The traffic safety of the Carin Car Information and Navigation System

Summary report

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**Samenvatting**

The Carin Car Information and Navigation system has been analysed on its possible positive and negative effects on traffic safety. Requirements have been defined by which the possible negative effects should be minimized or possibly eliminated and the possible positive effects enhanced. Possible positive effects that resulted from this analysis are: avoidance of search behaviour, avoidance of detours, avoidance of unsafe locations and situations, and information on the vehicle condition. Possible negative effects were: compact disc changing while driving, distraction by route guiding advices, untimely presentation of route guiding advices, obstruction of the driver's view, illegal route guiding advices, the reaction on a disregarding of a route guiding advice, and (part of) the system causing injuries in case of an accident.

On an important part of the above subjects a literature study has been conducted. The findings are discussed and gaps in the present knowledge indicated. The in-car presentation of route guiding advices may distract a driver from his tasks to keep course and to account for the other traffic and the traffic environment.

A distraction by route guiding pictograms from the task to keep course can be avoided by selecting pictograms that require a shorter interpretation time than the available time period between two successive course corrections. In a laboratory study on the distraction from the task to account for the other traffic, it was found that deteriorations mainly occurred in incident situations. The deteriorations are largest for stimuli from a location right in front of the car, especially for elder drivers. Under circumstances all pictograms caused deteriorations. In difficult situations complex pictograms cause more deteriorations than simple ones. Most sensitive to deteriorations are elderly drivers and young males when driving at high speeds.

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The traffic safety of the Carin car information and navigation system

Summary report

G. Blikman

Delft, 1988
Delft University of Technology
Department of Transportation Planning and Highway Engineering

In assignment of Philips International B.V.
Safety is one of the most difficult and complex aspects of the traffic system. The reason hereof is that safety is not simply a matter of averages, but of deteriorations from the average. In traffic numerous actions are executed 100 thousand times effortlessly, but the one time the traffic process is disturbed, an accident is the result with all possible serious consequences. Accidents seldom or never have one cause. Usually they are the result of a critical combination of many circumstances. Traffic safety research therefore concentrates on locating that critical situation, the chance or probability of occurrence of that situation and the consequences hereof.

With regards to the decision process on traffic safety, three phases can be discerned: the risk analysis, the risk assessment, and the risk control. The risk analysis is directed mainly at locating critical circumstances, the chance of occurrence and the consequences hereof with the aim to give a qualitative and if possible a quantitative description or the risks. This report is concentrated mainly on the risk analysis of the Carin system. In the risk assessment phase the acceptable risk is weighed out against other aspects, such as comfort, accessability, speed, costs, and the like. The risk control phase is pointed at the optimal design of a measurement. In a well structured decision process, the decision phases are separated as much as possible. If e.g. in the risk analysis phase other interests such as costs already play a role, no objective impression of the actual risks may be received.

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1. INTRODUCTION

A research has been carried out on the traffic safety of the Carin car information and navigation system. This research comprised of a thorough theoretical analysis, a literature study and a series of experiments on the distraction caused by visual route guiding information. The results of this study are described extensively in the reports IA, IB, and II. This report presents an oversight of the most important findings.

The research was started with an analysis of the traffic safety of the Carin system. This analysis brought forth a number of possible effects on traffic safety, both positive and negative. On a part of the found possible positive and negative effects further study turned out to be necessary. This was started with a literature study.

The results of the safety analysis and the literature study are described in chapter 3, after a brief description of the Carin system in chapter 2.

After the literature search, a number of subjects still required further study. It was decided to start this study with experiments on the distraction of drivers caused by the presentation of visual route guiding pictogrammes.

An account of this experiment is given in chapter 3.
2. THE CARIN SYSTEM

Carin is an electronic car information and navigation system that is currently being developed by Philips. The system determines optimum routes and guides drivers to their destination. The route guidance information is presented to the drivers primarily aurally. A small flat panel display on which schematic pictogrammes can be presented serves as secondary information source.

The user interface comprises of a simple keyboard for communication of the driver with the system, a speech synthesizer chip, and a small flat panel display (figure 2.1).

Carin Basic System

The speech synthesizer presents the route guiding advices to the driver. Route advices are primarily given auditorily for reasons of traffic safety, as the driver task is already heavily loaded with visual information. However, in some cases the aural route guiding advice may not be heard or understood. For those cases a visual support of the route advices through a flat panel display is thought necessary.

On the dashboard-mounted flat panel display simple route guiding pictogrammes are presented to support the aural route advices. These route guiding pictogrammes are schematic representations of junctions and routes to be followed, comparable to the pictogrammes...
on sign posts.

