DRIVER INFORMATION NEEDS

T. M. Allen, Michigan State University;
H. Lunenfeld, AIL, Division of Cutler-Hammer, Inc.; and
G. J. Alexander, U.S. Department of Transportation, Federal Highway Administration

The driving task was analyzed to determine the nature and interrelationship of the subtasks the driver performs and the information needed to perform them safely and efficiently. Data were developed using a modified information-decision-action task analysis method applied to several long driving trips. The task analysis provided the basis for categorizing the various component driving subtasks, identifying information needs associated with the subtasks and their present methods of satisfaction, and providing a structure to the driving task. Driving subtasks were categorized in accordance with information-decision-action complexity and ordered along a continuum. The subtasks were found to fall along a hierarchical scale. Vehicle control subtasks such as steering and speed control were ordered at the lowest level and identified as micro-performance (control). At an intermediate level, subtasks associated with response to road and traffic situations were identified as situational performance (guidance). The highest level subtasks, encompassing trip planning and preparation and route finding, were identified as macro-performance (navigation). Performance of subtasks at the high level of the hierarchy involves component performance at a lower level. Drivers search the environment for information needed to perform the various subtasks and shift attention from one information source to another by a process of load-shedding. When load-shedding is required due to the demands of the driving situation encountered, information associated with subtasks relative to the subjective needs of the driver is attended to, and other information sources are shed.

•THE importance of providing the driver with information needed to perform the driving task has been pointed out by Cumming (1), who states, "The road complex must provide for the operator a comprehensive display of information both in the formal sense of signs, signals, guidelines and edgeposts, and in the informal sense of clear visibility in all relevant directions." Design and placement of these formal displays must be compatible with the prevailing vehicle speeds, traffic pattern, and visual and response characteristics of the human operator. Moreover, they must be as free as possible of irrelevant, distracting material and should be able to function in spite of competing demands for attention.

The project statement of NCHRP Project 3-12 (2), which led to the research reported here, stated, "...with the ever-increasing demands of the driving task, there is urgent need for improvement in the understanding of the driver's needs for information and the means of communicating it to him."

NCHRP Project 3-12 was performed by AIL, a Division of Cutler-Hammer, and was designed to elicit answers to the following questions:

1. What information is needed by the highway users for their safe, convenient, efficient, and comfortable performance of the driving task?

Sponsored by Committee on Motorist Information Systems and presented at the 50th Annual Meeting.

2. What are the principal factors and interactions underlying the reception and use of this information?
3. To what extent can visual communication be used successfully?

The final report on this project was submitted to NCHRP (3).

The present paper reports one aspect of this research—the determination of the information needed by drivers and the principal factors and interactions underlying the reception and use of needed information.

THE DRIVING TASK

The purpose of information is to reduce uncertainty. As long as uncertainty exists, alternate possible decisions cannot be fully evaluated. In order to make rational decisions, the driver must reduce his uncertainty. The need to reduce uncertainty is generated from an information need that requires information for its satisfaction.

AIL thus started its investigation of the drivers' information needs by determining what the driver does. This analysis of the driving task gave an indication of the decisions that have to be made by the driver and, therefore, of the information required to make the decision.

An analytical method was required to determine the information needed by drivers and to provide a framework for conceptualizing the form and timing of information presentation so that it can be used most effectively. The "man-machine systems task analysis," used extensively in the analysis and design of military subsystems, was applied to this problem.

Driving Task Analysis Procedure

Task-analysis methods have had only limited application in driver-related research. A method similar to task analysis is the use of an "events recorder" by Greenshields (4), which has subsequently been used by Platt (5) and others for such uses as evaluating the effects of fatigue on driving performance. Other researchers such as Algea (6) and Biggs (7) have analyzed portions of the driving task, with particular attention to information inputs. Until recently, the only reported attempt to analyze the driving task as a whole has been that of Miller (8). However, the purpose of Miller's paper was to illustrate the technique of task analysis, using driving as an example. As such, it had neither the breadth nor attention to information inputs to satisfy the needs of this study.

Task analysis has been defined by Seale (9) as "... that portion of the total system analysis effort which defines systematically and in as much detail as possible at any given time, the stimulus inputs to the operator, the response output of the operator, and the operational environment in which he works."

On the basis of pilot runs using several task analysis procedures, the format that best served the objectives of this study was a modification of a task analysis method developed by one of the authors (10) in a military information needs and control actions study. This task analysis collected data (a) for each situation encountered in transit; (b) for each piece of information displayed; (c) on driver observations and expectancies relative to information needed; (d) reflecting road and traffic conditions; (e) on driver perception; (f) on driver cognition (evaluations, predictions, and decisions); (g) showing driver control responses; and (h) on feedback information.

This format was used to analyze verbal observations obtained from one long trip (from New York to Michigan) and several short trips on urban freeways. The data collected resulted in about 1,000 feet of tape-recorded task analysis data. Data from the tapes were analyzed and categorized into the subtasks representative of the behavior described on the tape and transposed into the form shown in Table 1. Further analysis of the data yielded the description of the driving task discussed in the following and information needs associated with the various driving subtasks.

