HUMAN FACTORS RESEARCH:

SOME GENERAL CONCEPTS AND TASK STATEMENTS

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The Human Factors Group concurs with the general philosophy at HSRI that a system approach is needed for the solution of the highway safety problem. In this regard the driver is viewed as one element of a complex system whose other basic components can be considered to be the vehicle and the environment in which it operates. Overall system performance will be affected by the capability of each of the components and by the extent of the variability that each component may undergo. It is well known that variability among drivers, or people in general, is an inherent characteristic. At the same time, however, variability in other components of the system, such as the vehicle and the environment, are also important factors. This means that the traffic system is one that can be characterized by a great amount of variability among its components, and so no simple formulas are likely to be found to express the state of this system. It is this variability and the interactions that occur between the components of the system that make the study of highway safety a very difficult one.

A basic consideration in Human Factors Research, therefore, will be to investigate human performance under a variety of conditions, and to investigate the performance of different individuals under this heterogenous set of situations. It is in this way that information will be obtained concerning the variability of the total system. This information should provide insight into the kinds of Human Factors design recommendations that should be implemented so that system variability is held within the limits to which man can adequately respond.

In the driving situation man can be considered to be an information channel, receiving inputs from stimuli, emenating from outside and from within the vehicle, to which he makes responses, the results of which are fed back to him so that the consequences of his actions may be realized. Numerous studies have been carried out to consider man as part of a control loop. However, none of the studies that have been carried out to this time have by any means considered the full complexity of the nature and number of stimuli to which a driver may be responding, and all attempts to model the driver-vehicle feedback system have been extreme oversimplifications.

Information exterior to the vehicle that is utilized by the driver can be in numerous forms. Basically, this will be concerned with information required to track the highway over which the vehicle is traveling. However, other sources of information, of current importance to a driver, may be concerned with direction information to insure that he will follow the route of his choice, information concerning other vehicles or obstacles on the highway, as well as the condition of the highway.

The vehicle itself is also a source of information to the driver, and numerous feedback loops are closed between him and the mechanism he is controlling. These sensory inputs arise from steering wheel torque, force exerted on the gas pedal or brake pedal, noises from the vehicle and tire-road contact, kinesthetic and proprioceptive sensations resulting from motions of the vehicle, as well as information displayed to the driver to indicate vehicle condition by the instrumentation. On the basis of this information the driver initiates responses and carries them out via his motor system. Very little is known to this time concerning the frequency or the nature of which particular loops are closed at any particular point in time during the driving task. Interacting with these stimuli and with the responses that the driver is called upon to make are the inherent characteristics of the driver himself, his personality, cognitive, perceptual-motor and judgemental characteristics. These in turn are influenced by the physiological condition of the driver when he is considered as a living organism. The presence of various disabilities from the normal or the presence of various drugs can further influence his response capability.

Present knowledge leaves us far short of a proper understanding of the highway safety problem and, in particular, of the dynamics of the driver in the highway system. The objective of the research to be carried out by the Human Factors Group at HSRI is to provide an integrated background of information concerning the role of the human which can be utilized to reduce traffic accidents.

GENERAL RESEARCH ORIENTATION

A broad spectrum of research techniques and levels of effort will be required. The kind of research activities to be undertaken will range from quite basic studies to those having direct application to the highway system. It is our intent to have the capability, in terms of personnel, to originate and lead research projects and, in line with the concept of a multi-disciplinary approach to the study of the highway problem, we shall anticipate working in close cooperation with members of other groups within the Institute or elsewhere, such as with members of the faculty of The University of Michigan. At the same time it is considered probable that novel research methodologies will be developed in order to make a proper attack upon the kinds of problems with which we will be involved. This means that considerable ingenuity and imagination will be demanded in view of the novelty of research in the man-machine-highway system.

While responsibility for projects emanating from the Human Factors Group will rest with one of its staff members, we also provide funds to support research carried out by other groups for which they are held responsible. We encourage the participation of students in our studies, and consider their inputs as valuable assets to our work. We look forward to attracting students of merit to work with us with a view to becoming expert researchers in the area of highway safety.

TASK STATEMENTS

The specific nature of the research studies that will be undertaken in the Human Factors Group cannot be predicted in detail in advance. However, general statements of the type of tasks that will be carried out can be made. Undoubtedly, the particular projects that the various staff members of the Human Factors Group find to be in their greatest line of interest, and which are considered to be of primary importance to the overall program, are those that will receive the most attention.

The Task Statements that are set forth below are stipulated in various degrees of detail, but the specific problems to be investigated and the actual techniques to be used will be determined by the investigator responsible for each project. The Task Statements are to be used as guidelines and to indicate the nature of the Human Factors research program.

1. The Role of Sensory Cues in Vehicle Tracking

A quite fundamental area of research in driving is the delineation of the nature of the cues used by drivers in controlling the vehicle. This Task Statement will be concerned only with the driver's control of the vehicle in terms of his ability to track the highway. The interest is to determine the role of the various sensory cues that are important to the driver in achieving this task. A number of methodological approaches are suggested as follows:

(a) Eye Camera. Some devices are now available which provide pictures, taken either by a film or TV camera, which indicate the general scene that the driver is looking at and also show, by means of an eye spot reflected from the cornea, the point of fixation of the eye at any instant in time. This technique lends itself quite well to determining the use made by the central field of view of the eyes for vehicle control. This method should be useful in determining the value of the gross cues utilized by the driver such as, the edges of the road, centerline markers, etc. Outside the present context the technique has value in showing the effect of other vehicles on the highway, highway characteristics and signposting techniques.