On option the user interface may be extended with an image display which can show an outline map of the area concerned complete with special locations such as motels, recreation centres, etcetera. For traffic safety reasons, this display is automatically turned off as the vehicle starts moving, which is measured by wheel sensors. During a trip, the only communication between the system and the driver is the aural route advice, supported by the visual advice on the flat panel display.
CHANGES IN MODAL SPLIT PROVOKED BY CARIN AND THE TOTAL EFFECTS OF SUCH A CHANGE PROBABLY WILL BE SMALL

HURRYING OF A DRIVER WILL BE:

- DECREASED AS WITH CARIN ROUTE SEARCHING CAN BE AVOIDED
- INDUCED AS THE CORRECT ESTIMATION OF THE TRAVEL TIME WILL BE MORE DIFFICULT

CHANGING COMPACT DISCS WHILE DRIVING MAY UNDER CIRCUMSTANCES ENDANGER TRAFFIC SAFETY AND SHOULD THEREFORE BE MADE IMPOSSIBLE

AURAL INFORMATION SEEMS TO DISTRACT DRIVERS LESS THAN VISUAL INFORMATION
3. TRAFFIC SAFETY ANALYSIS AND LITERATURE STUDY

In this chapter will be discussed what information the traffic safety analysis and the literature study have yielded in terms of possible effects, the consequences hereof for (the traffic safety of) the Carin system, and information that has yet to be gathered.

Change in modal split

The presence of a Carin system could provoke a change in modal split (vehicle choice) from public transport to cars. However, it is probable that these changes will be small. For, many buyers of the system will not be able to choose a means of transport, but have to use cars and trucks anyway. Furthermore, it is likely that the total effects of in change in modal split will be small, as the positive and negative effects may, under the present traffic circumstances, well neutralize each other.

Estimating travel time

An underestimation of the travel time by the driver, may lead to hurrying when the driver notices his error and therewith to travelling at higher speeds and taking more risks. In two ways the presence of a Carin system may influence the correct estimation of travel time. The first effect is a positive one: through Carin route searching and therewith search time can be avoided. This will eliminate the hurrying of a driver after a search has taken too much time.

The second effect influences traffic safety negatively. Drivers with a Carin system will be inclined to inform themselves less on their itinerary than drivers without Carin and thus will be less able to estimate their travel time correctly. An adequate intermediate solution will be to present not solely the travel distance, but also the road types on which the route will be driven. Thus the estimated travel time can be based on more data.

Disc changing while driving

Changing compact discs while driving may under circumstances endanger traffic safety and should therefore be made impossible. Drivers first should have to bring their vehicle to a stop before searching for a new disc and inserting the correct disc into the drive.

Distraction by route guiding advices

Aural information seems to distract drivers less than visual information. At least the workload for processing visual information
VISUAL MESSAGES SHOULD NOT BE SHOWN ON THE FLAT PANEL DISPLAY WITHOUT AN ACCOMPANYING AURAL ROUTE GUIDING ADVICE;

VISUAL MESSAGES SHOULD NOT BE PRESENTED BEFORE OR SIMULTANEOUSLY WITH THE ACCOMPANYING AURAL ROUTE ADVICE

THE AMOUNT OF COGNITIVE PROCESSING IS VERY IMPORTANT FOR THE EXTENT OF DISTRACTION CAUSED BY AURAL MESSAGES

IT WILL BE ESSENTIAL THAT THE CARIN AUDITORY ROUTE ADVICES REQUIRE VERY LITTLE THOUGHT OR INTERPRETATION

THE LUMINATION OF THE DISPLAY HAS TO BE SUFFICIENT IN THE DAYLIGHT AND YET MUST NOT BLIND AT NIGHT OR WHEN DRIVING IN A TUNNEL

IN THE STUDIED LITERATURE HARDLY ANY RELATION HAS BEEN PLACED BETWEEN THE TASK OF A DRIVER AND THE DISTRACTION FROM THIS TASK

ONE OF THE MAIN POSITIVE EFFECTS OF CARIN WILL BE THE AVOIDANCE OF SEARCH BEHAVIOUR
is considerably heavier than for processing the same information presented aurally. Thus, it is important that in the Carin system the visual messages stay only a secondary information source. Therefore, are two conditions. Firstly, visual messages should not be shown on the flat panel display without an accompanying aural route guiding advice. Secondly, visual messages should not be presented before or simultaneously with the accompanying aural route advice. Drivers should not be given a choice of information source.

**Distraction by aural route guiding advices**
The amount of cognitive processing required is very, if not most important for the extent of distraction caused by the presentation of aural messages: with an increase of the complexity of auditory messages, both peripheral vision and tracking accuracy deteriorate. Thus it will be essential that the Carin auditory route guiding advices transmitted to drivers require very little thought or interpretation by the driver before it can be acted upon. Also of influence on the amount of distraction caused by aural information may be the age and sex of drivers and tonal aspects of the voice synthesizer.

