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SAFETY IMPACTS OF IN - CAR NAVIGATION SYSTEMS

SUMMARY

In-car navigation systems constitute one of the most prominent groups of road traffic informatics developments, some systems are already on the market. To evaluate the safety related influences of these systems on driver behaviour empirical research is needed. In a study funded by BMW and DRIVE the authors were to answer the question which kind of test route would be appropriate for such research work. Here, some of the more principal Lines of reasoning Leading to the proposal of test route characteristics are presented.

At first, we List the possible effects, that navigation systems can have on driver behaviour and try to explain these effects within some theoretical framework.

problems of mental Load, visual distraction, over-reliance, deskilling, interactions with unprotected road-users and system misuse are discussed.

The next paragraph discusses various parameters of drivers and the road environment that possibly moderate the outcome of a study for each of the effects Listed above. The most important variables are the degree of driving experience, the driver's special abilities and their amount of local knowledge about the road network.

Some general conclusions from the discussion for test route selection are summarised.

1. SAFETY RELATED CHANGES IN DRIVER BEHAVIOUR DUE TO NAVIGATION SYSTEMS

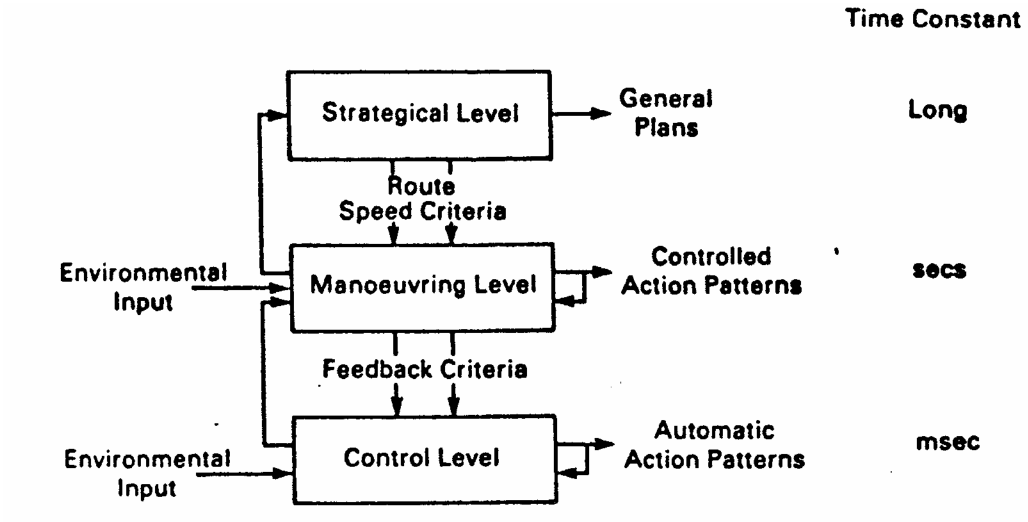
The development of NS has been motivated by a lot of possible positive effects concerning economical, ecological and safety aspects. We shall focus our attention in the following analysis on those effects of NS that are directly safety related. Of course, there are also indirect effects on safety, e.g. if the NS shortens the routes in time or space and thus changes the driving exposition.

This chapter tries to give a short description of possible effects of NS on driver behaviour at various levels of the driving task.

Two classes of models with different backgrounds and purposes have become useful —and therefore common— in distinguishing between different driving tasks and respective driver information processing activities. One class is in the tradition of the attempt to model driver behaviour as a hierarchical task (JOHANNSEN 1976, JANSSEN 1979), the other has been developed by RASMUSSEN (1983) in the context of supervisory control tasks. Recently, several authors have attempted to combine these models (e.g. PARKES 1989, RUMAR 1990, HALE et al 1990).

We shall use some of the concepts of these frameworks in the next chapters to describe the safety related aspects of driver behaviour which are likely to occur in the context of NS. We therefore give a brief description of the model.

Figure 1: Hierarchical structure of the road user task (after JANSSEN 1979)



The driving process is modelled as a hierarchical task structure. Performance is differentiated at three levels. On the strategic level the driver makes trip—specific decisions. He sets goals like definition of trip destination, sub-goals about what routes to take etc, i.e. he is planning his trip. Performance at this level is therefore directly related to the navigation task. If the navigation task is not automatised (like on daily used roads for the same purpose), it affords conscious processing at a knowledge-based leve 1.

