that extreme fatigue may be influenced by time of day effects and loss of sleep, and that undue interference might lead to stimulation of the driver and abnormal levels of arousal. This indicates that the investigations be carried out under conditions as near to normal working conditions as possible. For our first field study we were fortunate to obtain the cooperation of a large carrier of domestic foodstuffs, and we were able to carry-out measurements during normal operating conditions. An important decision was to observe each driver over two weeks of night shift. In this way we hoped to use the first few days to acclimatize the driver to the presence of an observer, and in the last week to be able to observe the effects of diurnal shift after the week-end break and the affects of accummulation of stress, loss of sleep etc., over the week. This resulted in only a few drivers being observed - a price we felt we were well advised to pay.

MEASUREMENTS

(i) Indicators of fatigue

Conditions clearly indicate that we should not interfere with the drivers if at all possible and we have restricted our measures a great deal. We are attempting to consider the effects of fatigue in terms of (a) driving performance, (b) physiology, (c) psychological performance, and (d) subjective assessment.

(a) Driving performance:	Steering wheel usage, engine speed variations and brake usage.
(b) Physiology:	Cardiac responses Body temperature (to be attempted) Biochemical changes (next field study) Photography of movements and facial expression (special field study)
(c) Psychological Performance:	Reaction time (not whilst driving) E.e.g. (next field study)
(d) Subjective assessment:	Comments of observer and driver.

(ii) Causes of fatigue

Here we take a very broad view ranging from environmental conditions to quality of sleep.

(a) Sleep log: Each driver completes a diary for four weeks, two weeks prior to our observation and two weeks whilst being observed. The diary covers sleep and wake time activity, together with questions relating to quality of sleep. Each driver is also asked to complete a detailed medical questionnaire.

(b)	Cab environment:	Noise (predicted from engine speed) Seat vibration (2 axes) Thermal conditions Low frequency noise (in future)
(c)	Road and Traffic conditions:	Observers comments Use of wipers, horn etc. Fore and aft ambient lighting (this indicates level of street lighting and glare, as well as traffic density)

ANALYSIS OF DATA

Analysis of data such as that described above presents a number of difficulties.

Firstly, there is no recognised treatment for most of the variables. For instance, the cardiac responses are probably the most investigated. However, our requirements differ from those of the clinician, and there are no set requirements for analysis of say heart rate variability. (Does one assume a normal distribution and calculate the standard deviation? Over what time period should one calculate the values?). At the other extreme, nothing is known of the effects of vibration on fatigue and how one should calculate some sort of 'vibration dose' to assess the possible accummulative load on the driver.

Having come to some conclusions as to the most applicable analysis technique for each parameter, one is faced with a variety of differing requirements of the analysis system. Cardiac function requires analysis of temporal variations. Steering wheel activity likewise, although measurement of the amplitude of the signal and detection of changes of direction are also required. It was decided that the vibration signals needed frequency weighting prior to an averaging process, supported by frequency analysis and treatment similar to that needed for steering wheel activity. E.e.g. analysis in this case usually relates to detection of alpha wave activity - a frequency analysis and detection process followed by a quantifying process. Clearly, this variety of requirements, coupled with detection of 'rare' occurrences (e.g. brake application) and the need to accommodate comments from the observer places great demands on an analysis system.

However, probably the most demanding factor is the quantity of data to be analysed - two weeks work (one driver) leads to some eighty hours of data to be analysed, some requiring bandwidths to 50 Hz.

Our solution to this problem has been to analyse as much as possible on-line, using analogue techniques. This results in a long (10 m) chart for each shift, so that we can scan the results for changes in the parameters measured. This is supported by off-line analysis of some data over fixed periods (e.g. heart rate variability) using analogue or digital techniques as required. Digital storage of all the raw data would be unduly expensive, and we hope to be able to use a small digital computer to facilitate parallel analogue and digital on-line analysis, with digital storage of pertinent data only.

OBSERVATIONS FROM TWO MONTH FIELD STUDY

Our first field study was completed this spring, and although detailed results are not yet available, some of our experiences are worth placing on record for the benefit of others. The study covered night driving from a single depot of a large carrier of domestic foodstuffs. It must be emphasised that we have excellent, and interested cooperation from drivers, unions and management. However, for a realistic study, the job of carrying goods has to come first, and this results in some restrictions on the research.

In order not to interfere with normal operation, we had to be able to load our equipment into the vehicle in a very short time at turn around. Fortunately, each driver normally stayed with one vehicle, so that we were able to fit all transducers to the vehicle over the weekend leaving installation of the recorder, connecting up, and calibration for each shift. Likewise, we could not encumber the driver with cables, nor clutter his cab with too much equipment. The continuous vibration of a heavy goods vehicle and the daily loading and unloading of equipment, place great demands on its physical reliability. We found too, that what might be a minor defect in a laboratory could be incurable for a tired observer, at night, in a moving vehicle, with pressure not to break the chain of two weeks data collection. This indicates that equipment has to be portable, reliable and simple to use and calibrate.

We found it possible not to interfere with the driver unduly. We used disposable e.c.g. electrodes (Hewlett Packard type 14245B). These are rather costly, but drivers were able to wear them for two or three days without change and with only slight allergic reaction. Thus only resistance checks and coupling to the equipment were needed at the beginning of each run. However, even this could cause difficulty if the driver arrived late for work, or if the operation had to be carried out in unsuitable circumstances. A hard rubber pad was used to house the vibration transducers at the seat. This moulded to the shape of the buttocks as the shift proceeded and resulted in a stably positioned, reasonably comfortable housing.

We found that there was quite a heavy work load on the observer. He may be as fatigued as the driver and it is probably advisable not to expect too much of him in his task (should one make use of the changes in the observer's performance as part of the experiment?). Unless a large number of observers participate, then each bears a heavy responsibility for continuous collection of useful data, whilst coping with unusual working conditions and in isolation from colleagues when problems arise.

THE FUTURE

The equipment used for our first study has been described elsewhere (Ruffell Smith - 1975). Pilot studies caused us to simplify this extensively, and continuous modifications eventually resulted in reduced reliability. As a result, we are building a modified measuring and recording system (outline in figure 1) which is smaller, more robust, and easier to use. Our experiences in the field have enabled us to simplify the equipment quite a lot so that it can be put to use in different ways if requirements change. Time division multiplexing and recording on cassette magnetic tape is still used as the basis. However, only analogue data is recorded, and data such as brake usage are accommodated by a large number of narrow bandwidth data channels. Our field experience indicated that it was vital for the observer to be able to check the recorded data in the field, and this facility has been included. The first recording system was small, but still lead to some restrictions (e.g. a driver in a sleeper cab could not stretch out fully during rest breaks), the new system is designed to fit between the observers feet or on his lap.

In our next field study we hope to include e.e.g. measurements, and urine analysis to fill two large gaps in the measuring scheme. We consider that diurnal changes in man need consideration and we would like to be able to record body core temperature. We would welcome suggestions for convenient, non-invasive techniques to do this.

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P D Thomas	- M.R.C. Environmental Physiology Unit, London.
H P Ruffell-Smith	- T.R.R.L. (Now at N.A.S.A., California).

