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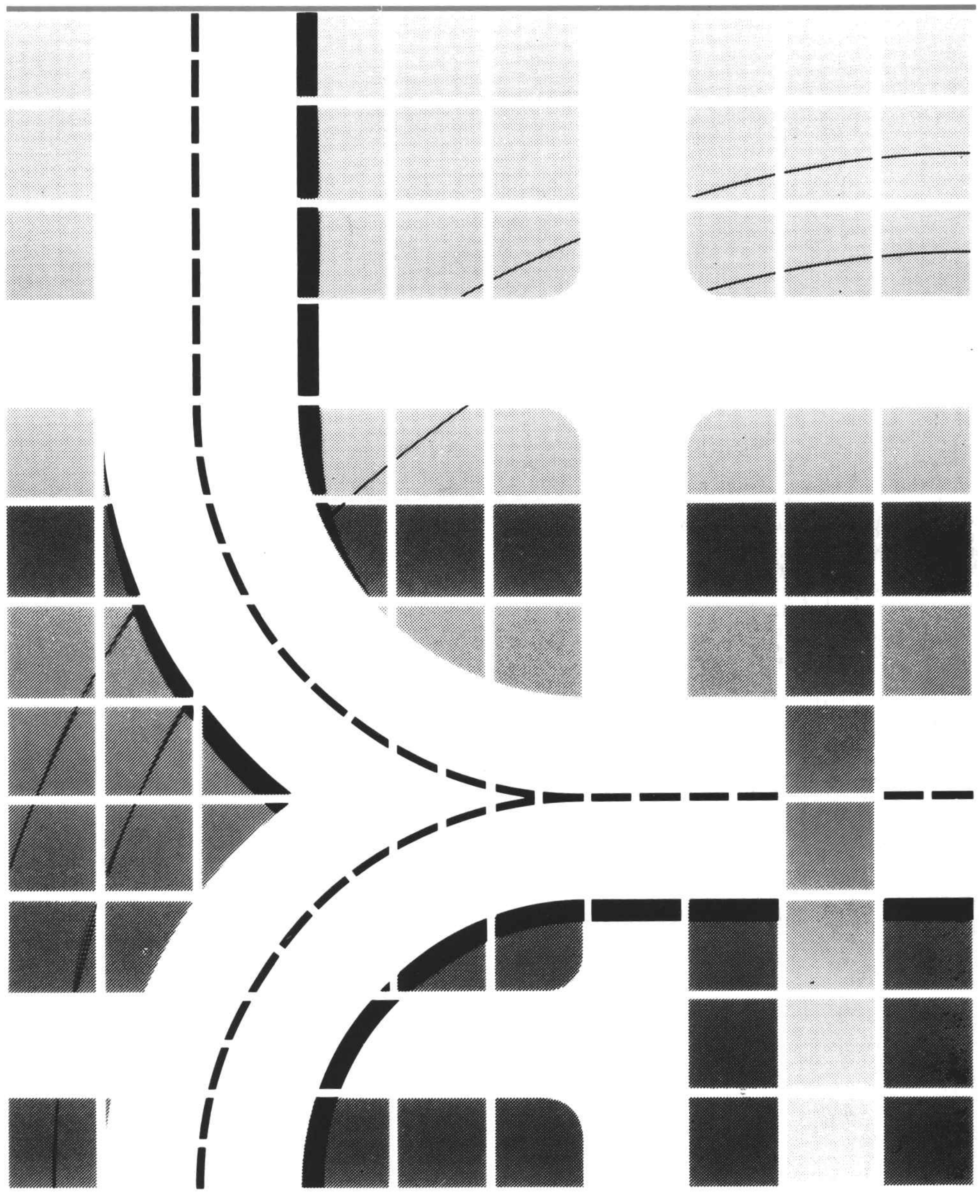
The Traffic Safety of the Carin Car Information and Navigation system II

Distraction by in-car visual route guiding pictogrammes

April 1988

G. Blikman



TU Delft
Delft University of Technology

Faculty of Civil Engineering
Department of Transportation Planning and Highway Engineering

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11. Samenvatting

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 pictogrammes from the task to keep course can be avoided by selecting pictogrammes 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 pictogrammes caused deteriorations. In difficult situations complex pictogrammes 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 II

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G. Blikman

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

In assignment of Philips International B.V.

PREFACE

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 occurrance 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 assesment, and the risk control.
The risk analysis is directed mainly at locating critical circumstances, the chance of occurrance and the consequencess 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 assesment 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.

Prof. E. Asmussen,
Delf University of Technology
Department of Transportation Planning and Highway Engineering
Traffic Safety Division

CONTENTS

1 INTRODUCTION

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, for reasons of traffic safety, presented to the drivers primarily aurally, 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 aural route advices is given through a dashboard-mounted flat panel display on which route guiding pictogrammes are presented. These pictogrammes are schematic representations of junctions and routes to be followed, comparable to the pictogrammes on sign posts.

In a previous study, the traffic safety of the Carin system has been analysed with the so-called phase model of the transport and traffic unsafety process and subsequently studied through a literature study (reports IA and IB).
From the analysis and subsequent literature study, it followed that little is known on the possible distraction of a driver from his driving task by the presentation of visual route guiding advices. Considering the great importance of this subject (regarding the possible consequences of distracted drivers on traffic safety), it was recommended to give prime priority to this subject in a follow-up study.

The underlying report is the result of this follow-up study. It describes a research on the effects of a presentation of visual route guiding advices on the driving task. For this purpose the driving task was divided into a task to follow a certain route, a task to keep course (tracking) and a task to watch the traffic and the traffic environment and react on it. Within the latter task two kinds of situations were distincted: encounter situations and incident situations[1] (chapter 2).
In chapter 3 a discussion is given of possible ways to determine the effects of route following through visual route guiding advices on the task to keep course and the task to account for the other traffic and the traffic environment. Also are priorities given for the different tests.
In chapter 4 a fully detailed description is given of the selected

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1) A description of these situations is presented in the enclosure

experimental programme. This includes an introduction (4.1), the requirements the experimental setting has to meet (4.2), the variables that play a role in the tests (4.3), the number of tests and test subjects (4.4), and the test procedure (4.5).
Chapter 5 presents the results of the experiments in 16 tables that each throw a light on the measured values from a different angle. In this chapter, no possible explanations and relation patterns are sought yet.
In chapter 6, finally, an evaluation of the results is given and conclusions are formulated on the extent of the distraction of a driver by in-car visual route guiding information and the variables that are of influence hereon.

2 THE DRIVING TASK

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. In a car with an information and navigation system like Carin, the driver is assisted in the following of his route. Of importance for traffic safety is the question whether the presentation of visual route guiding messages prevents the driver from performing his other two tasks.

In real traffic the distraction will often be minimal as drivers are in the first place guided by aural route guiding advices and are likely to at least have understood a part of the aural message, thus requiring only a quick glance at the visual route guiding advice to understand the entire message. However, drivers with a Carin system will certainly meet situations in which they do not hear or understand anything of the aural route guiding advice, in which case they have to receive the message completely through the route guiding pictogramme on the display. This situation can be marked as most critical, for it requires the longest interpretation times and the greatest amount of cognitive processing from the driver.
For two reasons this study on the possible distraction of drivers by visual route guiding advices, like any traffic safety study, should test the most critical situation. First, traffic unsafety always occurs in exceptional situations and is caused by a combination of critical circumstances. Second, if the most critical situation can be dealt with safely by a driver, the less critical situations surely will not cause any difficulties.
Therefore the study on any distraction of drivers by visual route guiding advices will be carried out without the presentation of aural route guiding advices.
In the following, distinction will be made between distraction from the tracking task and distraction from the task to watch the traffic and the traffic environment and react upon it.

<u>The tracking task</u>
To be able to examine the distraction from the tracking task, it is necessary to have knowledge of the way in which the tracking task is carried out.
In contrast to what may be thought, course holding is not and even can not be carried out by keeping a straight line. Due to the vehicle characteristics, vehicles slowly deteriorate from their straight line and generally drivers accept such a deterioration until they come too close to the borders of their lane. Then, drivers will correct their

course towards the centre of the lane. Thus they drive along zigzagging.
This strategy of drivers implicates, and this is confirmed in the literature, that drivers have at their disposal a certain amount of road section between two succeeding course corrections, depending on the heading angle, the lane width, and the car width. The lenght of the time a driver has at his disposal between two succeeding course corrections, varies with the speed of the car.
The course of drivers is influenced by the sight distance also. When the sight distance is very limited, as is the case when driving at night with dipped headlights, the preview time is small and the drivers will generally be slower in the undertaking of a course correction. This will result in smaller times to line crossing and a larger standard deviation of the lateral position in the lane.
Thus, to test wether a driver is distracted from his tracking task by a route guiding pictogramme, it is sufficient to check if the time during which drivers watch a pictogramme is greater than the time they have, under certain circumstances, between two succeeding course corrections.
The times between two succeeding course corrections have been investigated o.a. by Blaauw[1)]. He examined, under varying conditions, the times during which drivers voluntary occluded their vision during a tracking task. At these occluded runs, test subjects turned out to be quite able to stay in their lane, although the occlusions resulted in some larger standard deviations of the lateral position and the lateral speed and in smaller time to line crossings (meaning that a course correction is undertaken closer to the borders of the lane).
The occlusion times as found by Blaauw are shown in the figures 2.1.

The time between two successive course corrections also can be derived from the steering wheel reversal rates. Dominant frequency rates that are found in the literature and confirmed by Blaauw generally occur at 0,1-0,3 Hz and sometimes at 0,3-0,6 Hz, meaning that a steering correction is undertaken every 3,3-10 s and sometimes every 1,7-3 s.

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1) see also report IA and IB

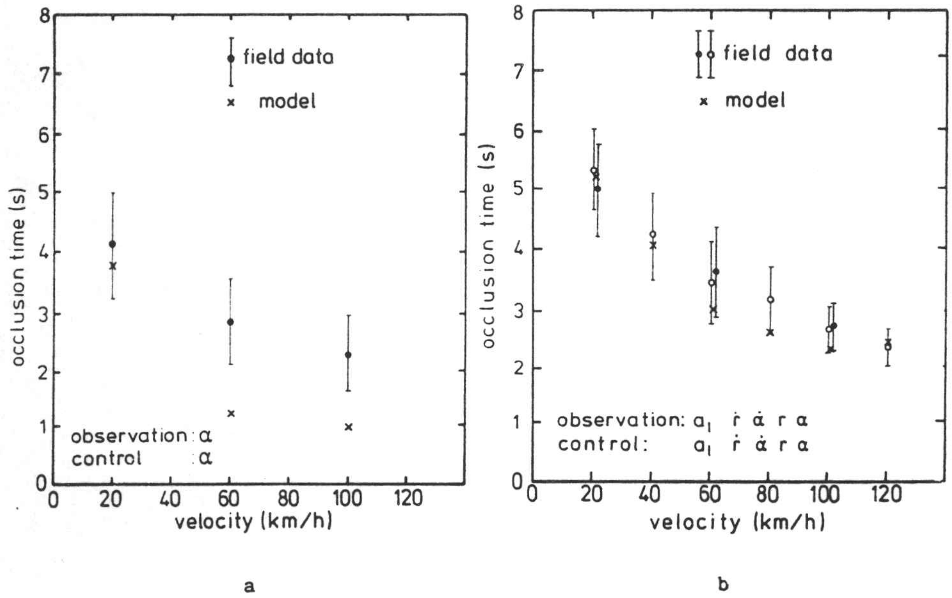

Figure 2.1: SDM predictions (symbols: x) for the mean occlusion time as a function of speed during the exclusive observation and control of lateral position (via the inclination angle a; figure a) and during the observation and control of all five perceptual cues (figure b); the field data present the mean values and standard deviations of measured occlusion times, for inexperienced (figure a) and experienced drivers (figure b); Source: Blaauw, 1984

It is suggested to select maximum times during which drivers may watch a pictogramme on the display, that are based on the median occlusion times above. It does not seem necessary to select a lower value, like a 15 percentile point, as the occlusion times depend on the situation and the driver strategy (drivers will e.g. choose a shorter occlusion time after a relatively large steering wheel correction) and drivers can, within certain limits, choose the times during which they watch the display. It is probable the that they will not select the most unsuitable moments to watch a pictogramme.

<u>The task to account for the other traffic and the traffic environment</u>

Within the driver task to account for other traffic and the traffic environment, distinction should be made between two entirely different situations that take place in respectively the encounter situation and in the incident situation (see also the enclosure).

In the encounter situation a driver meets an approaching vehicle, a pedestrian, a bend in the road, and the like. These are discontinuities that normally approach the driver with a relative low speed and leave him ample time for a decision and an adequate reaction.

An incident situation does not leave the driver much time for an adequate reaction. After the sudden detection of a danger, followed by the recognition of the danger, e.g. an other vehicle on a collision course, the driver has left very little time to successfully carry out an emergency manoeuvre.

These differences in situations of the traffic process have their effects on the task to watch the traffic. Before anything will be said on these differences, it may be usefull to give a short description of the way in which humans perceive.

The human eye consists of a foveal part and a peripheral part. The foveal part of the eye is small: it is a cone with a diameter of about 2^o. As no complete image of the surroundings can be received from such a limited vision, the foveal field is assisted by the peripheral field.
The peripheral field has two functions. Firstly, it stimulates head and eye movements which enable a foveal recognition of the objects that first have been seen peripherally. But often a foveal recognition is not necessary as the peripheral field serves humans to orientate themselves through the shape and pattern of the objects that are only seen peripherally. This is the second function of the peripheral field.
An important difference between foveal and peripheral vision is the way in which objects can be detected. With the foveal part of the eye objects can be detected both through the mechanism of colour contrast and luminance contrast, whereas in the peripheral field the detection of objects takes place mainly by luminance contrast (colours are hardly observed in the peripheral field).

For a driver peripheral vision is very important in the task to watch the traffic and the traffic environment. In the encounter situation it serves to detect a slowly approaching vehicle or situation. In the incident situation it helps to draw the attention on a sudden (unexpected) movement in the immediate environment of the driver.
There is a considerable difference between the peripheral task in the encounter and in the incident situation. In the encounter situation the peripheral field has to detect an object that approaches during a long time and only slowly reaches it's full distinction. In the incident situation the object is mostly seen very shortly, often almost as in a flash, but with full distinction.

In the literature no study has been found on the distraction of the task to watch the traffic and it's environment, taking into account the triple driver task and the different circumstances in the encounter and the traffic situation. One of the main tasks of this study therefore will be the determination of the extent of this distraction.

3. DETERMINING THE EFFECTS ON THE DRIVING TASK OF VISUAL ROUTE GUIDING ADVICES

From the previous chapter it followed that the study on the distraction of drivers by route guiding pictogrammes has to account for two effects. The first one is the effect on the tracking task, for which it is sufficient to examine if the time during which a driver watches a pictogramme does not exceed the time he has at his disposal between two succeeding course corrections.
Secondly, any effects on the task to watch the traffic and the traffic environment and react on it, have to be determined.
Before anything can be said on the possible distraction by visual route guiding messages, it has to be determined what styling method will be used for the route guiding messages, as the distraction from both the tracking task and the task to watch the traffic will be strongly related to the configuration of the visual messages.