(b) Eye Camera Techniques Correlated with Steering Actions. Another method, using basically the same system as in (a), should indicate the scene viewed by the driver and also could have superimposed upon it blips to indicate the occurrence of steering actions. In this way, a description could be obtained of the change in the scene that occurs between the steering responses of the driver. Thus, the gross nature of the cues utilized by the driver to enable him to reach a decision to make his response may be measured.

(c) Eye Camera: Critical Information Method. The Eye Camera would again be used but episcotisters would be placed in front of the eyes to reduce artificially the viewing time. In this way redundant eye movements should be reduced so that critical viewing patterns become evident. Again, steering wheel motions can be superimposed as above in (b). This method may also be useful for predicting the role of advance course information or lead time.

(d) Restriction of Visual Field: Direct Method. The windows and windshield of the vehicle could be blanked off as required to permit specific fields of view to be utilized by the driver. A driving task would be used and an index, such as tracking accuracy, could be measured. The work can be done both on straight roads and on curves and would produce gross estimates of the important aspects of the visual scene needed to perform this type of task.

(e) Restriction of Visual Field: Indirect Method. In this method the side windows, rear windows and the windshield are completely blanked off. A cathode ray tube is placed on the hood of the vehicle and a sensing device is mounted at the front bumper of the car to detect lateral position. This information is then displayed on the cathode ray tube. Different kinds of information can be displayed to the driver in this way--lateral position, lateral velocity, as well as higher derivatives; and it may also be possible to produce advance course information in this fashion. This method provides a precise control of the information presented to the driver and in this regard is superior to the other methods that have been suggested. However, there are complex apparatus problems to be solved before full use of this technique may be made.

(f) Television Display. A TV camera could be used to scan the field of view and the image presented on a monitor on the hood of the vehicle. The remaining windows on the vehicle, as well as the windshield, would be blanked off. The driver would again be asked to track the vehicle using the TV monitor as a display. This technique would again permit various degrees of restriction of the visual field by manipulating the field of view of the television camera or by blocking certain aspects of the scene from the display. It also would be a device by which advance course information can be controlled. Another advantage of this method is, for example, that the car reference can be eliminated.

(g) Regressional Analysis of Vehicle Motions. This method is based upon the concept that the motions of the vehicle, in the horizontal plane can be measured and, at the same time, values can be obtained of the responses made by the driver. At the instant that the driver responds to the vehicle in order to effect a lateral control response the vehicle motion responses would be measured. In fact some allowance would be made for the time lag in effecting the steering response. The vehicle responses to be measured may consist of the slip angle, heading angle and its derivatives, yaw velocity and its derivatives, lateral position and its derivatives. Other measures may also be obtained. A regressional analysis would then be run, and a predictive equation obtained in which the different vehicle and visual parameters, on which the driver may base his decision to affect the course change, will be given weights using the usual least squares criterion. The relative importance of the different parameters could, therefore, be obtained. The work could be done on straight roads, on curves, or at the approach to curves. It is considered that this could be a very fruitful approach.

(h) The Role of Sensory Cues Other Than Vision. The first six techniques that have been outlined here will be valuable for assessing the role of visual cues, which undoubtedly are of greatest importance in vehicle tracking. However, the role of kinesthetic and proprioceptive cues and the role of the vestibular system cannot be overlooked. In order to obtain some measure of the importance of these other sensory cues it would be possible to simulate, on a fixed simulation facility, the technique of (e) or (f). Present knowledge permits simulation of the response dynamics of the vehicle and feedback through the steering wheel. The identical task used in (e) or (f), using the same display, should be used with only the cues associated with the motion of the vehicle being absent. Comparison of performance under the actual car driving and the simulation tasks would provide some measure of relative importance of the various sensory cues. This work would be of critical importance for providing important design inputs for the design of a driving simulator.

2. Simulation

Simulation is an important research tool and there have been many discussions of the potential uses of this technique. Up to the present time, however, the research carried out with simulation devices, which attempt to replicate the driving situation to a lesser or greater extent, have been quite disappointing. The reason for this is that a good simulation device has not yet been developed. There are some obvious deficiencies in all current simulators and most of these can be traced to the design of the visual display which is, in all instances, a quite inadequate representation of the real situation. The reason for this inadequacy is that the knowledge required to design a proper display is not yet available. The studies to be carried out in the Task Statement (1) concerned with the role of sensory cues in vehicle tracking should provide the information that is needed. The ability to write analytical models of the vehicle, describing its dynamic response, and the availability of several systems which can produce feel feedbacks through the controls that interface with the driver, suggest that the hardware side of the problem--that concerned with simulating the vehicle--should pose no serious drawbacks. The questions are, therefore, those of providing the important sensory cues. Assuming that the importance of the various sensory cues can be assessed by the work proposed in the Task Statements (1), then it would be proposed to construct a driving simulator of sufficient fidelity to reproduce the real driving task. This is, of course, dependent upon the total needs of such a system and the ensuing cost and associated hardware problems. However, the use of such a device would be of great value in studying the driving task. Simulators of proper capability could be used for the study of vehicle handling, personality factors, drugs, value of driver training, etc. The Human Factors Group will pursue this problem when it appears to be one that is feasible on the basis of the knowledge that is available.