**Distraction by visual route guiding advices**
The lumination of the display has to be sufficient for the driver to see the pictograms in the daylight and yet must not blind the driver at night or when driving in a tunnel. Under circumstances, the presentation of visual route guiding information may cause deteriorations of the driving task. On the variables that influence this distraction hardly any information was presented. It is to be expected that the extent of distraction by visual route guiding advices is related to the amount of cognitive processing required. It is striking that in the studied literature hardly any relation had been placed between the task of the driver and the distraction from this task. In most reports it is im- or explicitly posed that driving is a mainly visual task and that thus the time that is spent on any additional visual tasks has to be minimised. Usually values of 1-2 s are mentioned but not explained.

**Avoidance of search behaviour**
One of the main positive effects of Carin will be the avoidance of search behaviour. Especially under difficult traffic conditions this effect of the Carin system will increase traffic safety enormously.
WITH A CARIN SYSTEM UNNECESSARY DETOURS WILL BE AVOIDED; THIS DECREASES THE EXPOSURE TO THE TRAFFIC RISKS

AFTER THE START OF AN AURAL ADVICE THERE HAS TO BE TIME FOR THE ADVICE TO BE SPOKEN, FOR THE DRIVER TO REACT, TO POSSIBLY INTERPRETE A ROUTE GUIDING PICTOGRAMME, TO REACT AGAIN, AND TO EXECUTE THE ACTION

IT IS RECOMMENDED TO CALCULATE WITH A REACTION TIME ON AURAL MESSAGES OF 3 S AND ON VISUAL MESSAGES OF 1.2 S
Avoidance of detours
With the presence of a Carin system, any unnecessary detours will be avoided and therewith the travel distances limited. This decreases the exposure to the traffic risks and therewith contributes positively to traffic safety.

Untimely presentation of route guiding advices
The Carin route guiding advices should be given well in time in order to give the driver enough time to execute whatever action is necessary. Sometimes (e.g., on a motorway), it will be preferable to present route guiding information at a certain distance before a junction, c.q. before the first sign posting. After the start of a Carin aural route guiding advice there has to be time for the aural advice to be spoken and for the driver to react, to possibly interpret a route guiding pictogramme, to react again, and to execute the necessary action.

Speaking times for aural route guiding advices
A choice can be made whether for each particular Carin route advice a calculation is made with the actual speaking time or whether for all route advices a calculation is made with the maximum speaking time of the longest route advice.

Reaction times
Reaction times have been reported varying from 400 to 4900 ms. Aural information is likely to be processed less fast than visual information as the "depth of processing" involved is higher and drivers will be less alerted when receiving aural information. The reaction time for aural messages may be supposed not to be extreme long as drivers still will have a reasonable level of alertness and the messages contain a certain urgency. It is recommended to have the Carin system calculate with a reaction time on aural messages of 3.0 s. It is suggested to calculate with reaction times on visual messages of 1.2 s. Although the reaction times suggested above are merely hypothetical, no high priority should be given to a reaction time study. For firstly, the reaction times are based on high percentile values. Secondly, higher reaction times than suggested can rather easily be compensated by a shorter time period for other actions.

Interpretation times for visual route guiding messages
The interpretation time for the Carin route guiding pictogrammes can
THE CONFIGURATION OF THE PICTOGRAMMES SHOULD BE SIMPLE; AN ADVICE CONTAINING MORE THAN ONE COMPONENT SHOULD PREFERABLY BE PRESENTED SEQUENTIALLY RATHER THAN SIMULTANEOUSLY; THE INFORMATION SHOULD FORM ONE FIGURE AND THE MOST IMPORTANT ROAD SHOULD BE ACCENTED VISUALLY
be minimal through a good design style. A good indication of easy interpretable styling methods is given by the configuration styles of figure 3.1. The configuration styles of figure 3.2 were less favourable.

Figure 3.1: Favourable configuration styles (source: Erke, Richter, and Richter)

Figure 3.2: Less favourable configuration styles (source: Erke, Richter, and Richter)

The configuration of the Carin route guiding pictogrammes should be simple. An advice containing more than one component should preferably be presented sequentially rather than simultaneously. The pictogrammes must give only that information the driver needs in order to execute a manoeuvre. The amount of information given should form one figure and the most important road should be accented visually. Very complex junctions like the cloverleaf and the multi-gore are often faced with the impossibility to design a picture that is both simple and an exact representation of the geometry. Experience with the route guiding pictogrammes is an important
IT IS SUGGESTED TO CALCULATE WITH THE COMFORTABLE AND SAFE VALUE OF 2 \( \text{m/s}^2 \) FOR THE DECELERATION.