3.1 Styling method

In an early development stage of the Carin system it has been decided to guide drivers through means of pictogrammes, stylised pictures of the oncoming junction and the route to follow. Naturally, for those pictogrammes that styling method has to be chosen that causes the least distraction.
This may seem contradictory to the fact that tests on the distraction by visual messages have yet to be conducted. However, to determine the styling method with the least distraction, it is not necessary to conduct extensive experiments that account for the exact driving circumstances and the driver task. If a representative feature can be found for the distraction that is caused by pictogrammes, it is sufficient to compare the scores of different styling methods on that particular feature.
According to the literature (reports IA and IB) the amount of cognitive processing is an important feature for the extent of the distraction. When the cognitive processing required increases, so both the reading time increases and the peripheral field narrows. Of these two consequences the reading time may easily be determined in an experimental setting.
The reading time of each pictogramme in a certain styling can easily be determined in a laboratory test without a simulated driving task. Such a testing method has the advantage of being simple and yet sufficient, as differrent styling methods can easily be compared and the one with the shortest reading times (and therefore the expected least distraction) selected easily.
The reading times for the pictogrammes may be tested tachistoscopic-

ally. If test subjects are presented all pictogrammes in the styling methods to be tested in a random sequence with a rising presentation time, the pictogrammes with the shortest reading times will be recognised first.

3.2 Distraction from the tracking task.

The time during which a driver watches his display must not exceed the maximum times that are based on the median occlusion times as found by Blaauw (see chapter 2). Thus the times during which drivers watch the Carin pictogrammes will have to be determined in an experimental setting. Herefore various testing methods can be applied that all have their advantages and disadvantages.

In a laboratory, the times during which pictogrammes are watched can be determined machine-paced and subject-paced.
In a machine-paced test, the pictogrammes are shown automatically during a predetermined time, e.g. through a tachistoscope. The advantage of such a test is that different pictogrammes can be compared objectively as the watching times are not influenced by the test subjects. The disadvantage is that the found watching times are much lower than under real traffic conditions. Herefore are two reasons.
Firstly, the times during which subjects move their head and eyes towards and from the display are not measured in the experiment, but are nevertheless part of the watching time in real traffic. Secondly, test subjects may still be interpreting what they have seen if no pictogramme is presented any longer. The second disadvantage can be overcome by subject-pace tests.
In subject-paced tests, the presentation time of a pictogramme is controlled by the test subjects themselves. Subjects may e.g. be shown a pictogramme as long as they push a button. If subjects are instructed to watch the pictogramme no longer than they need for the interpretation, than the time during which the button was pressed, is a measure for the watching time. This method has the disadvantage that the time during which test subjects move their head and eyes towards the display still are not accounted for.
To incorporate the head and eye movements into the measured watching time, the time can be determined through a video-registration. When a timer is positioned between the video-camera and the recorder, then the actual time will be projected on the video-tape. Through a slow motion display of the recordings, the watching time will then be able to be determined accurately. In this testing method the presentation of the display will be controlled automatically, but the presented

time will be much longer than necessary for the interpretation. Subjects will be required to watch the luminated display only as long as is necessary for the interpretation of the pictogramme. This testing method closely represents real traffic situations in which a driver looks straight ahead and only from time to time watches a pictogramme on the display in his dashboard. In order to increase the reliability of this test, subjects may be required to perform an easy additional task for which they have to look ahead also. This additional task can, but does not necessarily have to be a simulated driving task.

The last testing method also can be applied in real traffic situations. Therefore a camera has to be mounted into or onto the car for the registration of head and eye movements. The advantage of such real world tests is of course the high validity level. The disadvantages ly in the difficulties to carry out real world tests. Not only may the conduction of the tests in real traffic be objected by the authorities, it may also be difficult to find a representative sample of all road situations to be tested within a reasonable distance.

3.3 Distraction from the task to account for the other traffic and the traffic environment

To account for the other traffic and the traffic environment, a driver has to watch and react upon what he sees. As followed from the previous chapter, in this task peripheral vision is most important. Therefore, to test wether the presentation of visual route guiding information distracts a driver, it is sufficient to examine whether such a presentation leads to a deterioration of the peripheral reaction capability. In such a test, of course, distinction should be made between the encounter and the incident situation.

In a laboratory peripheral vision is often checked through a set of lights situated in the peripheral field round a test subject. Test subjects then are required to registrate the lumination of a peripheral light under varying testing circumstances.
To test whether route guiding pictogrammes have a deteriorating effect on peripheral vision, the peripheral reaction capability during the presentation of pictogrammes has to be compared with the achievements when no pictogrammes are shown. A deteriorated peripheral vision may manifest itself through a slower or incorrect reaction on the lumination of a peripheral light; in extreme cases no reaction at all may be given.
To successfully simulate real traffic situations in a laboratory, it

is essential that the driving task is simulated as accurately as possible. According to chapter 2, this requires a third task (next to reacting on the lumination of the peripheral lights, and attending to the pictogrammes) to simulate the tracking task. The tracking task should be able to be conducted without much effort, as in real traffic the tracking task is also executed automatically and requires little attention.

Distinction between the encounter situation and the incident situation can be created through different lumination patterns of the peripheral lights and different required reactions on those luminations.

Laboratory tests have three major advantages. Firstly, they are relative simple to conduct, as all environmental circumstances can be controlled and if desired be kept constant or eliminated. Secondly, it is possible to gradually vary all variables that influence the results and thus test a whole range of situations that can possibly occur. Thirdly, experiments can be repeated to test the reliability of the experiments. A disadvantage is of course that, however well thought over and occurately defined and conducted the tests are, no guarantee can be given that the test subjects in real traffic situations will (re)act the same as they have done in the laboratory. Therefore, the results of the tests will always have to be verified in real traffic, especially as the consequences of reaction failures in a laboratory test differ greatly from the consequences in real traffic.

The disadvantages of laboratory tests can be overcome by conducting real world tests. It must be considered, however, that with a growing reality level, the difficulties also increase (costs, risks, execution, interpretation of the results, and the like).

Furthermore, immediately starting a series of experiments with real world tests would most probably provide great difficulties in extracting the necessary information out of the results. For, the great amount of data that these experiments provide, are influenced by a large number of uncontrollable and partly even unknown variables. Without extensive theories and a set of all-explaning hypothesisses, it would be impossible to get to the bottom of the relations between the data.

The peripheral reaction capability will be difficult to test in real traffic situations, especially in incident situations: this would require the presentation of an unexpected event just at the time that a test car drives past and just at the time that the driver watches his display.

A risk that must be taken into account when conducting real world tests is the possibility of accidents. Especially as the aim of the experiments is to test the most critical situations, of which it is not known whether the test subjects all will be able to cope with, the chances on provoking an accident are far from imaginary.

An intermediate between real world experiments and laboratory tests is a testing programme with an instrumented car on a road stretch that is closed for all traffic. Such a testing programme could overcome part of the disadvantages of real world tests.
The disadvantage of an instrumented car test is the difficulty to test peripheral vision. With the absense of other traffic, this could be done through peripheral lights attached to the car. However, this could induce a change in the driver's priorities, as in real traffic failures in the task to watch the traffic have far greater consequences (this could lead to accidents) than failures in the detection of a peripheral light being luminated. This may well induce drivers to pay less attention to the peripheral vision task in the experiment than they would in real traffic.

3.4 Priorities

If not all experiments can be executed simultaneously, it is recommended to start with the one that is most critical. That a distraction from the tracking task is less critical than a distraction form the task to watch the traffic and the traffic environment and react upon it, will be explained in the following.
When a driver is distracted from the tracking task, this will not immediately lead to accidents. Usually moderate lane excessions can still be coped with more or less easy by the driver himself and/or other road users.
The task to watch the traffic can be rather critical. Especially within build-up areas drivers have a small preview time and encounters with other traffic often happen unexpectedly. In those cases even a small delay in the driver's reaction may cause an incident and possibly an accident. A delay in the reaction on any incidents will immediately lead to accidents.
From the above it will have become clear that tests on a possible distraction from the task to watch the traffic have been given priority above tests on a distraction from the tracking task.

4. EXPERIMENTAL PROGRAMME

4.1 Introduction

An experimental programme has been set up with the aim to determine the extent to which simple pictogrammes on a flat panel display distract drivers from their task to watch the traffic and the traffic environment and react upon it.

For the execution of the tests a choice had to be made between real world tests with a display build into a car and tests in a laboratory.
At first sight it would seem ideal to perform tests in real world situations in a great number of cars with build-in Carin systems during a very long time which enables the many subjects to acquire a great experience with the system. Ultimately, the conduction of real world tests will be essential to evaluate the effect on drivers of route guiding pictogrammes.
However, at the start of the experiments, it would not have been possible to extract the necessary information out of the results of the real world tests, as they provide a great amount of data which is not interpretable without any background theory or explaning hypothesisses. Besides, real world tests have the disadvantage that it will be very difficult to test the peripheral reaction capability. To do so, it would be necessary to provoke an unexpected event just at the time that a test car drives past and just at the time that the driver watches his display.
Therefore it was decided to postpone the real world tests to a next phase of the project and limit the tests in the first phase to laboratory experiments. The results of these laboratory tests are to provide the basis for the real world tests and thus minimize the disadvantages of such tests.

To test wether the peripheral vision of subjects is affected by the presentation of route guiding pictogrammes, a comparison had to be made between the reaction on a stimulus in the peripheral field of test subjects when they were watching a pictogramme and the reaction when no pictogrammes were shown. The stimuli were provided through the random lumination of one of a set of peripheral lights. Distinction between the encounter and the incident situation was made through different lumination patterns of the peripheral lights and different required reactions.
The route guiding pictogrammes were projected on a small display that was mounted into the dashboard.
Although a subject's tracking capabilities under varying conditions

were no part of the tests (the distraction from the tracking task was to be accounted for through a comparison of the times that are required to watch the pictogrammes and predetermined maximum watching times), it was decided to have subjects perform a tracking task during the tests in order to create realistic testing circumstances (see also 3.3).

To check wether subjects were actually watching a presented pictogramme, the head and eye movements of subjects were registered through a video camera. Attached to the recording system was a timer, that was visible in the video recordings, enabling the time during which test subjects watched a pictogramme to be read accurately through a slow motion display of the recordings.

During the experiments the test subjects were seated behind the steering wheel of a car from which the upper half had been removed to eliminate any dead angles and reflections in the windows and to create sufficient light for the video recordings.

During the tests, differences in the individual subjects (age, sex, driving experience, level of education and profession) and the subjects' experiences with the pictogrammes have been accounted for.

The testing conditions will be discussed in further detail in the following paragraphs.

4.2 Requirements

4.2.1 Peripheral reaction test

In the peripheral reaction test, subjects were required to react on the lumination of a set of lights, set in the peripheral field of test subjects. The peripheral lights were situated in a semi-circle round the test subjects at angles of 80°, 50°, and 20° with the line of sight.
For the position of the outer lights an angle of 80° was selected for it's closeness to the outer boundaries of the peripheral eye field (see also figure 4.1).
The inner lights were situated at 20° to ensure an incorporation into the field of vision. This field is build up by scanning the foveal vision from left to right. Usually, the field of vision covers an angle of 50°, 25° to the left and 25° to the right.
The two lights at 50° were situated exactly between the lights at 20° and 80°.

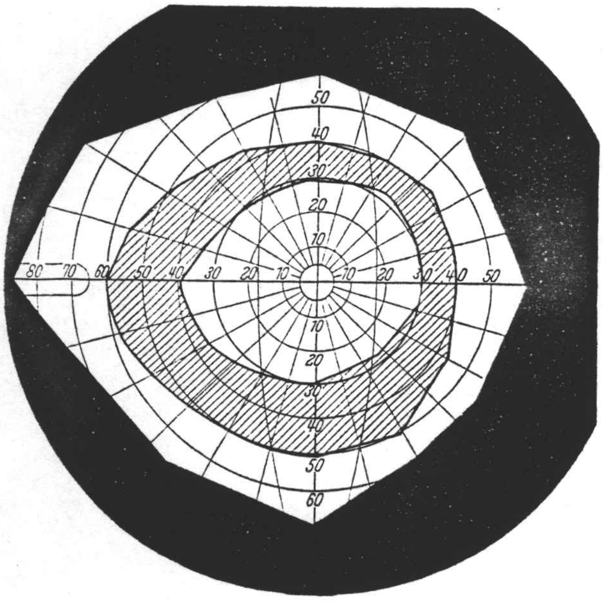

Figure 4.1: Vision of a normal (left) eye (outer boundaries), an eye wearing contact lenses (shaded part), and a bespectacled eye (inner boundaries); source: Gramberg-Danielsen, 1967

Although the angles of the peripheral lights with the line of sight remained constant in the simulation, wheras they change constantly in real traffic, this is fully justified by the fact that in the most critical situations (when two vehicles are in a collision course) the angle remains constant also.
The heights of the lights were to be the same as those of the vehicles a driver encounters in real life situations. This is difficult to precize as in real traffic the vehicles vary in height and have certain dimensions which the peripheral lights do not have. It was decided to position the lights at approximately the same height as the eyes of the test subjects (± 1,1 m) as this is the height at which a driver will start to search for traffic in real life and besides a height at which all traffic can be seen, whatever vehicle is encountered.
The set of lights was situated at a distance of approximately 5 m from the test subjects which was considered a minimum in order to be seen with unaccommodated or hardly accommodated eyes, which is representative for real traffic conditions.

The peripheral reaction test was conducted to test the ability of subjects to watch the traffic. In this task distinction had to be made between the encounter situation and the incident situation.

In the **encounter situation** a driver has to watch the traffic that approaches him gradually with often low relative speeds. These

conditions could be simulated by having the peripheral lights gradually reach their full brightness, followed by a lumination of some seconds. Thus, just as in real traffic, the illumination level of the encountering object on the driver's eye is increased slowly to it's maximum level. The time during which the lights had to be luminated for the simulation of the encounter situation will be discussed in the following.
Usually the velocity of vehicles is adjusted either to factors such as the speed limits and the engine capacity (mainly outside build-up areas) or to the traffic situation (mainly inside build-up areas). The latter situation is of importance to these experiments as it is the most critical one.
Speed is then restricted by the condition that after the detection of a vehicle a driver must be able to stop his vehicle in time with a moderate deceleration. Therefore drivers estimate the space that could be necessary and the space that is available and adjust their speed to this information. However, as estimations bring about failures, drivers have to take into account a safety margin.
This safety margin between the actual available and the possible necessary space, expressed in seconds, is the time a driver has to detect a vehicle and react upon this detection. The lenght of the safety margin varies from one person to another, but becomes smaller as the risk acceptance increases and as people become more experienced and their ability to estimate distances improves.
In the experiments a value of 5 s was chosen for the safety margins and therewith lumination times of the peripheral lights. This value, which is a maximum and representative for inexperienced drivers, was based on practical reasons: the longer the lumination time, the more possible differences in reaction time can be measured. However, a longer time than 5 s is meaningless as even the most inexperienced drivers will not need more time to detect oncoming traffic in an encounter situation.
(Sometimes, as a result of estimation failures, the actual available space is smaller than the necessary space. In that case it is no longer possible to stop gradually and with moderate decelerations: an emergency manoeuvre is needed to avoid an accident. This is an incident situation and is simulated as described further on in this paragraph).

The conspicuity of each of the lights of the set did not have to be extraordinary large as in real traffic vehicles that are encountered are not very conspicuous either. Therefore simple yellow lights did suffy.
The brightness of the lights depended on the laboratory and was related to the background. Bulbs of 60 W turned out to be well

suited. Behind the peripheral lights wooden fences were placed in a semi-circle to prevent the lights from being reflected in the walls of the laboratory. To be able to register even small differences, the maximum lumination level was adjusted in such a way that under normal circumstances they just could be detected and that in more extreme situations a part of the luminations could be expected not to be noticed.