The general plans from the strategic level have to be transformed into controlled patterns of action. Behaviour at this manoeuvring level is mainly rule—based, i.e. it follows learned "if—then" rules. The driver e.g. decides to overtake and retrieves the necessary information about the actions for that manoeuvre from long—term memory. Finally, on the control level of driving, strongly automatised action patterns dominate behaviour. Actions on that level are quick, efficient and can be taken without great subjective effort. They are called skills and they don't afford conscious attentional control by the driver. For an experienced driver, examples of skills are using the steering wheel, clutch, brake etc.

1.1 Mental bad

Mental bad has become a key concept in psychology and human factors research in the last decades. GSTALTER & FASTENMEIER (1987) have summarised the main theoretical assumptions and implications of the construct recently in an attempt to evaluate different stress-measurement techniques in the PROMETHEUS context. We therefore restrict our presentation here to aspects of mental bad that are of key importance for the construction and evaluation of NS.

The notion of mental bad in connection with NS is twofold: Some authors predict a decrease in the drivers mental bad, because less attention on the driver’s side would be needed for navigation purposes, others f ear an overload induced by the presentation of navigation information in highly demanding traffic situations.

How can a navigation system reduce mental workload?

Navigation, mainly consisting of route planning and route following is a knowledge-based activity located at the strategic level of the model in Figure 1. This kind of information processing is serial, slow and error—prone. Everything processed in this mode has to pass the bottleneck of conscious awareness. This kind of information processing is therefore extremely time— and resource—consuming. If a NS can substitute elements on the strategic level it has the potential to reduce the driver’s mental bad. This is, e.g., the case, if drivers don’t have to activate their knowledge about the road network (their “cognitive maps”) to decide between possible alternative ways during the trip.

Another way to decrease mental bad can be achieved by a shift from knowledge-based to rule-based behaviour, i.e. from the strategic to the manoeuvring bevel. If a NS tells or shows the driver to turn left at the next junction, the decision is taken over by the system and the task left over to the driver —prepare for the manoeuvres for the turning off— is a rule—based (or partly even sensorimotor) activity.

Still another possibility of reducing mental bad by the system can result from an easier perception and/or interpretation of useful navigation information via the NS compared to driving without the system (e.g. seeking and reading sign boards, street names etc versus having this information on the in—car display).

As the model of the driving task in figure 1 is a hierarchical one, you could suppose spare mental capacity on a higher level to be of use in terms of more attentional resources on the bower levels.

It is important to note that all potential benefits described above only apply to cases, where the driver really has to manage a knowledge—based navigation task. No effect on the driver’s mental bad can be expected on well—known routes between sources and destinations like workplace and home. Here the navigation task is automatised and subconsciously controlled.

But intelligent systems (e.g. LISB), which can supply the driver with recommendations based on real—time information about disturbances in traffic flow like jams or accidents can of course indirectly bower the driver’s mental bad by guiding him/her on routes with an easier driving task to perform.

Of course, all advantages listed above are only advantages in the sense that they can be achieved by an optimal design of the NS. PARKES (1989) and ZIMMER (1990) give detailed information about the requirements connected with the planning and construction of RTI systems. If the design of the system or the system-interface is bad, the system can become counterproductive. It can disturb and distract the driver, it can give the wrong kind of information and/or at a wrong point in time, or it can display information that is hard to understand etc. In total, badly designed systems can produce an increase in mental bad.

It follows that NS should be carefully designed and in any case their effects should be empirically tested, nevertheless.

What is the relationship between mental bad and safety?

It is often (more or less implicitly) assumed that an increase in strain or mental workload automatically impairs human performance. This is obviously wrong as long as the driver can cope with the situation by using greater mental effort. VERWEY & JANSSEN (1988) mention this point and refer to the distinction between "data—limited" and "resource—limited" conditions (NORMAN & BOBROW 1975): "In resource-limited conditions (i.e. in task conditions where the operator has no spare capacity), human performance is fully determined by the demands of the task and mental bad decrement will immediately result in performance increment. In data—limited conditions, however, (i.e. if spare capacity is available) performance corresponds less to mental bad, because humans can use spare capacity to compensate for extra task demands."

