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PERS.185 FATIGUE AS A CONTRIBUTING FACTOR IN THE CAUSATION OF TRAFFIC ACCIDENTS

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FATIGUE AS A CONTRIBUTING FACTOR IN THE CAUSATION OF TRAFFIC ACCIDENTS

1. Introduction

It is commonly believed that as a driver becomes fatigued his chances of having an accident increase. However since fatigue in its many forms can result from a multiplicity of causes acting either singly or in combination, it is difficult to determine what rules or principles are involved in its control or for its prevention. Therefore, each case must be judged according to its own peculiar characteristics.

If for example one drives a car in the city during rush hour it happens quite often that more information is presented to one than one is able to process, so that it is possible to feel completely exhausted after fifteen minutes of driving. However, things are quite different on a more restful Sunday morning when one goes out on a pleasure drive. The country-side is enjoyed because of its beauty, the conversation is interesting and one does not have a care in the world, so that after six or seven hours of driving, one might feel a little stiff but not fatigued. As we evaluate these examples we notice that not only our likes and dislikes influence the onset of fatigue, but also, among many other factors, the quantity of information processed.

We realize that a fatigued driver is not driving at full capacity and that therefore the chances of having an accident are increased. We want to find out what rôle fatigue plays in the causation of traffic accidents. Before we can do this, however, we have to define what fatigue is and how it can be measured.

11. What is Fatigue?

The most confusing problem in scientific research concerns our lack of understanding of what we call "fatigue". There are few people who would claim that they have never been fatigued. However there are few words in our vocabulary which have been less adequately described or understood. Because of this, definitions of the nature of fatigue are almost as numerous as articles written about this subject.

We may rightfully ask why there are so many different interpretations of fatigue. The answer may lie in the fact that the word does not have a specific scientific meaning. Even in medical research it is not a distinct clinical entity. The most acceptable meaning or definition would be that fatigue refers "to a group of phenomena associated with impairment, or loss, of efficiency and skill, and the development of anxiety, frustration or boredom". (McFarland[1], 1971.) Fatigue is a term which is used to classify certain phenomena that are not fully understood, as the term unconscious is used in psychology, particularly in psychoanalysis.

At present the most widely accepted explanation of fatigue is that it is an outcome of conflict and frustration within the individual. In its most extreme forms it can become chronic and develop into an anxiety neurosis. To try to limit the cause of fatigue to one single factor, however, may be misleading as the human body generally offsets any inefficient functioning in one direction by compensating at other levels.

Physiological Factors in Fatigue

Physiologists have attempted to relate fatigue to body chemistry and lack of oxygen, and to locate it in certain parts of the body. Bartley (1951) recognises three types of fatigue arising from different sources. These are, firstly, fatigue arising from exertion or the expenditure of muscular energy and requiring particular attention to the muscles involved. Secondly, fatigue can arise from performing acts of skill, or meeting demands involving activity of a restricted or predetermined nature, much of which is neuro-muscular in origin and which requires organization at various levels of the processes within the body. In a carefully controlled experiment, Benedict and Benedict (1933, quoted in McFarland,[2] 1971) found that sustained mental affort for several hours required only the calories contained in half a peanut'. Fatigue under this heading requires an understanding of matters relating to the organization of internal activity as well as, although to a lesser extent, to energy expenditure. Thirdly, there is fatigue caused by the interaction of the person as a total organism with his environment. In connection with driving, points two and three are of major importance, since this activity over long distances requires more than mental effort.

The chemistry of fatigue refers to: (1) the chemistry of metabolism, in which the ability to metabolize food intake at sufficient rates during exertion is crucial; (2) the chemistry which is influenced by the mood of the individual; (3) the chemistry of the hormonal system which is needed to maintain proper health; and (4) the chemistry involved in activating interoceptors which relay an awareness of tissue conditions to the centres of the brain. In driving, fatigue is produced by emotion or by prolonged mental effort resulting in a deterioration of mental performance, adaptation and skill. For this reason it would be of value to look also into the psychological aspects of fatigue.