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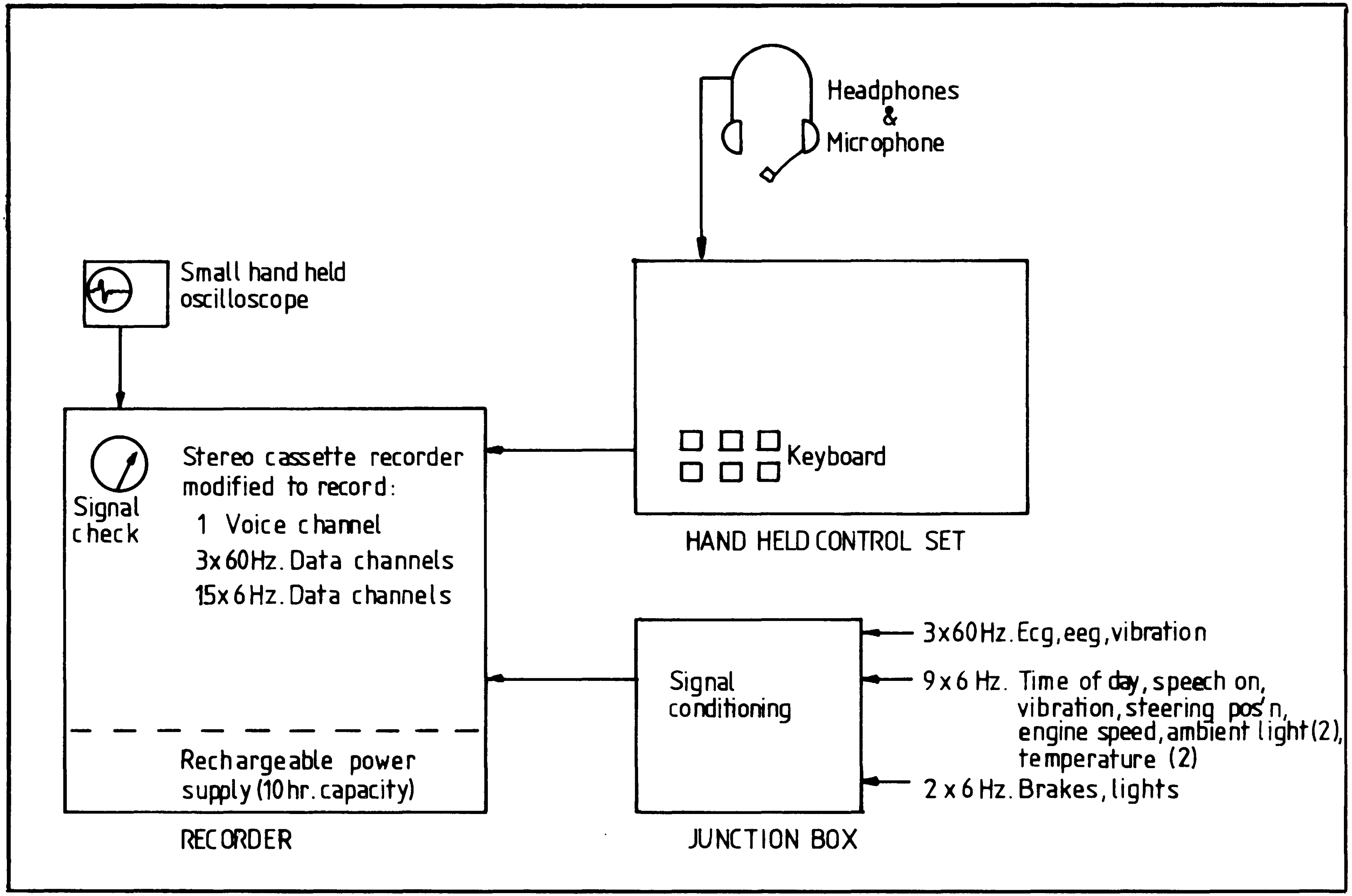
Headphones
&
Microphone
Small hand held
oscilloscope
Signal
check
Stereo cassette recorder
modified to record:
1 Voice channel
3x60Hz. Data channels
15x6Hz. Data channels
Rechargeable power
supply (10 hr. capacity)
RECORDER
Keyboard
HAND HELD CONTROL SET
Signal
conditioning
JUNCTION BOX
3x60Hz. Ecg, eeg, vibration
9x6 Hz. Time of day, speech on,
vibration, steering pos'n,
engine speed, ambient light (2),
temperature (2)
2x6 Hz. Brakes, lights

VIBRATION AND THE LORRY DRIVER

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ABSTRACT

One of the major environmental stressors to which the lorry driver is exposed is the continuous buffeting he receives as a result of the response of the vehicle to surface irregularities and engine vibration. As an environmental stressor, vibration presents peculiar problems for investigators in that the body has a variety of receptor organs responding to vibration, and a variety of transmission pathways to them. This has led to a situation where little reliable information is available despite a great deal of effort. One can generalise, however, and say that certain frequencies of vibration are to be avoided; that vibration, if left untreated, can affect health; and that vibration may be an important member of the stressor matrix.

INTRODUCTION

The lorry driver has to cope with a number of unusual environments, and probably the most obvious of them is the 'ride' or vibration of the cab. The forces impressed upon the driver can be in many directions and have a variety of pathways -via the seat pan, the seat back, the foot controls and the steering-wheel. The vibration sources are assumed to be the engine vibration and the response of the vehicle to surface irregularities. The vibration levels can be quite high, especially if the truck is unloaded.

Human sensations of vibration occur over a wide range of levels and frequencies. The level reached in trucks is variable, but usually roughly between 1 and 10 m/s^2 rms (see Lovesey E.J., 1971 and Stikeleather L.F., 1972) whereas what might be called 'discomfort' occurs around the 1 m/s^2 mark. As well as being uncomfortable, vibration can affect task performance and health. These effects occur over a relatively narrow frequency range from 1 to 20 Hz.

PROBLEMS

Unfortunately, vibration exemplifies the devious ways of most environmental stressors (Floyd W.F. and Sandover J., 1972). To quote Shoenberger (R.V. and Harris C.S., 1971) "...quantification of vibration responses will never reach the accuracy achieved in acoustics, due to such factors as the lack of a unique receptor for vibration, the multiplicity of vibration transmission paths, and the fact that vibration transmission to the body in the resonance range may be greatly altered by changes in body position and muscle tone".

Three groups of receptors (tactile, movement and posture pain) give information relevant to vibration and no one receptor or group of receptors can be said to be always dominant. To the biologist, a model may be a gross simplification of the mechanical characteristics of a seated man as responding to vibration in one direction at one point of entry. To the engineer asked to produce mathematical equations, the model may represent a nightmare.

Of one thing we can be certain. Vibration affects many tasks where vision and manual control are critical. The eyes and the visual display may move relative to each other at rates too high for the eye to follow, and the inertial effects of motion on the limbs can obviously lead to difficulties in motor control.

AVAILABLE EVIDENCE

As one might expect from the problems mentioned above, one can only give an apology in regard to hard fact. The problems are such that most research has been confined to vertical vibration. It is recognised that motion in other directions can have marked effects, but simple vertical vibration often seems to predominate. The effects of vertical vibration on visual tasks and control tasks, and,subjective reactions often show increased sensitivity at about 5 Hz. Much of the early data was inconsistent, even to the extent that what is considered by one experimenter to be at the threshold of perception, is close to what another considers to be intolerable! However, with good experimental design, one can use man as a transducer and consider vibration sensitivity at different levels and frequencies.

When considering vibration, measurements of motion are obviously worth observation, and many experimenters have risen to the task. A number have measured the transmission of vibration to the head and the mechanical impedance at the seat-man interface. A resonance phenomenon is usually demonstrated at about 5 Hz and this may be the source of the increased sensitivity to vibration often found in both task performance and subjective responses. The international standard assumes maximum sensitivity between 4 and

8 Hz (1 and 2 Hz for horizontal motion) for comfort, performance and health.

An overall assessment of our present understanding in relation to vertical vibration is given by Grether W.F., 1971. His conclusions were briefly: - Subjective estimates indicate maximum sensitivity at about 5 Hz., the frequency of major body resonances. Vibration causes impairment of visual acuity and manual control ability in the frequency ranges 10-25 Hz, and 5 Hz, respectively. Vibration had little effect on tasks involving the central neural processes - e.g. vigilance.

However, this is confined to only one aspect of the problem. Even at the qualitative level, we know little of the effects of vibration in more than one axis, of interections between vibration and other stressors, and of the effects of duration of exposure.

THE LORRY DRIVER

In most situations, the manual control task of the driver is not particularly difficult, and it would seem doubtful that vibration would have any marked effect. However, one has to consider whether vibration may affect the driver's health, his central neural processes, and if it influences fatigue.

An American survey (Gruber G.J. and Ziperman H.H., 1974) of long distance bus drivers offers evidence that their health may be affected as regards digestive, circulatory, muscular and back disorders. Together with the incidence of low-back trouble in tractor drivers, this suggests that vibration may be a factor leading to disorders of the lower-back (although poor posture could be equally to blame).

Despite Grether's negative findings in regard to vigilance tasks, one has to suspect that vibration may affect the central neural processes. If nothing else, the numerous receptors involved during vibration could be expected to be generating a stream of information, and contributing to the state of 'arousal'. Occasionally, experiments do indicate changes in performance at the cognitive level. For instance, Bulger P.M.J., 1972 observed a 'tunnel vision' phenomenon and Golkard T.J., 1972 observed decrements in performance at a difficult cognitive task. In addition, there are times when tracking performance improves under vibration compared with a control situation, as though vibration increased arousal. There is little useful evidence for or against Grether's view that vibration does not affect central neural processes, and the possibility has to be considered.

It is clear to most of us that a day spent in a bumpy vehicle can be physically tiring, and vibration certainly affects some functions such as breathing and the activity of some mucle groups. One must suspect therefore that vibration can be a factor leading to fatigue in the physical sense.

CONCLUSIONS

Little clear evidence is available, but sufficient exists to lead one to suspect that vibration may affect the health of lorry drivers, and that it contributes to the problem of fatigue. In both cases it is probable that vibration with a significant content in the frequency bands associated with body resonances has the greatest effect. In the case of fatigue, vibration may have two roles to play - as a contributory factor towards increased fatigue in the long term, or conceivably as an arousing factor working against such stressors as loss of sleep.

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EFFECTS OF PROLONGED DRIVING ON HEAVY GOODS VEHICLE DRIVING PERFORMANCE

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ABSTRACT

Twelve professional heavy goods vehicle (HGV) drivers were studied over an eleven hour driving period, undertaken by each driver for four consecutive days. Two age groups of driver and two operational shifts were included as additional independent variables. The driving performance of interest was mean time headway and its variability, monitored and recorded using a close circuit television system.

The only factor found to significantly affect time headway and its variability was the number of hours driven on the shift. The effect was independent of days driving, shift or age of driver and was interpreted in terms of a change in strategy adopted by drivers in different traffic environments.

Overall no evidence of impaired driving as a function of prolonged driving was found. Risk appeared greatest in the second and fifth hours and even then only a small proportion of time headway values could be described as risky. Furthermore, no significant effect of days driving was found indicating that a four day period of prolonged driving each day does not necessarily affect performance adversely.