THE BEST MESSAGE RECOLLECTION OCCURRED WITH SHORT STYLE MESSAGES.

CORRECT RECOLLECTIONS WERE FOUND FOR DIVERSION ROUTES CONTAINING 2-6 UNITS OF INFORMATION; DEPENDING ON THE TESTING METHOD; IT CAN NOT BE STATED THAT THE CARIN MESSAGES WILL NOT OR HARDLY NOT BE FORGOTTEN.

NO PART OF THE CARIN SYSTEM SHOULD UNDER ANY CIRCUMSTANCES OBSTRUCT (A PART OF) THE DRIVER'S VIEW.

IT SHOULD BE MADE CLEAR TO THE USERS THAT, AFTER AN IGNORATION OF A ROUTE ADVICE, CARIN IMMEDIATELY CALCULATES A NEW ROUTE.

IT WILL BE IMPORTANT TO POINT OUT THAT ROUTE ADVICES MAY BE ILLEGAL.
factor in reducing interpretation time.
To decrease the level of inexperience of novice users each buyer could be presented a manual with all possible pictogrammes. Better even would be a presentation on video tape.

**Times to execute a necessary action**
For the calculation of the braking time, the following data are required: the velocity of the car (measured continuously by the wheel sensors), the velocity in the bend (follows from the road class), the deceleration (suggested to be fixed at the comfortable and safe value of 2 m/s²), and the foot movement time from accelerator to brake pedal (can be fixed at 300 ms).
The time necessary to change lanes is not easily determined, as this varies strongly with the traffic flow intensity.

**The chances that route guiding messages are forgotten**
The time from the ending of a message to the message recollection has not found to be related to the retention rate (the tested time periods varied from 5 - 45 s).
The smallest error percentage occurred with messages in short style language as compared to staccato and conversational style.
The message load turned out to be the most critical factor in the message retention. The literature reports a correct recollection by all or almost all test subjects of diversion routes containing 2-6 units of information, dependend on the testing method.
The Carin route guiding messages will contain only one or two units of information, which does not mean that those messages will not or hardly not be forgotten. For firstly the messages as tested in the literature contained street and exit names, whereas the Carin messages will contain only numbers which were found to be recollected less easy. Secondly, for older people the percentage of subjects making a route error was found to be 10 - 20% higher than the values of younger subjects presented above.

**Obstruction of the driver's view**
No part of the Carin system should under any circumstances obstruct (a part of) the driver's view.

**Illegal route guiding advices**
It is likely that drivers start following-up route guiding advices blindly: after 1000 legal advices they do not expect the 1001st advice to be illegal. Therefore it should be made clear that should ever a route guiding advice be ignored, the Carin system immediately calculates a new route, starting from the present position.
It will be important to at least point out to drivers that route
IT IS PREFERABLE TO INFORM DRIVERS OF A DEVIATION AFTER THE
CALCULATION OF A NEW ROUTE AND INFORM THEM OF THIS ROUTE TOO.

THE CALCULATED INDICATOR NUMBERS ARE ROUGH ESTIMATIONS FOR THE RISKS
ON A CERTAIN ROAD.
guiding messages may be illegal and that the route guiding information comprises no commands but advices.

Reaction on a disregarding of a route guiding advice
The Carin system should inform drivers of a deviation from the planned route, on a location that is so far from the deviation point that any correction of the mistake by the driver is not possible. It is preferable to inform drivers of a deviation after the calculation of a new route and inform them of this new route too.

Avoiding unsafe locations and situations

The unsafety of certain roads, locations, manoeuvres and situations / The possibility to use traffic safety criteria.

The application of traffic safety criteria in the Carin system for calculating optimum routes is not simple, as unsafety is a complex dynamic process in which the interaction of a series of critical circumstances leads to an accident.

Table 3.1: Indicator numbers for the estimation of accidents with casualties; Source: Janssen, 1985

<table>
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<th>Kencijfers voor de schatting van het aantal letselongevallen</th>
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<th>per kruisingen per jaar</th>
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<td>per miljoen gere-</td>
<td>per totaal</td>
<td>ongevals-</td>
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<tr>
<td>autosnelweg</td>
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<tr>
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<tr>
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* \( f_1 = 1,12 \times I \times 0,34 \cdot 10^{-3} \); bij I = 40.000 motorvoertuigen per dag \( f_1 = 0,040 \)

** \( f_2 = 1,09 \times I \times 0,31 \cdot 10^{-3} \); bij I = 80.000 motorvoertuigen per dag \( f_2 = 0,035 \)

*** inclusief kruisingen
A way to weigh a safer route against a detour may be to compare the products of the travel time and the unsafety index.