The connection of the lights was such that they were able to be luminated slowly as it was decided to execute the change from lumination level zero to full brightness in 2 s and keep that lumination level for the resting 3 s. For in real traffic in the encounter situation oncoming vehicles also appear gradually in the eye sight of a driver. The lumination pattern of the lights is shown in figure 4.2.

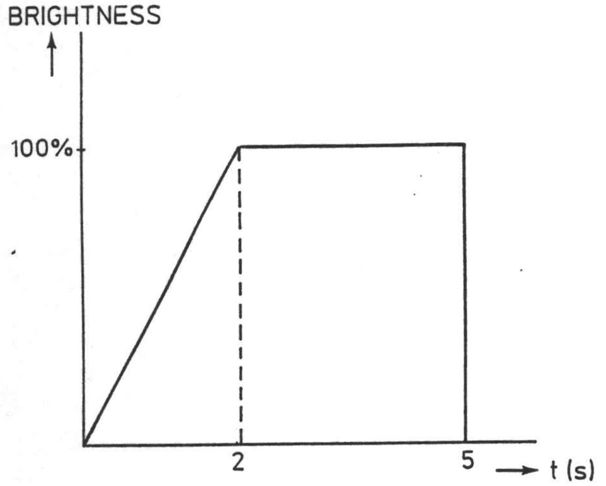

Figure 4.2 Lumination pattern of the yellow lights for the simulation of the encounter situation

Switching the lights on and off was not allowed to be accompanied by any sound in order not to draw the attention of subjects by sound before they were attracted by the route guiding signals.

Subjects were required to react on the lumination of a yellow light by pushing the horn lever situated in the centre of the steering wheel.

In an **incident situation** drivers do not immediately recognize the danger of an accident. At first there is only the sudden detection of a vehicle in the corner of an eye, immediately followed by a head turning and a foveal recognition of the vehicle being on a collision course. In the laboratory this was simulated by a set of two lights

which were luminated shortly after each other: the flashing of the yellow light had to draw the attention of a driver, while the lumination of a small red light next to it required a foveal recognition task. Therefore, next to each yellow light a small red one was attached.
The brightness of the red lights had to be small as it had not to be able to be detected peripherally, but had to be recognized foveally. The lumination level was adjusted to the requirement that the test subjects foveally could detect whether the light was off or on.
For the purpose of these tests a lumination time of the red light of 5 s was thought to be more than sufficient (figure 4.3).

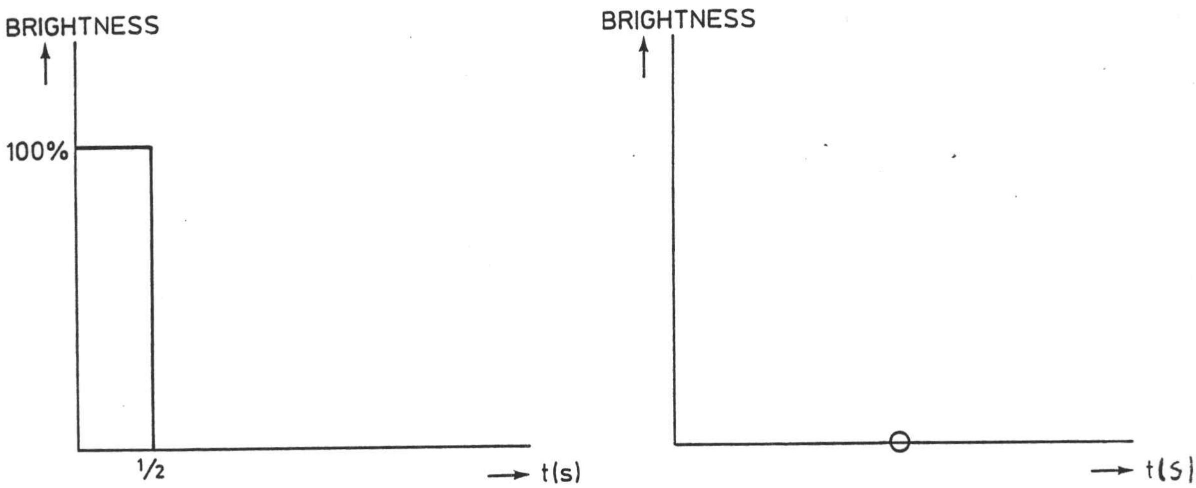

Figure 4.3: Lumination pattern of the yellow and red lights for the simulation of the incident situation

Not always the flashing of the yellow lights had to be accompanied by the lumination of the small red light very near the yellow one. For this could have induced test subjects to react only on the flashing of the yellow lights without taking notice of the red light. Therefore a dummy lumination pattern was used also (figure 4.4).

Subjects were to react on the flashing of a yellow light and the subsequent lumination of a red one by pressing the 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.
Accurate time registration was extremely important in this test. Tenths of seconds had to be able to be registered accurately. To be able to draw conclusions from the tests, it was registered when:
- a yellow light was on

- a red light was on
- the horn lever in the centre of the steering wheel was pushed
- the brake pedal was operated

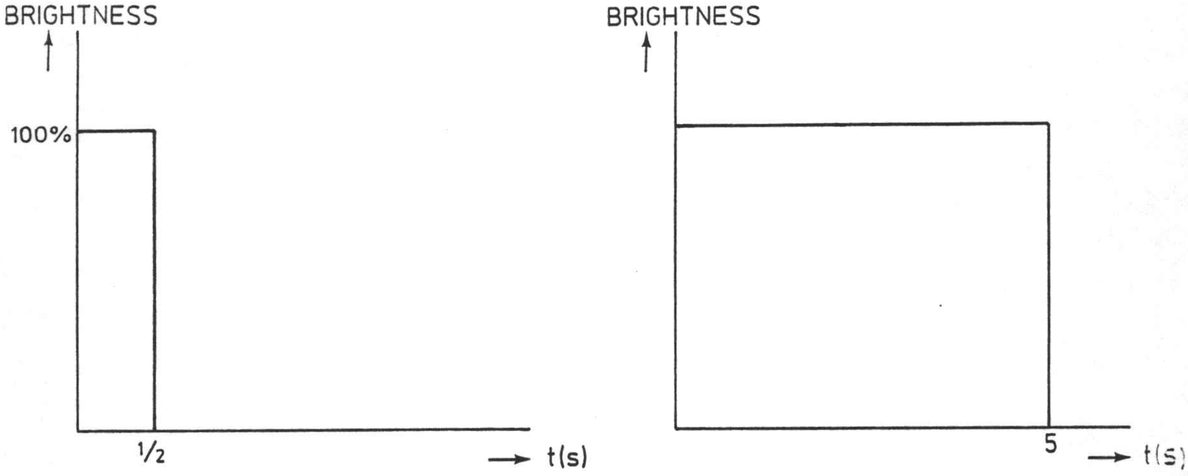

Figure 4.4: Lumination pattern for the flashing of a yellow light that was not accompanied by the lumination of a red light

4.2.2 Tracking task

Introduction

Subjects had to perform a tracking task during the tests in order to create realistic circumstances. In the laboratory this tracking task was simulated through a traffic simulator.

Generally speaking, the simulation of the tracking task should either be very simple or an exact copy of the reality (in which case an extreme complicated apparatus would be needed and the time to build it some four years). A compromise between a very simple and a very complicated simulator is not to be preferred as the result will be something that looks like reality but nevertheless has some slight deteriorations, which may greatly influence the test subjects and therewith the test results.

It was therefore decided to simulate the tracking task through a great schematisation. This had as extra advantage that the tracking task and the task to watch the traffic were equally schematized (as the task to watch the traffic has already been schematized through the peripheral lights).

A requirement for the schematized tracking task was that it is easily conducted and can be learned fastly. For subjects have to perform it automatically and out of their experience, just like the steering task in real traffic. It was decided to schematize the tracking task as the task to control a point on a monitor through the steering wheel and the accelerator pedal of the car in which the test subjects were seated during the experiments.

Schematisation

In real traffic the tracking task is performed automatically (out of experience) and without much effort. For a driver does not have to keep his vehicle on a straight course, but allows deteriorations from a straight line. The only requirement he has to meet is to keep his vehicle within his lane. Whenever the vehicle reaches the borders of the lane, in other words whenever the TLC (Time to Line Crossing) becomes too small, a course correction is undertaken to direct the vehicle towards the centre of the lane again.

The simulated tracking task was preferred to be able to be performed automatically also and to allow the same deteriorations from a straight line as in real traffic. Therefore the tracking task was simulated through keeping a figure on a monitor between two paralel lines (see figure 4.5). The dimensions were calculated thus that the ratio between the point to be controlled and the distance between the two paralel lines was the same as in real traffic. The calculation was made with a moderate car width of 1,6 m and a normal lane width of 3,6 m.

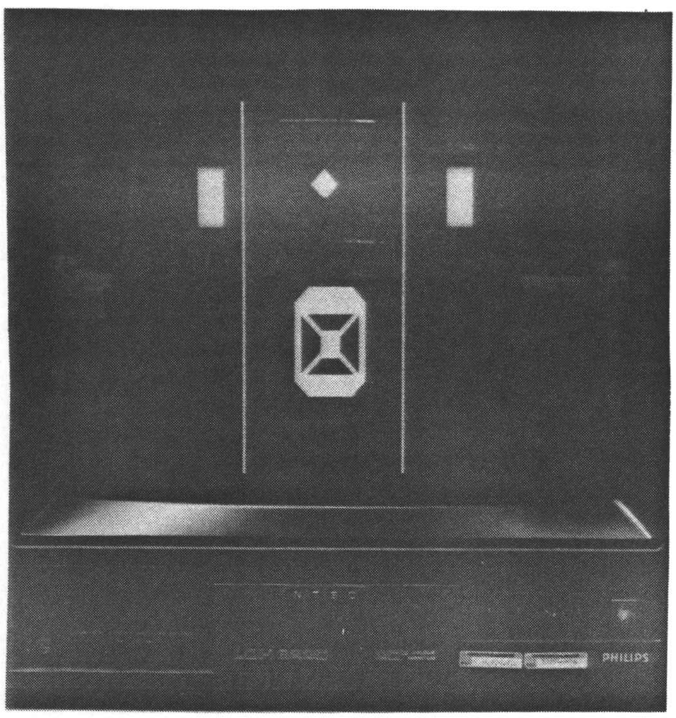

Figure 4.5: Monitor for the simulation of the traffic task

during the experiments, it was decided to register all lane excessions. For a considerable lane excession could be an indication of a tempory heavy workload. It should be noted that lane excessions were not registrated for reasons of traffic safety, as small and even moderate lane excessions hardly ever lead to accidents.

4.2.3 Route guiding messages

The route guiding messages of the future Carin system are to be followed by an action of the driver to change course. The function of these messages is to stimulate the driver to abandone his tracking task and start the necessary actions for an encounter situation. The messages clearly interfere with the tracking task. Therefore, the route guiding pictogrammes to be used in the laboratory test also had to interfere with the tracking task. (It should be noted that this interference is no more than logical and of no importance to this research on the traffic safety of the system, which is to test the effects of the presentation of the route guiding messages). An additional effect of the interference in the laboratory tests was the possibility to check wether the route guiding messages have been understood and followed up.
It turned out to be difficult to have the Carin route guiding advices that will be used in the future system interfere with the simulated tracking task that will be tested in the laboratory (messages like "Take the second exit at roundabout" have no meaning in the schematized tracking task). To overcome this problem either the tracking task or the pictogrammes had to be adapted to the possibilities. Adapting the tracking task would have been complicated as the possibilities for horizontal velocities were very limited. Therefore, first the possibilities for adapted route guiding pictogrammes were considered.
A possible adaption of the pictogrammes is to schematize them. In order to provoke a simular reaction as in real traffic, these schematized route guiding messages should contain the same kind of information as the real Carin messages. Therefore, the schematized messages should contain information on the action that has to be undertaken and on the place where that action has to be undertaken.
To indicate the place where a route advice has to be followed, dots could be generated that move from top to bottom over the monitor. The velocity of these dots then could simultaneously be an indication of the speed at which is driven and could be controlled by the test subjects through an accelerator pedal.
Examples of messages that could be given are mentioned below as well as schematized pictogrammes. The messages are presented in a sequence of a rising number of units of information.

advantages:

- starting at the basis: being able to examine wether messages have any effect at all upon the other tasks (tracking and watching the traffic)
- an equal degree of schematisation for all three tasks of drivers, as the tracking task and the task to watch the traffic have already been schematized
- route guiding advices that, just as in real traffic, interfere with the tracking task
- enabling a great and gradual variation of the complexity of the pictogrammes and thus being able to determine possible critical values

Besides these fundamental points, the schematized messages also had the advantage that the experiments could be started with immediately, without having to wait for the results of the research on the styling method.

The disadvantage of schematized messages is of course that it is not possible to determine the distraction for the actual Carin route guiding pictogrammes.
Although schematized messages would produce only one disadvantage, it was nevertheless an important one, as it concerned the aim of the experiments. Then again it can be questioned whether distractions that were acquired in experiments with a schematized tracking task and a schematized task to watch the traffic still are realistic.

Overlooking the advantages and disadvantages, it seemed favourable to start the experiments with schematized route guiding messages. The distraction of the real Carin messages then will have to be determined in a follow-up study.

It had to be registered when subjects attended to the route guiding messages in order to be able to compare the reactions during times when pictogrammes were being presented with the achievements when no pictogrammes were shown. It was not sufficient to register only the presentation of a route guiding pictogramme, as subjects were free in their choice to watch a pictogramme. Therefore video-recordings were made of head and eye movements of the test subjects.
Added to the video-signal was a timer signal, enabling an exact determination of the time during which the subjects watched a pictogramme through a slow-motion display of the recordings.

4.2.4 Experimental setting

In figure 4.6 an oversight is given of the attributes that have been used in the experiments.