INTRODUCTION

In 1970 the U.S. Bureau of Motor Carrier Safety investigated 286 commercial vehicle accidents and attributed 39% of these to the driver being either asleep at the wheel or inattentive. In the U.K. in the same year, after the introduction of a reduction of maximum permitted hours driving per day to 10 hours, a marked decline in accidents involving heavy goods vehicles was recorded. And in a study by Harris, Mackie et al. (1972) of the relationship between real and expected accident rates in one bus and two haulage companies, evidence was found for a disproportionate increase in riskiness after 7-10 hours of driving in one of the haulage companies and for a similar increase in the bus company after 7-8 hours of driving, but specifically for older drivers driving in darkness. These real accident analyses provide evidence consistent with the hypothesis that there is a relationship between prolonged HGV driving and accident risk.

In line with this evidence, there is some experimental support for an increase in riskiness associated with prolonged driving. Brown, Tickner and Simmonds (1970) investigated the riskiness of overtaking manoeuvres during four consecutive three-hour continuous driving sessions separated by short breaks. They found an increase in the proportion of risky to safe overtakings from the first to the fourth session. However despite this evidence confirmatory support for a 'fatigue' hypothesis is hard to find. One reason for this may well be that researchers have often studied changes in performance over time on a range of psychomotor tasks or in components of the driving task without demonstrating their relationship to the safety (or accident riskiness) of driving itself (e.g. Herbert and Jaynes, 1964; Safford and Rockwell, 1967; Harris, Mackie et al., 1972).

To avoid this problem it would seem to be of potential value to investigate some measure of driving performance which is more readily interpretable in terms of accident riskiness. One such measure is the time headway of a vehicle when it is following behind another one. If we let x be the rear of the leading vehicle and y the front of the following vehicle at time t, the time headway is the time in which the following vehicle travels from y to x. As succinctly expressed by Perchonok and Seguin (1964) it is the time to reach the location where the leading vehicle was. It is possible to establish a straight-forward criterion of safe following interval because with very short time headways between vehicles if the leading vehicle should stop abruptly a collision is virtually unavoidable. Time headway is also a useful measure because it records not a molecular component of the driving task but the integrated action of the driver and his vehicle in relation to the total road environment.

There have been no investigations of how or whether drivers' following abilities or strategies change under prolonged driving conditions although two studies have shown no reliable effects on headway of driving for either two hours (Lerner, Abbot and Sleight, 1964) or four (Rockwell and Snider, 1965). In an attempt to obtain further evidence in this area we carried out a study in which professional HGV drivers were observed over an eleven hour driving period which was undertaken by each driver for four consecutive days in order to examine not just the variable of prolonged hours but also the possibility of any cumulative effects from several days of prolonged driving.

METHOD

Subjects and Driving Task

Subjects were volunteer professional HGV drivers, each paid £77 for participating in the project. Two different age groups were selected with mean ages of 28.8 years (sd = 2.9) and 41.3 years (sd = 4.1) respectively. Each S was required to drive an instrumented 7-ton Bedford rigid van-type truck for 11 hours on each of four consecutive days over a preselected route of approximately 300 miles which was repeated on each day. The route consisted of two different loops out of and returning to Dublin, the same loop being driven first on each day. The driving was continuous except for a 30 min. meal break after 5½ hours and one 5 min. break during each session in order to refuel a petrol-driver AC generator which supplied power for the research instrumentation. Subjects in each age group were allocated at random for the duration of the experiment to one of two driving shifts which started either at 09.00 hrs or 15.00 hrs. These two shifts were selected because they were found in an earlier survey of the working conditions of HGV drivers to be the two most frequently operated commercial shifts in Ireland.

Performance measures

The driving performance measured was mean time headway and its variability for each hour travelled. These were monitored and recorded using a closed circuit television system mounted on the experimental HGV. The system involved two forward facing TV cameras and an application of the coincidence method of measuring distance and was specifically designed and developed for the project. It provided in the superimposed video images from the two cameras the necessary information to determine leading vehicle distance and, combined with speed information from a third camera, instantaneous time headway in any following episode. Provision was also made for recording time on task and vehicle braking, the latter information being used to help identify any major differences in the task demands of the different 5½ hour blocks and days of driving. A number of other dependent variables were also recorded such as subjects' own ratings of performance, fatigue and motivation and a profile of endocrine measures was also obtained, but these will not be discussed in this chapter.

RESULTS

Factorial analysis of variance and a subsequent t test showed that the second half of the late shift had significantly fewer braking episodes than any other period and that the second half of the early shift had significantly fewer episodes than the first half of either shift ($p \angle .01$, $df = 23$). The relevant means are presented in Table 1 below. It may be

Table 1
Mean frequency of braking episodes by shift and session half

Shift	First half	Second half
Early	99.6	70.8
Late	97.8	49.0

noted that despite the fact that the second half of the early shift occurred over exactly the same time of day as the first half of the late shift (15.00 hrs - 20.30 hrs) there was a significant difference in frequency of braking episodes. This is more likely to be due to different brake demands on the driver of different parts of the route driven rathen than a change in performance over time. However the main implication of these results is that the task demands on drivers were not the same for both parts of each shift or for both shifts.

Following episodes

A preliminary analysis was carried out of the amount and distribution of vehicle approach and following situations which occurred under the various conditions of the experiment. The total number of discrete observations (resulting from a sampling strategy of one per 5 sec. on average) was 9 446, which is equivalent to 787 minutes or about 13 hours of following. This amount is remarkably small over a total experimental driving period of 528 hours and represents only about 2.5 per cent of that total. This result supports the earlier observations of Rockwell and Snider (1965) who found that following episodes were rare and transient for truck drivers because they tended to minimise the influence of other vehicles on their own speed by either overtaking or falling well behind them.

Not only was the time spent behind other vehicles relatively short but it was also found that this time was not evenly distributed amongst the different driving shifts and hours of day. Of the total amount of vehicle approach and following which occurred, 62 per cent occurred in the early shift and 38 per cent in the late shift. Furthermore, out of a total number of possible mean values for each hour of day of 48, hours 4, 9 and 10 were found to have only 15, 9 and 12 values respectively. Because of the unreliability of the samples for these particular hours, they were excluded from further time headway analysis. It was also decided to similarly exclude hour 8 for which a very low number of discrete observations were recorded overall. Finally, in order to eliminate from the analysis all situations in which the following (i.e. experimental) vehicle approached a stopped, stopping or very slow front vehicle, all following episodes having both of two characteristics were excluded. There characteristics were a progressive decrease in distance headway (i.e. following vehicle getting progressively closer to leading vehicle) and a progressive speed decrease to a speed of less than 10 mph. The effect of this procedure was to require a considerably higher number of adjustments to the data for the periods corresponding to driving in the city compared with rural 'open' roads. City driving hours (essentially hours 1, 6 and 11) accounted for 80 per cent of the eliminated slowing and stopping sequences.

Time headway

The analysis of variance for the time headway data yielded only one significant result and that was a main effect for hours driving. Time headway for the second and fifth hour of driving was significantly shorter than for the first hour and each half of hour six ($p < .01$, df = 47, two-tailed test). The relevant means and standard deviations are presented below in Table 2. It may be noted that each half of the sixth hour of driving was treated separately because of the 30 min. meal break interposed between them.

Table 2

Mean time headway (in sec) by hour of driving

	Hour							
	1	2	3	5	6_1	6_2	7	11
Mean	2.98	2.50	2.73	2.54	3.00	2.97	2.74	2.80
Sd	0.81	0.89	0.94	0.91	0.96	1.08	0.80	0.88

Time headway variability

The analysis of time headway variability yielded only one significant effect and that also was a main effect for hours driving. The mean standard deviation value for each hour is presented in Table 3. In testing for differences between pairs of means it was found that for hours 3 and 5 time headway variability was significantly less ($p < .01$, df = 47, two-tailed test) than for hours 1, 2 and the first half of hour 6. It was also found that variability for hours 3, 5, 6_2, 7 and 11 was significantly less than for hour one.

Table 3

Mean time headway standard deviation by hour of driving.

	Hour							
	1	2	3	5	6_1	6_2	7	11
Mean	1.07	0.90	0.70	0.68	0.80	0.79	0.89	0.76
Sd	0.37	0.35	0.34	0.35	0.36	0.47	0.47	0.40

CONCLUSIONS

It appears from these results that the only significant factor affecting time headway and its variability was the number of hours driven on the shift, with relatively long headways occurring in hours one and six and relatively greater variability in hour one and to a lesser extent the first half of hour six. One problem in interpreting these observations simply as time-on-task effects is that the type of traffic environment experienced by the drivers varied in a more or less systematic manner with hours driven. Thus hours 1 and 6 in particular involved driving in relatively dense city traffic whereas most of the remainder of the time was spent on less congested rural trunk roads. Although hour 11 was also spent partly on city roads, this was for only a short duration and at times when traffic density had decreased considerably (i.e. 20.30 hrs and 02.30 hrs).