The use of part-task driving simulators appears to have more potential in the immediate future, especially for training purposes. The validity of such devices would have to be determined.

3. Vehicle Handling

Vehicle handling research is considered to be one of the major study areas of the Human Factors Group. Until a whole- or part-task driving simulator can be designed, handling studies will have to be done in the field with the use of real vehicles. The purpose of these studies is to obtain a better understanding of the man-machine relationships concerned with vehicle lateral as well as longitudinal control. Our interest is to establish psychophysical type relationships between engineering design variables and human performance.

At the same time we shall be concerned with variability between those who enter, or are now in, the driving population. In this way design concepts may be recommended of such a nature that the total variance of the system remains sufficiently narrow so as not to infringe upon those extremes where hazardous situations may arise, and where a loss of control of the vehicle may be the result. In these studies we expect to work closely with members of the Physical Factors Group at HSRI.

A major problem area to be attacked in the study of vehicle handling is the planning of sensitive criteria by which the man-machine system can be evaluated. Criteria that have been used to this time are of marginal satisfaction.

As an outgrowth of this work it would be hoped to develop an analytical description of the drivers control task, and to be able to write such a description to fit with the variability that may be experienced in the environment.

4. Displays and Controls

The value of providing the driver with various augmenting cues--to inform him of the state of his vehicle, the separation distance and relative velocity of other vehicles or obstructions on the highway, the state of the road to indicate the presence of a slippery surface, routing information, etc. should be studied. It will be necessary to determine the kind of information that should be displayed to the driver and, consequently, the means by which to display this information.

Research concerned with the design of controls can be of various kinds. For example, a display in the vehicle may indicate that a malfunction exists in the vehicle and the driver may then be required to operate certain controls in order to interrogate the system to determine the exact nature of the malfunction. Other aspects of research concerned with vehicle controls should be that in which analyses and alternatives to the present steering wheel and velocity controls are considered. The evaluation of such controls, in a sense, would constitute further research studies in vehicle handling. Definite advantages may arise not only in improvement in lateral and longitudinal vehicle control but it could be that, because of the nature of the control surface, overall improvements in the interior design of the vehicle may result with better protection against crash injury.

5. Rear Lighting and Signalling

The present rear lighting and signalling system of motor vehicles are undoubtedly not the optimum design. It would seem probable that a twofold improvement in the nature of the rear signalling system could be made.

In the first place, investigation should be concerned with determining the appropriate types of information that should be sent from the rear of the vehicle to the driver of following vehicles. At the present time approximately five indications of the actions being taken by a vehicle are given by the rear signalling system. It is possible that these are not the optimum types of information that should be transmitted.

Secondly, the present design of the rear-lighting system probably does not permit signals to be detected by following drivers with minimum time lag.

The research effort in this area, then, will have to determine the kinds of signals that should be transmitted and the means by which they are displayed. The analysis of rear-signalling displays should consider, at least, two criteria. One of these has to do with the ambiguity between signals presented by a particular system. Thus, a confusion analysis should be carried out to determine the ease of identification of the meaning of each signal transmitted by a hypothetical system. A second criterion has to do with the transmission time of each signal and this may be assessed on the basis of a reaction-time task structured in the form of a driving situation in which the subjects are carrying out a time-shared task. Other techniques may also be evolved.

A subsequent analysis must also consider those lights that are not signal lights such as, the marker lights or taillights on the vehicle. Further work is required into the means by which the visibility of parked vehicles may be increased. At the present time such vehicles are detected by their silhouettes being seen against a light background; or by reflected light from the body and body components, and from the reflectors that are now required on the rear of all vehicles.

Notice must be taken of the visual capacities of the driving population and the abnormalities in vision that are found there. The systems must be designed for ease of interpretation and detection by both color-normal and color-blind drivers. Another major consideration is that of the variability in the environment which may affect the transmission of the lights through the atmosphere and provide a variety of backgrounds which may affect performance of a lighting system.

6. Head Lighting

Research in headlighting will be concerned with the evaluation of headlamp beam patterns in order to determine the required beam distributions for meeting beams used in the various driving conditions. Major attention will be given to the meeting beams because they are used in situations which are critical in terms of visibility. When another vehicle is not approaching, the high beam may be used and there is little problem in providing sufficient light, properly distributed.

The same cannot be said, however, for the meeting beam in which a driver relies upon the illumination of the highway from his headlamps, while his visibility is impaired by the glare resulting from the oncoming vehicle's lights.

It will be necessary to carry out field studies in which various kinds of meeting situations are simulated using headlamps providing various beam distributions, so that an understanding can be obtained of the relationship between glare and illumination during the course of a meeting at night. Some techniques have already been developed by which visibility distances can be obtained and by which beam distributions can be compared and statistically evaluated. These methods have been found to have considerable reliability.

It is the ultimate objective of this research to provide an analytical model of at least the two-car meeting situation. In order to do this, a full understanding of the psychophysical relationships which are involved, will have to be obtained. The value of this work would be considerable in that it would be possible to specify the ideal beam distributions for single-lane and multi-lane highways. If such a model were then combined with analytical techniques for the design for headlamp units themselves, it should be possible to design optimal beam patterns for city and country driving situations.