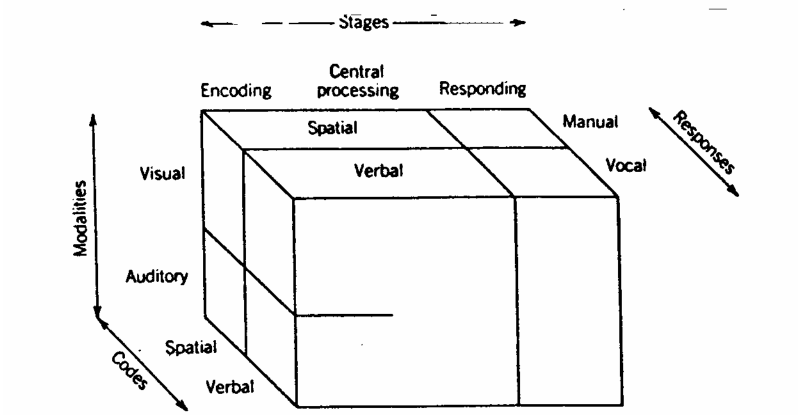
Another argument against a simple relationship between traffic safety and driver's mental bad is the fact that traffic participation is -at beast in many situations- a self-paced task. Drivers therefore have coping strategies (like reducing speed) to compensate for higher levels of mental bad. That drivers really behave in a way to hold task demands on a constant level ("strain homeostasis") has been shown in a number of investigations (GSTALTER 1985, HOYOS & KASTNER 1986, VAN WINSUM 1987).

For the topic under discussion here it follows that safetyrelated changes in mental bad due to NS should be studied under conditions near the resource limits.

1.2. Multiple resources

In the discussion above we have treated "resources" as a single, homogenous source of attentional capacity. This concept of attention as a flexible, time-sharing processing resource of limited capacity has been introduced by KAHNEMANN (1973). This has been shown to be too simple to explain certain phenomena of time-sharing performance (WICKENS 1984, 1987, FARBER 1987). Not only the level of task demand, but task structure became the object of research. A multiple—resource model was developed by WICKENS (1987) that conceived of resources as separate energy supply systems to different information processing structures. WICKENS (1987) modelled the human resource structure in a three—dimensional space.

Figure 2: A model of the multiple resources within the human processing system (after WICKENS 1987)



Obviously, this notion has important consequences for the design of information systems, if their interaction with drivers should result in data-limited structures. VERWEY & JANSSEN (1988, p.16) draw detailed inferences from the multiple—resource model for navigation system design, especially with regard to the question of when auditory or visual information presentation should be preferred. They conclude:

> "... it can be expected that the presentation of simple visual navigation information is less intrusive than auditory information, but at the same time more interfering with visual demands of the driving tasks. Predictions concerning the optimal presentation modality are therefore hard to make. Self—paced information, however, may induce integration of information intake with other driving tasks. Because the visual modality is better suited for self-paced information, visual route guidance information presentation may show more practice effects than auditory and, eventually, this may lead to an advantage for visual information."

How can overload influence safety?

According to RUNAR (1986) under normal driving conditions (data-limited case) the order of importance of information is the following: Highest priority for information about the road (control level), medium priority for information about the interaction with other vehicles (manoeuvring level) and lowest priority for navigation information (strategic level). But what happens if a driver cannot avoid a state of mental overload? VERWEY & JANSSEN assume that drivers are capable of ignoring less critical driving tasks (in terms of safety) to cope with overload conditions:

> ..... differences in mental bad as a result of navigation are expected to' exhibit themselves in tasks like driving speed, stopping time, navigational errors and mirror usage. No effects are expected on the occurrence of critical incidents." (VERWEY & JANSSEN 1988, p. 17)

This is an optimistic point of view. It could also be argued (as has been done e.g. by PARKES 1989), that drivers under overload conditions are liable to changes in the normal prioritisation of information. If navigational information is given priority over important aspects of the roadway ahead, critical situations will occur. This kind of prioritisation of the navigation task can be strengthened by so—called “command—effects” induced by a navigation system.

Conclusions

The current theoretical state of the art is insufficient. At the moment, NS can only be evaluated empirically. Investigations should be carried out under resource—limited conditions.

1.3. Visual distraction

The driving task puts a heavy bad on the visual channel; most of the information intake and feedback is visually controlled. Each distraction of the driver’s view therefore is a potential danger because relevant visual information from the roadway can get lost during the scanning of an in-car display. This obvious f act has been recognised early and led to research about the amount of distraction induced by visual displays. Various techniques have been developed to measure and quantify visual distraction. ROCKWELL (1988) has introduced the notion of “visual cost”. The most important parameter is the time, the driver is diverted from the front view. It can be split into glance frequency and glance duration. A high glance frequency can be a hint for bad memorability of the information presented at in-car displays, glance duration can be used to evaluate the ease of information extraction from the display. For more details on how to quantify “visual cost” using “visual matrices” see ROCKWELL (1988) and FAIRCLOUGH & PARKES (1990).