The absence of differences in time headway within the second half of each shift and more importantly the lack of differences between hours 1, 6_1, 6_2 and 11, a comparison which controls to some extent for traffic environment, argue against a simple time-on-task hypothesis. Indeed the results could be construed as an urban-rural effect with longer time headways associated with urban driving. Such an interpretation would be consistent with the results of a study by Lee (1971) who found an increase in time headway associated with an increase in traffic density.

There is some evidence that a higher tolerance of risk leads to shorter time headways (Wright & Sleight, 1962) and that a reduced visual field may lengthen it (Rockwell, 1972). If time headway is correlated with perceived risk then greater headways in dense urban traffic may reflect an increase in the perceived probability of a leading vehicle slowing down. Drivers may thus increase their headways as a precautionary measure.

The results for time headway variability showed a relatively high time headway standard deviation for the first hour, gradually decreasing to hour 5 and little change during the second half of the shift. One possible interpretation of this pattern (although it does not do justice to the general lack of hourly variation in the second half of the driving shift) is that it is a consequence of drivers' resistance to duplicating small changes in leading vehicle velocity, generally preferring to absorb such changes in distance headway changes (Rockwell and Snider, 1965). Because it may reasonably be assumed that in city driving leading vehicle velocity variance would be higher than in rural driving, one would expect greater variability of time headway in the city compared with the country. Furthermore it might be pointed out that the longer time headways associated with city driving would tend to make detection of leading vehicle velocity variation more difficult compared with the country (Rockwell, 1972) and in its turn increase time headway variability.

Some discussion has been given over to the significant hours of driving effects because they were found to be highly reliable, occurring independently of day of driving, age of driver and driving shift. But perhaps more important in the context of this study is the conclusion that no evidence of impaired driving as a function of prolonged driving has been found. Indeed, other things being equal, risk appeared greatest in the second and fifth hours and even then only a small proportion of time headways fell below the two-second value recommended in the U.K. for car drivers. Furthermore the accumulation of hours driving was also associated with a general decrease in time headway variability, indicating if anything an improvement in performance over time.

The observation that an 11 hour shift or four days of such prolonged driving did not affect the safety of performance as measured by our criteria of time headway and its variability may not appear quite so surprising if we take a hard look at our frequently tacit assumptions about performance-time functions. What may be important in the relationship between prolonged driving and impaired performance is not the simple additive effect of each additional hour but more the relationship between expected and actual task demands on the driver. When a driver expects to have to drive for 11 hours he may ration his effort to meet that requirement with no performance decrement. However, performance may well suffer in the last hours if the driver expected to finish after only 7 or 8 hours. At the very least, this hypothesis would appear to merit further research.

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COMMENTS FOLLOWING A PSYCHOSOCIOLOGICAL STUDY OF THE HEAVY GOODS VEHICLE DRIVER TRADE

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ABSTRACT

A psycho-sociological study of heavy goods vehicle drivers indicated that the concept of drivers fatigue being responsible for road traffic accidents should be modified to include the effects of working conditions on the job. These, as well as the problems they raise have been studied in an enquiry carried out in France.

INTRODUCTION

Some preliminary considerations should be made before reporting, not so much the results of an enquiry carried out in France in 1974, but the comments and conclusions which it led to.

When considering the problem of fatigue in relation to road traffic accidents of heavy goods vehicle (HGV) drivers on long routes one should note that:

.- Although fatigue affects most healthy or sick persons, there is general agreement that it vary and it even seems preferable to refer to different types or conditions of fatigue;

.- There is no single category of drivers. The most elementary dichotomy separates the professional driver from the road users. Thus, one can state that: the choice of the long distance HGV drivers' career, and the keeping it, involves an important selection amongst all vehicle drivers. Similarly one can say that the HGV driver is not a typical driver, but a very special type of driver. By extension one could add that there is also no typical HGV driver.

To paraphrase Jacob (1970) one can see in a group a population of individuals which are never identical. Each member has unique characteristics. There is no longer a model to which all the individuals could be refered to but a typical model made up of only the average properties of each individual. It is therefore necessary to know of the whole population through its distribution pattern, but the average individual is then only an abstraction. Only individuals with their peculiarities, differences and variables are real!

.- Accidents are fortuitous, exceptional and occur unexpectedly, perhaps even at random.

The complexity and ambiguity of the problem of the influence of drivers fatigue on road traffic accidents open up a number of avenues of investigation which in the absence of a general theory will depend on the defined aims. It seems therefore worthwhile, considering the above, mentioned points to state clearly the objectives sought. One could for instance, aim at defining the most adequate lesgislation to decrease the number of accidents by ascertaining the maximal tolerable driving hours, the breaks, etc. One could also think that the analysis of the present situation, as it is lived by the individuals, involves adaptation processes and regulatory mechanisms which allow to avoid some accidents. This second approach, which does not exclude the first, allows through a socio-psychological analysis of the HGV drivers' trade to point to some questions and hypotheses leading to further more precise studies, for example of a physiologic nature.

MATERIAL AND METHODS

The study was carried out by a team of two psychologists, a sociologist, an economist and a medical doctor.

It considered 51 HGV drivers, 30 retired HGV drivers and 7 apprentices.

For further details see the GETRAM report (Melier P et al. 1974).

RESULTS

A.- Work conditions

The job, as described by the long distance HGV drivers is often carried out in extreme working conditions, but it is compensated by a relative freedom in the work organization.

The difficulties and hardships of the working conditions stem from the long working hours and their lack of regularity. A number of studies and in particular HAMELIN (1975) have considered the work periods of HGV drivers. It appears the the latter feel they work long hours and they resent lost time. The work however is not a continuous one and irregular work schedules are followed by irregualr rest periods. Private activities and rest periods, depending mostly on work schedules, are also taken in part out of the family environment. Thus, here again, average figures only confuse the issue since they do not consider the effects of peak values.

Work is often carried out, if not under tension, at least with a feeling of insecurity, worry, fatigue and difficulties encountered. The lack of security derives from the hours of work, from the income often related to the first and from the uncertainty of loads for the return journey.

Drivers thus live in a constant apprehension of troubles of which they are not responsible such as break-downs which cause delays, of accidents and of failure to abide by regulations which may lead to a withdrawal of the drivers permit and the end of the job itself. The ambiguity of the HGV drivers status is due partly to the regulations supposed to protect him but which could penalize him very strongly, and partly to economic conditions which force him practicaly to break them (eg. driving above the allowed speed limit).

The HGVs' drivers work does not consist only in driving, but may also include repairs, maintenance, handling of goods, etc. These situations in fact are less exceptional than commonly imagined.

As for their health conditions, approximately 50 % of the drivers interviewed reported frequent or permanent disabilities due to their trade. The most important is related to the working environment: 60% of the troubles reported or feared to occur with a certain fatalism, are vertebral ones. But these actually require medical care or may lead to a change of job mostly in the age class over 35 years. A number of other affections are reported: hernia, contractures, varicose veins, ocular pains, decrease in vision, obesity. A smaller number reported gastric troubles (5%) or general fatigue (10%), or ascribed to fatigue back-ackes, head-ackes, nervous tension, irregular organic functions. The influence of age could not be ascertained, and the few references to fatigue covered all age groups.

One could wonder why so few troubles related to work conditions and not directly to the job were reported in these interviews. The HGV drivers' trade is a "hard" one calling for important and frequent changes in the normal sleep/wakefulness rhythm. As opposed to workers in industry where (Aanonsen 1959) up to 30% report digestive and nervous, particularly sleep, troubles, here only 2 out of 88 drivers interviewed mentioned difficulties with sleeping. It is interesting to note that almost 50% of the HGV drivers interviewed reported that besides work they either slept or "did nothing"! The ratio sleep/wakefulness over periods of one day, one week or one year may be most interesting to characterize the organizational activity. Nor have been considered here the family situation, the professional one, or the chances a driver has to work until retiring age.

Some pathological aspects are very probably masked by the fact that this was an enquete. They are:

.- troubles which could constitute causes of unfitness in the trade and which the drivers may even not admit to themselves (eg. decrease in vision).

.- troubles connected with the intake of drugs or alcohol. Admitting it would conflict with the professional ethics which boast of the health and strength of the HGV drivers. It is also a well known fact that being sober when driving is compatible with certain forms of alcoholism.

.- finaly, what is willingly not reported in the interviews will be even strongly avoided during the medical check-ups carried out at work (which over 50% do not trust or appreciate) and still more during the control visits which have to be made every 5 years to ascertain the aptitude for employment in the trade.

HGV drivers do not appreciate the present form of occupational medecine and a different more adequate one should be adopted.

B.- Compensation modalities

It will be necessary to limit oneself here to those noted during the survey:

.- The first level of compensation is that due to a relative freedom in the organization of the trip. This point is quoted by all drivers when, comparing their trade with others. It makes them feel closer to the artisans than to the salaried workmen. They do not have to "clock"!

This freedom of organization allows then to eat, stop and eventually sleep more or less when they deem it necessary. The breaks are more or less intuitive and may vary considerably from one individual to another (Bernoux et al. 1973).