7. Vision From the Driver's Seat

In an ideal situation, the driver should have 360° of vision about the vehicle. Obviously this is impractical, at least in present vehicle designs in which windshield pillars, door pillars, and rear-light pillars act as obstructions to vision.

Consideration will have to be given to the field of view presented forward of the vehicle in order to satisfy the needs for proper visibility in the forward hemisphere.

Vision to the rear is also a critical problem in present vehicle design. Research on rear vision needs to be done in order to devise a means of expanding the field of view of rear-vision devices and to reduce blind-spot areas. It will be important to insure that sufficient rearward information is presented in order to enable the driver to make accurate estimates of approach speeds of following vehicles so that he may safely carry out various turning maneuvers. This situation may be particularly critical under nighttime conditions when the cues available to the driver are markedly reduced. Consideration should also be given to the use of rearviewing devices that are designed to reduce the light reflected into the driver's eye from the headlamps of following vehicles. Investigations should be carried out in order to determine the effect that these devices have upon the estimation of the closing rate of following vehicles and their separation distance.

The location of rearview mirror devices should also be considered in terms of the forward field of view that may be obscured by them, the purpose being to reduce any important aspect of the forward field that may be covered by such devices. This may mean relocation of rearview mirrors and, indeed, the optimum location of such devices should be explored. Experimental devices to overcome some of the drawbacks of presently used systems should be designed and evaluated.

The use of devices that may augment the rearview mirror by providing synthetic cues of the presence of vehicles within prescribed radial distances and angles from the vehicle, may be examined. Close attention would have to be given to the design of such augmenting cue displays and their effects on other aspects of the driver's perceptual task.

8. Highway Characteristics

The highway is an important element in the man-machine traffic system and human engineering design considerations should enter into its construction. Relatively little work has been done in this area from a human factors point of view. It may be useful to obtain data concerning the characteristics of highways and their accident rates, taking into consideration the various pertinent variables and, on the basis of this information, carry out a factor-analysis in order to designate the human factors characteristics of high-accident highway designs. This may be one possible technique for the identification of accident producing variables. If the Task (1) studies are successful, they will lend some insight concerning the design of highways to improve driver capability in tracking the vehicle upon them. Highway characteristics may also be a factor in affecting driver judgment of velocity and safe spacing requirements, as well as of absolute visibility. The latter situation could be particularly pertinent in the night driving case where the surface characteristic of the highway and its inherent reflectance values can have a bearing upon visibility.

Knowledge of driver handling capability of various classes of vehicles under various driving conditions and velocities may provide information concerning the value of the maximum radii to be permitted for highway curves, and of the influence of camber and other road variables.

Various techniques should be examined to aid the driver in maintaining safe velocity and guidance of the vehicle. The purpose of such devices would be to present augmenting stimuli to the driver to enable him to predict further in advance, if necessary, the path to be followed. Such cues, it may be found, could be of particular value, under poor visibility conditions and in those situations where the highway may be partially obscured by snow. It may also be found desirable that some indication of variations in the coefficient of friction between the tires and the road may be indicated to the driver. The means for displaying these types of information, as considered useful, should be investigated.

Driver behavior in entering and exiting from limited access highways should be further studied with a view to providing the necessary information to the driver to enable him to carry out these acts in safety and without impeding the traffic flow.

In city conditions, the behavior of pedestrians should be further studied and means should be found for reducing the high accident frequency in which pedestrians are involved with motor vehicles. Proper means should be found for the control of pedestrian traffic and techniques should be investigated to provide pedestrians with adequate cues of the approach of vehicles, and they should be provided with guiding signals to indicate safety of passage. Studies should be undertaken to indicate the value of these types of devices and consideration should be given to their human engineering design. In view of the high accident frequency occurring at street intersections, further studies should be carried out to observe driver behavior in these instances.

9. Information from the Highway

Apart from defining the path that the vehicle is to follow the highway can be a source of useful information to the driver. At the present time the information is presented on signposts of some type or another. Some signs provide knowledge to the driver concerning the direction in which he is traveling and indicate the turnoffs that he should make at various stages along the route in order to reach his destination. Other signs indicate to the driver certain types of commands such as stop signals or yield signals, and another class of signs may indicate the presence of various hazards on the highway. Other kinds of information are sometimes displayed on signs that have the capability of presenting various kinds of information at different times. These have taken the form of television displays informing the driver of occurrences further up the road or of road conditions.

Present indications are that the art of signposting is not as far advanced as it may be. Information needs to be gathered concerning the placement of signs both so that they are adequately visible as the driver approaches them and with respect to the point of decision, such as the point where he makes his turnoff from the highway. Other studies should be concerned with traffic signals, which are another class of sign providing information of a command nature to the driver. Work in this context may be concerned also with the design of traffic signalling or control systems to achieve maximization of traffic flow.

In general, there has been a considerable amount of work carried out concerned with the actual design of signposting displays and numerous studies have shown the specifications for lettering and backgrounds for good visibility of signs. It seems possible, however, that the ideal symbology to be used in signposting has not yet been developed. This area requires further research.