The appliance of the safety criterion within build-up areas on the basis of the values of Table 3.1 is not recommended.
It is not possible to use in the Carin system detailed information from traffic safety studies. Therefore, it is recommendable to incorporate more general data into the Carin programme.

Janssen (S.T.M.C, 1985) calculated the average number of accidents with casualties per vehiclekilometre and per junction for 7 road classes outside residential areas and 2 within. The calculated numbers are only very rough estimations for the risks on a certain road, but nevertheless useful for Carin (table 3.1).

The extent to which traffic safety should be used as criterion for determining optimum routes

The extent to which the Carin system should select a safer route is difficult to indicate as this can not be determined objectively.

A way to weigh the advantage of a safer route against the disadvantage of a detour may be to compare the products of the travel time and the unsafety index of two alternative routes (see figure 3.3). To prevent Carin from selecting routes with excessive detours, the maximum detour percentage could be fixed at e.g. 15%.

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**Route A:**
- Motorway; 2 x 2 lanes
- Length: 90 km; 12 junctions
- Travel time T: 45 minutes
- Unsafty index S: \(90 \times 0.04 + 12 \times 0.82 = 13.4\) (see table 3.1)

**Route B:**
- Single carriageway road, prohibited for slow traffic
- Length: 67 km; 22 junctions
- Travel time T: 40 minutes
- Unsafty index S: \(67 \times 0.25 + 22 \times 0.36 = 24.67\) (see table 3.1)

\[\text{T.S (Route A)} = 45 \times 13.4 = 603 \quad \text{T.S (Route B)} = 40 \times 24.67 = 987\]

\[\Rightarrow \quad \text{According to the criterion of weighed safety, Route A should be selected in spite of its detour of 5 minutes}\]

---

*Figure 3.3: Comparison of two alternative routes via a weighed unsafety index.*

The appliance of the safety criterion within build-up areas on the basis of the values of table 3.1 is not to be recommended. Firstly, this would lead to the selection of many rat runs and therewith improper use of minor roads.

Secondly, the minor roads that would be selected for the through
THE INCORPORATION OF AN EXTENSIVE WARNING SYSTEM WILL CAUSE PROBLEMS

SUBMITTED TO A CONSTANT CHECK SHOULD BE THE BRAKING SYSTEM, TYRE WEAR, THE LIGHTING SYSTEM, THE STEERING SYSTEM, AND THE STEERING CHARACTERISTICS

SHARP EDGES AND PROTRUDING OBSTACLES ON ANY PART OF THE CAR IN SYSTEM SHOULD BE AVOIDED
going traffic would be unsafer than the low average value for the traffic unsafety index indicates.

The dangerous road situations a driver should be warned off
The incorporation of an extensive warning system will cause some problems. Traffic unsafety is caused by a combination of circumstances, meaning that a specific characteristic is only critical in combination with other circumstances. A sharp bend, for instance, will be unsafe in combination with a high speed, worn tyres, and a wet road surface, but absolutely safe in combination with a low speed and a dry road surface.

The incorporation of an adaption for receiving broadcast out-car warnings may be relatively simple. First this information may be rather general and contain only information on traffic jams, road works, frozen road surfaces, and the like (broadcast through the future Radio Data System e.g.). In a later stadium the information may be extended to local information broadcast via road-side transmitters.

Information on the vehicle condition
With an adequate coordination between the Carin design and car designs, a continuous check of vital parts of the vehicle could be made possible and the condition of the vehicle be presented to the driver. Submitted to this constant check should be for traffic safety reasons: the braking system, tyre wear, the lighting system, the steering system, and the steering characteristics.

Aggressive shape
Sharp edges and protruding obstacles on any part of the Carin system should be avoided. If this is absolutely impossible, aggressive parts should be adjusted in such a way that they break off in case of a collision. For the remote control unit a comfortably located container should be designed.
THE EFFECTS ON THE DRIVER PERFORMANCE OF VISUAL IN-CAR ROUTE GUIDING ADVICES HAVE BEEN RESEARCHED IN A LABORATORY.

IN THE LABORATORY THE DRIVER TASKS WERE SIMULATED CAREFULLY.

THE PICTOGRAMMES WERE PROJECTED ON A SMALL DISPLAY IN THE DASHBOARD OF THE MODIFIED CAR INTO WHICH TEST SUBJECTS WERE SEATED.
4 EXPERIMENTS ON THE DISTRACTION BY IN-CAR VISUAL ROUTE GUIDING PICTOGRAMMES

A series of laboratory experiments has been conducted with the aim to compare the performance of test subjects on the driver task during the presentation of route guiding pictograms with results when no pictograms were shown.