WIERWILLE et al (1988) and WIERWILLE et al (1989) could not find evidence for the intrusion of displays as navigation aids. They concluded that drivers are able to adapt their visual scan patterns appropriately. Although in the WIERWILLE et al (1989) study the level of visual demand imposed by the driving task was varied as well as the amount of traffic volume, we conclude that his subjects still drove in a state of “data—limited” processing (compare the discussion in the previous chapter).

PARKES (1989) and especially FAIRCLOUGH & PARKES (1990) have compared the distribution of visual attention in a field study. An in—car navigation device was tested against a map condition and compared to a control condition (no navigation component).

The following table summarises the results.

Table 1: Distribution of visual attention over the forward view for both conditions (n=10) compared to a control (n=24)

.	Control	Map	Computer
Rear view mirror	2.3	1.7	2.3
Roadway	92	67.2	76.1
Navigation device	---	22.1	12.1
Dashboard	1.5	0.2	0.3
TOTAL	95.8%	91.2%	90.8%

In the control condition, 92 % of the driver's visual attention was allocated to the roadway ahead. This number decreased considerably for the drivers with the navigation aid ("computer"), but even more in the map group (76% and 67%, respectively). For a detailed analysis see FAIRCLOUGH & PARKES (1990).

Sometimes it is argued that "auditory costs" should be considered in an analogous way by systems that make use of acoustic information presentation. These systems could disturb or even startle the driver by giving sudden unexpected messages. Moreover, noise from the traffic environment can be masked and the perception of the motor noise of the own vehicle distorted. Although these effects may occur, we don't treat "auditory costs" here as a special chapter or effect, because we don't see a direct relationship between the occurrence of these effects and specific traffic situations. If a system gives acoustic messages to the driver, the driver's reaction to the message should be observed; but the inclusion of specific traffic situations to test for these effects seems unnecessary to us.

It is important to note that the difference between driving in a well—known area (i.e. driving without a real navigation task involved) is very much easier than driving in strange environments. The difference in the visual distribution cited above therefore cannot be interpreted in the sense that the navigation device impairs traffic safety compared to "normal" conditions in strange environments (which are better approximated by the map condition). The amount of increased task complexity and thus reduced traffic safety induced by the search task has been demonstrated lately by ENGELS & DELLEN (1989) in a study comparing the accident risk of native and foreign drivers. Foreign drivers were significantly over-represented in the causation of those accidents which happened in a traffic situation involving an orientation component (e.g. in junctions, approaches to junctions, lane—changing), whereas other accident causes (e.g. speeds too high, headways too short) showed an equal distribution of accident causation proportion of foreigners and native drivers.

GALSTERER & GSTALTER (1990) could also show on the basis of error—data that a related sample of drivers had more safety—related problems in unknown parts of Berlin compared to their trips in well known parts of the road network.

In another study GALSTERER et al (1990) observed a significant increase in lane—exceedences by drivers with the LISB— navigation system compared to trips without an electronic device. They attributed the effect at least in part to visual distraction factors.

In total, a glimpse on the literature about the safety-related consequences of visual distraction by the use of navigation displays seems to sample confusing or even contradictory pieces of evidence. But reasoning about why and how visual distraction can influence safety leads back to the notion of mental workload discussed in some detail in the previous chapter. If we perceive the requirement of scanning a display as a classical dual task, adding mental workload to the primary task of driving, we would arrive at the same inference like that in Chapter 1.1: If the joint mental bad of primary and secondary task (both competing for the same kind of attentional resources!) reaches the bevel of resource—limited processing, driver performance is likely to deteriorate, possibly explainable in terms of a shift in RUMAR's prioritisation of information from different relevant sources.

In other words, in its consequences we might view hazards through visual distraction as a special case of the general mental bad topic or as a cause of reaching an overload level of information processing. Thus, if we take into consideration all other variables influencing drivers mental bad, we come to more conclusive results about the hazards induced by visual distraction through NS. In this context the varying results of experimental studies on the topic become more comprehensible.