Description of Driving Task

The driver performs a number of interrelated subtasks, some of them simultaneously. In developing an overall concept of the driving task, an analysis was

TABLE 1

VEHICLE CONTROL TASK ANALYSIS

Item		Speed (mph)	Road Conditions and Traffic Dynamics	Driver Dynamics			Vehicle Response	Feedback[b]	Distractions	Remarks	
No.	Elapsed Mileage			Perception	Cognition[a]	Response				Suggested Information Aids	Comments
1	—	—	—	—	—	—	—	—	—	—	—
1A	000.0	00	Parking lot	Rented car	EV—New car PR—All equipment operative DE—Since car rented must familiarize self with equipment	Enter car Adjust seat Adjust seat belt Adjust mirror Determine location of equipment	None	V/T	—	Gages and displays in car to show all systems operative	Predriving task
				All equipment adjusted	EV—All equipment adjusted PR—Will perform satisfactorily DE—Start car	Place key in ignition Turn key	Car starts	V/T/A	—	See above	First driver task under all situations Time: Morning Weather: Clear Driver: Alert
1B	000.0	20	Road: Single access lane feeding into "main" road Traffic: Access lane clear of traffic	Clear access lane leading into desired road	EV—Access lane clear PR—Will lead to desired road DE—Turn onto access lane	Put car into gear Turn wheel to desired direction Depress gas pedal lightly	Car moves onto access lane at 20 mph	V/T/K	Pedestrians	Directional information showing where access leads to	
	000.3	10	Road: Juncture of access lane and "main" road Traffic: Access lane clear of traffic	Yield sign	EV—Other cars have right-of-way PR—Will encounter traffic of "main" road but merge is such that entrance onto main road can be accomplished without full stop	Take foot off gas pedal and let car coast to merge point	Car slows	V/T/K	—	Description of traffic conditions ahead Directional information showing where "main" road leads Number and name of main road	Anticipatory task requiring vigilance on driver's part Could be danger point under poor ambient conditions

[a]EV = evaluation, PR = prediction, DE = decision.

[b]V = visual, T = tactile, A = auditory, K = kinesthetic.

performed of interrelationships among the subtasks. It was determined that these subtasks could be ordered into a hierarchy that describes the organizational content of the driving task. The hierarchy itself is ordered according to time scale and level of cognitive activity. The subtasks differ in the time scale relevant to their performance from fractions of a second for steering to minutes or hours for trip route finding. They also differ in the level of cognition (mental) required by the driver. The cognitive activity required for steering is nonverbal, highly overlearned by experience, and might be performed by an animal capable of operating the controls. The task of route finding, on the other hand, requires thinking in terms of abstract symbols, language, and maps.

Steering and speed control, which are continuous throughout the driving task, are involved in the performance of all higher level subtasks responding to road and traffic situations.

Figure 1 is a schematic representation of the hierarchical description of the driving task and ties together the concepts of levels of performance and primacy (horizontal axes) that will be discussed next. Figure 1 also indicates how classes of information needs (vertical axes) interact.

Levels of Performance—The vehicle-control subtasks low in the hierarchy are those observed in looking at the fine details of driving. They are referred to as microperformance, or control. Macro-performance, or navigation, refers to the large behavioral subtasks at the high end of the hierarchy. The remaining subtasks in between consist mainly of responding to roadway and traffic situations and are referred to as situational performance or guidance. Thus, this characterization in terms of behavioral subtask levels is referred to as levels of performance.

A partial listing of subtasks, in order from low to high on the hierarchy, includes steering, speed control, responses to road situations, carrying out maneuvers, bringing about a change of route, route finding, and trip planning. Analysis of the hierarchical ordering reveals that performance of a subtask at any level in the hierarchical scale affects each subtask lower in the hierarchy. For example, steering and speed control are involved in the performance of all tasks higher in the hierarchy, whereas executing a trip plan involves all subtasks lower in the hierarchy.

Attention—An important characteristic of the driving task description is that it describes which subtask the driver will and/or should attend to as a function of the demands of the situation. When performance demands are minimal for subtasks low on

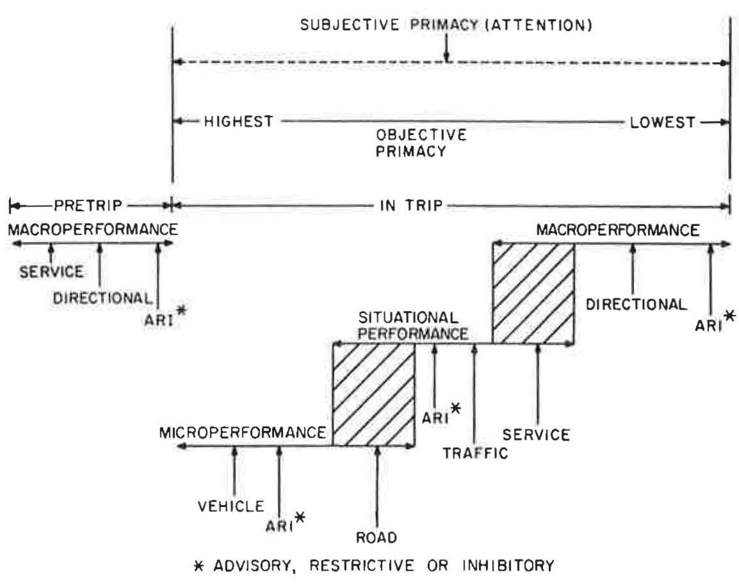

Figure 1. Description of driving task.