It would be interesting to determine with more accuracy the relation between different ways of spending time and the health conditions of an individual as it is being studied for fixed workers (Wisner and Carpentier, 1976 and Cazamian and Carpentier (in press). But if the situation was really so bad, could people keep working for years at such a pace? Is there not implicitly a repair of the working effort? But is it sufficient? Has the importance of the choice of food and of the atmosphere in which it is consumed been sufficiently investigated in occupational health?HGV drivers eat in places for them, chosen by them, where they know whom they could meet and eat with.

The notion of freedom concerns the performance of the trade and is defined in terms of autonomy (controlling part of the organization of work and time schedules), of decisions to be taken, of responsabilities. The driver must assume all responsabilities,not only during definite periods of time and in certain situations of the work tool and the load which are worth large sums of money, but also for the safety of other road users. His freedom means the absence of the "boss" during a large part of his working period, but also his physical loneliness during driving. Very few drivers refered however to freedom with regards to social or family structures.

.- The second level of compensation is that of belonging to a social group carrying out the same trade; a group described as a corporation with unwritten solidarity rules. This important feeling often found among workers (Bernoux et al 1973) is particularly acute with the HGV drivers.

In the trade, selection criteria do not follow a hierarchical system resulting from the specialized training available, but are more often influenced by the presumed qualities of the individuals and their holding the appropriate driving licence.

Promotion is rare whithin the transport organization. Unlike factory work, long distance transport is not a team job with a "chief", the driver can be "his own boss". Here the drivers find an improvement in their economic situation by the possibilities of being over-employed and eventually getting, off the records, the "good trips" rather than climbing the steps of a hierarchy which does not exist officially. Qualities required from a good HGV driver are the possibility to face various responsabilities, to take initiatives when difficulties arise during a trip and "not to give up". A driver will be considered a "real" one, the longer his trips and the more difficulties he overcame. Different from a normal worker he finds himself outside the norms of social classes, he is classified by the difficulties of his trade, and his duties not by a rank. At the limit, he may consider himself no longer as a salaried employee but as a manager (and not an administrator) of his work tool (truck), even of the load of goods carried.

He refuses the realities which make him a salaried worker. The usefulness of his work is quickly brought out: he has to carry goods from here to there ; he has the feeling of supplying the population with goods required and to participate directly to the running of trade and industry. The work done is justified by its completeness (transport is carried out from beginning to end; the driver is also a mechanic besides being a hauler). Part of the real work of the HGV driver and the image he makes of it corresponds more or less to an antithesis of the division of labour.

The trade is also lived with the opinion that it favours social relations with the drivers community; this argument is often a motivation for the young or apprentice drivers. The situations arising during the journeys create a particular type of communication with others. These others are not only neighbours but a series of individuals met along a route, encountered at stops, petrol pump attendants, innkeepers, customs men, policemen, other HGV drivers, customers, thus the feeling of meeting a lot of people. The road is personalized for the HGV driver.

C.- Facts, changes and prospects:

Differences are not influenced by the recruitement basis, e.g. the social structure of the HGV driver, but particularly by the practical conditions in which he carries out his trade :

.- Recruitment is, for 50% among children of HGV drivers, transporters and farmers, the other half is very heterogeneous. Education level is close to compulsory schooling. Those with a certificate of professional aptitude (CAP) are numerous. Previous trades are essentially manual ones.
Other modification factors are: a delayed entry in active life through an extension of general studies and partcularly the development of professional formation.

Retirement from the profession occurs at three life periods:

a) An early change may occur after a few months to a maximum of 2 years. Its quantitative importance could not be properly ascertained but should be studied further. The eventual finding of a large turn-over of new drivers presents certain risks, both from the transport and from the road safety points of view. What is known about this turn-over? Is it more frequent now?

b) A second period for change of profession can be situated between 35 and 45 years of age. Considered the wise age for reconversion, approximately 33% of the HGV drivers wish to change this time. What are the health conditions of these drivers? A swedish study indicates that 45 years is a critical age for fixed workers and that later adjustments are more costly (Ackerstedt, 1975).

c) The third age for retirement is the official one, which it is wished or claimed should be reduced to 55 years. It should be noted, however, that above the age of fifty visual difficulties of drivers at night increase very markedly (Adum 1975)

Changes which occured in the HGV drivers' trade are due to:

.- the construction of a network of special infrastructures made up of fast motorways and highways.

.- the congestion of urban and suburban roads and the intensification of road traffic in open country (particularly during the touristic season or in touristic regions).

.- the developments of vehicles, which show an improved performance in capacity and in speed. Improved habitability has been achieved but without evidence of easier or less tiring driving nor of a decrease in vibrations.

.- the increase in the tonnage of goods transported by road.

.- the increase in the number of employed HGV drivers.

.- the establishment of HGV drivers centers and regional freight offices.

.- the organization of a professional education with set rules and diplomas.

.- the increase of various controls during the journeys.

.- changes in national rules concerning road transport and to the perspective of a European regulation adopted in some countries of the European Community.

.- Finaly the effect of global economic development on a particular sector of employment considered safe because of expansion and continued growth in the past years, but which in fact the energy crisis and the economic recession seem to menace or modify favouring for instance the amalgamation of road transport concerns.

HGV drivers find themselves in a less "protected" situation, and thus in a less autonomous or original one compared with the general conditions of economic and social life. Initiatives and responsabilities involving changes in the trade practice are of various origin (state, profession, freighters, constructors etc.) The consequences of these initiatives do not affect drivers in a coherent way. Required to increase productivity on roads always more crowded and more dangerous, they ascribe the degradation of their work conditions to the general incoherence of their situation, which is worsened by the incoherence of the remedies suggested. They could drive faster on high-ways, with their more powerful vehicles, if traffic was less intense and more regulated, if at loading or unloading ends the freight was prepared and the operation was not delayed, finaly if there were less controls on hours of driving or mode of driving. Even their remuneration appears not certain and contradictory in its complexity.

CONCLUSION

The concept of fatigue should probably be abandoned for the HGV drivers and replaced by that of the impact of work conditions on the individual. The description of the work conditions has been sketched and outlined from interviews in this psycho-sociological study carried out to determine the reasons HGV drivers wished to change profession. The study was carried out in late 1974 when unemployment was existing and may have hidden the tendency to abbandon the trade or see its negative aspects. These studies have allowed to ascertain the existence of some compensatory mechanisms particular to the trade or to the image made of it, but have also brought out aspects which need further investigations such as the physiological and psychological conditions of HGV drivers after 5 to 10 years in the trade, the sociological and socio economic effects of recession on changes in the trade or/and to the image HGV drivers make of it or of themselves. What consequences would have the existence of a large difference between the true and the imagined work conditions of HGV drivers?

Answers to these questions will no doubt be obtained following further studies in the various disciplines mentioned.

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PROGRAMMES OF WORKSHOPS

I.- STUDIES ON CONDITIONS RELATING TO FATIGUE AND ACCIDENTS IN HEAVY GOODS VEHICLE DRIVERS :

1. INTRODUCTION
J.P. BULL, Industrial Injuries and Burns Unit, Accident Hospital, Bath Row, Birmingham B15 1NA, United Kingdom.

2. COMPUTER SEARCH OF PUBLISHED RESEARCH RELATING TO LORRY DRIVERS
P.E. MONGAR, Technical and Information Library, Transport and Road research Laboratory, Crowthorne, Berks RG11 6AU United Kingdom.

3. SELECTED BIBLIOGRAPHY RELEVANT TO STUDY OF WORKING CONDITIONS OF LORRY DRIVERS
H.P. RUFFEL SMITH, 55 Hallam Court, London W1, United Kingdom

4. STUDIES OF FATIGUE IN DRIVING
H.O. LISPER, Department of psychology, Uppsala Universiteit, Svartbacksgatan 10, S-753 Uppsala, Sweden.

5. STUDIES OF EFFECT OF SLEEP DEFICIT AND ERRATIC AND LONG WORKING HOURS ON RAILWAY DRIVERS
J. FORET, Laboratoire de Physiologie du travail, 41 rue Gay Lussac, F.75005 Paris, France.

6. A STUDY OF THE LORRY DRIVER'S TASK
W. BOCHER, Lehrstuhl für Verkehrserziehung an der Universität-GHS-Essen, Federal Republic of Germany.

7. WORKING CONDITIONS OF DRIVERS OF HEAVY GOODS VEHICLES. U.K. PROJECT
H.P. RUFFEL SMITH (see above)

8. ELECTROPHYSIOLOGICAL INDICATORS OF AROUSAL IN LORRY DRIVERS
F. LECRET, Organisme National de Sécurité Routière, Monthlery 91, France.

9. A STUDY OF WORKING CONDITIONS OF TRUCK DRIVERS IN FRANCE
P. HAMELIN, Organisme National de Sécurité Routère (see above)

10. VIBRATION AND THE LORRY DRIVER
J. SANDOVER, Department of human sciences, University of Technology Loughborough EE11 3TU, United Kingdom.

11. PROPOSAL FOR STUDY OF FATIGUE AND HEADWAY SELECTION IN LONG DISTANCE LORRY DRIVERS
R.C. FULLER, Department of psychology, Trinity College, Dublin 2, Ireland.