Psychological Aspects of Fatigue

An answer to the understanding of fatigue may lie in the psychological study of the role of the higher nervous functions. Psychologists have shown experimentally that certain mental functions show a decrease of efficiency through simple and prolonged repetition of arithmetical, light or colour naming tests. This decrease in efficiency has been described as mental lapse or blocking. Here the person finds it impossible to continue his activity without making frequent errors. As he becomes more and more exhausted or tired, these lapses become longer and the errors more frequent.

The emotional component of fatigue must be considered, although it is not easily measured. Normal persons can readily adapt themselves to new situations and temporary conflicts. However, if emotional stress and mental effort are continued for too long the ill effect is cumulative and is often called fatigue.

Skill fatigue, a concept which is also applicable in driving, has been developed by Bartlett[3], (1951). He used this concept in explaining the deterioration of performance in pilots. Simulated flying conditions were used in a standard Spitfire cockpit with full controls and instruments. Testing time varied from as little as two hours to an exhausting six or seven hours. Bartlett found that piloting errors due to the misuse of controls decreased throughout the experiments, but this improvement was more than offset by a deterioration in accuracy of timing and skill. As the trainees became more fatigued they continuously lowered their standards of accuracy and performance. Besides this, they failed to interpret instrument readings as part of a complete system and paid attention to one or other of the readings as separate parts or isolated instruments. With an increase of fatigue there was a decrease of the range of attention and the more distant instruments were usually ignored or forgotten. Most of all there was a general tendency for a sudden increase of errors at the end of a flight. A tired pilot, it seems, has an almost irresistable tendency to relax when he nears the airport.

III. How do we Measure Fatigue?

In proving the usefulness of a measure for fatigue, we must first of all objectively verify that the examinee subjected to the measure is in a state of fatigue. At the present stage, however, where no means of an objective identification of fatigue are available, we cannot but rely upon the verdict of common sense for the criteria. The problem comes partly from the breadth and variety of the word's meaning in common usage and partly from the relatively small amount of direct research in this area. It is assumed that many of the effects of fatigue account for the failure of experiments in other areas. Although some researchers (Muscio[4], 1921, Browne[5], 1953) have questioned the acceptability of fatigue as a subject for investigation, it is generally accepted that these effects are important and worthy of investigation. It was estimated by Floyd and Welford[6], (1953) that the cost of fatigue to industry in England amounts to tens of millions of pounds per year. However the contributions of fatigue to road accidents is not known but it can be assumed that the cost to South Africa in this respect must also be very high.

Fatigue resulting from Stress

Stress has always been a factor affecting human behaviour, and contributes much to fatigue. Two physiologists, Cannon and Selye, made contributions in this area. Cannon[7], (1932) mentions the ways in which the body maintains a physiologic constancy or steadiness under conditions of fatigue, disturbance and frustration.

Selye[8], (1956) has observed specific nervous and humoral alterations reflecting the general adaptation of the organism to stress.

From these investigations it was deduced that measurable substances in the blood and urine indicate glandular responses of the body to stress. It is therefore possible that stress can produce the underlying physical basis for chronic fatigue. It is easily understandable that emotional stress can have serious physiological results for persons in situations where there is little or no chance to correct error. McFarland and Moseley[9], (1954) mention that activities of a stressful nature which do not lead to physical exhaustion, nevertheless severely deplete energy reserves shown to be associated with deficiencies in hormone production of the adrenal cortex. Michaels[10], (1960) and Hulbert[11], (1957) investigated the galvanic response during driving. They found a considerable arousal level in traffic, particularly at intersections. During driving, even a healthy driver could become fatigued, because repeated emotional arousals over short intervals of time build up on each other so that a slight irritation can produce an unexpectedly strong response.

