Chapter 2
Driving: task and environment

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2.0. Chapter outline

This chapter provides a descriptive background of the driving task. Specifically it deals with those aspects of the driving context that are of special relevance to the human driver. This context is structurally determined by the triad driver-vehicle-road (Section 2.1) and functionally by situation-action elements that are revealed by driving task analyses (Section 2.2). In section 2.3 the focus is on road infrastructure, environmental conditions, and traffic management. Here the question is what problems these components of the traffic system are known to create for the human driver and how they might be overcome by various kinds of support. Specifically the question is what environment-oriented support will most facilitate driving performance. In Section 2.4 the same question is raised with respect to the vehicle: what information is needed for vehicle operation to be as smooth and effective as possible? In the light of the GIDS project it is important to determine what aspects of the driving task are amenable to RTI-technology; after all, smart roads and smart vehicles will be dependent on smart drivers for a very long time to come. This topic is discussed in Section 2.5 and in the final section (Section 2.6) some conclusions are drawn.

2.1 The environment-vehicle-driver system

Together with air and waterway transport the road traffic system serves as an important economic factor in modern society. However, in contrast to, for example, air traffic, the role of human control in road traffic is still relatively large. The importance of human control in car driving by contrast with piloting an airplane can be exemplified by the following observations. On the one hand driving under normal circumstances is a comparatively easy task. This conclusion is obvious from the number of lessons a normal person needs in order to acquire the basic driving skills. On the other hand, the variability of driving situations and their correct evaluation is immensely large compared with air traffic situations. This argument is supported by the ubiquitous application of autopilots in all modern airplanes. Autopilots can take over a great many actions because of the predictability of air traffic situations and the clear criteria for their evaluation. Furthermore, it is possible to specify pilot associate systems because of the strict rules applying to flying manoeuvres.

To understand the specific nature of the driving task and the possibilities of RTI systems we must realize that many if not most individual drivers travel from one place to another at self-chosen times, with self-chosen vehicles along self-chosen roads. During their journey they meet hundreds of other traffic participants, which makes driving seem like the task of a bird flying in a flock and finding its way within a myriad of environmental constraints. Nature has equipped birds with elementary sensors which prevent them from colliding despite their high flying speeds. Highly skilled automobile drivers, those who have become one with their vehicle, may reach a similar level of automatic error prevention. Nevertheless, humans may fail for a variety of reasons and consequently road traffic may result in serious accidents and inefficient use of the roadway system. Accidents are seldom attributable to a single cause, but are most often related to a combination of driver, vehicle, and/or environmental factors. Driver failure may result from a lack of skill, which in turn may result from inexperience or from factors such as fatigue or alcohol. The driving environment adds some potential accident causes to human failure. Visibility may be reduced by darkness, rain, or fog. In addition, roadway quality may be limited because of wear and tear, or inappropriate design. Finally, drivers may be confronted with the limitations of vehicle controllability, or with vehicle failure.

Designers of the roadway system have taken many of these factors into account. Visibility problems, for instance, are coped with by modern public lighting and traffic information systems, and roadways are designed in accordance with category-related design rules which allow drivers to behave in an anticipatory way. Nevertheless the damage caused by traffic accidents and pollution is generally judged to be unacceptable, which has led to the conclusion that fundamental innovations are needed to make road traffic suitable for the 21st century. The use of modern information and communication technologies is considered one potential basis for such innovation. A fruitful application of Road Transport Informatics should be based on an evaluation of the accident-related failures of the dynamic triad environment-vehicle-driver to function properly. Analysis of the automobile driver's task in terms of hierarchical task levels and situation-action elements may provide the basis for such an evaluation (Michon, 1985, 1989; Aasman & Michon, 1992).