12. PROPOSAL FOR STUDY OF PSYCHOPHYSIOLOGICAL AND PSYCHOENDOCRINE FACTORS
J. CULLEN, Department of psychiatry, University College of Dublin, St James Hospital, Dublin 8, Ireland.

13. PSYCHOLOGICAL DETERMINANTS OF MEASURES AND METHODOLOGY IN DRIVING FATIGUE RESEARCH
I.D. BROWN, MRC Applied Psychology Unit, 15 Chaucer Road, Cambridge CB2 2EF, United Kingdom.

14. A POSSIBLE MECHANISM OF HIGHWAY DROWSINESS
J.A. MICHON, Instituut voor Experimentele Psychologie der Rijksuniversiteit te Groningen, Biologish Centrum, Velugel D, Kerklaan 30, Haren, The Netherlands.

II.- PSYCHO-BIOLOGICAL FACTORS IN THE BREAKDOWN OF DRIVING SKILLS:

1. HUMAN ENDOCRINE PROFILES
A. DARRAGH, Psychoendocrine Unit, Department of Psychiatry, U.C.D., St. James' Hospital, Dublin 8, Ireland.

2. BEHAVIOURAL EFFECTS OF PITUITARY-ADRENAL SYSTEM HORMONES
H. RIGTER, Organon International B.V., P.O. Box 20, Oss, The Netherlands.

3. RESEARCH DESIGN IN THE STUDY OF EFFECTS OF PHYSIOLOGICAL STRESS ON PERFORMANCE
I. BROWN, MRC Applied Psychology Unit, 15 Chaucer Road, Cambridge CB2 2EF, United Kingdom.

4. RATING BIOLOGICAL AGE
M. ASIEL, Université Libre de Bruxelles, Faculté de Medecine et de Pharmacie, Laboratoire d Epidemiologie, Rue Belliard 100, 1040 Bruxelles, Belgium.

5. DIET, MEAL-BREAKS, BLOOD-SUGAR AND PERFORMANCE
J. VALLANCE-OWEN, Department of Medicine, Royal Victoria Hospital, Belfast, Northern Ireland.

6. STRESS AND THE WORKING CONDITIONS OF HEAVY GOODS VEHICLE DRIVERS
J. RIEMERSMA, Institute for Perception, TNO, Soesterberg, Kampweg 5, Postbus 23, The Netherlands.

7. PHYSIOLOGICAL FACTORS INFLUENCING VISUAL PERFORMANCE
F. HOLLWICH, Universität Augenklinik, 44 Münster (Westf.), Westring 15, Federal German Republic.

III.- INFLUENCE DE LA FATIGUE DES CONDUCTEURS SUR LES ACCIDENTS DE LA ROUTE

1. EXPOSE INTRODUCTIF AU COLLOQUE
J. LEPLAT, Ecole Pratique des Hautes Etudes, Laboratoire de psychologie du travail, 41 rue Gay Lussac, 75005 Paris, France.

2. SOME THEORIES AND EXPERIMENTAL RESULTS
T. FORBES, Highway Traffic Safety Center, Michigan State University, East Lansing, Michigan, United States of America.

3. L'APPROCHE SOCIO-ECONOMIQUE DANS SA CONTRIBUTION A L'ETUDE DE "LA FATIGUE" DES CONDUCTEURS PROFESSIONNELS
   P. HAMELIN, Organisme National de la Sécurité Routière (ONSER), Monthlery, France.

4. APPORTS D'UNE ENQUETE PSYCHOSOCIOLOGIQUE A' LA CONNAISSANCE DU METIER DE CONDUCTEUR ROUTIER
   F. LILLE, Laboratoire de Physiologie, CHU Pitie Salpetriere, Paris 75634, France.

5. ALTERATION DES FONCTIONS VISUELLES ET FATIGUE
   P. REY, Institut de médecine sociale et préventive, Université de Genève, 20 Quai Ernest Ansermet, 1205 Genève, Switzerland.

6. VISUAL INFORMATION PROCESSING AND DROWNSINESS IN DRIVERS
   J.A. MICHON, Instituut voor Experimentele Psychologie der Rijksuniversiteit te Groningen, Biologish Centrum, Velugel D, Kerklaan 30, Haren, The Netherlands.

7. A REVIEW OF CURRENT THINKING AND RESEARCH POSSIBILITIES
   J.H. CULLEN, Psychosomatic Unit, Department of Psychiatry, U.C.D., St. James' Hospital, Dublin 8, Ireland.

8. FATIGUE IN DRIVING AND ACCIDENTS
   R. NÄÄTÄNEN, Department of Psychology, University of Helsinki, Finland.

9. IS BRAKING NECESSARY?
   M. HELANDER, Department of Ergonomics, Luleå University of Technology, Sweden

10. FATIGUE AND ACCIDENTS
    D.J. HIEATT, Department of Ecology, University of Toronto, Canada.

11. STUDY OF THE WORKING CONDITIONS OF HEAVY GOODS VEHICLE DRIVERS
    J. SANDOVER, Department of Human Sciences, University of Technology, Loughborough

12. L'INFLUENCE DE LA FATIGUE DES CONDUCTEURS SUR LES ACCIDENTS DE LA ROUTE
    J. O' HANLON, Institut für Hygiene und Arbeitsphysiologie der Eidgenössischen Technischen Hochschule, CH-Zurich.

13. A PSYCHOLOGIST'S VIEW OF DRIVING FATIGUE, ITS MEASUREMENT, AND POSSIBLE COUNTERMEASURES
    I.D. BROWN, Medical Research Council, Applied Psychology Unit, 15 Chaucer Road, Cambridge, England.

CONCLUSIONS FROM DISCUSSIONS OF WORKSHOPS

Reports by the organizers of the workshops were submitted to the Working Group on Toxic and Psychological Factors of Road Traffic Accidents. The following conclusions from discussions of the papers presented have been extracted from these reports.

I. RESEARCH ON FATIGUE AND ACCIDENTS OF HEAVY GOODS VEHICLE DRIVERS

Organizer: Dr J. P. Bull

Review of the published work on fatigue and driving behaviour confirmed that very little previous study had been made on this topic in Europe in spite of its relevance to accident causation and to the various regulations imposed by different countries upon hours and conditions of work of HGV drivers. In view of this paucity of information relating to drivers of lorries the findings of studies in Sweden of car drivers (Lisper) and of traindrivers in France (Foret) were explored. These gave important indications of promising lines of approach. The Swedish studies were experimental observations of car drivers and emphasised the use of reaction time as an index of fatigue. The effects on this of age, experience of driving, temperature, personality type and certain drugs were reported with special observations on drivers who fell asleep during the tests. The French study showed the implications of working periods such as the sliding shift system used by the French railways. Though vibration and other conditions of this responsible work are important factors, the disturbance of personal and social life by the shift system was thought to be the chief contributor to fatigue. This may be exacerbated by noisy conditions in places used for sleeping away from home. Duration of sleep was found to vary inversely with starting time of the sleep period after midnight. These effects were more marked in older workers - a finding which has important implications for extrapolation of experimental findings on young subjects to workers of other ages. These considerations were relevant to a study of the components of the lorry driver's task described by Böcher (Germany). This showed the important differences between the type and duration of tasks of drivers of different types of vehicle. Further data is becoming available in the driver testing programme of the TÜ-VR Institute.

Ruffel Smith (U.K.) described the collaboration between the MRC and the Transport and Road Research Laboratory to study psychophysiological and performance changes of HGV drivers with the aim of detecting features leading to drowsiness and falling asleep on normal runs. The equipment for measuring and recording the physical conditions including accelerations vibration, noise, climate and carbon monoxide inside the cab were demonstrated. This apparatus, together with that for recording measurements of psychophysiological changes of task demands and of driver performance has been assembled in portable packages which can be used in a normal vehicle, the driver being accompanied by a research observer. Another study of psychophysiological changes of lorry drivers including monitoring of EEG was described by Lecret (France). This compared drivers who worked regular daily hours with other working an "18 hour day" and showed much more evidence of fatigue in the latter group. Hamelin (France) drew attention to the many social factors connected with the work of lorry drivers which might contribute to fatigue. He described current work which it was hoped would be followed by a statistical study of the effects of different methods for organising the mode of work. He confirmed the relatively high proportion of accidents involving lorries and the high proportion of fatalities associated with such accidents. This was in line with the U.K. accident statistics reported by Ruffell Smith.

Several contributors mentioned the prominence of vibration in the working environment of lorry drivers. Sandover (U.K.) described the main physical variables of this type of stress and the extent of the present rather limited information on effects on man particularly in the driving situation.

Fuller and Cullen (Ireland) described related proposals for a study of changes in driving performance and endocrine factors during the lorry driver's task. Headway selection by the driver was proposed as a critical measure of fatigue state. There are now new techniques for estimating changes of the endocrine state which probably underlie the onset of fatigue and drowsiness. These can now be investigated by relatively simple sampling procedures and might well give a lead to methods of understanding and prevention.