4.1 Experimental setting

Car driving is a triple task: under all circumstances a driver has to keep his vehicle on the road (tracking), to account for the other traffic and the traffic environment, and to follow his route. Of importance for traffic safety is the question whether the presentation of visual route guiding messages, which assist the driver in the following of his route, prevents the driver from performing his other two tasks.

This was studied in a series of laboratory experiments. The study was carried out without the presentation of aural route guiding advices, as this situation can be marked as most critical.

Figure 4.1 Dashboard-mounted display for the projection of pictograms.
THE TRACKING TASK WAS SIMULATED BY KEEPING A FIGURE ON A MONITOR BETWEEN TWO PARALLEL LINES
During the experiments at certain intervals, pictogrammes were projected on a small display mounted into the dashboard of the car in which test subjects were seated (figures 4.1 and 4.2). These pictogrammes were schematised versions of the real Carin pictogrammes adapted for use in a laboratory.

Figure 4.2: Modified car in which test subjects were seated

The simulated tracking task was preferred to be able to be performed automatically and to allow the same deteriorations from a straight line as in real traffic. This was achieved by a figure on a monitor to be kept between two parallel lines (figure 4.3).

Figure 4.3: Monitor for the simulation of the traffic task
THE TASK TO ACCOUNT FOR THE OTHER TRAFFIC WAS SIMULATED THROUGH A PERIPHERAL REACTION TEST; DISTINCTION WAS MADE BETWEEN ENCOUNTER SITUATIONS AND INCIDENT SITUATIONS
The tracking task was executed through a steering wheel. The lateral speed was related to the longitudinal speed, which was able to be adjusted by the test subjects themselves through means of an accelerator pedal.

The task to account for the traffic and the traffic environment was simulated through a peripheral reaction test in which distinction was made between the encounter situation and the incident situation. Encounter situations were simulated by having yellow peripheral lights gradually reach their full brightness, followed by a lumination of some seconds. Subjects were required to react by pushing the horn lever situated in the centre of the steering wheel. Incident situations were simulated by the flashing of a yellow light followed by a small red light next to it. Not always the flashing of the yellow lights was accompanied by the lumination of the small red light very near the yellow one. Subjects were to react on the flashing of a yellow light and the subsequent lumination of a red one by pressing a brake pedal. When the flashing of a yellow light was not succeeded by the lumination of a red light, subjects were required not to take any action. The peripheral lights were situated in a semi-circle round the test subjects, at a distance of 5 m, set at 20°, 50°, and 80° on either side of the line of sight.

The whole experiment was controlled by a personal computer (IBM-AT). Head and eye movements of test subjects were recorded through a video camera (figure 4.5)

Figure 4.5: Through the video recordings it was checked whether the test subjects were watching a presented pictogramme or attended themselves to the tracking task during the presentation of a route guiding pictogramme
OF THE VARIABLES THAT WERE OF INFLUENCE ON THE RESULTS OF THE
EXPERIMENTS THE MOST EXTREME MANIFESTATIONS WERE USED, AS UNSAFETY IS
THE RESULT OF A COMBINATION OF THE MOST CRITICAL CIRCUMSTANCES.
4.2 Variables

Allowance had to be made for the variables that are of influence on the results of the experiments. Of the variables to be tested, the most extreme manifestations were used in the tests. For traffic unsafety is the result of a combination of critical circumstances. Under normal circumstances an average driver will not experience any difficulties in safely dealing with route guiding pictogrammes.

Experience with the peripheral reaction task
The test subjects were given ample opportunity to practise the required reaction on the lumination of the yellow and red peripheral lights in order to acquire the same skill as for actions in real traffic.

Complexity of the peripheral reaction task
The peripheral reaction task comprised of simulations of encounter situations (lumination pattern 1), of incident situations (lumination pattern 2), and of a dummy lumination pattern to keep test subjects alert.

In the test the three lumination patterns occurred in the ratio:

pattern 1 : pattern 2 : pattern 3 = 1 : 1 : \( \frac{1}{3} \)

The peripheral detection capability was tested with peripheral lights, set at 20\(^\circ\), 50\(^\circ\), and 80\(^\circ\) on either side of the line of sight.

Experience with the tracking task
The tracking task had to be well under control by each test subject just as in real traffic situations. Therefore subjects were given opportunity to practice the tracking task before the tests until their skill was sufficient.

Complexity of the tracking task
The complexity of the tracking task increases as the speed becomes higher.

To create realistic circumstances, the test subjects were free to determine their "speeds" themselves and thus choose their own stress level. This was realized by defining a maximum speed below which subjects could freely adjust their speed through the accelerator pedal of the test car. To test the effects of speed, one group of subjects was allowed a higher maximum speed than the other ones.
Experience with the route guiding pictograms
Experience with the route guiding pictograms will result in shorter interpretation times and may also result in a smaller amount of cognitive processing required. To prevent subjects from becoming experienced already in the first series of tests, the duration of the tests was limited for each subject to approximately three quarters of an hour.