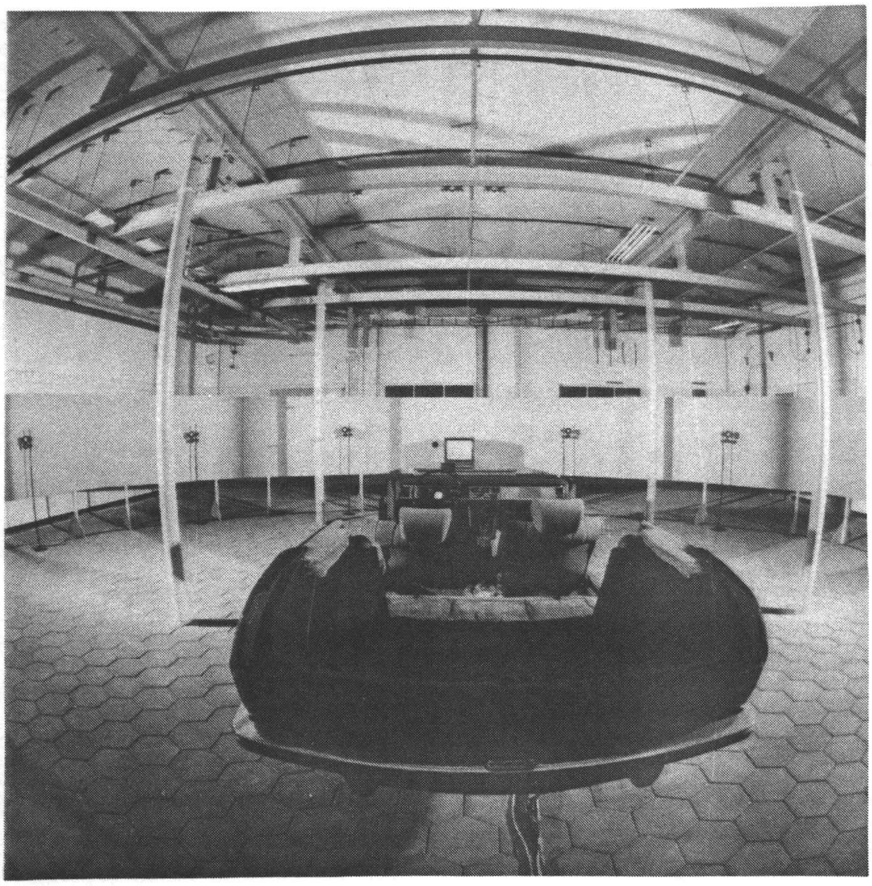

Figure 4.6: Oversight of the experimental setting

During the tests subjects were seated in the driver seat of a modified car (figure 4.7). Of this car the doors, the upper half, and the rear seats had been removed, as it were to schematize the car also, to prevent an impression of a test in a real car with only a schematized tracking task and a schematized task to watch the traffic.

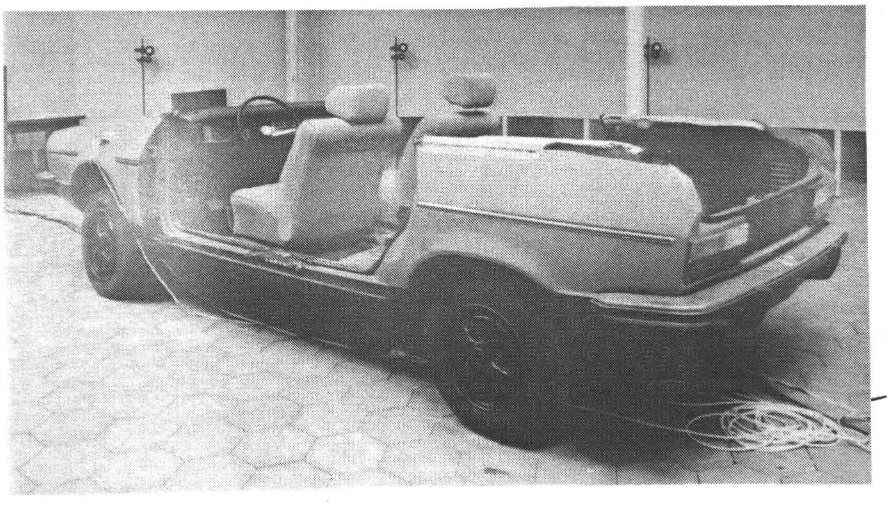

Figure 4.7: Modified car in which test subjects were seated

In the dashboard of the car a small display was mounted for the projection of route guiding pictogrammes (figure 4.8).

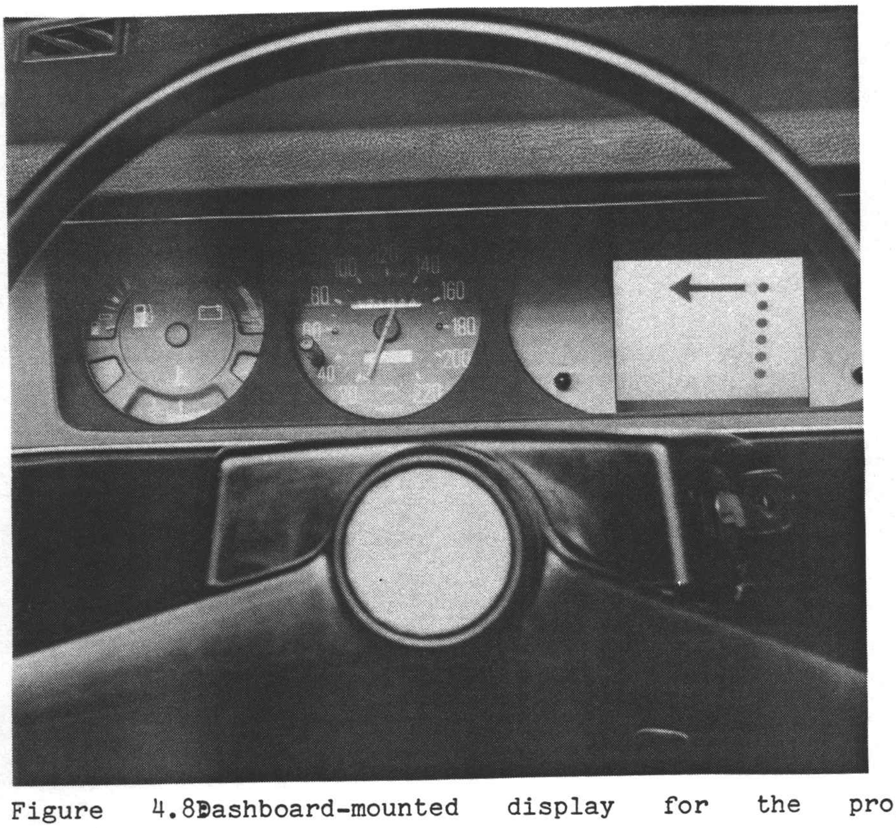

Figure 4.8: Dashboard-mounted display for the projection of pictogrammes.

From the engine compartment the engine had been removed to make place for the attachment of pot meters on the steering apparatus and the accelerator pedal and the connection of switches to the brake pedal and the horn button. In the engine compartment a slide projector was located for the projection of pictogrammes on the small display in the dashboard.

In a semi-circle round the test subjects, at a distance of 5 m, sets of a yellow and a red peripheral light were situated, set at 20°, 50°, and 80° on either side of the line of sight. Behind the peripheral lights a wooden fence had been erected to guarantee a neutral, non-disturbing, and non-reflecting background.

5 m in front of the test subjects a monitor was situated on which the simulated tracking task had to be carried out.

The video camera was located next to the monitor behind the wooden fence. The recordings of head and eye movements were made through a hole in the fence at the test subjects eye height, thus enabling the registration of test subjects' point of attention (figure 4.9)

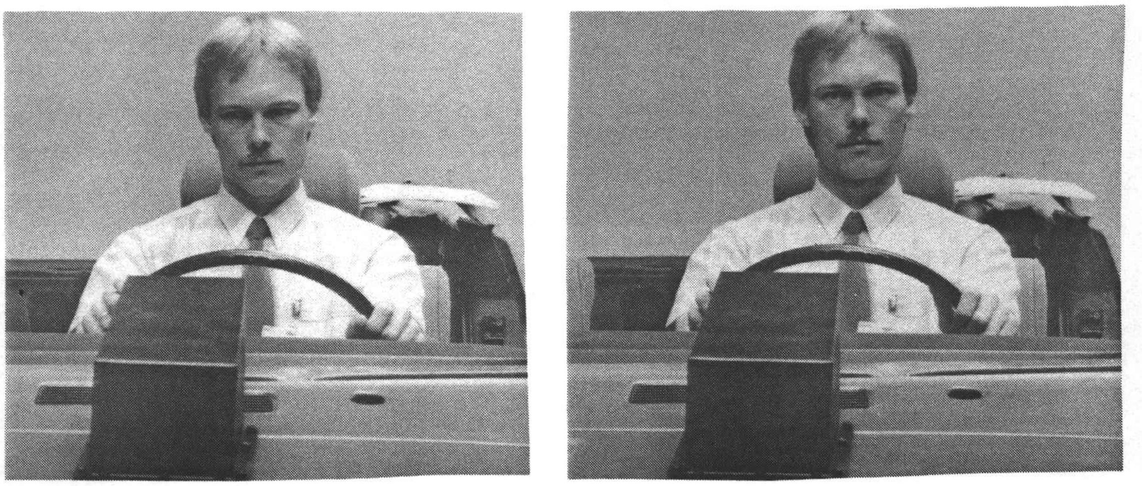

Figure 4.9: Through the video recordings it was checked whether the test subjects were watching the presented pictogramme or attended themselves to the tracking task

The whole experiment was controlled by a personal computer (IBM-AT). It arranged the initiation of the events and registrated all actions and reactions. The computer was placed on a desk behind the car, separated from the test subjects by a wooden fence. During the experiments the experimentator operated the computer and kept an oversight through a monitor on which the experiments were displayed. The video recorder and video timer were also placed on the desk behind the car.

4.3 Variables

4.3.1 Introduction

To test wether the presentation of route guiding messages has any effect on the task to watch the traffic and the traffic environment and react upon it, the peripheral reaction capability of subjects during the watching of a pictogramme was to be compared with the reaction when no pictogrammes were watched.
During the testing of the peripheral reaction, allowance had to be made for the variables that could influence the results of the experiments. Of these variables, mentioned below, the for the tests most extreme manifestations had to be used. For traffic unsafety is the result of a combination of critical circumstances. Under normal circumstances the average driver will not experience any difficulties in safely dealing with route guiding pictogrammes. Critical, from a traffic safety point of view, are the circumstances in which a group of non-average drivers under infrequently occurring circumstances has to interprete route guiding pictogrammes. It was necessary to search for the most extreme manifestations of the following variables:
- experience with the peripheral reaction task
- complexity of the peripheral reaction task
- experience with the tracking task
- complexity of the tracking task
- experience with the route guiding pictogrammes
- complexity of the route guiding pictogrammes
- characteristics of the test subjects

The points mentioned above will be discussed in the following.

4.3.2 Experience with the peripheral reaction task

The peripheral reaction task was to simulate encounter and incident situations in real traffic. In both these situations a driver does not have to think long over the action to be undertaken in order to avoid an incident, respectively an accident. This also had to be the case in the laboratory experiments. Therefore the test subjects were given ample opportunity to practise the required reaction on the lumination of the yellow and red peripheral lights.

4.3.3 Complexity of the peripheral reaction task

The peripheral reaction task distinguished two situations to be tested: a simulation of the encounter situation and a simulation of the incident situation. In the encounter situation subjects were required to push a horn lever after the gradual lumination of a yellow light (lumination pattern 1).
The incident situation required an engagement of the brake pedal after the flashing of a yellow light and the subsequent lumination of a red light (lumination pattern 2). To insure that subjects indeed performed a foveal recognition task, a third situation had been introduced (see also 4.2.1). According to this third lumination pattern the flashing of the yellow light was not followed by the lumination of a red light.
The ratio in which the three lumination patterns occurred in the tests was: lumination pattern 1 : lumination 2 : lumination pattern 3 = 1 : 1 : ½

The peripheral detection capability was tested with six peripheral lights, set at 20°, 50°, and 80° on either side of the line of sight. As vision is symmetrical[1)] it was justifiable to examine the results of the right and left light at each angle with the line of sight together, leaving three manifestations of the variable to be researched.

4.3.4 Experience with the tracking task

The tracking task had to be well under control by each test subject before the start of the experiments, as in real traffic situations also only people are involved who have ample skill to keep the vehicle on course. This may seem to be in contrast with the many accidents that happen yearly in which only one vehicle is involved. However, most of these accidents happen as a result of encounters (swerving to avoid an oncoming vehicle, no control of the vehicle in a sharp bend, and the like). Principally, all drivers are capable of keeping their vehicle on the road. Only under certain critical circumstances accidents may happen as result of e.g. a low attention level, an overestimation of the tracking capability, or an underestimation of the situation.
In the laboratory tests the same conditions had to be present as in

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1) see e.g.: Grambergen-Danielsen, B, 1967
or: Holloway, C.H. & Wright, P, 1980

real traffic situations, meaning that although critical circumstances also had to be able to appear and cause a deterioration of the tracking performance, basically subjects had to be able to perform the tracking task perfectly well.
To meet this condition subjects were to practice the tracking task before the tests until their skill was sufficient. As the tracking task was relative simple, practising for at the most a quarter of an hour was turned out to be highly sufficient to prevent subjects from making tracking errors.

4.3.5 Complexity of the tracking task

The complexity of the tracking task, which increases as the speed becomes higher, certainly influences the peripheral detection capability: when the attention largely has to be focused on tracking, the peripheral field narrows. However, not the peripheral detection capability itself was of importance, but the influence of the presentation of pictogrammes on the peripheral detection capability.
Therefore it was of interest wether any deterioration of the peripheral detection capability was larger at high speeds than at low speeds.
To create realistic circumstances, the test subjects had to be free to choose their own stress level and determine their "speeds" themselves. 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.

4.3.6 Experience with the route guiding pictogrammes

Experience with the route guiding pictogrammes will result in shorter interpretation times and may also result in a smaller amount of cognitive processing required. Whereas first the pictogrammes have to be "explored" to receive the route guiding message, later on a quick look may be sufficient to recognize a pictogramme by it's pattern (see also the reports IA and IB). Subjects who are experienced with a route guiding pictogramme will tend to gloss over familiar elements and concentrate on the changeable parts of the pictogramme.
It must be kept in mind, that route guiding pictogrammes are a secondary source of information for drivers. Their first information source is the auditive route advice. Only if the aural messages have not been heard or understood, assistence from the display is needed. It is to be expected that this will not happen so frequently, that a

high level of experience is achieved very soon. Therefore the results of subjects who are experienced with the pictogrammes as well as subjects inexperienced with them are of importance.
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.

4.3.7 Complexity of the route guiding pictogrammes

The complexity of the route guiding pictogrammes 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 it's turn may affect the peripheral detection capability through a narrowing of the peripheral field.
Thus, complex route guiding pictogrammes could prevent the detection of the slowly brightening of a yellow peripheral light (encounter situation) or the lumination of a red light, preceded by the flashing of the accompanying yellow peripheral light (incident situation).
Although a whole range of pictogrammes with varying complexity may be used in the Carin system, the basic question that had to be answered was whether a complex route guiding pictogramme distracts drivers more than a simple pictogramme.
Therefore it was sufficient to test a (series of) simple route guiding pictogrammes and a (series of) complex pictogrammes, thus leaving only two manifestations to be tested. The tested pictogrammes are presented in appendix III.

4.3.8 Characteristics of the test subjects

The characteristics of test subjects are of great importance for the way in which tasks are performed. The characteristics that could be of importance for these experiments are caused by age, sex, driving experience, educational level, and profession.
The tasks that had to be executed in the experiments were tracking, watching the peripheral lights and reacting upon their lumination, and interpreting the route guiding pictogrammes and following a route. These tasks were to be executed mainly simultaneously and only partly sequentially.
In the following will be described what the effects may be of the characteristics of the test subjects on the performance of the different tasks.

Tracking task

Old people have more difficulty in tracking than young ones, but they overcompensate their infirmities by driving slowly. Young, especially male drivers show a tendency to speeding and taking high risks. This is confirmed by the accident rates: elderly people seldom or never are involved in accidents with only one vehicle. The major part of these accidents are caused by young, mainly male, inexperienced drivers. They are probably the most critical group concerning the tracking task. Their concentration on tracking, due to the speeding, may lead to a neglection of other tasks.