the hierarchy, these are performed with little conscious attention. In these cases, the driver's attention may be directed toward subtasks higher in the hierarchy. However, when high-performance demands occur for a subtask at any level, the driver should not attend to subtasks higher in the hierarchy but still must attend to those lower in the hierarchy. For example, on a straight road in free-flowing traffic, a driver can attend to route finding. However, an event on the road such as a vehicle cutting him off causes his attention to shift from route finding. He cannot, however, ignore the control subtasks lower on the hierarchy—each of these must be performed in response to the traffic situation. Thus, the hierarchy describes the "load-shedding" behavior of the driver—when the driver becomes overloaded by a subtask at one level of performance, he sheds all tasks higher but not those lower.

Primacy—The description permits establishing a priority or primacy of subtasks and their associated information needs; information needs lower in the hierarchy have priority over needs higher in the hierarchy. This priority follows from the "load-shedding" of subtasks described above. For example, if a hazardous traffic situation demands the driver's attention, he may fail to receive the message of guide signs. If the driver has inadequate information to perform a necessary control or guidance subtask that requires his attention, information relevant to subtasks higher in the hierarchy should not be presented to him at this time. Lower priority information, if presented vividly, could distract him from obtaining the higher priority information he needs.

Expectancy—An important factor in describing the driving task is expectancy. The driver has an expectation of the vehicle response to his steering movements, learned by experience. Similarly, he has expectations concerning the curvature of the roadway, behavior of other vehicles, and the signs he will find to direct him on his route. The expectancies, which apply to very short distances ahead at the low end of the hierarchy and long distances ahead for subtasks on the higher end of the hierarchy, play an important part in the integration of the driving task. When such expectancies are not fulfilled for one of the subtasks, performance of that subtask, and perhaps subtasks lower in the hierarchy, may be seriously disrupted and result in hazardous driving.

DRIVER INFORMATION NEEDS

After developing a structure for the driving task and its constituent subtasks, the information needs associated with these subtasks were organized in accordance with the hierarchical conceptualization. Although it was not possible to provide an inventory of driver information needs that took into account all possible trips and situations, it was possible to derive a list of information needs representative of the types of needs associated with typical subtasks. These needs, discussed in the context of the relevant major levels of performance categories of subtasks, are discussed next.

Control (Micro-Performance) Information Needs

There are essentially two major control subtasks at the micro level—steering control and speed control, with elements of each involved in all major subtasks in driving at the micro and situational level.

Steering Control—The major information needs associated with steering control involve vehicle response characteristics and vehicle location information and all changes thereof.

The following is a simplified discussion of the steering control subtask indicating how the information required for the task is used by the driver.

In the simplified case of a flat, straight road, the driver only requires lateral position information with respect to the road to apply minute steering corrections and thus maintain a "steady state" (11). The time frame for such vehicle control activities is on the order of ½ second. For the horizontal curve, larger control actions are required to maintain lateral position commensurate with the geometrics of the curve, and several seconds may be required to track the curve.

The steering subtask requires the driver to maintain spatial orientation with respect to the roadway immediately ahead of him. Because this task is lowest on the hierarchy, this information is of highest priority. Thus, one of the most basic information needs is location and relative lateral movement with respect to the roadway. Gordon (12) and Michaels and Cozan (13) indicate that perception of road edges and lane divisions satisfies these needs. Feedback of the vehicle's response to steering wheel movements is also necessary.

The driver-vehicle-road system has been viewed as analogous to a closed-loop servo-mechanical system by Algea (6), Rashevsky (11), and Biggs (7). The driver receives visual feedback of changes in position and orientation with respect to the road. He also receives "seat of the pants" feedback (kinesthetic and tactual), associated with centrifugal acceleration of the vehicle and lateral slope of the highway. If centrifugal force is sufficiently high to be near the frictional resistance of the tires, tire noise may inform the driver of an impending skid.

Information on changes in vehicle response is important when high demands are placed on the steering task. The driver learns by experience the responses of the vehicle to his steering wheel movements (the handling characteristics of the vehicle) and integrates these with his perception of position, lateral motion, and orientation. The steering required in most driving situations is heavily overlearned and can be carried out without conscious attention. However, emergency situations might require steering performance beyond the limits of the driver's experience. Speed (velocity) and changes in speed (acceleration and deceleration) are the main information needs obtained by visual perception of the environment, aided by the speedometer. Tactile and kinesthetic perception of accelerator and brake pedal and vehicle response is also an information reception channel.

Speed Control—To maintain a steady speed on a flat road, the driver's task is comparable to steering on a straight road, requiring only minor control actions. Changes in vertical alignment require larger changes in accelerator and/or brake use (14). Barch (15) found that drivers could make accurate speed judgments without a speedometer. Consistent overestimates or underestimates were associated with the speed to which the driver was adapted. Barch failed to find the "velocitation" (underestimates of low speeds associated with long periods of driving at high speeds) which is commonly believed to exist. Denton (16) attempted to establish a subjective scale of speed. He found consistent errors in speed judgment associated with adaptation, environment, day versus night, and physical state of the driver.