Complexity of the route guiding pictograms
The complexity of the route guiding pictograms is the most important factor for the duration of the interpretation time and could also have effect on the concentration with which is watched, which in its turn may affect the peripheral detection capability through a narrowing of the peripheral field. To test this, a series of simple route guiding pictograms and a series of complex pictograms were used in the experiments.

Characteristics of the test subjects
The characteristics of test subjects are of great importance for the way in which tasks are performed: tracking, watching the peripheral lights and reacting upon their lumination, and interpreting the route guiding pictograms and following a route. These tasks were to be executed mainly simultaneously and only partly sequentially.

Tracking is more difficult for old people than for young ones, but they overcompensate their infirmities by driving slowly. Young, especially male drivers show a tendency to speeding and taking high risks.

The peripheral detection capability is strongly influenced by age. With the growing of the years it deteriorates, which is a handicap even more as old people also have difficulty in turning their heads, which otherwise could have compensated the deteriorated peripheral vision.

The subjects have to react on the lighting of the peripheral lamps. As the reaction velocity deteriorates with age, older people will score less on this task than younger ones.

The task to interpret the route guiding pictograms is most difficult for elder people as they experience more difficulty in learning something new and in remembering something that has recently been learned.

The accommodation of the eyes, which is necessary to focus the eyes from a point in the distance onto the display, also becomes more difficult as people grow older.

In the interpretation of the schematized route guiding pictograms people with a low level of education and a profession in which little thinking is necessary may experience greater difficulties
THE IN-CAR PRESENTATION OF PICTOGRAMMES UNDER CIRCUMSTANCES DOES LEAD TO A DETERIORATION OF THE REACTION CAPABILITY

THE GROUP OF YOUNG MALE DRIVERS MOST OFTEN DEMONSTRATED A DETERIORATED REACTION PERFORMANCE

ELDERLY DRIVERS SHOW A DETERIORATED REACTION PERFORMANCE AT COMPLEX PICTOGRAMMES IN THE INCIDENT SITUATION AND FOR STIMULI COMING FROM LIGHTS AT 20°
The ability to perform a multiple task deteriorates with a climbing of the years. Old people prefer to execute actions sequentially rather than simultaneously.

Thus three groups of people were, for different reasons, marked as possibly critical:

- young male drivers (aged 18 - 24)
- elderly people (60+)
- people with a low level of education and a profession in which little thinking is necessary

To enable a comment on these groups, they were compared with a reference group of non-critical drivers, consisting of:

- people of moderate age (35-45), of both sexes, and with a moderate to high level of education and a profession in accordance with the education

4.3 Results

Overlooking the outcome of the experiments, the conclusion seems justified that the in-car presentation of pictogrammes under circumstances does lead to a deterioration of the reaction capability.

4.3.1 Groups of test subjects

**Group I: young male drivers**
The group of young male drivers most often demonstrated a deteriorated reaction performance, resulting not so much in longer reaction times as in more reaction failures. Cause for the deteriorated reaction capability presumably is the higher task load as a result of the self-selected higher speed, in combination with the inexperience of the subjects.

**Group II: elderly drivers**
Elderly drivers show a deteriorated reaction performance (that is already low without pictogrammes being shown) at complex pictogrammes in the incident situation and for stimuli coming from lights at 20°. The latter may be related to a typical characteristic of elderly people: a deteriorated peripheral vision.
WITHIN THE GROUP OF DRIVERS WITH A LOW EDUCATIONAL LEVEL MAJOR REACTION TIME INCREASES OCCURRED SELDOMLY

SUBJECTS OF THE REFERENCE GROUP DO NOT PROMINENTLY DISTINCT THEMSELVES ON ONE OR MORE ASPECTS

DRIVERS HARDLY ARE DISTRACTED BY ROUTE GUIDING PICTOGRAMMES IN THE ENCOUNTER SITUATION BUT ARE DISTRACTED IN INCIDENT SITUATIONS
Group III: drivers with a low educational level

Within group III, major reaction time increases occurred seldomly. If they happened it was in the incident situation and especially at the presentation of complex pictograms.

Group IV: reference group

Subjects of the reference group do not prominently distinguish themselves on one or more of the aspects that may influence the deterioration of the reaction performance. In the incident situation they frequently experience major reaction time increases.

4.3.2 Variables

Situation of the traffic process

Drivers hardly are distracted by route guiding pictograms in the encounter situation, but in incident situations the presentation of a stimulus at a moment when subjects watch the display leads to considerable larger reaction times.