Conclusion

Visual distraction through the use of in—car navigation systems can be potentially dangerous. If, therefore, a given NS is suspected to divert the driver's view too often or for a too long time span from the roadway ahead, this assumption has to be tested empirically.

1.4. Over-reliance

Over-reliance on technical systems, sometimes referred to as "overconfidence" means too much trust into the system. A typical case might be as follows. The driver has made a destination input into the navigation system in an unknown traffic environment. When he books at the display later on, he sees that his destination is at a right angle to the left of his car's position and he approaches a junction. That arrangement may influence him to try to turn left at the intersection. If his reliance on the system is very strong he may attempt to turn bet, even if it is prohibited at that junction. This effect is sometimes referred to as a "command—effect". The tendency to "obey" the system's message will be strengthened by the "confirming bias" people have: we always try to obtain information which justifies our actions and tend to ignore contradictory evidence (see e.g. MICHON et al 1990, REASON 1990).

Over-reliance will probably vary with the experience a driver has in using the system and with the driver's knowledge about the system's performance and failures. Probably, system "intelligence" will also influence the liability of the driver to command—effects.

Conclusion

For the present discussion it is important to note that in a study of a NS the routes chosen should include features, where over-reliance—effects can show up.

1.5 Deterioration of skills

Deskilling is often mentioned as a peril of automation. It means that a human operator, whose task (or parts of it) have been taken over by machines looses his/her skill because of back of practice. If — in an emergency situation— the operator has to go back to manual control, various factors work in favour of ineffective control. BAINBRIDGE (1983, p. 775):

> "... a formerly experienced operator who has been monitoring an automated process may now be an in experienced one. If he takes over, he may set the process into oscillation. He may have to wait for feedback, rather than controlling by open—bop, and it will be difficult for him to interpret whether the feedback shows that there is something wrong with the system or more simply that he has misjudged his control action. He will need to make actions to counteract his ineffective control, which will add to his workload."

Deterioration of skills has sometimes been found in pilots who had used auto-pilot-systems for longer time-periods (DREYFUS & DREYFUS 1986), as well as in the case of supervisory control tasks in power plants (SHARIT et al 1987, SHERIDAN 1987).

In our opinion, no skills of the driver are substituted by current NS. But as RASMUSSEN (198 6, p.113) points out:

> "An important point is that it is not the behavioural patterns of the higher levels that are becoming automated skills. Automated time—space behavioural patterns are developing while they are controlled and supervised by the higher level activities, which will eventually deteriorate, and their basis as knowledge and rubes may deteriorate."

What kind of knowledge could deteriorate through long-term use of NS? To answer this question one needs to know how drivers navigate in unknown environments, i.e. what kinds of knowledge they acquire and use. There is a back of experimental studies in this respect. SCHRAAGEN (1989) has recently reviewed the concepts from cognitive science that could be fruitful for this topic. He proposes three types of spatial knowledge, organised hierarchically: landmark and sensorimotor knowledge, procedural or route knowledge and surveyk knowledge. In principle, features of all three types of knowledge could deteriorate through long-term use of NS. Will map-reading ability decrease? Does

NS-use diminish driver's knowledge about traffic signs?

These questions can only be answered by long—term studies.

Conclusion

Although often mentioned in the context of in-car NS, it is not quite clear what skills can deteriorate on the driver's side. Moreover, possible skill deterioration would probably take its time. Therefore, we don't see a necessity of regarding deskilling as a permanent danger involved in the introduction of NS.

1.6. Problems with pedestrians and cyclists

This is no real aspect of its own: Paying less attention to unprotected road—users by drivers using NS is a function or consequence of more general aspects like "mental bad" or "visual distraction". It is nevertheless treated in an extra paragraph here because of its great accident potential and expected accident severity. ZIMMER (1990) lists "perceiving of unprotected road—users" under the heading "possible negative effects of driving aids", but he doesn't comment on it. RISSER et ab (1982). and GALSTERER & GSTALTER (1990), and CHALOUPKA et al. (1991) could demonstrate less careful driving with respect to unprotected road—users and worse information acquisition by drivers that had orientation problems.

Conclusion

Because of the relationship between driver orientation and safety of pedestrians and cyclists, test routes should always contain areas with unprotected traffic participants, when a NS is under study.