Furthermore, a sustained state of emotional arousal in a driver, over a short period of time, has the result that for some time afterwards it is more difficult than usual to elicit an emotional response. This seems to be a protective process which will save the driver from the complete depletion of his energy reserves and it is accompanied by a loss of interest in the environment.

The most important source of emotional arousal and stress in traffic conditions is interpersonal relationships. This can be unresolved personal conflicts before driving and also conflict arising from a number of traffic situations. It happens also quite frequently that one is added to the other making it even more difficult to cope with the situation.

It is well known that fatigue and anxiety are related and that one may act on the other and magnify it. This does not apply only to the neurotic person, but also to the normal person since both have latent anxieties which may be accentuated if they become fatigued.

Fatigue and the Time Factor

No person would argue with the statement that "the longer you drive the more fatigued you become". In other words driving skill can be impaired by the time factor. In order to measure the deterioration of a complex skill such as driving, isolated reactions should not be studied. Most drivers have their own individual style or pattern of driving from which they might deviate in certain circumstances. Up to now no technique has been developed which is able to examine changes in the driving pattern of the individual, or what causes them. However, such techniques are now in a process of development but it is important that the testing situation should be similar to the actual driving situation. Tension, stress and motivation which are not part of the road driving situation should not arise. Welford[12], (1953) mentioned that research on "fatigue in general" has been exploratory and inconclusive, however "the way has been cleared for a definite attack on the problem" and that we have reached "the end of the beginning". To our misfortune, this does not apply to driving fatigue, where the basic knowledge of both fatigue and driving performance is lacking. Here even the beginning has not been reached.

In an investigation by Jones et al.[13], (1947), 889 long distance truck drivers from three cities were stopped just before reaching their destination, taken from the vehicle and tested. The results of the tests were compared with a control group, matched as to hours of sleep, who had not driven. The "reaction-co-ordination time" measures, e.g. hand steadiness, body sway and speed of tapping, showed the greatest differences between the two groups. The results indicated a consistent decrease in psychomotor performance with an increase in driving time. However, no sharp break in the results could be found, which would have indicated the onset of fatigue. The authors concluded that long hours of driving reduced efficiency and safety of driving.

In another experiment Ryan and Warren,[14] (1936) using six drivers as subjects during one-hour and ten-hour driving spells, showed a strong effect of prolonged driving on steadiness and co-ordination reaction. However the investigation was of limited value due to non-validated measures. Lauer and Suhr,[15] (1958) attempted to compare laboratory experiments in simulated car driving with actual driving. They found that rest periods do much to reduce deterioration of performance during long distance driving.

In order to study fatigue during long hours of driving, McFarland and Moseley,[16] (1954) observed and classified the activities of two bus drivers on regularly scheduled passenger runs. They compared the performance during the first and last half hours of the long drive and found a considerable reduction in the number of steering wheel movements in the last half hour. However, an analysis of the data on the activities recorded for the first five minutes of each of the seven successive half hours showed no significant differences.

An investigation of near accidents was reported by Potts,[17] (1951) and McFarland and Mosely,[18] (1954). They studied seventeen long distance truck drivers on 20 trips averaging 250 miles per trip on which they were accompanied by observers. The results led to an unexpected conclusion. Observations indicated that an increase in the driving period, far from being negative, led to a reduction in near accidents. It appears that fatigue arising in one area is more than compensated for in another. This was not an isolated finding, but is supported by a number of other American studies on long distance truck accidents. It has also been mentioned by McFarland and Moseley[19], (1954) that two large insurance companies reported that approximately 60 per cent of all long distance truck accidents in 1949 occurred during the first $3\frac{1}{2}$ hours of driving. These researchers indicate, that as well as lack of sleep or rest, anxiety and other emotional problems due to off-duty interpersonal relationships may contribute to the pattern of accident behaviour.