Principles for selection of methods of study of psychological effects were suggested by Brown (U. K.). Adverse effects would be expected to be most marked when time-on-test and time-of-day combined to cause deterioration. Faulty attentional selectivity with reduced sensitivity to the relative importance of cues for action were then likely. Michon (Netherlands) outlined possible psychological mechanisms for drowsiness of drivers and explained methods of study which had been used in recent experiments. He described an "intentive" type of visual scanning associated with predictable visual presentations which tended to lead to alpha EEG activity and drowsiness. This was contrasted with "attentive" control associated with arousal and evoked by unpredictable presentations. He also gave an account of a recent experimental study in the Netherlands of night car driving. This included sophisticated recording of physiological and psychological responses and of driving performance. A log was also maintained by an observer. By computer analysis it is hoped to show correlations between the different variables. Further similar studies of lorry drivers are proposed.

In discussion attention was drawn to the valuable parallel experience in the French pilot studies of lorry drivers, the studies in the U.K. project and of car drivers in the Netherlands which are to be extended to include lorry drivers. Many valuable exchanges of findings and techniques between these projects were made. Extension of research techniques to include endocrine changes was welcomed and Professor Weiner made arrangements for exchange visits of staff with the Dublin group. It was agreed that for such studies there is great merit in sharing tests between laboratories to increase efficiency and to check that measurement techniques were satisfactory. The corresponding need to standardise other methods, e.g. physiological measurements and psychological tests was also emphasised.

Arising from the French studies was the important consideration that investigations of drivers working on limited hours not exceeding, for instance, the 10 hour day limit of the U.K. regulations, might not reveal the serious problems of fatigue of drivers working much longer hours than these. Some material for such a survey of actual hours of driving and type of work is available from the German studies reported by Böcher, but this needs to be extended to include the conditions in different countries and to include consideration of drivers working periods of duty in excess of the nominal or proposed regulations.

Methods to improve the information on the relation of fatigue to accidents involving lorries were discussed. Miss Sabey (U.K.) reported that since the introduction in 1971 in the U.K. of the limitation of working hours based on 10 hours driving per day, there had been a drop in accidents involving lorries. There appeared, however, to be no clear evidence that there would be further advantages in reducing the permitted hours to 8 and this was currently an important question at EEC. An earlier questionnaire from the secretary of the CRM ad hoc Working Group to the various EEC countries had failed to provide satisfactory statistics of lorry accidents. The mode of presentation of questionnaires to government statistical departments is sometimes inappropriate. One needs to state the questions on which information was required rather than to detail specific sub-questions. Whether these are answerable depends on the way in which the data are stored; it is often, however, possible to provide relevant information if the underlying problem is explained.

In a further discussion of the principles of experimental studies, Brown (U. K.) suggested that national differences could usefully be treated as independent variables in an international programme of research. A number of differences had been mentioned during the symposium, for instance the differing proportions of drivers driving alone, the differing proportions of prolonged monotonous journeys or of use of motorways as compared with single lane roads. Other comparisons could be made between the easy terrain of, for instance, the Netherlands and that of mountainous country; traffic density and weather conditions could also be made bases of comparison. On a more psychological level traffic violations and attitudes to alcohol and to risk-taking appeared to be different in different countries and their effects might be compared. Another important variable, that of age, was emphasised by Grattan (U.K.). He suggested that younger drivers often react quite favourably to adverse environments so that in them there might be no detriment to performance in stress. This however changes with advancing years and would make it essential that experimental observations were made on a wide range of ages. At present many are only lorry drivers temporarily and change occupation later in life. As lorry driving becomes a more definite "profession", the effects of conditions upon older drivers will be more important.

These exchanges of information and opinion were agreed to be extremely helpful and Sandover cited his experience on research on vibration to suggest the great value of discussions, such as this, which involved people directly concerned with a limited field of study. Such meetings provide mutual encouragement and information leading to greater efficiency of research effort.

Comments and Conclusions

In spite of the existence of several international bodies with an interest in promoting research on road traffic accidents (e. g. WHO, OECD, the Council of Europe, ECMT) it is significant that the group of workers who attended our discussions had never previously met together to discuss their common interest in study of the working conditions and accidents of lorry drivers. Other international bodies meet at government and administrative levels, but apparently seldom at working bench level. At the other extreme international scientific meetings have more general interests and only exceptionally fulfil the needs of such an applied topic. Another feature specific to this kind of research is that it is commonly a small part of a research programme dominated by other disciplines, be they engineering, legal or academic, and are under a corresponding variety of governmental departments. This accentuates the research worker's isolation and makes the value of international discussion and collaboration with workers of similar interests correspondingly greater.

The work in France and the Netherlands was found to be of direct relevance to the U. K. project and further collaboration would be of great value. Details of variables measured, (e. g. Electroencephalogram (France)), techniques of measurement (e. g. the ICARUS tracking recorder (Netherlands)) and of analysis (manual plus computer (U. K.) and sampling plus computer (Netherlands)) were discussed to mutual advantage. Extension of the present projects should include the psycho-endocrine approach proposed by Ireland and if a multi-centre study can be developed it should include comparisons based on international difference both of the tasks and of personalities and attitudes of drivers.

Apart from the specific developments of observational study and measurement of responses of drivers, there are clearly other more general factors relating to fatigue which merit study. In some circumstances clearly excessive and irregular hours are being worked. These are much more likely to contribute to accidents than the moderate hours being studied in some experimental projects. As with railway drivers, there may also be other factors such as conditions at overnight stops and at refreshment halts which are important in relation to fatigue.

II. PSYCHO-BIOLOGICAL FACTORS IN THE BREAKDOWN OF DRIVING SKILLS

Organizer: Dr J. Cullen

Some account of the origins of the Workshop on Psycho-biological Factors in the Breakdown of Driving Skills is owed to the reader of this report on its proceedings. The proposal arose from a consensus amongst participants at the earlier Workshop convened by the Ad Hoc Committee and held at the Transport and Road Research Laboratories at Crowthorne in England. This consensus represented the view of the participants that a fresh look at recent advances in the sciences cognate to the biomedical and psycho-biological fields was overdue for workers in the area of driver behaviour and traffic accidents.

It was felt that a number of major developments had taken place especially in psychoendocrinology and in psychophysiology in recent years. New theoretical frames for thinking had also been developed in the behavioural sciences, but these developments had not as yet been generally integrated into the perspectives of those engaged in research on driver behaviour. A big problem was presented by the tendency for new and specialised information to remain locked in separate jargon compartments. Furthermore, evaluation and application of new knowledge clearly demanded considerable interdisciplinary collaboration and communication.

The Workshop tried to cover a broad spectrum of recent research in the biomedical and psychobiological sciences. Some of those who participated had not previously applied their knowledge to the road accident research area, but in the Workshop readily showed a willingness and facility to do this in discussion with other participants with long experience in studying driver behaviour.

The discussions ranged from detailed reportage of factual information about psychobiological mechanisms to considerations of how new, and perhaps some older, insights might be incorporated into driver training and education. It became apparent also that those who might have statutory powers (e. g. physicians) to support a license or restrict the license for drivers did not have ready access to information about physiological risk factors. The poverty of biomedical criteria for licensing was brought out several times by speakers. There was awareness, of course, that the socio-political trade-off of road accident levels, deaths and injuries against transportation and environmental planning needs was indicating a need for common-sense and realism in this area. Nevertheless, it was argued that there was a real need to clarify and express the role of psycho-biological factors in driver competence, efficacy and efficiency.

"Fitness to drive" was seen to be a variable and vulnerable state. It was seen to be influenced by many biological factors, for example age, time of day, diet and stress. The emphasis on the psychobiological status of the driver from time to time included consideration of factors which lay outside the actual time of driving. Intercurrent life stresses and events might set the stage for a cascade of adaptive failures which could lead to a disasterous shift in risk-taking or psycho-motor competence. Dietary excesses or "the morning after the night before" of extra alcohol intake could shift the factors in the direction of decompensation in skill.

The Workshop achieved a considerable degree of success in raising the level of awareness between disciplines. However, it seems to me, in retrospect, as a Convenor, that this success was only partial. There is still an urgent need for a comprehensive review of the status of many of the existing approaches to the study of driver behaviour. The valuable contribution made over many years by applied psychologists to our knowledge of vigilance, skilled performance and ergonomics generally cannot be overestimated. Nevertheless, if one reads this literature, one is frequently struck by the fact that personality variables are referred to as significant in the discussion sections of scientific papers. Despite this, little work has been done in this area, in recent years, which reconciles new insights into the psycho-biological bases of personality with traditional personality theoretical constructs. Earlier work on this topic could provide a useful base for new studies (e.g. Farmer and Chambers, 1939; Tillman and Hobbs, 1949; Davis and Coiley, 1959; Shaw, 1965; Parry, 1968).

Over the past decade or so the psycho-biology of adaptation, behaviour control and coping has taken major strides. New theories and constructs of considerably greater unifying power for the complex mechanisms involved have emerged. These promise very fruitful ways of looking at human behaviour in situations demanding sustained high levels of performance under stress. The modulation of arousal so that optimal levels are sustained is now seen to be under constant cognitive control. Expectancies and control determine many of these processes. Their breakdown has been described in an extensive review by Seligman (1975).