In real traffic the driving experience may be of importance also. In general, people with a little experience ($\pm$ 10.000 km) are the most critical group as they overestimate their still limited capabilities. Very experienced drivers seldom make mistakes in tracking and if they do they know how to correct them. Novice drivers tend to overcompensate their lack of experience by driving slowly. However, as the schematized tracking task in the experiments is not equal to the tracking task in a car, the effects of driving experience are uncertain as test subjects may adapt different criteria for tracking in the laboratory tests than for real world tracking.

Task to watch the peripheral lights and react upon their lumination

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

Temporal critical circumstances like exhaustion, use of alcohol or drugs, illness, or distraction may also be of influence on the performance as they lead to a low level of attention. On the other hand may haste lead to looking far ahead and a concentration on tracking and a neglection of the peripheral tasks.

The subjects have to react on the lighting of the peripheral lamps by pushing a horn lever or, after foveally recognizing a red lamp, by activating the brake pedal. Although, the reaction velocity differs from one person to another and is dependent on temporary circumstances, it can be stated that it deteriorates with age. Therefore, older people will score less on this task than younger ones.

Task to interprete the route guiding pictogrammes

Elder people have more difficulty in learning something new and in remembering something that has recently been learned. As a result of this their level of experience with the route guiding pictogrammes will rise only slowly, if it rises at all (the pictogrammes will

seldomly be necessary to inform drivers). In contrast with the elder drivers, the young ones will learn quickly and soon have reached a reasonable level of experience to interprete the pictogrammes with a quick look.
The accommodation of the eyes, which is necessay to focus the eyes from a point in the distance onto the display, becomes more difficult as people grow older.
The level of education and the profession of subjects may play a role in the speed with which the pictogrammes are learned. It is conceivable that people with a low level of education and a profession in which little thinking is necessary experience greater difficulties in interpreting the schematized route guiding pictogrammes.

Multiple tasks

The ability to perform a multiple task deteriorates with a climbing of the years. Old people prefer to execute actions sequentially rather than simultaneously. This may lead to a concentration on the pictogrammes and a neglection of the peripheral reaction task.

Conclusions

Overlooking the above, three groups of people were, for different reasons, marked as possibly critical. These are:

- 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, it was decided to compare them 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

4.4 Number of tests and test subjects

The number of tests and test subjects depended on the number of variables and their manifestations to be tested. From the previous paragraph it follows that four groups of subjects were to be tested: a reference group, a group of young male subjects, a group of old people, and a group with a low educational level. Of these subjects,

the young male ones were critical when the level of attention that is needed for the tracking task was high ("at high speeds") and thus had to be tested under difficult tracking conditions.
Of each group of subjects any deterioration of the peripheral detection capability was tested for 3 lumination patterns in the ratio 1:1:½, at 20°, 50°, and 80° on either side of the line of sight. This deterioration of the peripheral detection capability was to be tested both during the presentattion of simple and complex route guiding pictogrammes.
The remaining variables could be eliminated by having the test subjects practise and by conducting two series of experiments. An oversight of the variables and their manifestations to be tested is presented below.

- experience with the peripheral reaction task		-
- complexity of the peripheral reaction task:	lumination pattern	2½
	peripheral light	3
- experience with the tracking task		-
- complexity of the tracking task / characteristics test subjects		4
- experience with the route guiding pictogrammes		-
- complexity of the route guiding pictogrammes		2

From the above it follows that the number of situations that had to be tested in each series of tests was 2½ x 3 x 4 x 2 = 60.

The duration of the first series of tests for each subject was limited to approximately 45 minutes as subjects were expected to be still relative inexperienced with the route guiding pictogrammes.
The average time between two succeeding pictogrammes was fixed at 30 s with a uniform distribution of the intervals between 15 and 45 s, thus enabling test subjects both to execute whatever action was required by the pictogramme and recuperate from the action and to create a low level of expectancy for the next pictogramme.
The above durations of each test and distribution of the time intervals between pictogrammes enabled the presentation of 90 pictogrammes. However, this amount was reduced to 80, as the slide container turned out to be able to hold only 80 slides and subjects were not to be disturbed by a container change during the tests.
It was decided not to luminate a peripheral light at the presentation of every pictogramme. To create a low expectancy level with the test subjects, peripheral lights were luminated only in approximathly one third of all the times a pictogramme was presented, i.e. at 30 of the 80 presentations.

A minimal value for the number of tests per situation to be able to draw conclusions seemed 12. Previously in this paragraph the number of situations to be tested was determined at 60, or 60/4 = 15 per group of test subjects.
Out of these values it follows that the number of test subjects had to be 12x15/30 = 6 per group of test subjects, or 24 subjects in total.

4.5 Procedure

The route guiding pictogrammes to be presented during each test were ordered randomly and in such a way that the chances on a simple route guiding pictogramme were equal to the chances on a complex pictogramme. The sequence of the pictogrammes was determined before the series of experiments and remained unchanged during a series.
The time intervals between the presentations of the route guiding pictogrammes had to vary randomly also as a great regularity would have created a high level of expectancy with the test subjects, which had to be avoided. As is mentioned previously in this chapter, the median value of the intervals was fixed at approximately 30 s. The intervals between pictogrammes were given a uniform distribution with a minimum and maximum of respectively 15 and 45 s. However, when test subjects were not able to follow-up a route guiding advice within the planned time interval, this was registered by the computer and the presentation of the next route guiding advice delayed until the previous advice had been executed.

The peripheral lights had to be luminated both when route guiding pictogrammes were presented and when no such pictogrammes were shown. The events at which a lumination of a peripheral light was accompanied by the presentation of a pictogramme consisted of 15 different combinations of the variables "phase of the accident process", "angle with the line of sight", and "complexity of the route guiding pictogramme". Each of these combinations was tested twice during one experiment. In order to avoid a high level of expectancy, these 30 events were distributed randomly over the in total 80 times that a route guiding pictogramme was presented.
The luminations of peripheral lights at times when no route guiding pictogrammes were presented, comprised of 7½ combinations. Each of these combinations was tested as often as the tests during the presentation of a route guiding pictogramme, namely twice per subject. To avoid interference with the route guiding pictogrammes, these 15 tests were situated in the greatest intervals between two successive pictogrammes.

Each of the selected test subjects was send a description of the test in advance, containing information on the experimental setting, the tracking task, the peripheral reaction task, and the task to follow-up some route guiding advices.
Before the start of the tests subjects were shown the set-up of the laboratory and the whole procedure was explained to them aurally. Subsequently they were given opportunity to study a sheet with the route guiding pictogrammes to be expected. They were instructed to accurately follow-up the route guiding advices (as they would have done in real traffic).
Before actually beginning the tests, subjects could practise the tasks to be performed. They began with only the steering task. When they could accomplish this task effortlessly, the peripheral reaction task was added to the exercise. Finally they were also presented a sample of route guiding pictogrammes. Only when they turned out to be able to control all tasks simultaneously, the real tests were started.

Throughout the whole series of tests video recordings were made of the head and eye movements of the test subjects. Furthermore time registration was made of:

- the lumination of the yellow lights
- the lumination of the red lights
- the activation of the horn lever
- the activation of the brake pedal
- any lane excessions

5. RESULTS

5.1 Introduction

This chapter presents oversights of the experimental results. Accentuated are changes in reaction time averages and changes in percentage reaction failures, arranged per group of test subjects and per angle with the line of sight of the periheral lights.
More detailed data can be found in appendix V. The interpretation and evaluation of the results is carried out in chapter 6.
When taking notice of the reaction times, it has to be taken into account that reaction times were recorded up to 5 s only, as the maximium lumination time of the peripheral lights also had been set at 5 s (see 4.2.1).
The setting of a maximum reaction time influences the results. Therefore the results have been analysed twice: once with all reaction times and once without the reaction failures (reaction time of 5 s). In the second case the reaction failures have been analysed separately.

5.2 All test subjects

Table 5.1 displays the changes in reaction time averages during the presentation of simple and complex pictogrammes, as compared to the situation without pictogrammes, for all test subjects of group I (young males), group II (elderly drivers), group III (drivers with a low educational level), and group IV (reference group). As this presentation does not provide a good oversight, the most important changes have been taken apart.
Table 5.2 presents an oversight of reaction time changes larger than 15%. The value of 15% may be somewhat arbitrary. Smalller reaction time changes were considered meaningless. Not only may they be caused by stochastic fluctuations, the practical consequences of a reaction time change of a few tenths of seconds are also small.
The omission of small effects is no quarantee for statistical significance. Therefore all changes in reaction time averages have been tested on their statistical significance (= 0.05) through Wilcoxon's test.
Tested have been the following hypothesisses.

H_1: the reaction times are larger/smaller at the presentation of simple pictogrammes than without any pictogrammes shown

H_2: the reaction times at complex pictogrammes are larger/smaller than when no pictogrammes are shown

H_3: the reaction times are larger/smaller at the presentation of complex pictogrammes than at the presentation of simple pictogrammes.

It turned out that none of the reaction time decreases were statistical significant. The results are gathered in table 5.3.

The results of the tables 5.1, 5.2, and 5.3 include reaction failures that have been attributed the reaction time of 5 s. Through omitting these situations in which test subjects did not react at all upon the lumination of a peripheral light, the results transform to the figures of the tables 5.4, 5.5, and 5.6.
The changes in percentage reaction failures are displayed in table 5.7. Table 5.8 presents the reaction failures of more than 15% and more than 1.

Table 5.1: Changes in reaction time averages

Group	angle peripheral light	Encounter situations (Lumination pattern 1)		Incident situations (Lumination pattern 2)	
		Simple pictogrammes	Complex pictogrammes	Simple pictogrammes	Complex pictogrammes
I	80°	+ 6%	- 3%	+ 32%	+ 63%
	50°	- 9%	+ 6%	- 33%	+ 33%
	20°	- 9%	+ 6%	+ 27%	+ 47%
II	80°	- 9%	- 7%	+ 23%	+ 13%
	50°	- 8%	+ 3%	--	+ 15%
	20°	+ 17%	+ 20%	+ 10%	+ 14%
III	80°	- 5%	+ 8%	- 8%	+ 12%
	50°	+ 19%	+ 11%	+ 10%	+ 19%
	20°	+ 3%	+ 3%	+ 11%	+ 44%
IV	80°	- 3%	--	+ 23%	+ 18%
	50°	--	+ 11%	+ 19%	+ 38%
	20°	- 6%	+ 6%	+ 30%	+ 15%
all	80°	- 3%	- 3%	+ 17%	+ 25%
	50°	--	+ 8%	--	+ 27%
	20°	+ 3%	+ 9%	+ 22%	+ 33%

Table 5.2: Changes in reaction time averages larger than 15%

Group	angle peripheral light	Encounter situations (Lumination pattern 1)		Incident situations (Lumination pattern 2)	
		Simple pictogrammes	Complex pictogrammes	Simple pictogrammes	Complex pictogrammes
I	80°			+ 32%	+ 63%
	50°			- 33%	+ 33%
	20°			+ 27%	+ 47%
II	80°			+ 23%	
	50°				
	20°	+ 17%	+ 20%		
III	80°				
	50°	+ 19%			+ 19%
	20°				+ 44%
IV	80°			+ 23%	+ 18%
	50°			+ 19%	+ 38%
	20°			+ 30%	
all	80°			+ 17%	+ 25%
	50°				+ 27%
	20°			+ 22%	+ 33%

Table 5.3: Statistical significant (α = 0,05) reaction time increases

Group	angle peripheral light	Encounter situations (Lumination pattern 1) H_1[1)]	H_2[2)]	H_3[3)]	Incident situations (Lumination pattern 2) H_1[1)]	H_2[2)]	H_3[3)]
I	80°					+ 63%	
	50°						+ 100%
	20°				+ 27%	+ 47%	
II	80°						
	50°						+ 15%
	20°						
III	80°						
	50°						
	20°						+ 44%
IV	80°				+ 23%		
	50°						
	20°						

1) H_1: Reaction times at simple pictogrammes larger than without any pictogrammes shown

2) H_2: Reaction times at complex pictogrammes larger than without any pictogrammes shown

3) H_2: Reaction times at complex pictogrammes larger than at simple pictogrammes

Table 5.4: Changes in reaction time averages when reaction failures are omitted from the results

Group	angle peripheral light	Encounter situations (Lumination pattern 1)		Incident situations (Lumination pattern 2)	
		Simple pictogrammes	Complex pictogrammes	Simple pictogrammes	Complex pictogrammes
I	80°	+ 3%	- 8%	- 11%	+ 11%
	50°	--	+ 6%	- 26%	+ 5%
	20°	- 6%	- 6%	+ 27%	+ 13%
II	80°	- 3%	- 8%	+ 37%	+ 32%
	50°	- 5%	- 11%	- 5%	+ 25%
	20°	+ 7%	+ 10%	+ 11%	+ 16%
III	80°	--	+ 3%	+ 5%	+ 25%
	50°	+ 3%	+ 3%	+ 15%	+ 25%
	20°	+ 6%	+ 3%	+ 11%	+ 28%
IV	80°	+ 3%	- 3%	+ 20%	+ 15%
	50°	- 3%	+ 6%	+ 6%	+ 11%
	20°	--	+ 13%	+ 30%	+ 15%
all	80°	--	- 3%	+ 16%	+ 26%
	50°	--	+ 3%	--	+ 21%
	20°	--	+ 6%	+ 17%	+ 17%

Table 5.5: Changes in reaction time averages larger than 15% when reaction failures are omitted from the results

Group	angle peripheral light	Encounter situations (Lumination pattern 1)		Incident situations (Lumination pattern 2)	
		Simple pictogrammes	Complex pictogrammes	Simple pictogrammes	Complex pictogrammes
I	80°				
	50°			- 26%	
	20°			+ 27%	
II	80°			+ 37%	+ 32%
	50°				+ 25%
	20°				+ 16%
III	80°				+ 25%
	50°				+ 25%
	20°				+ 28%
IV	80°			+ 20%	
	50°				
	20°			+ 30%	
all	80°			+ 16%	+ 26%
	50°				+ 21%
	20°			+ 17%	+ 17%

Table 5.6: Statistical significant (α= 0,05) reaction time increases when reaction failures are omitted from the results

Group	angle peripheral light	Encounter situations (Lumination pattern 1)			Incident situations (Lumination pattern 2)		
		H_1 1)	H_2 2)	H_3 3)	H_1 1)	H_2 2)	H_3 3)
I	80°						
	50°						
	20°					+ 27%	
II	80°						
	50°					+ 25%	+ 32%
	20°						
III	80°						
	50°						
	20°					+ 28%	
IV	80°				+ 20%		
	50°						
	20°	+ 13%					

1) H_1: Reaction times at simple pictogrammes larger than without any pictogrammes shown

2) H_2: Reaction times at complex pictogrammes larger than without any pictogrammes shown

3) H_3: Reaction times at complex pictogrammes larger than at simple pictogrammmes

Table 5.7: Changes in percentage reaction failures

Group	angle peripheral light	Encounter situations (Lumination pattern 1)		Incident situations (Lumination pattern 2)	
		Simple pictogrammes	Complex pictogrammes	Simple pictogrammes	Complex pictogrammes
I	80°	+ 13%	+ 9%	+ 22%	+ 33%
	50°	- 16%	+ 2%	- 5%	+ 20%
	20°	- 5%	+ 20%	--	+ 17%
II	80°	- 28%	- 10%	+ 10%	--
	50°	- 17%	+ 18%	--	- 2%
	20°	+ 18%	+ 18%	+ 4%	+ 4%
III	80°	- 19%	+ 11%	- 7%	- 7%
	50°	+ 44%	+ 17%	- 5%	- 5%
	20°	- 5%	+ 4%	--	+ 13%
IV	80°	- 5%	+ 10%	+ 3%	+ 3%
	50°	+ 3%	+ 16%	+ 7%	+ 20%
	20°	- 10%	- 10%	--	--
all	80°	- 9%	+ 5%	+ 7%	+ 8%
	50°	+ 2%	+ 14%	--	+ 9%
	20°	+ 2%	+ 8%	+ 2%	+ 10%

Table 5.8: Changes in percentage reaction failures larger than 15% and larger than 1

Group	angle peripheral light	Encounter situations (Lumination pattern 1)		Incident situations (Lumination pattern 2)	
		Simple pictogrammes	Complex pictogrammes	Simple pictogrammes	Complex pictogrammes
I	80°			+ 22%	+ 33%
	50°	- 16%			+ 20%
	20°		+ 20%		+ 17%
II	80°	- 28%			
	50°	- 17%	+ 18%		
	20°	+ 18%	+ 18%		
III	80°	- 19%			
	50°	+ 44%	+ 17%		
	20°				
IV	80°				
	50°		+ 16%		+ 20%
	20°				
all	80°				
	50°				
	20°				

5.3 Homogenised groups

Purpose of the classification of the test subjects into four groups was to create sub-populations of a homogeneous character. The behaviour of some of the test subjects during the experiments, however, gave ground to the suspicion that they were not representative for the group they had been placed in. Therefore the analysisses have been repeated with the suspected non-representative subjects removed from the groups. Thus, two subjects have been removed from group I (young males), one subject from group II (elderly drivers), and two test subjects from group III (drivers with a low educational level).