Sussman et al.,[20] (1970) using 69 subjects and a CAL driving simulator found that a driver's ability to maintain his vehicle on the road under non-alerting (non-fatiguing) conditions decreased linearly with time over four hours. The rate of steering wheel corrections also decrease linearly over this time. They found a negative correlation between position error and steering wheel correction frequency. This seems to indicate that either the subject perceptually samples road position less frequently after driving for many hours, or he processes and reacts to his road position less frequently over that time. Furthermore, it was found that measurement of position accuracy during a simulated emergency indicates that the driver is less likely to be able to control his vehicle properly during an emergency after four hours of driving than after one hour of driving. This decrease in control during the simulated emergency is most severe when the driver has been exposed to loud noise.

Another phenomenon about which very little is known is the "hypnotic effect" of long monotonous journeys (Haber et al.,[21] 1954). Here the driver may experience an inability to appreciate his speed in terms of stopping distance, or he may fall into a state of "trance" brought about by travelling mile after mile of monotonous highway. McFarland and Moseley,[22] (1954) mentioned that hypnogogic hallucinations are experienced after long distances by drivers who imagine that they see something on the road and then make emergency stops. Quite often accidents arise in these circumstances. This phenomenon occurs mostly at night and has been reported by long distance truck drivers.

Sleep and Emotion

If we are really interested in understanding fatigue we should not neglect the emotional aspects. Lindsley,[23] (1951) and Magoun,[24] (1958) linked emotion, arousal and sleep. They are considered as a continuum from deep coma, through relaxed wakefulness to extreme excitement and emotional disturbance, with loss of control and disruption of skilful activity.

It is interesting to note that there is little deterioration in performance with loss of sleep. Warren and Clark,[25] (1937) reported that after 65 hours without sleep there was little impairment of performance even though the person had to struggle to keep awake. Laslett (Seashore,[26] (1957)), who had no difficulty in finding volunteers for his experiment on lack of sleep and using his friends as a control group, concluded that the motivation of being in a difficult experiment helps to compensate for any negative effect of sleep lost.

Deterioration of performance due to lack of sleep can be noted more readily in a more complex continuous task, such as driving in traffic, rather than a task of simple nature and where there is more opportunity for rest. McFarland and Moseley[27], (1954) as well as Seashore[28], (1957) report that subjects arouse themselves momentarily, but if continuous performance is tested there appears to be difficulty in maintaining the state of arousal even for experiments lasting only a few minutes.

Malmo's[29] (1957) experimental evidence supports the idea of a state of arousal or an intensity dimension of behaviour. Other research such as that of Lindsley[30], (1951), Duffy[31], (1951), Hebb [32], (1955) and Schlosberg[33], (1954) seem to agree. Experiments by Stennett[34], (1957) and Survillo[35], (1956) on the relationship of physiological measures to the level of motivation suggest that the measures may serve to quantify this factor of arousal.

IV. Some Possible Methods of Measuring Fatigue

At the beginning of the section " How do we measure fatigue?" it was suggested that the problem of fatigue would be clarified if an objective measure of fatigue could be found; and in the section on "Sleep and Emotion", it was suggested that a raised threshold of arousal following a period of stress is another description for a kind of fatigue produced by driving.

If we identify driving fatigue with a raised threshold of arousal, then the arousal value will be extremely important. It can be assumed that if the subject's interest in a certain test itself is of short duration when he is fatigued but sustained for a much longer period when he is fresh, this then would give us a measure of fatigue. If the attention of the subject is focussed, then the test has arousal value. However, we have to keep in mind that there are other contributing factors such as personal satisfaction in co-operating, competition, and the self-knowledge gained from the results. Because of these factors basic research on tests of fatigue must be conducted as far as possible without the subject's knowledge.

Physiological Methods

It is indisputable that the most satisfactory measure of fatigue would be a physiological one. Up to now, the usefulness of such attempted measures has been hindered by practical difficulties.