Speed control has also been characterized by a servo-mechanical model, with the data of Todosiev et al. (17) generally congruent with such a model.

Speed control affects steering, even in simple cases, as shown by Wohl (18). The speed of the vehicle on a given horizontal curve affects steering greatly, and braking to the point of skidding makes steering control almost impossible. Vehicle control requires integration of the two tasks and anticipation of imminent vehicle control needs. In addition to maintaining the desired speed, the driver must observe changing conditions and respond so that he will arrive at every point in the traffic situation at a speed at which he can control his vehicle safely on the desired path.

Speed control requires attention further down the road than does steering. In addition to visibility of the roadway sufficient to bring the vehicle there at a "safe" speed, any conditions of the roadway not consistent with driver expectancy represent special information needs. Warning signs to some extent currently provide for these needs.

Guidance (Situational Performance) Information Needs

Whereas the control subtasks are very limited, the guidance subtasks at the situational level are as varied as the number and types of road and traffic situations encountered. Therefore, only a few examples of situational performance subtasks are presented. However, as a general rule it can be stated that the information needs at this level involve information relative to all aspects of the highway system, such as other cars, road geometrics, obstacles, and weather conditions.

Vehicle guidance may be characterized as the object of maintaining the most efficient and safe course, relative to static and dynamic factors in the environment that are generally beyond the driver's control. Performance at this level is a function of the driver's perception of a situation and his ability to respond in an appropriate manner. Therefore, the driver must have a store of a priori knowledge on which to base his control actions as well as an understanding of what the situation demands. Some examples of situational performance subtasks are as follows:

1. Car following—In car following, the driver is constantly modifying his car's speed to maintain a safe gap between his car and the vehicle he is following. Thus, in this situation he is time-sharing tracking with speed control activity. He has to know, as a minimum, lead car speed, changes in its speed, how fast he is traveling, and the relative distance between his vehicle and the lead vehicle.
2. Overtaking and passing—A second guidance subtask that commonly occurs is passing, which involves, in addition to speed control, modifications in the basic tracking activity. In passing, the driver is required to know control information, such as how fast the lead car is traveling and the acceptable gap. He must, in terms of control actions, know how to maneuver his vehicle so as to use the adjacent lane gap most safely.
3. Other situational subtasks—Among the guidance subtasks that may occur are avoidance of pedestrians, response to traffic signals, advisory signs, and other formal information carriers such as stop signals at railroad crossings.

In all cases, the important point, in terms of information needs, is that the driver must receive information so that (a) he is aware of the occurrence of a situation, and (b) he knows what the situation is. Furthermore, he must possess the skills and a priori knowledge that will enable him to make the appropriate steering and speed control responses. He should also have information (feedback) that will indicate the adequacy of his response.

The driver is constantly time-sharing subtasks at this and lower levels. Two or more guidance subtasks may occur simultaneously or in close time proximity. Moreover, control actions may not be compatible, again pointing to the importance of experience, skill, and a priori knowledge throughout the driving task.

At the situational level, the driver must scan the environment and obtain information from many sources (19) to maintain an appreciation of a dynamic situation. He must also rely on judgment, prediction, and estimation, as well as feedback, to maintain what Schlesinger and Safren (20) characterize as an "area of safe travel" relative to his car and the elements of the highway system. Although elements of cognitive behavior at the guidance level are similar to those at the control level (6), a higher level of decision-making is required for most guidance tasks.

Information needed by the driver at the guidance level is that which enables him to maintain a complete appreciation of all events that could possibly affect his safe travel. Thus, he needs information on the relationship of his vehicle to the road, other vehicles, and the environment.

Studies on situational information requirements have included research on the ability of drivers to detect the speed and gap of other cars. Olson et al. (21) found that drivers were accurate in determining whether the distance between their car and a lead car was increasing or decreasing but that they tended to underestimate the relative speed differential between their car and the one in front of it. Braunstein and Laughery (22) found that drivers responded to the occurrence of acceleration and deceleration rather than the magnitude.

Several studies [Hoppe and Lauer (23) and Stalder and Lauer (24)] concerned the perception of motion between vehicles under reduced and night visibility conditions. These showed that better visibility makes it easier to perceive whether a car is coming toward you or going away from you and also that the greater the speed the more difficult it is to perceive speed, all other things being equal.

Several studies were directed toward gap and following distance. Wright and Sleight (25) discussed the "rule of ten," calling for one car length spacing for each 10 mph of speed, and characterized it as being unrealistic. A study by Lerner et al. (26) attempted to determine how following distance on the highway was affected by day versus night, trip duration, traffic, and speed. They found that the only factor of the four tested that affected following distance was speed, with greater following distances found at higher speeds. Several investigators attempted to provide displays to give supplemental gap information. Bierley (27) tested two types of vehicle spacing visual displays. One provided the actual distance between the driver and a lead car, and the other provided the algebraic sum of the gap and the relative vehicle speed. He found that the latter display increased spacing stability. Fenton (28) proposed a tactile display for gap information that used the same principle that Bierley's algebraic summing display used. Both of these displays offer significant improvement over the present unaided means of determining gaps.