A different concept, having the same general aim of providing the driver with information from the roadway, has received some attention--particularly by the automobile companies. In this instance information is presented to the driver by a sensor within the vehicle which is responsive to roadside transmitters. This type of installation would require sending units placed at certain points along the roadway which would have certain advantages over fixed sign facilities, since the information they could broadcast could be entirely versatile and, hence, they could be responsive to changing conditions. The best means of displaying the information to a driver without distracting his attention from his primary task would require study as would the kinds of messages that it may be felt to be useful to present to the driver. Furthermore, such a flexible system may be one that would permit the driver to ask questions concerning his environment of the system. Basically, therefore, there are two sources of human factors research concerned with information from the roadway. These can be considered to be the fixed type information producing facilities and the variable or adaptive systems. The basic human factors research questions that have to be asked of both these systems are concerned with the type of information that should be presented and the best means for displaying it.

10. Drugs

There have been a number of studies that have shown a relationship between the frequency of accidents and the alcohol content of drivers. There have also been other studies to indicate that quite low levels of alcohol do impair a number of perceptual motor skills. Some of these studies have been concerned with the evaluation of environmental effects such as day and nighttime visibility conditions and the effects of headlamp glare, and some studies have been carried out using real vehicles in some simulation of the driving task. Numerous studies have also used laboratory tasks primarily of a tracking nature. Alcohol has also been found to affect human reaction time and some visual abilities. It can be safely stated that for most individuals fairly low alcohol levels, of the order of .05%, will have a detrimental effect upon an individual's ability to drive. Evidently some of the deterioration in performance is due to reduction in manual dexterity, in ability to sense vital information, and probably in the driver's ability to make rational judgments. In the latter context, however, relatively little work has been done to determine the effects of alcohol upon human decision making processes, and this would appear to be an interesting area for further studies. However, the debilitating effects of alcohol upon safe driving have been established beyond any doubt, and further work to establish this effect is not needed. More to the point, therefore, may be studies concerned with alleviating this problem and attempting to identify the drinking-drivers responsible for accidents. To this end it would be desirable to construct some prognostic device which may be administered as part of the licensing procedure. If a high accident-potential group of drinking drivers could be successfully identified, it would then be necessary to provide for remedial services. The nature of the remedy for such a problem is not presently understood and research would have to be done to evaluate different treatment methodologies.

While alcohol has been identified as a major drug related to the traffic accident problem evidence is accumulating to indicate that other drugs may also play an increasingly important role. It would, therefore, be pertinent to carry out studies concerned with psychomotor, decision-making and risk-taking effects of drugs that are categorized as depressants, halucinogens, antidepressants, antihistamines, amphetamines, etc. Some work should be carried out to determine the amount of impairment caused by the presence of these drugs not only taken singly but in combinations. It has been suggested that the interaction between drugs may lead to serious impairments in drivers. For example, it has been found that accidents have been caused by a combination of alcohol and barbiturates taken in doses that, when considered individually, would probably have had negligible effects. Little is known at the present time of the effects upon human performance of a number of drugs present at the same time in an individual's bloodstream.

Another avenue of investigation may be concerned with the identification and measurement of the performance of the chronically sick individual. The work of Waller has suggested that those suffering from cardiovascular disease tended to show a distinct increase in frequency of accidents in a period two years prior to the time of their stroke. Similarly, another group worthy of investigation are of course the alcoholics that have been tangentially referred to earlier. When more information is documented concerning the effect of drugs and diseases upon human performance relevant to the driving task, it may then become necessary to determine means of detecting these individuals before they become an accident statistic.

11. Fatigue

The role of operator fatigue in highway accidents is not understood at this time. There are a number of problems that hinder investigation in this area. In the first place no satisfactory definition of the term "fatigue" has yet been obtained. The reason for this is that fatigue can have many bases and these are obviously of a physiological and psychological origin. It will, therefore, be important to provide a definition of fatigue in terms that are amenable to investigation. It would be suggested that an operational definition of the term could be employed.

Relatively little work has been done to study the effects of fatigue but some accident statistical type data have been obtained relating hours of driving to accident probability. These data generally are not clear-cut. These statistical studies have sometimes shown that accidents tend to occur most frequently in the early stages of a trip, and some truck data show that approximately the first 4-hour period is the most dangerous, with subsequent hours behind the wheel resulting in fewer accidents. It would not have been expected that the data show this type of trend on the basis of intuition. Some laboratory studies have been carried out to determine the effects of time on various vigilance tasks and these usually have found significant decrements to occur. Some work has also been done in which physiological measurements were taken while a driver carried out his tasks over fairly long time periods, but there is little relation that has been established between physiological indices and some a priori index of fatigue that could be measured. Apparently, little noticeable change in driving efficiency was noted during these experiments. However, this may be due to the fact that rather gross, insensitive measures of driving performance were utilized.

It would be fruitful perhaps to carry out some initial laboratory studies in which sensitive criteria of human performance are utilized concommitantly with measurement of physiological changes. On this basis it may be possible to obtain some correlations between physiological activity and the observed performance on some perceptual-motor tasks. The effect of time on the task could therefore be established. If correlations of this nature could be obtained, then the physiological measures themselves could be used as indicators of "fatigue," and similar measures could then be recorded during the driving situation. This would mean that overt bodily activity measurements could be used to indicate the onset and perhaps the extent of fatigue in the driving task. Fatigue in this situation would then be measured in terms of the psychomotor abilities that were measured in the original laboratory studies. The fatigue would, therefore, be measured operationally in terms of those initial psychological variables. It is possible that if a technique of this type could be developed, and if sensitive indices were obtained, the method could be applied to the evaluation of different driving tasks such as in the day or at night, as well as the effects of driving upon different kinds of highways, such as two-lane highways and multiple lane, restricted access, roads. The effects of vehicular design variables could also be evaluated.