The electroencephalogram has been used (Lindsley[36], 1951, Crawford[37], 1955 Lindsley et al.[38], 1949, Moruzzi and Magoun[39], 1949) to show an activation pattern which may be found to give a measure of effort and of a subsequently raised threshold of arousal. The change in electrical skin resistance (GSR) with sweating is a favoured measure of emotional response. Changes can be recorded but it is hard to estimate the actual level of the activity of the sweat glands. Among many other physiological measures of emotional arousal we find blood pressure and volume, electrocardiogram heart rate, respiration, skin temperature, pupilliary response, salivary secretion, pilomotor response, chemical sweating indices, analysis of blood, saliva, urine, metabolic rate, muscle tension, eye blink, and tremor. It is therefore not possible to make use of the absolute value of these measures.

Many of the above measures have been examined by Schnore[40], (1959). He found that under standard conditions there were not only individual differences in arousal threshold, but also that there were large variations between the subjects. Schnore points out that despite idiosyncratic differences in the results, individuals placed in an arousing situation will show increases in most functions, although the general level may vary from one person to the next.

A review of more recent research on fatigue does not add much to what has already been said. In Japan, Fukui and Morioka,[41] (1971) are using a method of measuring the blink value of the eye in their study of fatigue. Dukes-Dobos,[42] (1971) is experimenting with fatigue from the point of view of urinary metabolites. Donoso, Apud and Lundgren,[43] (1971) give direct estimation of circulatory fatigue using a bicycle ergometer. Morioka, Numajiri, Onishi and Sasaki,[44] (1971) investigated mechanical and physiological efficiency of muscular work with different muscle groups. In Australia, Welch, Longley and Lomaev,[45] (1971) measure fatigue in hot working conditions. Takakuwa,[46] (1971) investigated the maintaining of concentration as a measure of mental stress and fatigue. Another investigation involving mainly psychological methods of fatigue has been reproted by Grandjean, Wotzka, Schaad and Gilgen,[47] (1971). They studied fatigue and stress in air controllers. The measures used were critical fusion frequency, tapping test, self-rating and catecholamine excretion in urine. They found a marked decrease in values after the 6th hour of work, and during the night the test values were lower. They hypothesized that all measures are indicative of a common state of fatigue. Practical application of some of the methods to drivers could perhaps be approximated by giving them a sedative after a period of driving and then measuring the time before it takes effect.

Psychological Methods

One of the easiest methods of testing fatigue is to give the person involved a self-rating scale. However, the results are considered questionable. Another example would be Kay's[48], (1955) immediate serial recall test and the solving of difficult problems. In Kay's test, buttons had to be pressed in response to the appearance of light signals. The test was sensitive to fatigue, the effects differing with age. The problem-solving experiment proved that fatigued subjects new to the task were less succesful than those tested for the first time when they were fresh.

Since one's arousal is adversely affected by fatigue, it would seem that the best way to test a person for fatigue would be to measure his level of arousal. This should be done in such a way that there is no opportunity for compensation of error, or time for the subject to arouse himself if he is not ready. Tests of this nature would be relevant to driving. The task in question would have to be paced and varied so that lower standards of performance could be noted. This task should best be administered within the vehicle. As part of this method, fatigue could be measured by an increase in the driver's work load, eg. engaging him in another task while driving. The driver could add digits, listen to numbers and notice when certain numbers are repeated. This kind of test was used by Brown and Poulton,[49] (1961). When driving requires more attention the error score on the other task may be expected to increase. Using this method Brown and Poulton measured sensitivity to traffic, but the same or a more complicated method could measure sensitivity to fatigue. However, the shortcoming of nearly all of these methods is that any addition to driving may reduce fatigue by adding some diverting interest.