2.2 Driving task analysis

Task analysis has been used in a wide variety of domains, generally as a forerunner to the development of a performance model of some skill, in order to promote understanding or as a way of supporting performance in a particular domain. A range of task analysis techniques have been employed (Meister, 1985), but virtually all share a tendency to seek to identify the operations involved in performing a task rather than the mental processes which must subserve such operations. There is, therefore, a tendency to attempt to describe observable performance, that is, execution, rather than to identify how such performance is initiated, planned and controlled. This may in part be due to the fact that task analyses tend to be carried out by expert analysts who consider the behaviour of others, or by experts in a particular domain who do not have the intention (or the psychological competence) to carry out a more cognitively oriented analysis. It should be emphasized that this observation in no way detracts from the importance of the careful and authoritative work of, for example, McKnight and Adams (1970 a, b) who are responsible for the most extensive and detailed description of the driving task, originally carried out in order to improve the quality of driver training and driver education in the United States.

McKnight and Adams analysis of what the driver has to do distinguishes 43 separate main tasks which are further broken down into some 1700 sub-tasks. Each of these is further classified into the activities the analyst surmises to be required for such tasks to be performed successfully (Figure 2.1). McKnight and Adams also painstakingly detail available evidence on the likely importance of particular activities indicating, for example, what is known about the contribution which an activity makes to accident causation. As has been pointed out by Groeger (1987), among others, the McKnight and Adams analysis, extensive as it is, is not a theory of learning or instruction. Neither is it a description of how the task is actually performed by the driver. As such we must be cautious about the use to which the results of such an analysis are put, especially where *performance support* is the particular goal to be achieved, as is obviously the case within GIDS. While McKnight and Adams should not be blamed for not considering the processes which underlie performance, as their purpose was not to develop an electronic in-car support system, their task analysis is only of partial use to the GIDS design.

Task 31: Following

			Criticality
31-1	MAINTAINS ADEQUATE FOLLOWING DISTANCE FROM LEAD VEHICLE		
31-11	Maintains appropriate following distance behind lead vehicle to allow for stopping car in advance of lead vehicle if necessary *	16	XXXXX
31-12	Maintains at least 500 feet separation distance behind emergency vehicles *	0	XXX
31-13	Increases separation distance		
31-131	When following		
31-1311	Oversize vehicles that obsecure forward visibility *	6	XXXX
31-1312	Vehicles which stop frequently (transit and school buses, post office and delivery vans)	11	XXXX
31-1313	Two wheeled vehicles (motorcycles and bicycles) *	6	XXX
31-1314	Vehicles carrying protruding loads *	0	XXX
31-1315	Vehicles driving erratically	9	XXXX
31-132	On wet or icy roads *	13	XXXXX
31-133	Under conditions of poor visibility (see 51, Weather)	12	XXXXX
31-134	In conditions of darkness (see 52, Night Driving)	8	XXXX

Figure 2.1 An example of the McKnight and Adams task

It would perhaps seem obvious to state that training or support should conform to the way in which the task is actually carried out. However, in many cases the detailed characteristics of human information processing in a particular driving task are not known. The implications of this can perhaps be made clear by the following example.

Suppose a driver is approaching a quiet signalized junction, when the traffic lights change from GREEN to AMBER. The purpose of the support system is to aid the driver in making the appropriate STOP or GO decision, failure to do so being a major contributing factor in accidents at intersections. Accounts of how drivers perform such a task appeal to some notion which involves the driver assessing when the junction will be reached (see Allsop, Brown, Groeger, & Robertson, 1990). It is at least conceivable that such assessments may be made either by estimating the distance to be travelled and the approach speed, or by somehow detecting the rate of expansion of the image of the junction on the retina and estimating the time which would elapse before it is reached. The latter explanation, based on Gibson's (1968) ecological optics, has enjoyed some currency but is challenged by the recent work reported by Cavallo and Laurent (1988) and by Groeger and Cavallo (1991), who show evidence for the distance/speed explanation. Whatever the means by which drivers assess when the junction will be reached, it should be clear that providing the driver with extra information about actual approach speed or actual distance to be travelled is unlikely to be beneficial if information directly available from the changing optic array is used for speed or distance perception. Similarly extra information about the time it will take to reach the intersection is unlikely to be helpful if the driver's real difficulty lies in accurately assessing the distance to be travelled. Also, it is conceivable that such support might prove damaging if, for example, the driver's focusing on an in-car screen disrupts the maintenance of some visual or spatial image of the external scene, as may auditory messages such as "two seconds" or "100 metres" if the driver cannot gauge exactly how such physical parameters relate to the external scene. Simple STOP or GO advice would only be appropriate if the reaction time and speed preferences of the driver could be taken into account.