The study of fatigue is undoubtedly linked to studies concerned with the effects of drugs upon driver performance and the interaction of these effects should be studied. Ultimately, it may be possible to provide some design requirements for devices to maintain the alertness of the driver. This is the purpose of a number of devices that are being marketed, but it does not appear that any of the methods that have been used so far are functional.

12. Ride and Vibration

The topic of vehicle ride and the ensuing vibrations that impinge upon the operator can be regarded as a useful one for research by the human factors group. For passenger cars vehicle ride is probably not to be considered as a problem in regard to traffic accidents. Passenger vehicle ride is undoubtedly at a very high level and it is doubtful that any performance decrements can be attributed to its quality at this time. Similarly, general standards of comfort in seating in combination with the suspension system of the vehicle provide for a comfortable ride sensation, and one that should not cause fatigue.

However, the same situation probably does not apply to different classes of vehicles. In particular, consideration should be given to the ride phenomena of trucks and tractor-trailer combinations. In view of the high mileages and long hours spent behind the wheel by the operators of commercial vehicles, attention should be given to providing a comfortable work environment for the commercial vehicle driver. Investigations should be carried out concerning the nature of the inputs to the driver, such as the vertical accelerations and roll and pitch velocities, in order to obtain some insight to the type of vibrations that are experienced by the operators of these vehicles. Studies should then be carried out to determine the effects upon comfort, fatigue and psychomotor performance caused by a representative spectrum of vibratory inputs to determine if they lead to impairment of the driving task. At the same time physiological measurements should also be taken.

This type of work has been carried out in the aircraft context where psychomotor tasks were performed by pilots who were subjected to various durations of vibration. Frequently, sinusoidal inputs have been used; but more recently random inputs, of known spectral power distributions, were employed.

Similar approaches could be used in evaluating decrements that may be associated with truck ride. However, most of the significant studies have utilized integrated error measurements averaged over time to indicate performance on psychomotor tasks. It is possible that this type of measurement may hide some of the significant effects of vibration by not presenting the variance in the subject's output. These studies have frequently found that vibration impairs tracking capability, but that this impairment is not a function of the duration of vibration. Also it has been reported that there seems to be little effect due to intensity of vibration, at least within levels where the RMS "g" values were varied from $\pm.1$ to $\pm.2$. In these studies reaction time was generally not affected by vibration power nor duration, but responses to vigilance tasks were generally exhibiting higher latencies when vibration was being used; but, again, there was no differential effect due to the vibration intensity. It could be that the significant events concerning the subject's response were not being measured by the techniques that have been used and, in fact, were obscured by them. It does not seem impossible that events of critical significance may indeed have occurred during the vibration periods, which lasted for six hours in some studies, and that these events could in and of themselves be highly significant to the completion of a complex task such as flying an aircraft at low altitude or driving a truck at high velocity. It would be suggested that somewhat different measurement techniques be employed that more directly indicate the total span of an individual's performance.

The results of this work may suggest further studies concerned with seat design for commercial vehicles or improvements in suspension systems, and perhaps a changed layout of the control and display systems. As an adjunct to studies in vibration, followup studies

studies should be carried out of drivers of heavy commercial vehicles to determine medical impairment that may have arisen as a result of their profession. There are indications that there is progressive physical degeneration associated with various industrial occupations. It could be that similar investigations would show an effect due to vibration upon the health of the commercial vehicle driver. The nature of such progressive disabilities would be further indications of the type of remedial measures that could be recommended.

13. Driver Training, Improvement, and Education

The methods used for the initial training of drivers require careful investigation. Relatively little work has been done to determine the effectiveness of various techniques employed for driver training. Driver training usually is given to young persons prior to qualification for their first driver's license. Most driver training is carried out in the public schools, by private driver tuition organizations, or by relatives and friends of the individual. A number of states are now requiring that a formal driver training course be taken before a license will be granted. This would seem to offer an opportunity for standardization of the techniques to be used. Basic questions remain concerning the content, the type of equipment to be used and the education of the driver training instructor needed for an effective program.

In this regard it would be invaluable to be able to formulate the hierarchy of skills needed for the driving task. Such a taxonomy could then be used to structure course content to maximize learning. At the same time basic principles of human learning should be employed in the design of driver training courses. Research in driver training should also include development of techniques for the continuous evaluation of students so that their progress in the course may become known. In this way students who may have particular problems in certain aspects of the course could be given more specialized attention in those specific areas. Inherently, this implies that techniques would be available by which the success of driver training courses could be evaluated, and research to determine the validity of these techniques is another prime consideration.

Few studies have been carried out to determine if driver training is beneficial. Frequently, where studies have been attempted, poor experimental design has led to an inability to make proper extrapolations from the data. A basic fault in some of these studies has been that appropriate control groups were not available. In view of the disproportionate number of accidents in which young drivers are at fault, driver training should be a major area for researchers in accident prevention.