Recent research in using psychological methods has been reported mostly from Japan. Kashiwagi,[50] (1971) produced a psychological rating of human fatigue. He believes that it is possible to judge human fatigue from a person's appearance. He constructed a fatigue rating scale. Kogi and Saito,[51] (1971) reported a factor-analytic study of phase discrimination in mental fatigue measuring critical flicker frequency and choice reaction time during a 24-hour shift. Yoshitake,[52] (1971) studied the relation between symptoms and the feeling of fatigue. In an experiment in England, Grant,[53] (1971) investigated the concept of fatigue and vigilance in relation to railway operation. He found that fatigue in train driving exists, even although drivers of modern locomotives do not expend much physical energy. Fatigue in drivers does arise, not only from overloading the human system but from underloading, or monotony, which is produced by prolonged inaction and stress. One of the aims of Grant's study was to detect what environmental information the driver acts upon, to what extent he relies on memory of the track, and how the environment could be enriched so that vigilance is improved and the onset of fatigue averted. It is generally accepted that compensation occurs so that with the onset of fatigue less important aspects of a task will be neglected to keep the load of the task within the capabilities of the subject. If the load of the task increases, the first things the driver sacrifices are his social courtesies; he forgets to give way to pedestrians and other vehicles, or to dip his headlights at night. He might also become impatient more easily and blow the horn more often. For this reason horn blowing and the non-dipping of headlights could be a measure of fatigue. This would have the advantage of not changing the task from driving to a special test, nor introducing other variables which might hinder the comfort of normal driving. As with all other procedures, there are also difficulties here. It might be difficult to control the environment and the measure would lose some sensitivity. But most of all, if the driver knew that he was being tested, he would have added interest and the measure would lose its value.

The Greenshields Drivometer

In my opinion the best possible measurement of fatigue is the Greenshields Drivometer which is mounted in the glove-compartment of a vehicle. This instrument was developed in 1960 and has been improved since that time. It is described in detail in Greenshields,[54] (1962); Platt,[55] (1962, 1964a, 1964b and 1964c). It has been used in a Ford Fairlane 500 four door sedan. The vehicle was equipped with seat belts, power steering, power brakes, and dual brake and accelerator pedals. Platt,[56] (1964c), states that the purpose of the drivometer is to measure " the fundamental actions of the driver in controlling direction and speed of his vehicle and in addition to measure the fundamental parameters of vehicle motion". Figure 1 shows the modified Greenshields Drivometer as used by Platt (1964c). Platt,[57] (1964c) mentions that previous experiments have shown that steering wheel reversal, which is the same as vehicle tracking cycle rate, is the most sensitive variable to driver, environment and vehicle characteristics.