The main thought behind these omissions was that through homogenisations the variances would decrease and therewith more changes in

reaction time averages would become statistical significant.
From a traffic safety point of view, such an omission is justifiable as one of the aims of the experiments was to discern a sub-group that is most critical to the presentation of in-car visual information.
The results of the homogenised groups are displayed in the tables 5.9, 5.10, and 5.11. With the omission of reaction failures, these results change into the values of the tables 5.12, 5.13, and 5.14. The changes in percentage reaction failures are shown in table 5.15. In table 5.16 an oversight is given of the changes that are larger than 15% and larger than 1.

Table 5.9: Changes in reaction time averages; homogenised groups

Group	angle peripheral light	Encounter situations (Lumination pattern 1)		Incident situations (Lumination pattern 2)	
		Simple pictogrammes	Complex pictogrammes	Simple pictogrammes	Complex pictogrammes
I	80^{o}	+ 11%	--	+ 50%	+ 65%
	50^{o}	- 14%	+ 9%	- 51%	+ 41%
	20^{o}	- 6%	+ 16%	+ 26%	+ 73%
II	80^{o}	- 7%	- 7%	+ 30%	+ 9%
	50^{o}	- 13%	+ 5%	- 30%	+ 7%
	20^{o}	+ 24%	+ 17%	+ 41%	+ 24%
III	80^{o}	- 5%	+ 5%	+ 17%	+ 39%
	50^{o}	--	+ 11%	+ 13%	+ 30%
	20^{o}	+ 9%	+ 6%	+ 21%	+ 26%
IV	80^{o}	- 3%	--	+ 23%	+ 18%
	50^{o}	--	+ 11%	+ 19%	+ 38%
	20^{o}	- 6%	+ 6%	+ 30%	+ 15%

Table 5.10 Changes in reaction time averages larger than 15%; homogenised groups

Group	angle peripheral light	Encounter situations (Lumination pattern 1)		Incident situations (Lumination pattern 2)	
		Simple pictogrammes	Complex pictogrammes	Simple pictogrammes	Complex pictogrammes
I	80°			+ 50%	+ 65%
	50°			- 51%	+ 41%
	20°		+ 16%	+ 26%	+ 73%
II	80°			+ 30%	
	50°			- 30%	
	20°	+ 24%	+ 17%	+ 41%	+ 24%
III	80°			+ 17%	+ 39%
	50°				+ 30%
	20°			+ 21%	+ 26%
IV	80°			+ 23%	+ 18%
	50°			+ 19%	+ 38%
	20°			+ 30%	

Table 5.11 Statistical significant ($\alpha = 0,05$) reaction time increases; homogenised groups

Group	angle peripheral light	Encounter situations (Lumination pattern 1)			Incident situations (Lumination pattern 2)		
		H_1 1)	H_2 2)	H_3 3)	H_1 1)	H_2 2)	H_3 3)
I	80°						
	50°			+ 27%			
	20°					+ 73%	
II	80°						
	50°						+ 53%
	20°	+ 24%					
III	80°						
	50°						
	20°					+ 26%	
IV	80°				+ 23%		
	50°						
	20°						

1) H_1: Reaction times at simple pictogrammes larger than without any pictogrammes shown

2) H_2: Reaction times at complex pictogrammes larger than without any pictogrammes shown

3) H_3: Reaction times at complex pictogrammes larger than at simple pictogrammes

Table 5.12: Changes in reaction time averages; homogenised groups, reaction failures omitted from the results

Group	angle peripheral light	Encounter situations (Lumination pattern 1)		Incident situations (Lumination pattern 2)	
		Simple pictogrammes	Complex pictogrammes	Simple pictogrammes	Complex pictogrammes
I	80°	+ 6%	- 6%	--	+ 30%
	50°	- 6%	+ 3%	- 35%	- 10%
	20°	--	--	+ 27%	+ 20%
II	80°	- 5%	- 7%	+ 50%	+ 22%
	50°	- 6%	- 11%	--	+ 37%
	20°	+ 10%	+ 10%	+ 12%	+ 24%
III	80°	--	--	+ 10%	+ 30%
	50°	--	+ 6%	+ 24%	+ 43%
	20°	+ 13%	+ 9%	+ 21%	+ 26%
IV	80°	+ 3%	- 3%	+ 20%	+ 15%
	50°	- 3%	+ 6%	+ 6%	+ 1%
	20°	--	+ 13%	+ 30%	+ 15%

Table 5.13: Changes in reaction time averages larger than 15%; homogenised groups; reaction failures omitted from the results

Group	angle peripheral light	Encounter situations (Lumination pattern 1)		Incident situations (Lumination pattern 2)	
		Simple pictogrammes	Complex pictogrammes	Simple pictogrammes	Complex pictogrammes
I	80°				+ 30%
	50°			- 35%	
	20°			+ 27%	+ 20%
II	80°			+ 50%	+ 22%
	50°				+ 37%
	20°				+ 24%
III	80°				+ 30%
	50°			+ 24%	+ 43%
	20°			+ 21%	+ 26%
IV	80°			+ 20%	
	50°				
	20°			+ 30%	

Table 5.14: Statistical significant (α = 0,05) reaction time increases; homogenised groups, reaction failures omitted from the results

Group	angle peripheral light	Encounter situations (Lumination pattern 1)			Incident situations (Lumination pattern 2)		
		H_1 1)	H_2 2)	H_3 3)	H_1 1)	H_2 2)	H_3 3)
I	80°						
	50°			+ 10%			
	20°						
II	80°						
	50°					+ 37%	+ 37%
	20°						
III	80°						
	50°						
	20°					+ 26%	
IV	80°				+ 20%		
	50°						
	20°		+ 13%				

1) H_1: Reaction times at simple pictogrammes larger than without any pictogrammes shown

2) H_2: Reaction times at complex pictogrammes larger than without any pictogrammes shown

3) H_3: Reaction times at complex pictogrammes larger than at simple pictogrammes

Table 5.15: Changes in percentage reaction failures; homogenised groups

Group	angle peripheral light	Encounter situations (Lumination pattern 1)		Lumination pattern 2 (Lumination pattern 2)	
		Simple pictogrammes	Complex pictogrammes	Simple pictogrammes	Complex pictogrammes
I	80°	+ 17%	+ 13%	+ 33%	+ 29%
	50°	- 14%	+ 15%	- 6%	+ 34%
	20°	- 8%	+ 26%	--	+ 25%
II	80°	- 23%	- 12%	+ 21%	+ 4%
	50°	- 17%	+ 33%	- 24%	- 13%
	20°	+ 22%	+ 11%	+ 14%	--
III	80°	- 13%	+ 16%	+ 6%	+ 14%
	50°		+ 14%	- 8%	- 8%
	20°	- 7%	- 7%	--	--
IV	80°	- 5%	+ 10%	+ 3%	+ 3%
	50°	+ 3%	+ 16%	+ 7%	+ 20%
	20°	- 10%	- 10%	--	--

Table 5.16: Changes in percentage reaction failures larger than 15% and larger than 1; homogenised groups

Group	angle peripheral light	Encounter situations (Lumination pattern 1)		Incident situations (Lumination pattern 2)	
		Simple pictogrammes	Complex pictogrammes	Simple pictogrammes	Complex pictogrammes
I	80^{o}	+ 17%		+ 33%	+ 29%
	50^{o}				+ 34%
	20^{o}		+ 26%		+ 25%
II	80^{o}	- 23%		+ 21%	
	50^{o}	- 17%	+ 33%	- 24%	
	20^{o}	+ 22%			
III	80^{o}		+ 16%		
	50^{o}				
	20^{o}				
IV	80^{o}				
	50^{o}		+ 16%		+ 20%
	20^{o}				

6 EVALUATION AND DISCUSSION

6.1 Introduction

Aim of the experiments was to determine the effects on the driver's reaction capability of the presentation of visual route guiding advices through pictogrammes on a dashboard-mounted display and to determine the variables that are of influence hereon. This was tested through the reaction of test subjects on the lumination of peripheral lights under varying circumstances. The reactions at moments when the test subjects were not watching a pictogramme is compared with the reaction when they are watching a pictogramme.
The evaluation of the results is not without difficulty. The reasons herefore are twofold. First, any relations in the experimental data may well be suppressed by stochastic fluctuations caused by non-controllable parameters such as the temporary attention level of the test subjects, the direction in which a test subject is watching at the moment a peripheral light is luminated, an inaccurate execution of the reaction task, the temporary workload for tracking, and the like.
Second, the number of test subjects and tests was rather small in relation to the number of explanatory variables to be accounted for. Although this was a design feature of the tests (they were ment to be indicative, to determine the variables that are of influence on the reaction of a driver), it does prevent on one hand the detection of small effects and on the other hand the drawing of conclusions from small differences in the reactions of the test subjects.
The above limitations had to be kept in mind at the interpretation of the results.

To be tested were the effects on the driver's reaction capability of the variables "Complexity of the route guiding pictogrammes" and "Characteristics of the test subjects / complexity of the tracking task". These effects had to be determined under varying circumstances: at two different situations of the traffic process (encounter situations and incident situations, represented through two different lumination patterns of the peripheral lights) and at three different angles of the peripheral lights with the line of sight (20^o, 50^o, and 80^o).
First, the results will be evaluated per group of test subjects (paragraph 6.2). In paragraph 6.3 the effects of the different variables will be discussed in more general terms and possible explanations for the found relations will be put forward. The chapter will be summarised in paragraph 6.4.

The discussions all are based primarily on table 5.2 that contains the changes in average reaction time larger than 15%. This table is the most general one from which no possible relevant information has been omitted. Whenever the results give cause to this, the attention is also focussed on the other tables of chapter 5.

6.2 Results per group of test subjects

6.2.1 Group I: young male drivers

Group I consists of young male drivers, varying in age from 18-24 years. In real traffic situations, drivers of this group are inclined to speeding and taking more risks than the average driver. Therefore the test subjects of group I were given the opportunity of selecting, through the accelerator pedal of the test car, a high speed of the figure to be controlled on the monitor in front of them.
Indeed it followed from the results that drivers of other groups needed on average 14-22% more time to conduct the same test sequence.

For the test subjects of group I no major reaction time increases occurred in the encounter situation. In contrast herewith, in the incident situation the presentation of a pictogramme was accompagnied by a major increase of the average reaction time in 5 of the 6 situations (table 5.2).
Of these increases many turned out to be statistical significant (table 5.3). It is striking that of the in total 7 statistical significant reaction time increases, 4 occurred in group I.
The homogenised group I demonstrates the same pattern as described above, only with less statistical significance.
The omission of reaction failures from the results shows a remarkable change in the reaction time increases: of the original 5 major reaction time increases only 1 is left. An explanation herefore is found in table 5.8: major increases in percentages reaction failures have replaced the increases in reaction time.
Apparently, for the test subjects of group I the presentation of pictogrammes does not lead so much to longer reactions as to more reaction failures.

The effects of the angle of the peripheral lights with the line of sight are difficult to judge from table 5.2. At the most can be stated that the test subjects of group I are less liable to react considerably slower if the signal comes from a light at 50^{o} with the line of sight. The results of the homogenised group I (table 5.10) slightly implicate a greater deteriorating effect of pictogrammes if the signals are coming from lights at 20°.

The complexity of route guiding pictogrammes hardly seems to be related to the number of reaction time increases. From table 5.2, however, it follows that the increase itself is larger for complex pictogrammes than for simple ones.
When reaction failures are omitted, again, it turns out that in table 5.2 the larger increases of complex pictogrammes are not caused by longer reaction times, but by more reaction failures (table 5.5 and 5.8).

Summarising the above, it can be stated that young males drive faster than average drivers. Perhaps as a result of this driving behaviour, that is accompagnied with a high task load, and in combination with their inexperience, in difficult situations their reaction capability is deteriorated more often than of test subjects from other groups.
This deterioration manifests itself not through reaction time increases, but through more failures to react at all.
These failures occur especially in incident situations. Complex pictogrammes cause larger increases in percentage reaction failures than simple ones. There is a slight indication that the effects are larger for stimuli from lights situated in front of the test subjects and smaller for stimuli from 50° with the line of sight.

6.2.2 Group II: elderly drivers

The test subjects of group II are elderly drivers of over 60 years of age. In comparison with the average driver, subjects of this group have a smaller peripheral field, stiffer muscles, and a slower reaction capability.
The results of this group can be characterised by long reaction times and large percentages reaction failures, sometimes as much as 50%. This indicates that the task to react on the lumination of a peripheral light while simultaneously performing a tracking task was difficult for the test subjects of group II. However, not the reaction capability itself was of importance in the tests, but the changes herein as a result of the presentation of route guiding pictogrammes.

At first sight the presentation of route guiding pictogrammes seems to have small effects on the reaction times. From the tables 5.1 and 5.2 it follows that major incraeses of the reaction time averages occurred only in three situations. However, this result is misleading: the large percentage of reaction failures disguises the

reaction time changes [1].
When the reaction failures are omitted (table 5.5), it shows that in the incident situation the presentation of complex pictogrammes in all situations leads to a major increase of the average reaction time. In the encounter situation this is the case only in one situation.
Homogenisation of group II reveals an other striking effect: at the presentation of a pictogramme major reaction time increases always occur when the stimulus is send from a lights at 20^{o} with the line of sight (table 5.10).
The percentages reaction failures are large, but seem hardly influenced by the presentation of route guiding pictogrammes. In some situations pictogrammes lead to an increase of the percentage failures and in other cases to a decrease, seemingly without any pattern. These fluctuations therefore are supposed to be stochastical.

The effects of the situation of the traffic proces and the complexity of the route guiding pictogrammes become manifest in table 5.5: the presentation of complex route guiding pictogrammes in the incident situation causes major reaction time increases in all situations.

The number of statistical significant changes of average reaction times is small. Therefore, the above relations consist of a conciderable level of uncertainty.