1.7. System misuse

New systems can often be misused in the sense that it is fun to play with them, to explore their possibilities etc. This is of particular importance if a driver plays with a NS during driving. But we are not going to establish "system misuse" in our list of effects of NS on behaviour, because of two main reasons. At first, even if playing with the system can be observed in a study it can be assumed that this kind of behaviour will not last for long. Moreover, this kind of system misuse doesn't seem to be site—specific, i.e. we wouldn't expect it to show up at certain kinds of roads.

Another kind of "misuse" is wrong interaction with the NS. This is an important aspect as well. Display and dialogue design should be carefully managed in the sense that errors in interaction with the NS are minimised. Proposals and requirements for good interface design can be taken from a large number of guidelines and design rubes or even standards.

2. RELEVANT CHARACTERISTICS OF DRIVERS AND THE ROAD ENVIRONMENT

In the following paragraphs, we shortly discuss critical variables of the driver, road environment and format of a display, which will considerably moderate the amount of strain induced by visual distraction.

2.1. Driving experience and driving skill

Like all skill acquisition processes, learning to drive a car to a considerable extent consists of substituting knowledge—based behaviour by rubes and rule—based behaviour shifts with growing experience to the bevel of automatic skill—based behaviour. Experienced drivers therefore have much more spare mental capacity that can be used to talk, listen to the radio, etc. compared to beginners. Different strategies of eye movements between beginners and experienced drivers have already been shown by MOURANT & ROCKWELL (1970). Experienced drivers combine various skills into more holistic strategies. This kind of skill integration favours experienced drivers in the task of including additional information requirements -like booking at a display- over beginners. This fact is possibly limited to the case of self—paced information.

It follows that a careful examination of the driver’s experience should take place in attempts to evaluate visual distraction by NS.

2.2. Map reading ability

The spatial ability of drivers varies to a large extent. People with bow spatial ability are going to have great problems reading a map but also problems of orientation with the “help” of displays using spatial representations of the road environment (like e.g. Travel-Pilot). This will certainly strongly effect the glance duration and thereby modify the extent to which visual distraction from the front view will be found in a study.

Several investigations have shown that approximately 40 % of the adult population have considerable problems in map reading. Especially in the case of experimental studies with small numbers of subjects, map—reading ability has to be taken into account as an important moderator variable affecting the degree of visual distraction by NS.

2.3. Complexity of the driving task

Mental bad will easier reach resource-limits of the driver the more complex a driving task is. Complexity differs between static characteristics of the road environment (e.g. different types of roads and junctions), the manoeuvres required (e.g. turning off versus straight ahead) and the time—variable parameters (e.g. traffic flow). The more complex the primary task of driving, the less spare capacity will be left. Task demand for this reason has to be controlled in experiments assessing the safety impacts of NS.

2.4. Knowledge of the road network

The same logic applies to the degree of knowledge a driver has about an environment. This can be confounded with the purpose of the trip (e.g. routes driven for professional reasons will tend to be better known than ravely used routes for recreational purposes).

2.5. Modality and format of the display

A number of studies has compared visual against auditory information given by NS. A detailed discussion of the advantages and drawbacks of both input modalities can be found in VERWEY & JANSSEN (1988). Some systems combine both input channels (e.g. LISB). The driver is alerted by an auditory signal when a message is displayed on the monitor. Oversimplified, auditory information seems to be better suited for drivers not used to electronic route guidance. With practice the visual modality may have advantages because it allows for better skill integration.

Modality effects have to be separated from differences caused by stimulus properties of the display. The level of pacing, the coding of information, hardware characteristics and the overall design of the interface clearly have great influences on how much a NS can interfere with the visual attention required by the driving task. General statements of the principles that should guide the design of the interface can be found in ZIMMER (1990).

3. CONCLUSIONS

There is a bot of possible effects that a navigation system can have on the safe conduct of a car. Even if a system is carefully designed according to the task at hand and to the design guidelines concerning the man—machine interface, this does not guarantee safety. New systems therefore always will have to be tested empirical by.

For positive and negative effects of the system oppearing during test drives it is proposed to choose a combination of test route characteristics and subjects that achieve a performance near resource—limited conditions. Because some driver variables, mainly driving experience, spatial abilities and the degree of local knowledge about the test area influence mental bad of the driver heavily, for experienced drivers the complexity of the traffic sites should be very high, whereas for novices and elderly, foreigners or people with bow spatial abilities average driving conditions will suffice.