Another important area of study, in the present context, is that concerned with driver improvement. Not all states have any formal means by which driver improvement methods may be applied. The role of driver improvement techniques should be to change the attitudes, knowledge and skills of drivers who presently hold licenses. Little data are presently available concerning the success of driver improvement schools in those states that have made some effort to institute these. The results of research studies concerned with techniques of instruction such as those carried out by Malfetti at Columbia and Schlesinger at George Washington University also leave this question unanswered. Driver improvement schools vary greatly in their course content, the education of the instructors, the financing and their sponsorship. Referrals to these schools are made largely from adult courts, juvenile courts, by motor vehicle departments, police departments, and from private concerns. Some volunteers, it has been noted, also attend these schools. The teaching methods employed range from the use of lectures, discussions, films and slides, analysis of action situations and other methods. The instructional aids and devices that are used in the improvement sessions consist of films, blackboards, recordings, various forms of psycho-physical testing equipment, driving simulators, and cars. Ralatively little is known about the value of these techniques. Some studies have been done concerning the use of driver training simulators suggesting that the use of these devices does permit a reduction in the number of hours that are needed behind the wheel of a vehicle. However, there is a great paucity of research in this area and much more needs to be done. The economic costs of driver training and of driver improvement courses are extremely high and in proportion to this amount of research that has been carried out to evaluate the value of various methods has been quite small. Perhaps the leaders in the field of driver improvement are the U. S. Armed Forces. The Air Force, for example, has recently instituted a driver improvement course which all airmen under the age of 25 years must attend. Programmed instruction forms the basis of the course. It should be possible to make evaluations of the effectiveness of this program.

Driver education should be a continuous process and it probably largely consists of the attempt to maintain adequate levels of skill and attitudes toward the driving task. Means should be developed by which the driving public can be continually made aware of their responsibilities while driving and the need to remain at peak efficiency and vigilance. This is a complex task. At least one study has indicated that the periodic safety campaigns which have been aimed at reducing accidents have little effect because they tend to be ignored by those people whom they are attempting to influence.

In view of the importance of feedback for the maintenance of skilled performance and its necessity for learning, it becomes fairly clear why the problem of driver education exists. There are probably few tasks where the operator receives such infrequent feedback as in driving. When feedback is received it is usually in the form of negative reinforcement, such as a ticket for a traffic violation. The use of sparse feedback in the form of negative reinforcers is quite contrary to accepted principles of learning. Techniques for providing frequent positive reinforcement of driving action may be required to maintain improved driver performance.

14. Field Observations of Driver Behavior

Laboratory studies and experiments carried out in the field suffer from the shortcoming that they are, in essence, simulations of some real task. There is, therefore, always some danger in extrapolating the data from the experimental situation to the operational one. Subjects who are being used in an experiment, even when all other considerations appear to be quite realistic such as the driving of a vehicle within a traffic stream, nonetheless are aware of the fact that their performance is being observed and, hence, some question can arise as to whether they are behaving as they would if unobserved. Real problems arise in attempting to validate experimental work to determine how well it does, in fact, describe driver behavior in the real world. In order to overcome these objections as well as to measure driver behavior in the real task setting without the use of subjects who are aware that they are being monitored, it will be necessary to make observations of drivers and pedestrians without their being aware of the fact that measurements are being taken of their behavior. These types of data have been obtained in the past, particularly in connection with traffic flow studies, and all accident statistical data are of this nature. However, it is extremely difficult to make extrapolations of driver behavior from accident statistics. This is supported by the very poor correlations that have been obtained between accidents and various characteristics of drivers, or indeed of other aspects of the highway system. There are of course many advantages to controlled experimentation carried out in the field or the laboratory such as the ability to make accurate measurements of variables that are manipulated at the will of the experimenter. However, it seems possible that observation of driver behavior can be carried out to yield information of great value leading to a basic understanding of numerous aspects of human factors which affect accident production. For example, in order to study the overtaking behavior of drivers, it would be feasible to monitor various sections of highway. By means of television recording equipment the points at which a driver makes a decision to overtake another vehicle--in terms of the available sight distance, the velocity of his vehicle and the vehicle being overtaken, and the distance and velocity of approaching traffic--could be measured. Some experimental studies have been carried out attempting to delineate driver judgment in this situation. The field observations would permit an evaluation of the validity of the experimental studies in overtaking to be made.

This information would be basic to the formulation of data that could be applied to a mathematical model of driver overtaking behavior. These data would also indicate the nature of risk-taking behavior that was observed on the highway, and it may be possible by interviewing the drivers concerned to determine the basis upon which they made a decision to overtake or not overtake as the case may be. Undoubtedly, if enough observations were made, particularly in locations having a history of high accident probability, observations would be obtained of collisions. The recording apparatus would permit a full analysis of the situation leading to the accident to be made.

Also, the criterion chosen for making a decision to overtake or not to overtake may be a fairly sensitive index of driver performance, and it may be possible to find personality, socio-economic, perceptual and psychomotor variables that show a correlation with the performance index. It could be that driver characteristics are found which have predictive validity in terms of a concept involving the acceptance of high-risk situations. Follow-up studies would then determine whether these types of drivers are also those who are involved in accidents or who cause accident-producing situations.

Other kinds of critical incident type behavior may be observed in a similar way. For instance, behavior of traffic at intersections having various kinds of traffic controls, at the entrance and exit ramps of limited access high speed highways, at the approaches to corners and hills on two-lane highways, and the effects of adverse weather and road conditions could be studied.