Another group of studies was directed toward the ability of drivers to make judgments in passing situations. Bjorkman (29) reported, in an experiment design to determine how accurately a driver is able to estimate where he will meet an oncoming car, that subjects made errors toward the midpoint between the two cars rather than the actual meeting point.

In a study by Crawford (30) designed to determine how well a driver can decide whether to pass a lead car, he found that in over 8 percent of the cases the drivers were wrong. Jones and Heimstra (31) performed a study to determine how accurately drivers could estimate the "clearance time" required to pass another car (by "clearance time" they were referring to the last possible moment that drivers could make a passing maneuver). They concluded that drivers could not make this judgment accurately.

A study by Brown (32) indicated that a car radio seemed to have a beneficial rather than a detrimental effect on driving in both "light" and "heavy" traffic. A study by Hulbert (33) attempted to determine whether driver galvanic skin response (GSR) could be used to record traffic events; his results indicated that they could not be used. A similar finding was made by Taylor (34), who attempted to correlate drivers' GSR's and accident rate, with negative results.

Finally several studies on intervehicle communication were performed. Gibbs et al. (35) compared the European illuminated mobile arm turn indicator with the U.S. flashing lights, with results showing the U.S. system to be superior. Shor (36) studied nonverbal expectations as a means of intervehicular communications and concluded that confusion in driving in traffic results from misinterpretation of other drivers' intentions due to different driving patterns in different locations.

It is seen that considerable study of the perceptual and cognitive factors associated with the various situational subtasks and their integration is required. Similarly, the information needs associated with these subtasks must also be more precisely determined.

Navigation (Macro-performance) Information Needs

To fully describe the driving task, the third level of driving performance—the navigational level—must be considered. This level takes into account the way in which the driver plans a trip and executes his trip plan in transit. Thus, the macro-performance level consists of two phases: trip preparation and planning, which is usually a pretrip activity, and direction finding, which occurs while in transit.

Trip Preparation and Planning—Drivers use various means to formulate trip plans depending on experience, pretrip sources, and nature of trip. The means can be as formal as having the trip planned by a touring service or as simple as using a familiar route. It may consist of a driver reading existing maps and formulating the trip on his own receiving verbal instructions, or having a conceptualization, however vague, of where his destination is in relation to known routes and past experience, with the driver hoping for directional signs that will lead him to his destination. However minimal the preparation, it is unlikely that a driver will attempt to get to some destination completely unprepared.

The results of a direction-finding analysis have shown the importance of good trip preparation. The better prepared the driver is, the easier will be his direction-finding task, regardless of how poor the in-trip directional information is.

Direction Finding—During the direction-finding phase, the driver on the road must find his destination in the highway system in accordance with his trip plan and the directional information received in transit. He must thus share navigational subtasks with subtasks at the other driving levels. The navigational subtasks are further complicated because the information needed at this level, although essentially directional, may include consideration of such things as availability of services, availability of alternate routes, etc. Needs of the driver and/or his passengers that may arise in transit also affect the driver's information needs at this level.

Conversely, micro-performance and situational performance factors can also affect the macro-performance level. For example, a vehicle malfunction can lead to the

TABLE 2

DIRECTIONAL MACRO-PERFORMANCE INFORMATION NEEDS

Item	Information Need	Definition	Present Means of Reception and Transmission
1	Directions to intermediate destination[a] (type need)	Information telling driver how to find his way to an intermediate destination (stopover, rest area, city along the way, interchange, etc.)	Visual—perception of signs (LONG ISLAND EXPRESSWAY NEXT EXIT) A priori—pretrip mapping, oral instructions In trip—determined by asking someone in transit
2	Directions to final destination (type need)	Information telling driver how to find his way to final destination (end of trip)	Visual—perception of signs (NEW YORK CITY STRAIGHT AHEAD) A priori—determined by maps, oral instructions, etc. In transit—determined by asking someone in transit
3	Distance to intermediate destination	Indication to driver of how far (in road miles) he must travel to arrive at his intermediate destination	Visual—perception of signing (NEW YORK 90 MILES) A priori—knowledge of distance from map
4	Alternate route; overall (type need)	Indication of different routes available to arrive at destination	Visual—perception of signs (NEW YORK VIA PARKWAY OR EXPRESSWAY) A priori—determined by prior mapping In transit—determined by asking someone in transit
5	Alternate route; segment (type need)	Indication of alternate routes available in the event of tie-up	Visual—perception of signs (ALTERNATE ROUTE TO BROOKLYN NEXT EXIT) A priori—prior knowledge of alternate route Auditory—commercial radio
6	Designation; road name/number (specific need)	Indication of road name and/or number	Visual—perception of signs (US 1) A priori—pretrip determination
7	Designation; interchange (specific need)	Indication of interchange name and/or number	Visual—perception of signs (EXIT 41) A priori—pretrip determination from maps, etc.
8	Designation; entrance (specific need)	Indication of entrance name and/or number	Visual—perception of signs (ENTRANCE TO INTERSTATE 95 NORTHBOUND) A priori—pretrip determination from maps, etc.
9	Designation; exit (specific need)	Indication of exit name and/or number	Visual—perception of signs (EXIT 17—NEW YORK) A priori—prior knowledge from maps, etc.
10	Designation; turn-off (specific need)	Indication of turn-off name and/or number (point other than an exit, entrance, or interchange)	Visual—perception of signs (ENTRANCE TO HOLIDAY INN PARKING LOT) A priori—determined from maps, etc.
11	Elapsed mileage (type need)	Indication of distance traveled (from some reference point)	Visual—perception of odometer Visual—perception of mileposts
12	Distance to final destination (type need)	Indication of miles to go to destination	Visual—perception of signs (NEW YORK 100 MILES) A priori—pretrip knowledge from maps, etc.