Detailed instructions how to proceed in optimising the test route complexity for given samples of subjects are given in our research report (GSTALTER & FASTENMEIER 1991).

Once the difficulty of the overall test route has been selected the researcher should refer to a list of special traffic situations that allow for a testing of visual distraction and over-reliance effects.

Because of the great vulnerability of pedestrians and cyclists a safety evaluation should also include areas with sufficient numbers of unprotected road users.

All the necessary details for these subtasks can be found in GSTALTER & FASTENMEIER (1991).

4. PUTTING THINGS TOGETHER: EFFECTS OF NAVIGATION SYSTEMS ON DIFFERENT GROUPS OF DRIVERS

Chapter 1 has reviewed several possible influences NS can have on driver behaviour, Chapter 2 has argued that certain characteristics of drivers might moderate these effects. Chapters 1 and 4 try to combine the information from both chapters.

Chapter 5 finally will give detailed information on how a test route should be constructed to achieve high or medium complexity.

Drivers handicapped by inexperience, bow spatial ability and each of prior knowledge about the road network they have to navigate through are going to reach resource—limited information processing structures quite early. We therefore propose test routes with normal complexity and average traffic flow. The greater the driving experience, the better the drivers spatial abilities and the better the local knowledge of the test area, the more spare mental capacity these kind of drivers' will have. For effects of the NS on these drivers to emerge, the researcher should choose difficult traffic situations to allow for resource—limited conditions. Besides this general choice rube for the route's degree of complexity, special traffic sites or situations should be incorporated if "Visual cost", "Over-reliance" or "Pedestrians and cyclists" as effects can be assumed to occur because of the characteristics of the system under study. The next chapter will discuss, what situations should be included for what effects.

4.1.Mental load

As stated above, medium route complexity should be chosen, if the test drivers are novice or elderly drivers, if they have little orientation abilities or if they do not know the test areas. The contrary applies for experienced drivers, high spatial ability people and drivers with much local knowledge. They will only reach resource-limited conditions in difficult traffic situations. Of course, the distinctions taken between the drivers' variables are very rough. Moreover, subjects will probably seldom combine all good or all bad characteristics to represent "best case" or "worst case" groups of test drivers.
With respect to mental bad we propose to establish a route in a city because of its higher complexity over rural traffic situations and its greater economy in gathering relevant data on driving behaviour.

4.2.Visual cost

Visual costs of the use of NS are likely to occur in urban traffic conditions. But there is reason to believe that effects on drivers visual distraction can manifest themselves on rural streets as well. Whereas route—following is easy on motorways it may be quite a difficult task on rural streets with many curves, bad visibility or slopes. The course of the road cannot be anticipated as easy as on a motorway and thus affords more visual control of the roadway ahead. Distraction caused by the visual demands of reading an in—car display therefore could show observable effects on driver behaviour.

4.3. Over-reliance

Over-reliance effects can be studied in certain traffic sites which are listed in chapter 5. If a NS is suspected to facilitate over-reliance effects, these situations should be incorporated into test routes with medium complexity for novice and elderly drivers, foreign drivers or subjects with bow spatial ability. Traffic situations with overconfidence effects can be imagined on all kind of roads. If a researcher therefore has enough resources he is advised to check for these effects on rural and urban — roads. Even experienced drivers can be liable to over-reliance for reasons other than high mental bad. It may therefore not be necessary to confront them with high complexity conditions, unless they are judged to posses high spatial abilities. If drivers hold good general knowledge of the road environment but not a complete representation of all details (like the occurrence of one—way streets, the prohibition of turning manoeuvres at certain junctions etc) they may be liable to over-reliance effects under high complexity conditions. If they perfectly know the routes, e.g. because they are part of a daily routine, no over-reliance effects are likely to emerge. We would therefore not propose to include special over-reliance situations for these drivers.

4.4. Pedestrians and cyclists

A possible danger to unprotected road—users through NS use can never be excluded (exception: on motorways). Test routes should therefore always be composed in a way to ascertain the occurrence of pedestrians and bicyclists along parts of the track. That does not mean, that the route should be constructed to include large residential areas, but to allow for encounters with pedestrians on crosswalks etc. The advice to pay special attention to problems with unprotected road users is independent of driver characteristics.

5. TASK ELEMENTS FOR SPECIAL EFFECTS

This chapter lists certain traffic situations that should be included in test routes, if the NS under study can be suspected to be liable to divert the driver's visual attention, to produce over-reliance, or may bead to hazardous situations for unprotected road users. These situations should be included for both high and medium complexity test routes and should be involved in greater numbers then a representative route would allow for.