This serves also to illustrate some other shortcomings of the traditional task description approach. It is known, for example, that factors such as age, fitness, goals and time pressure all distort reaction times. An indication of the time remaining before the junction will be reached, if it is to prove helpful, must therefore take into account variations within and between individual drivers. Generally, task analysis methods fail to explicate how such individual differences, or how a choice of alternative ways of meeting the demands of the task, can be included. Such analyses also fail to incorporate the fact that the way in which the task is performed by inexperienced and experienced drivers may fundamentally differ (see Cavallo & Laurent, 1988). Obviously, only an account of the processing underlying the activity to be performed can meet such needs.

Given the difficulties inherent in interpreting and applying the traditional formal task analysis of the driving task, it would be easy to conclude that this approach is of little use in the development of a support system such as GIDS, the hallmark of which is adaptability to changing circumstances and driver needs. But this is not the case. The McKnight and Adams account of the tasks drivers must perform remains the most detailed and comprehensive description of this task domain and it has been used extensively, as will be seen in later sections of this book, in the initial task description and design of some components of the GIDS prototype. As will also be clear from subsequent sections, the most serious shortcoming of the McKnight and Adams work, namely the failure to provide adequate behavioural corroboration of the task descriptions formulated, has also been addressed, and as a result proposals for supporting drivers are based on empirical data collected by various teams within the consortium, rather than on arbitrary accounts of the driving task.

Actually the approach of GIDS has been to provide a basic reference model which quantitatively describes the optimum driver action and vehicle motion characteristics for a particular manoeuvre. This model takes account of driver, vehicle, and traffic characteristics and, as such serves as an adaptive, normative description of behaviour. Thus, aspects like driver age and experience, vehicle weight and dimensions, and traffic density become the natural components of the driver support system, which is meant to help the driver's navigation, manoeuvring and vehicle control performance in a variety of circumstances.

2.3 Infrastructure

Many problems that traffic participants encounter on the road are caused by the fact that the existing roadway infrastructure and traffic control system have been suboptimally designed. Actually the roadway system in most Western countries is based on a mixture of historical and modern design principles. Modern highways and new towns are connected with a road network which, in many cases, has its origins in the nineteenth century. Consequently drivers, cyclists, and pedestrians are confronted with a variety of not quite compatible traffic circumstances which makes their task quite complex.

Currently roads are designed in accordance with a series of design rules that belong to a certain road categorization scheme. Specific behavioural rules, for instance about speed limits, are associated with each road category. Drivers' expectations about the chance of meeting other traffic are also governed by the design principles for a special road category. Theoretically this design philosophy ought to result in almost perfect driving behaviour. However, in practice several problems may occur. In many cases drivers can hardly distinguish between different road categories. On the one hand, this is caused by ambiguity in the use of specific category-related design features. On the other hand, local circumstances often force the road engineer to use substandard solutions: for instance, relatively short sight distances. Furthermore, the question arises whether so-called optimal technical solutions for, say, intersection design are really optimal from the driver's point of view.