[a]Applicable to "service-macro" destinations.

macro-performance activity of finding available emergency services. A situational example is traffic congestion that could lead to the macro-performance activity of finding an alternate route. The manner in which the driver accomplishes the in-transit phase of the macro-performance level is essentially cognitive. He searches for, or has his attention drawn to, macro-performance information, which he compares with his trip plan to decide what control action is required.

In-trip presentation of macro-performance information is made primarily by means of guide and service signs. However, receipt of information from in-trip sources other than signs (landmarks, service stations, billboards, etc.) is also a factor.

Because information received from guide and service signs is verbal or symbolic the cognitive level required for macro-performance behavior is almost entirely verbal and abstract and may required complex decisions on the part of the driver.

Inventory of Information Needs

Information needs were categorized in accordance with information inputs to the driver. The results of this categorization were combined with the levels of performance to provide eight categories of information need: (a) vehicle micro-performance; (b) ARI micro-performance (ARI refers to the advisory, restrictive, or inhibitory factors that cannot be specifically categorized under vehicle, road, traffic, service, or directional); (c) road micro-situational performance; (d) traffic situational; (e) ARI situational; (f) service macro-performance; (g) directional macro-performance; and (h) ARI macro-performance.

Table 2 is an example of one table from the inventory. A full set of tables is given in the project report (3).

DISCUSSION OF FINDINGS

This paper has characterized the driving task and information needed by the driver. The practical utility of the findings is their application in driver information systems. This discussion, therefore, considers the design of information systems for the driver.

Basic Requirements

Based on this conceptualization of the driving task, an inventory of drivers' information needs arrived at through task analysis procedures, and considerations of the nature of the driving population and of the highway system that have been detailed elsewhere (3), a set of basic requirements of a highway information system was derived. The system must be (a) user centered; (b) applicable to the existing highway system; (c) usable by all drivers at all times; (d) fail-safe; (e) compatible and evolutionary; and (f) economically feasible.

All elements and interfaces of the system should be evaluated with respect to these requirements and, in the case of conflicts, a minimax solution should be found.

Application of Factors

Five basic tenets for the systematic presentation of information needed by the driver are as follows:

1. First things first—primacy;
2. Do not overload—processing channel limitations;
3. Do it before they get on the road—a priori knowledge;
4. Keep them busy—spreading; and
5. Do not surprise them—expectancy.

Primacy—Driver information needs must be satisfied in accordance with the objective primacy of the highway system. Because of the way in which the driving task is performed and the differences in driver behavior at each level of performance, the form of information presentation at each level will differ.

Because control (micro-performance) information is highest on the primacy scale, it must be presented before guidance (situational) and navigation (macro-performance) information whenever competing needs exist. It is suggested that the information providing potential of the vehicle subsystem be optimized by appropriate design.

Two means are recommended for satisfying road micro-situational performance information needs. The first is to provide continuous adequate marking and delineations so that the driver can determine immediately his lateral and longitudinal position on the road. The use of some means of telling the driver when he is running off the road, or inadvertently changing lanes, is also recommended. This aspect of the micro-performance is amenable to in-vehicle display. The second means is by eliminating these needs by design. Avoidance of severe alignment changes, poor road surfaces, and difficult grade changes minimizes the driver's need for road micro-situational information.

Although the information needs associated with the situational level of performance are lower on the primacy scale than the micro-performance, the importance of satisfying them adequately should not be understated. Once micro-performance information needs are satisfied, situational performance needs have highest primacy.

The driver is required to rely on his capability for estimation, prediction, and judgment to perform adequately at the situational performance level. In high traffic density situations, because of the more complex decisions required, there is a higher probability that the driver will make a mistake in estimation, prediction, or judgment. Because errors at this level of performance can and usually do have catastrophic results, it is recommended that a maximum application of formal aiding techniques be made in this area. Intervehicular communication techniques should also be considered in great detail.

Macro-performance information needs are lowest on the primacy scale and are most amenable to delay. There is no way to satisfy the macro-performance needs for all drivers without considering the importance of the pretrip a priori knowledge requirements. A great portion of the macro-performance information needs can and should be satisfied before the driver even starts driving. Given adequate trip planning, all that is needed in the way of on-line directional macro-performance information presentation is information that relates the driver's trip plan to what he receives in transit—that is, telling him where he is and which way he is going. At the macro-performance level signs are a valid means of presenting information.

Processing Limitations—As the information challenge increases, a point is reached where the driver is unable to handle and process the amount of information required to resolve the uncertainty of the decision. It is at this point that the driver's channel capacity is said to have been exceeded.

As time pressure increases, it is simpler for the driver to make a series of uncomplicated decisions compared with his having to make a few more complex decisions. This is because a simpler decision takes less time; hence, more simple decisions can be made in any given time period. However, with no time pressure, the opposite is true because a driver can resolve more uncertainty in a more complex decision.