Visual distraction

Visual distraction can be dangerous and can have observable effects where the expectation of the driver is not in sufficient accordance with traffic reality in the near future. Driving behaviour —like most human behaviour— is strongly governed by continuity phenomena (NÄÄTÄNEN & SUMMALA 1976): In the absence of contradictory cues drivers anticipate the traffic environment to "behave" in a consistent, predictable way. That argument holds true for street characteristics (a motorway is supposed to continue as a motorway beyond a curve, a street going up a hill straight ahead is expected to bead straight ahead down the other side of the hill, etc.) as well as behaviour of other traffic participants (e. g., "common movement illusion", constant speeds and directions). Visual distraction therefore can become dangerous in situations where the diversion from the front view can bead the driver to miss visual cues from the road environment that signalise deviations from the continuos and "normally", expected traffic situations. Typical observations that can often be traced back to visual distraction are lane exceedences, especially when the route guidance deviates from usual standards. Other disturbances caused by visual distraction could be late or erroneous decisions and control actions.

Include for rural areas:
— narrow roads
— roads with curves and slopes
- curves with unusual radius and bad visibility
— narrowing roads
— junctions with unusual geometry and their approaches

Include for urban areas:
— work sites
— bane closures
— set—off carriageways

Over-reliance

Over-reliance in the sense that a driver strictly accepts all system proposals can lead to insufficient route selection if the system is not really good. But in most cases this will only bead to loss of time or comfort, create anger, etc. More interesting for our topic is the case where a system proposes a behaviour that can be dangerous (or is prohibited) or seems to do so. If a system gives a spatial representation of the road environment and indicates car position and travel destination (as Travel pilot for instance does), include situations, where the nearest way to the destination is not the best to reach it. Of special interest are cases where the nearest route is

— a one—way street in the wrong direction
- is prohibited or only for residents
— can only be reached by a prohibited manoeuvre

Over-reliance can probably also manifest itself in sudden manoeuvres meant to prepare for system proposals; e. g., a sudden lane—change without proper preparation (booking into a mirror, signalising the intention to other road users) if the system advises the drivers to turn off at the next junction. Therefore, include multilane approaches to all kinds of junctions. Overconfidence can also occur in situations where system proposals contradict alternative evidence from sign—boards (both in urban and rural areas).

Include parts of motorways near parking lots, access points, service areas.

Pedestrians and cyclists

In urban areas:

- Include 04,05,06,07
— Include pedestrian crossings on Cl to 07, if possible:
- Include Cl to 07 with cyclists but without bicycle crossings or bicycle ways;
  if possible:
- Include Kl to K4 with pedestrian crossings, especially with car turning right (left in UK)

in rural areas:

— Include narrow, complex local traffic guidance.

SUMMARY

How to proceed in constructing a test route for a given NS:

Given a certain NS, what are the most suited test routes to check the systems influence on driver behaviour with regard to safety effects? The following procedure, ordered into different steps, shows how this report can help to construct a suited source and destination for an experimental evaluation.

Step 1: Find the group of drivers the system is intended for

Step 2: Find the best suited degree of complexity of the test route

Step 3: Find the typical elements of a route with the given degree of complexity from Chapter 5.1.

Step 4: By referring to Chapter 2, are visual distraction or over-reliance possible effects of the system you are going to study?

Step 5: If you found one or more special effects in the previous step, turn to Chapter 5 to find the traffic situations these special effects can occur in, and include these situations in your route.

Step 6: Find a real course that approximately fulfils the demands of Steps 3 and 5

Step 7: If you have some degrees of freedom left, try to define start and destination of the test trip to shift the route towards representativeness. Use the information from Chapter 5 and the appendix.

Remarks: If the group of drivers the system is to support is unspecified, prefer worst case conditions, e.g. select novice and/or elderly drivers as subjects. This is because positive as well as negative effects of the system on driver performance will show up more clearly with these drivers.

If you don’t want to explore a general purpose navigation system but a system with a very specific application, say an address finding system for taxi drivers, then you should draw a representative sample of taxi drivers, define the events you want to observe as safety indices and accompany the taxi drivers for a certain time interval on the job. The narrower the application idea of the system is, and the better specified the target group of potential users is, the more is the question of what test route to select can be answered.

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