The effects of sustained levels of arousal on the endocrine system nowadays present a complex picture of interaction between hormones and brain function. The hypothalamic - pituitary - adrenal system, for example responds in stress and arousal. However, pituitary and adrenal hormones also modulate the cognitive processing functions in the brain. De Wied (1977) has reviewed this area of work on the influence of pituitary and adrenal hormones on arousal in limbic mid-brain structures. We have, therefore, a situation where through learning experiences very basic psycho-biological determinants of behaviour can be shaped. Modes of response can become stereotyped and habitual. Personality factors now take on a new connotation in terms of habitual response and coping patterns which have psychoendocrine dimensions. A useful review of the interaction of hormones and behaviour has been undertaken by Levine (1972).

A significant contribution to road traffic accident causation has come from alterations in internal biochemical states either through the imbibing of pharmacological agents or through endogenous metabolic processes. As long ago as 1958 George Drew found a significant effect of personality variables in determining the breakdown of skilled performance under the influence of alcohol. Clearly the area of personality factors in road accidents demands considerable reconsideration. A "concerted action" programme under Community auspices should take this into account.

In summary, the need to identify clearly the many contributory factors, one or all of which might enter into a spiral downwards in skilled performance was emphasised in the concluding discussions. A more dynamic view of the issues was emerging and a blending of clinical and scientific insights seemed long overdue. Above all, the danger of overoptimism that a single measure, whether biological, biochemical or psychological, might become available to enable us to specify the safe or risky driver emerged unchallenged. A profile of several factors would need to be elicited, but this would be put to its best use as a framework for education for the driver in self-monitoring and self-critique.

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III. L'INFLUENCE DE LA FATIGUE DES CONDUCTEURS SUR LES ACCIDENTS DE LA ROUTE

(The Influence of Drivers' Fatigue on Road Accidents)

Organizer: Miss Françoise Lecret

It was necessary when preparing the workshop on the influence of fatigue in road traffic accidents to limit the concept of fatigue and to consider mainly its indicators and determinants before attempting to relate any possible influence to the incidence of road traffic accidents. By bringing together in such a scientific meeting specialists in the various disciplines of physiology, psychology and road research, an attempt was made to establish this possible relation on the basis of hard facts so as to have a realistic picture which may allow to initiate or modify future research in the field.

The relation between fatigue and accidents is often not obvious. There exist regulatory mechanisms by which the same result can occur due to several different processes, while it is also possible that the final result is unaffected by the disturbance of a particular mechanism. Leplat recommended in this respect that the mechanisms of regulation themselves be studied to be able to assess alterations caused by fatigue. He suggested that basic knowledge of the nature of the drivers' fatigue, of the demands of driving and of the evaluation of the drivers' ability as well as the interaction between these factors be studied. Forbes continued on this argument pointing out the multiple causes of accidents and the complexity of the drivers' task in avoiding dangerous situations. In the talks and in the discussions, again various indicators of fatigue were reviewed in relation to the deterioration of performance during prolonged driving. O'Hanlon reported in this respect that there was a clear electro-physiological evidence of greater reduced vigilance in the tired driver. Sandover described a range of observations and measurements on driving performance of professional heavy goods vehicle drivers and the variations observed in different work conditions.

The complexity of visual performance was brought out by Miss Rey. She considered the immediate visual alteration caused by the lack of adaptation to the requested rhythm as opposed to the delayed visual alteration which does not necessarily disappear with the elimination of the cause. Night driving in particular was considered and it was suggested that special techniques be adapted when studying these very special requirements.

The endocrinological aspects of fatigue which can now be studied by techniques developed in Ireland to investigate stress, anxiety and changes during sleep were reported by Cullen. This technique which was described in greater detail at the workshop on psycho-biological factors in the breakdown of driving skills, allows to determine variations by regular blood sampling during the sleep or without the knowledge of the investigated subject. Cullen emphasised that variables one tried to manipulate in the theoretical constructs of fatigue, stress, anxiety, etc. are all common; human behaviour, even at its worst, is extraordinarily unitary with an interaction of functions that provide adaptability and many alternative options for adequate responding. The potential now available for the elucidation of some of the problems in the stress-fatigue syndrome was discussed.

Environmental factors in the production of fatigue include the physical environment of road and driving compartments as well as the human aspects influenced by personal or work conditions. Sandover, Hamelin and Françoise Lille as well as other speakers reported and raised discussions on the working conditions, of drivers of heavy goods vehicles. While Françoise Lille commenting on the multidisciplinary study insisted on the working conditions influencing the attitudes of drivers. Hamelin considered more particularly the work/rest periods and their influence on the driving ability. He felt the socio-economic factor is of major importance in this field since it regulates the existing constraints. He was not yet, however, convinced of the relation between conditions of excessive driving and the final accident criteria.

Following the distinction drawn by Michon between the attentive and intentive visual perception, this approach was welcomed as an example of the need to bring together the indicators of fatigue and their determining mechanisms. Analogies were drawn to studies of the effects of alcohol and drugs.

It was concluded that one cannot speak of the relation of fatigue to accidents unless one defines it by a complex of determinants which must include individual variations and a number of poorly understood mechanisms. The faulty strategies of tired drivers were discussed by Naatanen and he suggested that a subject tended to maintain a constancy of risk. This concept agrees with results obtained by O'Hanlon in studies of truck accidents.

An important topic of discussion of this workshop was the relation between results obtained using different indicators and the final criterion of safety, the accident itself. In fact, even though one can understand the interplay of factors which are involved in the process leading to a feeling of tiredness or a deterioration of skill, it is necessary to know the indicators of this fatigue. Their choice is therefore of great importance. One must consider first of all the whole range of indicators and not their mean value, furthermore, results may follow from studies of convergence of data rather than from the spread of only one parameter, for it is important to consider the multipolarity of the phenomena, the unstable character of a parameter and the particular property to be ascribed to each indicator. Thus, for instance, the validity of the electroencephalogram indicator was discussed at length to ascertain that one has really only a characteristic index of the vigilance of the subject studied even then the sensory modalities in which it occurs would have to be defined (Miss Lille).

One cannot refer to response mechanisms if one is limited to the responses only, i.e. to the outputs of the system (Leplat), thus the importance of the compensatory mechanisms. These elements, which are often quoted, form many partial responses of the individual to a task of which he perceives with his captors only a modulated, regulated, adapted response; if the answer is not adapted, then one could not even state at which level the system failed; hence the necessity of a conceptual model to include these intermediary phenomena, placed for our convenience in the "black box", so as to state hypotheses on their operation and to develop experimental procedures.

Physiologic indicators must be considered and their importance will depend on the analysis of the situation which brings us back to a notion of vigilance. Many dark areas in this field were reported, e.g. variations in vigilance during the nycthemeral cycle, and particularly during driving, the importance of the time of day or night, and also the mental load of the driver (Brown), the physiologic effects on sleep and the life habits and/or the overwork of HGV drivers were raised (Hamelin).

Miss Rey, in the field of visual information pointed out the fact that during this workshop the visual process had been considered as a whole, yet if one was interested in what reached the eye and how it reached it, in other terms to the visual strategy, one could, by so doing, introduce very easily an analytical error. The example is worth considering particularly when Miss Rey shows that during night driving as opposed to day driving, a specific organisation of the retina surface is much more involved than any conscious phenomenon of the driver. Faulty decisions are made because the complex visual system is not well understood. It is therefore advisable to establish physiologic facts ascribed to the various driving situations, based on sound knowledge of the operation of the visual system and of its sensitivity, a field so far restricted to psychophysicians and not given much importance in road traffic accident studies.

The same caution was stated when extrapolating results obtained in different conditions and which could have different implications. A particular point was made of the hazard of applying blindly to European conditions results and conclusions reached in the USA.

It is worth while mentioning some suggested applications of previous results. Helander aims at defining with multiple indicators, highway zones characterised by their comfort. Brown reported on a series of recent studies aiming at modifying the behaviour of drivers by the use of some devices on the roads. O'Hanlon described an experiment which aimed at marking with sound the "dark spots of sleep" on California highways. Some devices integrated to vehicles were described by Brown.

Miss Rey reported in particular the mediocrity of the visual examination when delivering driving permits, and the errors made when road infrastructure are conceived without the expert opinion of a true specialist leading as it happened to faulty luminous signaling.

After these two days of discussion it seems still worth while to use the term "fatigue" in road safety considerations and research, even though one should define this concept attributing adequate weight to its various components. At these different levels it will be necessary to study the vigilance phenomena, physical pain of muscular type, the process of visual information, etc. The concept of fatigue covers a field of study with indeed different approaches but which are nevertheless complementary.

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The subjects were:

(a) Conditions relating to fatigue and accidents of heavy goods vehicle drivers; Crowthorne, United Kingdom (24-25 March 1975),

(b) Psychobiological factors in the breakdown of driving skills; Dublin, Ireland 14-15 January 1976), and

(c) Influence of drivers fatigue on road traffic accidents; Dourdan, France 30 September - 1 October 1976).

The workshops aimed to assess the current situation and knowledge of particular facets of the subject, to review the research methods used in the various laboratories of the European Community, to determine the need and desire for inter-European collaboration and to allow scientists to exchange freely results and views on their research topics. The field purposely left broad, some overlapping was to be expected considering the wide variety of human factors which are potential determinants of road traffic accidents.

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