The systematic presentation of information needed by the driver must consider the processing channel limitation of the driver. The driver should not be overloaded in terms of either his attention-paying and load-shedding ability or his information-processing channel capacity.

A Priori Knowledge—The driver brings a body of knowledge, experience, and skills to the driving task. This "a priori information" is supplemented by the information acquired in preparation for a specific trip.

It can be assumed that he can add, subtract, deal in fractions, and read and comprehend simple English. It can further be assumed that the highway user starts off with the ability to operate a motor vehicle, the basic knowledge of laws and rules necessary to obtain a driver's license, and more or less specific information about his trip destination. The degree of knowledge and ability in other fields, examples of which are listed, is more uncertain and should be investigated:

1. General knowledge of geography. Distance and direction relationship of destination to origin and of destination to nearest prominent landmark or town.

2. Ability to read a map. Knowledge of where to obtain maps, and knowledge of which maps to obtain.

3. Ability to understand compass direction. Ability to translate changes of course into driving maneuvers (for example, westbound to northbound requires a right turn).

4. Ability to understand weather reports and translate them into roadway and visibility conditions.

5. Ability to translate distance into driving time under prevailing conditions.

6. Degree of familiarity with highway and interchange types and elements.

Spreading—There are times during the driving task when the driver's processing capacity is fully used or overloaded as well as times when his processing capacity is almost completely unused. Both unused processing capacity and overloaded processing capacity present serious problems.

When the driver has little to do, representative of the condition where the driver's processing capacity is almost completely unused, there are two possible problems. The first problem involves the self-pacing attribute of the driver. Self-pacing refers to the fact that drivers seem to prefer to set their pace in accordance with their own subjective concept of what they can do.

In locations where little in the way of events or signals is occurring (for example, on rural freeways), the external pacing of the road is very low. When the external pacing of the road is low, drivers have been found to create their own work in order to satisfy their self-pacing. Thus, if little is occurring, drivers may execute unnecessary and even dangerous maneuvers to do. A second problem in low signal areas is that of vigilance, where operators have been found to miss needed signals for no apparent reason. This is an important consideration for the older driver who has been found to be less vigilant than the younger driver.

In high-signal areas, where many signals are competing for the driver's attention, entirely different problems exist. If the driver's processing capacity is overloaded, he may miss signals because he was unable to load-shed properly. He may also be faced with the problem of not having enough time to make a decision, leading to confusion or decisions made on the basis of incomplete information.

One way to avoid the problem caused by too few or by too many signals is by applying the principle of spreading. In applying this principle of spreading, the driver attention demand situation with peaks (too much information) and valleys (too little information) is determined. The objective primacy of the situation is determined, and the less important information needs at the peak where too much is occurring are transferred to the valleys, thus approaching an even distribution of information presentation and minimizing the problems of low and high signal areas.

Expectancy—Expectancies are a function of the driver's experience and a priori knowledge. An important part of driver education is the development of a set of realistic expectancies.

Micro-performance expectancies are those associated with the vehicle and its position on the road. That drivers expect their vehicles to respond to their control actions is indicative of expectancy at this level. Once position on the road has been established, the driver relies on inference and prediction to maintain his position on the road. Anything occurring that is not within the realm of what the driver expects can lead to trouble. Micro-performance expectancies operate below the level of consciousness.

The importance of expectancies is perhaps the greatest at the situational level. Alignment changes provide examples of how expectancies at this level can be structured. Drivers expect some alignment changes on all roads and, depending on their experience on the particular type of road, expect to make speed and tracking corrections. Warning signs must be used to structure driver expectancies. Few drivers expect lane drops and other changes in cross section. Therefore, warnings of these changes are necessary.

Another class of expectancies involves interchange geometrics such as whether exists are on the left or right. Since left exits and entrances are seldom encountered, they are counter to driver expectancies. Currently very little information on type and configuration of interchange is presented to the driver. His expectancies are rarely structured except by a priori knowledge.

If a car's left-turn signal is on, the car is expected to turn left. Similarly, when approaching a green light, the driver expects cross traffic to stop. Intervehicular signaling is indicative of expectancy structuring at this level.

A third category of expectancies involves direction-finding information needs. An important aspect of these expectancies is that they are most amenable to structuring because so much of the macro-performance level involves pretrip preparation. The driver expects to find in-trip cues that correspond to his trip plan. He expects to find signs telling him where he is and which way he is going. He also expects to find information telling him where services are located and how to get to them. At the macro-performance level of driving, the greatest potential exists for structuring expectancies (through maps) and then satisfying these expectancies (through signs).