That all is not well seems to be evident from the fact that various information systems have been developed to provide additional information to the road user. Road signs warn of oncoming hazards and give information about local traffic rules in terms of speed limits, right of way, etc. In many cases these signs are necessary to compensate for suboptimal design charactistics. The modern use of signs and signals may also form an integrated part of a specific road category. Route signs that are placed well in advance will help the driver to behave in an anticipatory way. When approaching an intersection, vehicle-actuated traffic signals may serve as an intelligent tool which controls the right-of-way rule in a traffic-dependent manner. Road delineation systems not only guide the driver along the road, but may also give information about local overtaking possibilities. Driving performance on a suboptimally designed road may reach a critical level in darkness and/or bad weather. Even for an experienced driver, vehicle control may become a difficult task in conditions of heavy wind or on a slippery road. In many cases such circumstances occur in combination with bad visibility, because of rain, fog, or snow. The relatively high number of bad-weather accidents and the seriousness of these accidents indicates that drivers are not well prepared for such conditions. Apart from general warning signs which indicate the potential occurrence of rain or fog, the road infrastructure usually provides little help on this point. Nevertheless, in their integrated form modern road designs and traffic information systems may give the road infrastructure an almost perfect appearance. Particularly in such a case, it is important to realize that many parts of this infrastructure are not suited to meet the demands placed on them by the (imperfect) road user. Traffic participants do and will continue to make errors. A future, more safe and efficient infrastructure should therefore be based on roadway design rules and supportive driver information systems that can help to avoid or compensate for these errors.

GIDS is designed such that roadside and in-vehicle information sources can be combined in a way which takes account of driver characteristics. Traffic-dependent in-veroute information via variable message signs may well be integrated with in-vehicle *navigation* support. Roadside advisory speed and headway warnings should be designed in combination with in-car intelligent cruise-control and collision-avoidance systems. These systems may be applied together with green-phased traffic signals and speed limitation systems for safe and efficient traffic control and driver *manoeuvring*. Lane crossing, because of narrow lanes and/or driver inattention, may be supervised and corrected by an integrated roadside/in-vehicle warning system for proper *vehicle control*. GIDS should manage the information stream related to these navigation, manoeuvring, and control support functions in a user-friendly way.

2.4 Vehicle

Vehicle control constitutes the basic task element in driving. Following the roadway curvature and path control between other traffic participants and obstacles require correct steering and speed control actions. Vehicle stability and controllability is largely speed dependent. In other words, speed and steering control should be carried out in a highly correlated manner. Drivers may have problems in adapting speed in an anticipatory way in order to prevent traffic conflicts. Active warnings alongside the road or in-vehicle can be used to give immediate feedback about the discrepancy between actual and safe speed.

In future vehicles, steering and speed control will be combined with the supervision and handling of a complex set of in-vehicle instrumentation, that is, route guidance, radio, telephone, etc. The introduction and wider use of such systems may result in dramatic consequences if their design is not based on knowledge about the factors influencing driver information processing capacity and workload. Regarding information presentation and control, the questions should be considered of what mode (visual, auditory, tactile) and at which moments information should be presented, and how natural and artificial intelligence should interact.

Information presentation

To drive safely, drivers have to pay close attention to the road scene, in order to keep their vehicle on the correct trajectory, to avoid obstacles, to read road signs, to respect traffic rules, etc. Consulting in-vehicle displays may conflict with these driving requirements, particularly if the design of these devices has not been ergonomically defined. Deficient design and organization of such displays may cause various sorts of problems:

- difficulties in searching for or reading information, thus increasing duration and number of visual glances away from road scene, and increasing attentional effort;
- difficulties in understanding symbols and information, thus causing misunderstanding and confusion;
- difficulty in taking into account simultaneously a great amount of in-car data, thus increasing the mental workload of the driver. As a consequence, bad designs of in-car displays may disrupt the driving task, causing near-accidents (such as lane deviation, violation of traffic rules) or actual accidents;
- to circumvent these problems, an intelligent structure has emerged, represented by the GIDS system. The purpose of this intelligent interface is to integrate new information and communication functions into cars in order to manage the ergonomics of the various messages presented (or the type of control required) their presentation and the personal characteristics of each driver. The main objectives of an intelligent interface are adaptation to a specific context, understanding what drivers require, reasoning from pre-assimilated information and the acquisition of new information. The aim is to facilitate driver understanding, by presenting information in an appropriate form, taking account of the specificity of each user, each situation and their needs.