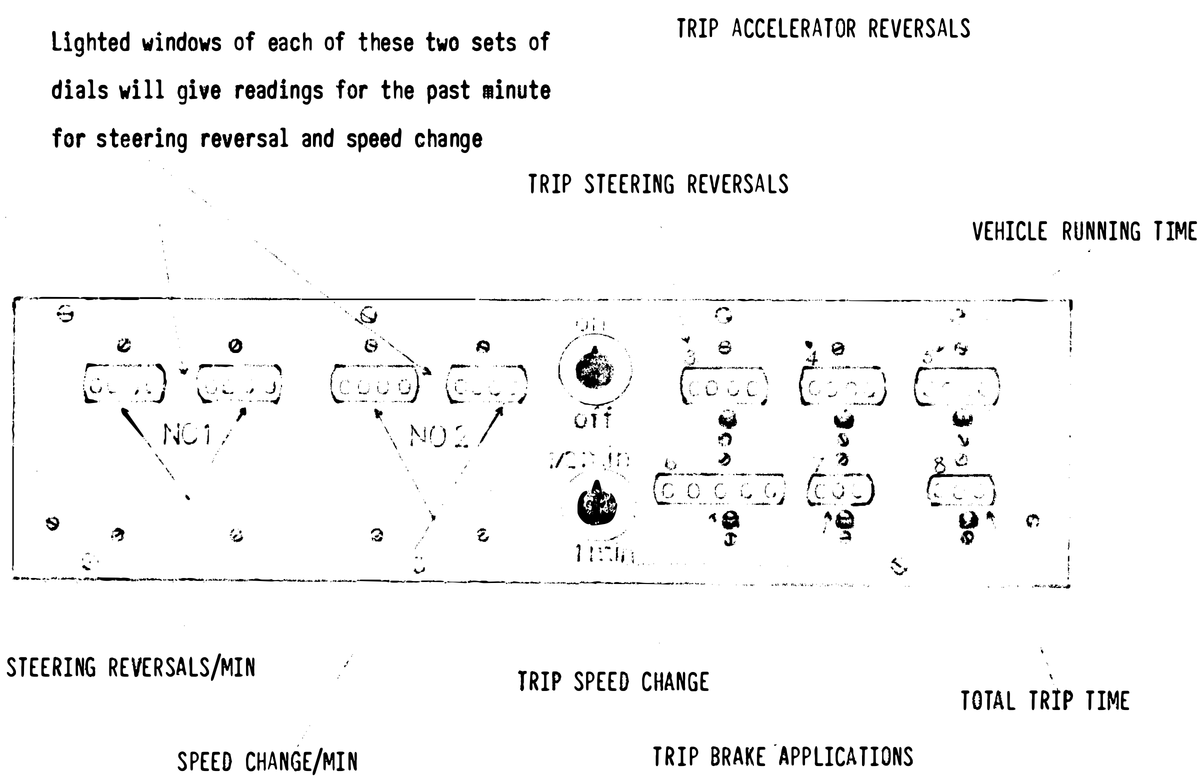

Fig. 1. Modified Greenshields Drivometer from Pratt 1964c

In addition, speed change rate, e.g. the number of increases or decreases in vehicle speed, and accelerator reversal and brake applications are also important measures of driving behaviour. No. 1 of the Drivometer (see Figure 1) consists of two counters which work as a unit recording the steering wheel reversal rate on a minute-by-minute basis. No. 2 consists of two counters which record the speed change rate for each minute. One counter is recording, the other is adding the total count for the preceding minute. No. 3 gives a cumulative count of steering wheel reversals from the start of the test run. No. 4 gives the total number of accelerator reversals. No. 5 records the time vehicle is in motion. No. 6 records total speed change in miles per hour. No. 7 records brake application and No. 8 total time of the trip. To this unit could be added a camera attachment for automatic recording of data.

The modified Greenshields Drivometer seems to be, in my opinion, the best instrument to establish the measurable limits of fatigue and its degrees on a population of drivers in a real life driving situation. Studies with this instrument will permit evaluation of direct and indirect causes of driver fatigue and a development of a set of rules as counter-measures.

Platt,[58] (1964c) used two drivers in his experiment on a 1200 mile trip. He claims that the effects of driver control, can be monitored by the Drivometer. Platt developed a series of empirical equations to produce a measure of driver performance compared to driver's norm. These equations are derived from the results of the research conducted to date. The test runs have given us a broad base for a study of driver fatigue in an actual driving situation.

V. Case Studies of Road Traffic Accidents in South Africa.

One of the most important studies concerning traffic accidents was reported by Odendaal[59] in 1968. The objective of the investigation was to determine the factors which contribute to accidents. The team consisted of a civil engineer, a sociologist and a motor vehicle technician, and they investigated 109 accidents in the Pretoria area involving 200 participants. Some 1166 contributing factors were found and classified as performance failure of accident participants (582 factors) or attributes of participants (452 factors), "vehicles" (53 factors) and the "trafficway" (79 factors.

From the point of fatigue the following could be more closely investigated. Could some of the 119 drivers or pedestrians who failed to see traffic hazards at all or in time have been fatigued? Did some of the 127 participants make wrong assumptions in respect of the traffic situation because they were fatigued? Were the faulty operating habits of 82 participants due to some form of fatigue? Was the inattentiveness of some of the 60 participants due to fatigue? The answer to these questions appears to be clouded by the fact that the identification of contributing factors to accidents was often only subjective.