Overlooking the results of the group II test subjects, it can be noted that elderly drivers experience much difficulty with the simultaneous reaction and tracking task, which manifests itself through higher than average reaction times and many reaction failures.
The number of reaction failures is hardly influenced by the presentation of route guiding pictogrammes, but the reaction time is. Especially complex pictogrammes in the incident situation lead to major reaction time increases. Furthermore, elderly drivers seem to be affected by the presentation of route guiding pictogrammes more when having to react on stimuli from lights at 20^{o} than on stimuli from other lights.

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[1] See also appendix IV

6.2.3 Group III: drivers with a low educational level

Group III consists of test subjects with a low level of education and a profession that requires little cognitive processing.
Within group III, major reaction time increases occurred seldomly, as can be derived from table 5.2. An indication of the presentation of complex pictogrammes in the incident situation being the most critical combination, is given by two of the three major reaction time increases taking place under these circumstances. A confirmation of this indication is given after the omission of reaction failures (table 5.5) and after the homogenisation of group III (table 5.10).
For the homogenised group III simple pictogrammes in the incident situation also induce major reaction time increases for stimuli from lights at 20^{o} and 80^{o} with the line of sight.
As for group II, the number of statistical significancies is small and the percentage reaction failures is hardly affected by the presentation of pictogrammes.

Evaluating the above, again, it can be noted that major reaction time increases happen in the incident situation and especially at the presentation of complex pictogrammes.

6.2.4 Group IV: reference group

The test subjects of group IV belonged to neither of the groups I, II, and III, that were considered critical from a traffic safety point of view to one or more of the tasks to be executed in the tests and in real traffic situations with a Carin system build into a car.
Group IV consisted of test subjects of 35 to 45 years of age with an intermediate to high level of education.

Major reaction time increases occurred frequently in the incident situation, in casu in 5 of the 6 situations (table 5.2). In the encounter situation no major reaction time increases showed. Only 1 of the 5 increases in the incident situation turned out to be statistical significant (table 5.3).
After the omission of reaction failures, only 2 major reaction time increases are left (tabel 5.5). This is an indication, which is confirmed in the tables 5.6 and 5.7, that the increases in table 5.2 are partly the result of larger reaction time values and partly of a larger percentage reaction failures.
From the results no conclusion can be drawn that complex pictogrammes cause larger deteriorations of the reaction capability than simple ones.

Homogenisation of the groups left group IV unchanged. Therefore, the results of the homogenised and non-homogenised groups IV are identical.

Summarising the found relations it can be concluded that the test subjects of group IV do not prominently distinct themselves on one or more of the aspects that may be of influence on the deterioration of the reaction capability.
The only variable that is of considerable influence, is the situation of the traffic process: all major reaction time increases occurred in the incident situation against no one in the encounter situation.

6.3 Variables

6.3.1 Situation of the traffic process

From the analysisisses of the groups I, II, III, and IV it follows that the deteriorating effect of the pictogrammes on the reaction capability is much smaller in the encounter situation than in the incident situation. But also when is not differentiated over the four groups, the tendency is clear: in encounter situations 3 major changes in reaction time averages manifested themselves against 19 major changes in incident situations (table 5.2).
When is looked at the statistical significant reaction time incresases, the differences are even more striking: none of the 7 statistical significant reaction time increases took place in the encounter situation (table 5.3).
The remaining tables on reaction time changes confirm the tendency of the tables 5.2 and 5.3. In table 5.1, in which also small reaction time changes have been incorporated, it can be noted that in the encounter situation the presentation of a pictogramme, especially a simple one, is frequently accompagnied with even a small decrease of the reaction time.
The changes in percentage reaction failures (table 5.8) are less distinct than the changes in reaction time, although the indications tend to lead to the same results. In the encounter situation both major increases and major decreases in percentage reaction failures manifest themselves, whereas in the incident situation only major increases occur.
A statistical analysis on the significance of the results on percentage reaction failures can not be made as all test subjects participated in only one experiment.

For the relative low impact of pictogrammes in the encounter

situation, a fourfold possible explanations can be put forward. First, at the start of the encounter situation the lumination level of the peripheral lights still is very low, making it hard to discern a lumination, even when no pictogramme is shown. The reasons herefore already have been mentioned in 4.2.1: the urgency of reaction in the encounter situation is only moderate, which is expressed via the gradual lumination of the peripheral lights. (In real traffic oncoming and crossing vehicles also approach gradually.) This results in considerable larger reaction times in the encounter situation as compared to incident situation reaction times and therefore in a larger sensitivity to reaction time increases in the incident situation as compared with 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 be able to respond quicker (in casu: pressing the horn lever) when watching the dashboard than when they attend themselves to the steering task on a monitor in front them. For, when test subjects are watching a pictogramme that is projected on a display in the dash board , the horn button is already within their field of vision, making a turning of the head, followed by a quick search superfluous.
It must be kept in mind that 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.

The implications of the above are that drivers hardly are distracted by route guiding pictogrammes in the encounter situation but are distracted in incident situations, leading to considerable larger reaction times (up to 60% larger, according to the tables 5.2 and 5.3, i.e. a 1.2 s longer reaction time (see appendix V)).
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 pictogrammes.
Further research on the effects of in-car visual information on the reaction capability of drivers in incident situations and on the

variables that are of influence hereof, is strongly recommended.

6.3.2 Angle with the line of sight

Table 5.2 shows that major reaction time increases occurred for stimuli from lights at 20°, 50°, and 80°, 6 times, 6 times and 5 times respectively. However, to come to a verdict on the effects of the angle with the line of sight on any deterioration of the reaction capability during the presentation of a pictogramme, table 5.2 is not sufficient as it is the result of a combination of a multiplicity of relations.

Differentiation between the groups of test subjects is necessary to discern any patterns.

In the discussion of the results per group of test subjects in paragraph 6.2, two effects distincted themselves. First, the deteriorating effect of pictogrammes seems less for stimuli coming from the lights at 50° than for stimuli from other lights. This indication manifests itself for the test subjects from group I (table 5.2) and for subjects from the homogenised groups II and III (table 5.10). A smaller deteriorating effect of pictogrammes when the stimuli are presented from lights at 50° with the line of sight may have been caused by the fact that signals from this angle always will have to be noticed peripherally, regardless whether the test subjects are watching a pictogramme or are attending themselves to the tracking task. Normally objects at an angle of 50° with the line of sight are not incorporated into the field of vision (that is restricted to ± 50°: 25° to the left and 25° to the right).

The second effect is the greater liability to a deteriorating reaction capability when the signal comes from one of the lights at 20°. Especially for the test subjects of the homogenised group II (elderly people) this effect is striking: major reaction times occurred for all situations in which stimuli were presented from lights at 20° whereas in only one of the situations in which the signal did not come from a light at 20°, a major reaction time increase was registered.

The deterioration for signals from lights at 80° is larger than for signals from 50°, which could have been caused by a narrowing of the peripheral field through which signals from 80° are no longer incorporated in the field of vision.

Even without differentiation between the groups of test subjects, table 5.10 shows the relative large number of major reaction time increases for signals from lights at 20° as compared to signals from other lights: major increases happened 10, 4, and 7 times for signals from lights at 20°, 50°, and 80° respectively.

Two explanations can be put forward for a possible larger sensitivity for reaction time increases of stimuli from lights at 20^o with the line of sight. Firstly, when the driver is attending to his tracking task only, lights at 20^o will often be seen foveally. For, these lights are incorporated in the field of vision. When a driver is attending to the dashboard a foveal detection of the signal is not possible. It will be clear that a foveal detection of a stimulus enables a driver to react quicker than when his attention is drawn through the peripheral part of the eye. In the latter case he has to turn his head and/or eyes and search foveally for the light. This is not necessary when the signal is seen foveally immediately.
Secondly, when the driver looks straight ahead the lights at 20^o with the line of sight are close to the centre of the field of vision, whereas their position when the driver watches the dashboard is somewhere in the outer areas of the peripheral eye sight. Furthermore the boundaries of the peripheral eye sight ly at apporoximately 50^o in vertical direction for the average human being (circa 80^o in horizontal direction, see also figure 4.1), meaning that when a driver watches the dashboard, the lights at 20^o with the sight line are near the boundaries of the peripheral eye sight. This aspect even more counts for elderly drivers, as peripheral vision deteriorates with age. The difference in the vertical position of the lights in the eye sight is as good as absent for the lights at 80^o with the line of sight and intermediate for the lights at 50^o.

If pictogrammes would indeed induce most reaction time increases for stimuli coming from points in front of the car, this would be a most unhappy coincidence, as most of the traffic a driver has to account for is coming from that direction.
Further tests on the distraction of drivers by route guiding pictogrammes from stimuli presented somewhere in front of the car seem advisory. It is also worthwhile to research whether this distraction can be decreased by positioning the flat panel display, onto which the pictogrammes are projected, higher on the dashboard. Thus stimuli presented in front of the car would be projected nearer the centre of the driver's vision during times that he watches the display. Especially for elderly drivers this would seem an improvement. To realise any higher location of the Carin display on the dashboard, the cooperation of car manufacturers wil be indispensable, as the Carin display is to be incorporated into the total dashboard and instrument configuration.

deteriorated reaction performances, but on average the extent of this deterioration was smaller than for complex pictogrammes under the same conditions.

That the effect of the complexity of route guiding pictogrammes did not manifest itself more substantially, 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 coordinance with the designed real Carin pictogrammes. It is likely that pictogrammes containing more units of information will cause larger deteriorations of the reaction capability. For, as has already been mentioned report IA, the interpretation time for a picture increases more than linearly with it's complexity. It seems recommendable to test this in a follow-up study.

7 Summary

In this report a research has been described on the possible distraction of a driver by the presentation of visual route guiding messages that are momentary being considered as a secondary information source in the Carin car information and navigation system.
It was showed that the driver task is threefold. The presentation of route guiding pictogrammes which assist the driver in following his route, should not distract him from his other two tasks: tracking and accounting for the other traffic and the traffic environment. To determine this, a thorough analysis was made of the way in which those two tasks normally are executed.
The tracking task is carried out by the driver via the undertaking of small course corrections every few seconds. Thus route guiding pictogrammes will not distract a driver from his tracking task, as long as the time necessary for interpretation of the presented pictogramme and turning the attention to and from the display, is smaller than the time drivers have at their disposal between two successive course corrections. These time intervals can be derived from the existing literature. The research on interpretation times for pictogrammes should not be machine-paced but subject-paced in order to represent real traffic situations as close as possible.
Within the task to account for the other traffic and the traffic environment distinction should be made between to different situations of the traffic process: encounter situations and incident situations. In the first case a driver encounters a relative slowly approaching vehicle and has left ample time to react. In the second situation a driver is faced with the necessity to quickly carry out an emergeney manoeuvre in order to avoid an accident.

A laboratory experiment has been set up to research the possible distraction of presenting route guiding messages on the task to account for the other traffic and the traffic environment. Great care has been taken to simulate real traffic situations as good as possible, taking into account the tasks to be executed and the way in which they are executed in real traffic situations.
Test subjects have been requested to react on the lumination of sets of peripheral lights while simultaneously conducting a tracking task. The different situations of the traffic process have been represented by different lumination patterns and different required reactions.
From time to time route guiding pictogrammes were shown on the presentation of which the subjects were requested to take action.
The results of the reaction tests at periods when subjects were watching the route guiding pictogrammes have been compared with the

results when no pictogrammes were shown.
In the tests allowance has been made for the variables that could be of influence on the results. Of these variables the most extreme manifestations were used, as traffic unsafety is the result of a combination of the most critical circumstances. The variables that have been accounted for are mentioned in the discussion of the results.

Overlooking the outcome of the laboratory experiments, the conclusion seems justified that the in-car presentation of pictogrammes under circumstances does lead to a deterioration of the reaction capability. In the following these circumstances will be reviewed briefly.

Most important for the extent of the deteriorating effects on the reaction performance is the situation of the traffic process. In the encounter situation hardly any deteriorations occur. Opposed to this, in the incident situation the lumination of a peripheral light at a moment when a test subject is watching a pictogramme most frequently is accompagnied by a deteriorated reaction performance.
These deteriorated reactions in the incident situation are very serious, as they can not be eliminated by changing some variables. At the most the deteriorations can be decreased slightly by an adequate selection of pictogrammes. For, the test subjects of the groups II and III (and only of those two groups) experience a smaller deterioration at the presentation of simple pictogrammes.
The consequences of most deteriorations occurring in incident situations are severe, as in the incident situation life-saving emergency manoeuvres have to be executed timely and adequatly, whereas in encounter situations drivers still have left some seconds to react. Fortunately, the chances on a deterioration of the reaction performance in the incident situations (that in it self already happens with a low frequency) are not large as the incident situation should start during the period that a driver watches a pictogramme.

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 pictogrammes, although the influence varies over the four groups of test subjects.
The deteriorating effect of pictogrammes seems less when the stimuli are presented from an angle of 50^{o} with the line of sight. This is supposed to be related to the little differences between the situation in which subjects are watching a pictogramme and the situation

in which they are attending themselves to the tracking task: in both situations a signal from 50^o has to be detected peripherally.
Opposed to this, the deteriorations are larger when the stimulus is given from a light at 20^o 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^o. 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^o-50^o with the sight line. An apparent smaller deterioration of the reaction capability for stimuli from about 50^o therefore would be favourable, but a larger sensitivity to deteriorations for stiumuli from $\pm$ 20^o would be most unhappy.
A possible way to reduce the many reaction time increases for stimuli from 20^o, could be a higher positioning of the pictogramme display in the car.

The relation between the complexity of the pictogrammes and the extent of the deteriorations of the reaction capability is not as manifest as may have been expected. This may have been due to the high reality level of the pictogrammes: the complex pictogrammes still contained only two units of information, just as is planned for the real Carin pictogrammes. More complex pictogrammes might have caused larger deteriorations.
The experimental results seem to lead to the conclusion that in normal situations complex pictogrammes cause no extra deterioration of the reaction capability, but under difficult circumstances they do. Thus, the complexity of pictogrammes turned out to have no effect for the test subjects of the reference group, a slight effect for subjects with a low educational level and a profession that requires little cognitive processing, and a considerable effect for elder drivers and for young male drivers at high speeds.
The results lead to the conclusion that the pictogrammes should be very simple and quickly interpretable, as even the tested complex pictogrammes (that still were relative simple) caused, under circumstances, larger deteriorations of the reaction performance than simple pictogrammes. It should be kept in mind though that even the simple pictogrammes caused deteriorations.

The experiments show that not all drivers are equally distracted by the presentation of pictogrammes.
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.
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.
Drivers with a low educational level and a profession that requires little cognitive processing experience few deteriorations of the reaction capability. They seemed to be affected especially by the presentation of complex pictogrammes in the incident situation.
Subjects of the reference group do not prominently distinct 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.

Epilogue

Through the laboratory experiments it has been demonstrated that, under circumstances, the presentation of pictogrammes does lead to a deteriorated reaction capability and therewith to a decrease of traffic safety. However, this should not immediately lead to the conclusion that the Carin visual information displays therefore must not be build into cars. The reasons herefore are threefold.
First, a driver seldomly will have to use the pictogrammes, as the Carin visual information display serves only as a secondary information source. Only if drivers do not hear or understand the aural route guiding advice (completely) they will attend themselves to the display.
Second, the pictogrammes will not very frequently cause deteriorations. For, they cause most deteriorations in relative seldom occurring situations that an incident situation starts at a moment when a driver is watching a pictogramme.
Third, the distraction by visual information displays is only one of a whole series of possible positive and negative effects on the traffic safety of the Carin system (see report IA). An enormous advantage of the Carin system e.g. is that search behaviour, that probably is far more distracting than the presentation of pictogrammes, can be avoided. The distraction caused by visual information displays will have to be balanced with all other effects of the system.