The consequences of these implications would be serious for real traffic situations: the relative less critical (encounter) situations, in which drivers have ample time to react, still would be able to be dealt with sufficiently, but the execution of the correct and timely action in the most critical situation (incident situation), in which an accident can only be prevented through a quick emergency manoeuvre, would be affected by the presentation of pictograms.

For the relative low impact in the encounter situation, a fourfold possible explanations can be put forward. First, the urgency of reaction in the encounter situation is only moderate (which is expressed via the gradual illumination of the peripheral lights in the experiments and a gradual approach of oncoming and crossing vehicles in real traffic). This results in considerable larger reaction times in the encounter situation than in the incident situation. Therefore the sensitivity to reaction time increases in the incident situation is considerably larger than in the encounter situation.

Second, test subjects may have been adapting a high attention level during the simultaneous interpretation of a pictogramme and the execution of the steering task. This may have been sufficient to compensate the higher task load in the encounter situation, but insufficient to do the same in the incident situation.

Third, test subjects may have been alerted during the presentation of a pictogramme, more or less expecting a stimulus.

Fourth, test subjects may have been able to respond quicker (in casu: pressing the horn lever) during the watching of the dashboard, when the horn button is already within their field of vision, than
THE DETERIORATING EFFECT OF PICTOGRAMMES SEEMS LESS WHEN THE STIMULI ARE PRESENTED FROM AN ANGLE OF 50° WITH THE LINE OF SIGHT AND LARGER WHEN THE STIMULI COME FROM AN ANGLE OF 20°.

THE REACTION TIME INCREASES FOR STIMULI FROM 20° MAY BE REDUCED BY POSITIONING THE PICTOGRAMME DISPLAY HIGHER IN THE CAR.

THE EFFECT OF THE PICTOGRAMME COMPLEXITY WAS NOT AS MANIFEST AS MAY HAVE BEEN EXPECTED; THIS MAY HAVE BEEN CAUSED BY THE STILL RELATIVE SIMPLE CONFIGURATION OF THE COMPLEX PICTOGRAMMES.
when they attend themselves to the steering task on a monitor in front of them.

Of the four possible explanations above, only the first and second are connected with real traffic situations and the third and fourth are related to the experimental setting.

Angle with the line of sight
The effects of the angle between the line of sight and the direction from which a stimulus is presented does not seem to be without influence on the deteriorating effect of the presentation of pictograms, although the influence varies over the four groups of test subjects.

The deteriorating effect of pictograms seems less when the stimuli are presented from an angle of 50° with the line of sight. This is supposed to be related to the little differences between the situation in which subjects are watching a pictogram and the situation in which they are attending themselves to the tracking task: in both situations a signal from 50° has to be detected peripherally.

Opposed to this, the deteriorations are larger when the stimulus is given from a light at 20° with the sight line. Presumably this is caused by the good sight drivers normally have over that location, an advantage that is lost when drivers watch the dashboard. Especially elderly drivers suffer under a large deterioration of the reaction capability for stimuli from lights at 20°. This is expected to be related to the deteriorated peripheral vision of elderly people.

The consequences of the above for real life traffic are contrary. It is to be expected that the larger part of the traffic a driver has to account for, approaches from an angle of some 20°-50° with the sight line. An apparent smaller deterioration of the reaction capability for stimuli from about 50° therefore would be favourable, but a larger sensitivity to deteriorations for stimuli from + 20° would be most unhappy.

A possible way to reduce the many reaction time increases for stimuli from 20°, could be a higher positioning of the pictogramme display in the car.

Complexity of route guiding pictograms
The effect of the route guiding pictogramme complexity was not for all groups of test subjects as manifest as may have been expected. This may have been caused by the high reality level of the complex pictogrammes. For, the selected complex pictogrammes still contained no more than two units of information, in coordination with the designed real Carin pictogrammes. It is likely that pictogrammes containing more units of information will cause larger deteriorations
SIMPLE PICTOGRAMES ALSO INDUCED REACTION TIME INCREASES, BUT ON AVERAGE THE EXTENT OF THE DETERIORATION WAS SMALLER THAN FOR COMPLEX PICTOGRAMES.
of the reaction capability.
The complexity seems to have the least effects on subjects of group IV (reference group) and the most on the test subjects of group I (young male drivers) and group II (elderly drivers). It seems that the extra work load of interpreting a complex pictogramme, under normal conditions causes no larger deterioration of the reaction performance than interpreting a simple pictogramme. However, under certain critical circumstances (heavy task load for tracking, inexperienced drivers, elderly drivers, or drivers not used to a cognitive processing task), a complex pictogramme does seem to lead to larger deteriorations. It should be noted though, that simple pictograms also induced deteriorated reaction performances, but on average the extent of this deterioration was smaller than for complex pictogrammes under the same conditions.
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