A closer analysis of Odendaal's report shows that alertness and concentration were divided into 66 attributes in respect of 60 participants (29,7%) involved in 49 accidents (45,0%). Ten per cent of participants in individual accidents were classified as inattentive. However, only in 9 accidents (8,3%) was fatigue given as the reason for the accident. This fatigue was in 5 cases due to lack of sleep. Daydreaming or some related phenomenon was seen as the cause of 16 accidents (14,7%).

Odendaal reports that 79,8% of the accidents are virtually synonomous with incorrect assumptions or predictions made by the road users in respect of the behaviour of other road users, traffic and road conditions. Some of these interpretations of failure to avoid an accident could be attributed to fatigue.

Odendaal readily admits that questions of completeness and reliability of human factors, objectivity of investigators, and methods of analysis, contributed to limitations of the value of his report. However, since police reports on accidents do not investigate the fatigue factor, or comment thereon only in isolated cases, these are not objective enough. The Odendaal report therefore is the best record we have in South Africa. Furthermore, research on traffic accidents continues at the National Institute for Road Research and several reports are in progress.

VI. Conclusion

Fatigue originating from prolonged activity at one task may be transferred to and measured by another. In general we can say that there are two aspects of fatigue in driving. The first gives rise to the question: to what extent does driving lead to fatigue? The second question is, how fatigued has a person to be before it affects his driving? It is quite possible that driving produces a considerable amount of fatigue, but the driver is not sensitive to it. On the other hand, driving performance may be sensitive to fatigue, but fatigue produced in driving is of limited nature. Here research might help to distinguish between these possibilities. However, research is hampered by lack of knowledge of driving performance and fatigue. New experimental techniques have to be developed.

We have to admit that the type of fatigue produced in driving is different from that produced by physical exercise, since it is caused by traffic and other environmental conditions which produce arousal of varying degrees. Some emotional arousal if repeated over a short period, produces oversensitive behaviour in most people, which causes slight irritation. However if this period of prolonged irritation is increased and the state of arousal is affected to such a degree that it may lead to an increase in the risk of accidents, not only to the driver but also to the other drivers who are part of his environment.

VII. Recommendations.

It is clear that the concept "fatigue" and its involvement in accident causation have not been researched to the extent that any clear-cut conclusions could emerge. Further research with specific objectives is therefore indicated.

The Odendaal investigation referred to earlier pointed to probable involvement of fatigue in a considerable proportion of the accidents investigated. It is, however, an open question whether the true extent of the involvement of fatigue can ever be assessed by adopting a case study strategy which has to rely, of necessity, on circumstantial and largely introspective evidence. At present, police procedures do not make any provision for the measurement of fatigue through either subjective descriptions or laboratory techniques immediately after the occurrence of an accident. It seems hardly practicable or feasible to establish such administrative procedures within the framework of existing legislation and priorities. The matter is furthermore complicated by the fact that all minor accidents involving no injuries are only to be reported to a police station within a fairly lenient period specified by the law.

The Greenshields Drivometer, discussed earlier, has some appealing features, notably its face validity and obvious relevance to the test at hand. The standardization of the instrument for the reliable assessment of fatigue and the introduction of properly calibrated fatigue inducing situations, however, would pose severe practical problems.

In the final analysis, the task of driving a motor vehicle can be viewed as dependent on the constant monitoring and effective processing of information presented at varying speeds and with varying degrees of importance. These situations can be simulated in the laboratory and subject responses measured with a considerable degree of accuracy. Standardized fatigue inducing situations such as noise, high temperatures, atmospheric humidity, and boredom can be created by means of specialized equipment in the possession of the N.I.P.R. Facilities also exist for the extensive measurement of physiological correlates of fatigue and levels of arousal. It is therefore proposed that the decrements of the quality and rate of information processing under conditions of externally induced fatigue be investigated. Should a significant deterioration in these facilities be demonstrated, a scientific basis would be established for the introduction of e.g. enforced rest pauses for professional drivers, and public enlightenment campaigns.

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