The effect of alcohol upon driving behavior can be investigated in field studies without the driver knowing that his performance is being measured. In this regard it would also be important to obtain further information upon the drinking habits of drivers such as the amount of alcohol consumed, the place in which the drinking is done, the time of day or night, and the distances that these persons subsequently drive.

The general approach that has been suggested here should lead to analytical models of decision making in certain aspects of the driving task, improve current knowledge of traffic flow theory and increase the scope of present models, provide a sensitive criterion of driver risk-taking performance, and evaluate the correlation of this criterion with various personal attributes of the driver. The method may also lead to a backlog of data that is useful in the design of driver training and education techniques as well as providing guidelines for design of highways and driver aids.

15. Analytical Models of the Driving Task

There have been numerous attempts to provide analytical models of the response characteristics of the aircraft pilot, and similar techniques have been applied to modeling simple control aspects of automobile driving. There are an abundance of theories to describe this activity but relatively little work that has any validity to it. The usual frame of reference that has been taken by investigators in providing analytical models of the driver's lateral control task are those that follow a cybernetic theory, and hence consider the driver in a closed loop man-machine system. This orientation in itself may well be open to question. In any event, at this time, very scant information is available concerning the types of feedback loops that the driver closes, and virtually no information is available concerning which particular loops may be closed at a particular point in time.

Basic information needed to provide even the simplest model of the driving task is lacking at this time. Similarly, the concepts that have been used by which to simulate the driving task so that experimental verification of a model may be obtained have been quite inappropriate. The research in simulation has been discussed in Task-2 and some aspects of modeling of the longitudinal control task have been mentioned in Task-14. Both longitudinal and lateral control are important elements of the driver's task and both require study. However, it is essential to obtain the basic information which must be available before a conceptual model of the driving task can be developed, and thus a great deal of basic information concerning the types of sensory inputs that are utilized by drivers needs to be obtained. When such information becomes known, then it may be appropriate to build analytical models describing the driver's stimulus-response relationships. Knowledge of decision making used by drivers in various situations, the effects of environmental variables as well as those of the surrounding traffic situations, and the personal attributes and physiological state of the driver should ultimately enter into any sophisticated model in order to provide some predictive value to the analysis. This is obviously an extremely complex task but one which should be one of the long term aims of the human factors group.

16. Human Engineering of the Vehicle

Human engineering design considerations of the vehicle are concerned with the layout and design of displays such as instrumentation and warning lights and the design of controls such as knobs for actuating various car accessories, levers, steering wheels, and pedals. Display design should bear in mind visual characteristics of the driving population as well as the seated position of the range of drivers to provide adequate visibility under all lighting conditions. Design of hand and foot controls should permit positive actuation and identification of the control within the reach capabilities of drivers. Thus, controls and displays must be laid out properly within the driver's work space which in turn is designed on the basis of anthropometric data. Anthropometric data referenced to the driving population recently became available. There is a need to obtain data for the driver population describing force capability in the operation of hand and foot controls.

The most important component in the driver's work space concerns the dimensions and adjustments available for the seat. Sufficient room must be provided to allow the driver to adequately manipulate his controls and to provide proper visibility through windshields, side and rear windows of the vehicle.

Another aspect of human engineering criteria for the interior design of the vehicle concerns the design of the control surfaces to reduce their potential for crash injury production. The exterior design of the vehicle should also be such that no sharp edges are present in order to minimize injury to pedestrians.

The human engineering investigations will also be concerned with the maintenance and service tasks required to keep the vehicle in proper operating condition.

It may be considered fruitful to carry out overall human engineering evaluations of a representative segment of the products of various manufacturers in each model year. The results of such measurements would indicate the design changes that may be recommended to result in improved driver performance and protection and for better vehicle maintenance. The results of this work may also point out new areas of research needed to supply gaps in current knowledge.

17. Development of Tests and Attitude Scales

There will be numerous requirements to develop tests and attitude measuring devices by various groups within HSRI including the Human Factors group. The training of some of the members of the Human Factors group is such that they are a natural resource for the development of these types of devices and, therefore, they could provide a service to other groups as needed. Within the programs that have been outlined a number of requirements have already been mentioned. Examples of other needs may be those that reflect changes in the licensing procedures of drivers for which new tests of known validity may be developed.

With respect to the improvement of the maintenance of vehicles it may be practical to develop tests for the selection of those with an aptitude for such tasks.

An important aspect of human engineering design is that the design is acceptable to those who must use it and in this regard attitude scales are needed to measure the acceptance of human engineering design proposals. For example, although new cars are now equipped with seat belts relatively few drivers and passengers make use of them. Seat belts have been shown to be capable of reducing injuries and fatalities by a significant margin. However, while the engineering design of the seat belt may be appropriate, it is of little use unless the individual decides to use it. More consideration should, therefore, have been given to the design of seat belts so as to encourage their use by vehicle occupants. Measurement of attitudes towards seat belts may have provided some important information concerning their design. Thus an underlying concept in the design of such a system is that it be designed for use. Depending upon the results of an attitude survey, an occupant restraint system may have to be designed in such a way that the occupant is considered as a passive agent and is automatically made a part of the system when he enters the vehicle. On the other hand survey results may indicate that the use of certain human engineering design criteria may sufficiently encourage the use of the restraint system, so that the occupant may be considered as an active agent who acts voluntarily to make use of the system. Basic design decisions should therefore be made in terms of the attitudes and motivations of the user, as well as from an economic and engineering point of view.