Basic issues on dialogue control and information management

It should be emphasized that whilst conventional dashboard ergonomics (e.g., Labiale, 1990) takes into account a *surface ergonomics* of the vehicle displays, the intelligent interface of GIDS uses not only this surface interface, but also requires new ergonomic developments, which we might call *cognitive ergonomics.* Cognitive ergonomics requires definitions of new criteria (Labiale, 1991) concerning information management by an intelligent co-driver, such as GIDS. These criteria concern:

- absence of competition with other sources of visual data on the dashboard and for other media such as audio messages and manual controls;
- relevance of the content and timing of the data supplied in terms of the road situation and drivers' expectations;
- adaptation to the personal characteristics of drivers (e.g., experience, age, handicap, driving style) and to the manner in which drivers request information and dialogue;
- respect of personal preferences for independence;
- reliability of data supplied, enabling the creation of driver confidence.

This set of requirements has led the GIDS consortium to consider a broad spectrum of interface components as potential information systems, including visual displays, voice generation, and active control. Proper implementation of non-visual information systems, distribution of messages over time and adaptation to the skills of individual drivers may together keep driver workload low and facilitate information processing. Defining information management and dialogue structure along these lines may, furthermore, ensure that drivers will accept such support functions and that safety and comfort are improved.

Controls

Most aspects mentioned for information presentation are also relevant for control design. However, two main differences should be noted, one positive and one negative. Whereas the presentation of information on displays is mainly externally triggered (by the car or the environment), controls are activated in a driver-paced fashion. This means that drivers are better able to decide at what time they wish to focus their attention on the control inside the car. Unfortunately, however, the mean search and handling times exceed those for attending to displays.

A study by Burger et al. (1977) concludes that at least 7.5 per cent of all accidents result from a mismatch in the driver/vehicle system. So, the question arises, what the characteristics are of these mismatches. To understand the problems of poorly designed controls one must consider the fact that controls have an actuating and a feedback function. With respect to the actuating function, controls must be positioned within the optimal reaching area of the driver. But this area is quite small, because of the length of the driver's arms and legs and restricted space in the car (cf. ISO 3436.3 and ISO 3958). To optimize the feedback part of controls, they should be visible and self-explanatory. Self-explanatory means, for example, a toggle switch in the up-position is set to 'on', in the down-position to 'off' (at least, that is what continental European designers consider 'self-explanatory'!).

The attribute 'self-explanatory' implies that every driver will spontaneously operate a specific control correctly without training. Self-explanatory properties of controls may further be improved by providing active feedback via a particular manipulator (Godthelp, 1990). Force feedback via the pedals and steering wheel have been adopted, in principle, as components of the GIDS human-machine interface. These active controls can provide information about occasional speed or lateral path errors. Intelligent controls will thus be a part of an adaptive information system which improves vehicle control and reduces related workload levels.

2.5 Road transport informatics

The question what benefits can be expected from Road Transport Informatics (RTI) systems leads to totally different answers and predictions by different experts. Ad hoc evaluations of safety benefits from new vehicle technologies reveal a wide range of results for similar systems from different experts and also great variety between the functions (PRO-GEN Safety Group, 1989). The main dispute between the various experts as to whether RTI systems can reduce accident rates by 5, 10 or more per cent is inappropriate. A more consistent evaluation pattern requires several distinctions.

The first important aspect to bear in mind is that RTI systems can, though not necessarily do, help the driver to perform better by reducing errors and accidents. This means that one must take into account that drivers are not only information-driven, but also motivation-driven. RTI systems are especially helpful where information deficits lead to wrong or inappropriate behaviour. They are almost useless, however, when motivational factors dominate in dangerous or incorrect driving behaviour. Acceptable and accepted RTI systems must be compatible with the intentions of the driver. Unreliability and low acceptance will frustrate wide distribution, which is itself a precondition for the success of such systems. It should be noted at this point that most estimates of the success of RTI systems presuppose a high equipment penetration. Also, reliability problems are often ignored. Theoretically, reliability is treated as a precondition for installing a new RTI system. However, everyday experience with new cars shows that the reliability of new technical systems is far below the desirable level. Anti-collision or distance-keeping systems are prominent examples. Currently these systems guarantee high reliability only at the price of false alarms, which themselves cause acceptance and safety problems. A system that warns unnecessarily often and too early will be switched off by the user and therefore be useless!