REFERENCES

1. Cumming, R. W. Progress Report of Human Factors Committee. Australian Road Research, Dec. 1962.
2. NCHRP Project 3-12. Project Statement, April 1966.
3. Alexander, King, and Warskow. Development of Information Requirements and Transmission Techniques for Highway Users. AIL, Division of Cutler-Hammer, Nov. 1967.
4. Greenshields, B. D. Driving Behavior and Related Problems. Highway Research Record 35, 1963, pp. 14-31.
5. Platt, F. M. A New Method of Measuring the Effects of Continued Driving Performance. Highway Research Record 25, 1963, pp. 33-57.
6. Algea, C. W. A Development of a Conceptual Framework for the Driving Task. Human Factors, Vol. 6, No. 4, 1964, pp. 375-382.
7. Biggs, N. L. Directional Guidance of Motor Vehicles—A Preliminary Survey and Analysis. Ergonomics, Vol. 9, No. 3, 1966, pp. 193-202.
8. Miller, R. B. A Method for Man-Machine Task Analysis. WADC-TR-53-137, Wright Air Development Center, Dayton, Ohio, 1953.
9. Seale, L. M. Purpose of Task Analysis, Methods of Obtaining Task Analysis Information, Time Phasing. Conference on the Uses of Task Analysis in the Derivation of Training and Training Equipment, Wright Air Development Center, Dayton, Ohio, 1959.
10. Alexander, G. J. Task Analysis to Determine Information Needs and Control Actions for Personnel in a Military Tactical Mission. AIL, Division of Cutler-Hammer, 1966 (unpublished).
11. Rashevsky, N. Man-Machine Interaction in Automobile Driving. Traffic Safety Research Review, Vol. 9, 1965, pp. 101-107.
12. Gordon, D. A. Experimental Isolation of the Driver's Visual Input. Human Factors, Vol. 8, No. 2, 1966, pp. 129-137.
13. Michaels, R. M., and Cozan, L. W. Perceptual and Field Factors Causing Lateral Displacement. Highway Research Record 25, 1963, pp. 1-13.
14. Lefeve, B. A. Speed Characteristics on Vertical Curves. HRB Proc., Vol. 32, 1953, pp. 395-413.
15. Barch, A. M. Judgments of Speed on the Open Highway. Jour. Appl. Psychol., Vol. 42, No. 6, 1958, pp. 362-366.
16. Denton, G. G. A Subjective Scale of Speed When Driving a Motor Vehicle. Ergonomics, Vol. 9, No. 3, 1966, pp. 203-210.
17. Todosiev, E. P. The Action Point Model of the Driver-Vehicle System. Engineering Experiment Station Report EES 202A-3, Ohio State University, 1963.
18. Wohl, J. G. Man-Machine Steering Dynamics. Human Factors, Vol. 3, No. 4, 1961, pp. 222-228.
19. Cumming, R. W. The Analysis of Skills in Driving. Australian Road Research, Vol. 9, 1964, pp. 4-14.
20. Schlesinger, L. E., and Safren, M. A. Perceptual Analysis of the Driving Task. Highway Research Record 84, 1963, pp. 54-61.

Olson, P. L., Wachsler, R. A., and Bauer, H. J. Driver Judgments of Relative Car Velocities. Jour. Appl. Psychol., Vol. 45, No. 3, 1961, pp. 161-164.

Braunstein, M. L., and Laughery, K. R. Detection of Vehicle Velocity Changes During Expressway Driving. Human Factors, Vol. 6, No. 4, 1964, pp. 327-331.

Hoppe, D. R., and Lauer, A. R. Factors Affecting the Perception of Relative Motion and Distance Between Vehicles at Night. HRB Bull. 43, 1951, pp. 1-17.

Stalder, H. I., and Lauer, A. R. Effect of Pattern Distribution on Perception of Relative Motion in Low Levels of Illumination. HRB Bull. 56, 1952, pp. 25-36.

Wright, S., and Sleight, R. B. How Close Is Too Close? Traffic Safety, 1961.

Lerner, H. D., Abbott, H. E., and Sleight, R. B. Following Distance on the Highway Related to Speed, Trip Duration, Traffic and Illumination. Human Factors, Vol. 6, No. 4, 1964, pp. 343-350.

Bierley, R. L. Investigation of an Intervehicle Spacing Display. Highway Research Record 25, 1963, pp. 58-75.

Fenton, R. E. An Improved Man-Machine Interface for the Driver-Vehicle System. Report given at the 7th IEEE Symposium on Human Factors in Electronics, May 1966.

Bjorkman, M. An Exploratory Study of Predictive Judgments in a Traffic Situation. Scandinavian Jour. of Psychol., Vol. 4, No. 2, 1962, pp. 65-76.

Crawford, A. The Overtaking Driver. Ergonomics, Vol. 6, No. 2, 1963, pp. 153-170.

Jones, H. V., and Heimstra, N. W. Ability of Drivers to Make Critical Passing Judgments. Jour. Eng. Psychol. Vol. 3, No. 4, 1964, pp. 117-122.

Brown, I. D. Effect of a Car Radio on Driving in Traffic. Ergonomics, Vol. 8, No. 4, 1965, pp. 475-479.

Hulbert, S. F. Drivers' GSR's in Traffic. Percept. Mot. Skills, Vol. 7, 1957, pp. 305-315.

Taylor, D. H. Drivers' Galvanic Skin Response and the Risk of Accident. Ergonomics, Vol. 7, No. 4, 1964, pp. 439-451.

Gibbs, C. B., Davidson, A., and Shackel, B. Car Turning Signals and Delays in Responding to Visual Information. APU 176/52, Sept. 1952.

Shor, R. E. Shared Patterns of Nonverbal Normative Expectations in Automobile Driving. Jour. Soc. Psychol., Vol. 62 (First Half), 1964, pp. 155-163.