To understand and evaluate possible benefits of RTI systems in general and of the GIDS system in particular, a categorization of the driving task is necessary. Following the categorization made in Section 2.2, the driving task can be structured at three levels. These levels are navigation, manoeuvring, and control. At the navigation level drivers choose their destination and desired route. Their choice may depend on specific goals or traffic conditions. They may, for example, choose different routes if they are on a holiday or a business trip, if they desire to admire the scenery or to travel the fastest way. It is obvious that such choices will influence their information needs. Because human perception and information processing are conceptually- rather than data-driven processes (cf. Norman & Bobrow, 1975), the decision to take a specific route changes the information flow, the load and the benefit of an RTI system. During their trip drivers will meet other cars, pedestrians, cyclists, etc., and they must relate their intentions and actions to those of other road users. This level of action is termed manoeuvring. Typical actions are distance keeping, lane changing, overtaking, passing other vehicles or crossing an intersection. The lowest level of car driving behaviour, handling and control, covers actions like steering, acceleration, and deceleration. At this microlevel, a driver's actions are influenced by actions at the manoeuvring and navigation level, and also by the reactions of the car and the sensations and perceptions of the driver. Single accidents, like veering off the road or driving too fast on a bend, are typical examples of faulty control behaviour. It should be emphasized that at this level the coupling between perception and action is very important in guaranteeing immediate and correct reactions by the driver. In other words, the value of RTI functions, such as lane keeping support, is intrinsically related to their ergonomic design (see Sections 4.6 and 5.1). While the direct impact of wrong reactions at the handling or the manoeuvring level is widely accepted, the influence of navigational problems on traffic safety and accident rates is often ignored. However, as Färber et al. (1986), and Engels and Dellen (1989) have shown, drivers who are unfamiliar with the locale and/or disorientated cause more accidents or traffic conflicts than drivers who know where they are and where they need to go.

A further and equally important aspect is inter-individual variability. A review of the literature on work psychology reveals that it is shortsighted to 'optimize' work environments with regard to a 'standard' person. Extrapolating this insight to RTI systems, we must consider individual differences as an important factor. A function that is helpful to one driver (e.g., distance keeping) can annoy and, as a consequence, disturb others. Support systems must therefore be adaptive.

The final important aspect of evaluations of the benefit of RTI systems is how to assess the overall safety of a combination of functions. As PRO-GEN (1989) pointed out, "to estimate the potential impact on safety of a group of these functions, it is not possible simply to add up the separate potentials." Or, as Gestalt psychology stipulated, the whole is more than the sum of its parts. In order to make intelligent use of and obtain maximum benefits from RTI systems we must take into account mutual interactions. Interactions can be positive in the sense of synergetic effects, but also negative or antagonistic. So, what do we know at present about the potential impact of RTI systems on traffic safety? We know that it depends on several variables. Only a system which takes all these variables into account will use RTI systems in a productive manner.

2.6 Conclusions

In summary it can be concluded that the application of modern communication technologies to road traffic requires a careful consideration of drivers' information needs. The driving task is a complex combination of subtasks, each of which may form a basis for the commission of fatal errors. Driver support systems should therefore be designed such that the major subtasks in driving, that is, navigation, manoeuvring, and vehicle control are dealt with in an integrated manner. A detailed description of drivers' potential errors and their underlying causes should form the basis for a normative driver model which serves as a reference for the appropriate warning strategies. Warnings should be self-explanatory and presented in accordance with rules derived from modern cognitive ergonomics. Proper implementation of non-visual information systems, distribution of messages over time and adaptation of support to the skills and expectations of individual drivers should keep the workload low and facilitate information processing.

Ultimate safety and efficiency will depend on drivers' motives and intentions. RTI systems will be effective only if they help the driver in a way which is recognized and accepted by individuals and by society.

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