Furthermore, it must be considered that the laboratory experiments were indicative. It is strongly recommended to verify the results in real world tests, and perhaps even in more extensive laboratory experiments.

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Appendix I: Calculation of the minimal lateral speed

To simulate the natural lateral drift of vehicles in real traffic in the experimental setting of the laboratory tests, the figure on the monitor that was to be controlled by the test subjects was given a minimal lateral speed. Whenever the position of the steering wheel ordered a lateral speed smaller than the minimal one, this command was overruled and the lateral speed given the value of the minimal lateral speed.

The minimal lateral speed was calculated through the minimal steering wheel reversal rates and the median values for the times to line crossing. According to the literature (see reports IA and IB), at velocities of ca. 100 km/h the minimal value for the steering wheel reversal rate is ± 0,1 Hz, meaning that a driver corrects his course at least once every 10 s.

Blaauw (reports IA and IB) found, at 100 km/h, median left and right time to line crossings (TLC) of respectively 8,5 and 6,4 s. In this case the use of a median value is acceptable, as large TLC-values will not occur simultaneously with the minimal steering wheel reversal rate.

With these data the minimal lateral speed v_x(min,100) at longitudinal speeds of 100 km/h (28 m/s), given a car width of 1,6 m and a lane width of 3,6 m, can be calculated as (figure a.1):

$$v_x(\text{min},100) = (3{,}6 - 1{,}6)\ \text{m} \ / \ (8{,}5 + 10 + 6{,}4)\ \text{s} = 0{,}08\ \text{m/s}$$

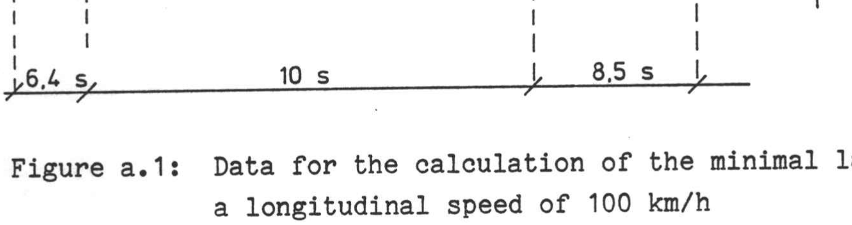


Figure a.1: Data for the calculation of the minimal lateral speed at a longitudinal speed of 100 km/h

For other longitudinal speeds than 100 km/h, the minimal lateral speed was calculated as a linear inter- or extrapolation of the minimal lateral speed at 100 km/h:

$v_x(min) = (v_y / 100) . v_x(min,100)$,   with:

$v_x(min)$: the minimal lateral speed (m/s)
$v_x(min,100)$: the minimal lateral speed (m/s) at a longitudinal speed of 100 km/h
v_y : the longitudinal speed (km/h)

Appendix II: The relation between the lateral speed and the longitudinal speed

Given the small heading angles that occur in the tracking task, the lateral speed can be described as a linear function of the longitudinal speed. The relation between the lateral speed v_x and the longitudinal speed v_y was expressed by the following relation:

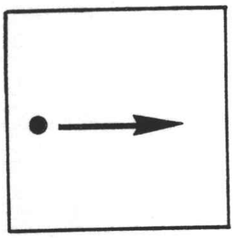
$v_x = C \cdot (p_s - \frac{1}{2}p_s(max)) / \frac{1}{2}p_s(max) \cdot v_y$, with:

v_x	: the lateral speed (m/s)
v_y	: the longitudinal speed (m/s)
p_s	: the signal from the pot meter attached to the steering wheel (Volts)
$p_s(max)$	: the maximum signal from the pot meter attached to the steering wheel (Volts)
C	: constant

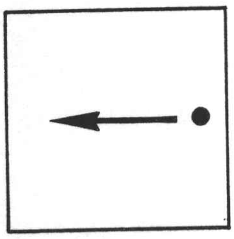
The constant C was determined from the values that occur during an overtaking manoeuvre. From previous experiments it is known that an average lane change when overtaking at a speed of 100 km/h is carried out in ± 3 s with a turning of the steering wheel of 20°. Thus the average lateral speed then, given a lane width of 3,6 m, is 3,6 / 3 = 1,2 m/s. From these values the constant C was calculated after measuring the signal from the pot meter at a 20° turning of the steering wheel.

Appendix III: Tested pictogrammes

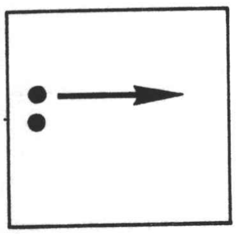
During each experiment 80 pictogrammes have been presented. In half of the times the presented pictogramme was a simple one. The other 40 times a complex pictogramme was presented.
The series of simple pictogrammes and their meaning are displayed below:



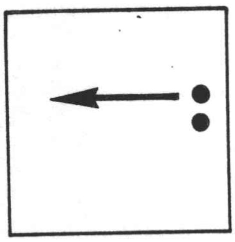
Drive right at the first dot[1)]



Drive left at the first dot



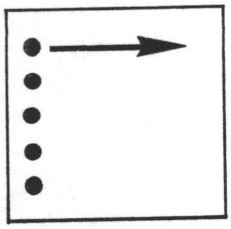
Drive right at the second dot



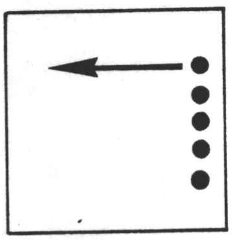
Drive left at the second dot

1) This pictogramme requests test subjects to abandone the tracking task and move the vehicle on the screen in front of them to the right

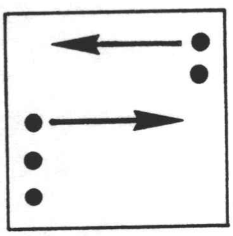
In contrast with the simple pictogrammes, the pictogrammes of the complex series could not be overlooked with a quick glance. The following complex pictogrammes have been used:



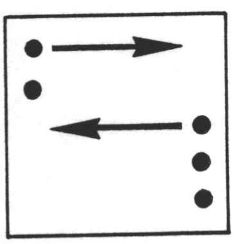
Drive right at the fifth dot



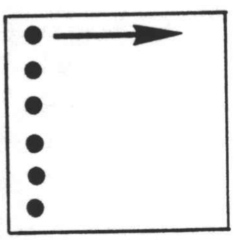
Drive left at the fifth dot



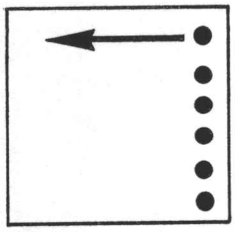
Drive right at the third dot and then left at the second dot



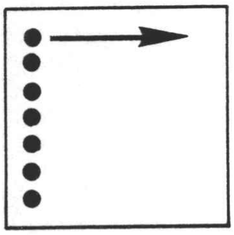
Drive left at the third dot and then right at the second dot



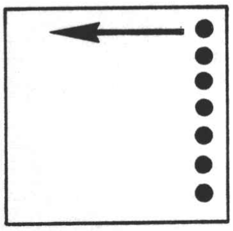
Drive right at the sixth dot



Drive left at the sixth dot



Drive right at the seventh dot



Drive left at the seventh dot

Appendix IV: The effects of the percentage reaction failures on the changes in average reaction times

In the tests, reaction failures have been attributed a fixed maximum reaction time value. This has to be taken into account when interpreting the results, as large percentages reaction failures may well disguise major changes in average reaction times. This will be demonstrated below.

When no pictogrammes are shown, the average reaction time can be described as:

$$\bar{r} = \frac{f \cdot n \cdot r_f + (1 - f) \cdot n \cdot \bar{r}_{np}}{f \cdot n + (1 - f) \cdot n} = f \cdot r_f + (1 - f) \cdot \bar{r}_{np} \qquad (1)$$

with:

$\bar{r}$: average reaction time
r_f : reaction time value that is attributed to reaction failures
$\bar{r}_{np}$: average reaction time of the situations in which subjects did not fail to react and no pictogramme was shown
n : number of tests
f : fraction reaction failures

In the same way the average reaction time when pictogrammes are presented can be defined as:

$$\bar{r} = f\, r_f + (1 - f)\, \bar{r}_p \qquad (2)$$

with:

r_p : average reaction time of the situations in which subjects did not fail to react and pictogrammes were shown

The percentage reaction time increase (p) follows from:

$$p = \frac{f \cdot r_f + (1 - f) \cdot \bar{r}_p}{f \cdot r_f + (1 - f) \cdot \bar{r}_{np}} \cdot 100\% \qquad (3)$$

From quotation (3) it easily follows that if the fraction reaction failures increases, the percentage reaction time increase becomes smaller. This disadvantage can be overcome by omitting reaction failures from the results.

Appendix V: Experimental data

Test subjects group I
Average reaction time ($\bar{x}$), standard devaition (s), number of tests (n);

picto-gramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	$\bar{x}$	3,6	3,5	3,2	1,9	2,1	1,5
	s	0,7	0,8	0,6	0,5	1,0	0,3
	n	14	19	19	17	22	17
simple	$\bar{x}$	3,8	3,2	2,9	2,5	1,4	1,9
	s	0,7	0,3	0,4	1,5	0,4	0,4
	n	8	4	8	9	4	5
complex	$\bar{x}$	3,5	3,7	3,4	3,1	2,8	2,2
	s	0,7	0,8	1,1	1,5	1,5	1,4
	n	11	11	8	9	8	12

Test subjects group II
Average reaction time ($\bar{x}$), standard deviation (s), number of tests (n);

picto-gramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	$\bar{x}$	4,5	4,0	3,0	3,1	2,6	2,1
	s	0,6	0,8	0,4	1,6	1,3	1,0
	n	13	15	12	15	20	15
simple	$\bar{x}$	4,1	3,7	3,5	3,8	2,6	2,3
	s	0,7	0,7	0,8	1,4	1,4	1,1
	n	11	10	11	8	5	9
complex	$\bar{x}$	4,2	4,1	3,6	3,5	3,0	2,4
	s	0,8	1,0	0,8	1,5	1,2	1,1
	n	11	11	11	10	11	9

Test subjects group III
Average reaction time ($\bar{x}$), standard deviation (s), number of tests (n);

picto-gramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	$\bar{x}$	4,0	3,6	3,4	2,6	2,1	1,8
	s	0,7	0,6	0,7	1,3	0,8	0,4
	n	16	17	21	15	20	18
simple	$\bar{x}$	3,8	4,3	3,5	2,4	2,3	2,0
	s	0,5	0,9	0,3	1,1	0,8	0,4
	n	7	4	4	8	5	8
complex	$\bar{x}$	4,3	4,0	3,5	2,9	2,5	2,6
	s	0,7	0,7	0,7	1,2	1,1	1,1
	n	10	13	11	8	7	8

Test subjects group IV
Average reaction time ($\bar{x}$), standard deviation (s), number of tests (n);

picto-gramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	$\bar{x}$	3,8	3,5	3,2	2,2	2,1	2,0
	s	0,8	0,7	0,7	1,2	1,1	0,6
	n	13	18	21	14	20	19
simple	$\bar{x}$	3,7	3,5	3,0	2,7	2,5	2,6
	s	0,8	0,7	0,5	1,0	1,3	1,5
	n	10	7	7	10	6	7
complex	$\bar{x}$	3,8	3,9	3,4	2,6	2,9	2,3
	s	0,8	0,9	0,6	1,3	1,6	0,6
	n	12	11	8	10	10	8

Test subjects group III
Average reaction time ($\bar{x}$), standard deviation (s), number of tests (n);

picto-gramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	$\bar{x}$	4,0	3,6	3,4	2,6	2,1	1,8
	s	0,7	0,6	0,7	1,3	0,8	0,4
	n	16	17	21	15	20	18
simple	$\bar{x}$	3,8	4,3	3,5	2,4	2,3	2,0
	s	0,5	0,9	0,3	1,1	0,8	0,4
	n	7	4	4	8	5	8
complex	$\bar{x}$	4,3	4,0	3,5	2,9	2,5	2,6
	s	0,7	0,7	0,7	1,2	1,1	1,1
	n	10	13	11	8	7	8

Test subjects group IV
Average reaction time ($\bar{x}$), standard deviation (s), number of tests (n);

picto-gramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	$\bar{x}$	3,8	3,5	3,2	2,2	2,1	2,0
	s	0,8	0,7	0,7	1,2	1,1	0,6
	n	13	18	21	14	20	19
simple	$\bar{x}$	3,7	3,5	3,0	2,7	2,5	2,6
	s	0,8	0,7	0,5	1,0	1,3	1,5
	n	10	7	7	10	6	7
complex	$\bar{x}$	3,8	3,9	3,4	2,6	2,9	2,3
	s	0,8	0,9	0,6	1,3	1,6	0,6
	n	12	11	8	10	10	8

All test subjects
Average reaction time ($\bar{x}$), standard deviation (s), number of tests (n);

pictogramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	$\bar{x}$	4,0	3,6	3,2	2,4	2,2	1,8
	s	0,7	0,7	0,6	1,3	1,1	0,6
	n	56	69	73	61	82	69
simple	$\bar{x}$	3,9	3,6	3,3	2,8	2,2	2,2
	s	0,7	0,7	0,6	1,4	1,1	1,0
	n	36	25	30	35	20	29
complex	$\bar{x}$	3,9	3,9	3,5	3,0	2,8	2,4
	s	0,8	0,8	0,8	1,4	1,3	1,1
	n	44	46	38	37	36	37

Test subjects group I, omission of reaction failures
Average reaction time ($\bar{x}$), standard deviation (s), number of tests (n);

picto-gramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	$\bar{x}$	3,6	3,2	3,1	1,9	1,9	1,5
	s	0,7	0,3	0,4	0,5	0,8	0,3
	n	14	16	18	17	21	17
simple	$\bar{x}$	3,7	3,2	2,9	1,7	1,4	1,9
	s	0,6	0,3	0,4	0,6	0,4	0,4
	n	7	4	8	7	4	5
complex	$\bar{x}$	3,3	3,4	2,9	2,1	2,0	1,7
	s	0,5	0,5	0,4	0,6	0,7	0,5
	n	10	9	6	6	6	10

Test subjects group: I
Percentage reaction failures (f) and number of tests (n)

picto-gramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	f	--	16%	5%	--	5%	7%
	n	14	19	19	17	22	17
simple	f	13%	--	--	22%	--	--
	n	8	4	8	9	4	5
complex	f	9%	18%	25%	33%	25%	17%
	n	11	11	8	9	8	12

Test subjects group II, omission of reaction failures
Average reaction time ($\bar{x}$), standard deviation (s), number of tests (n);

picto-gramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	$\bar{x}$	4,0	3,7	3,0	1,9	2.0	1,8
	s	0,5	0,5	0,4	0,3	0,5	0,5
	n	7	11	12	9	16	14
simple	$\bar{x}$	3,9	3,5	3,2	2,6	1,9	2,0
	s	0,5	0,6	0,3	0,9	0,3	0,3
	n	9	9	9	4	4	8
complex	$\bar{x}$	3,7	3,3	3,3	2,5	2,5	2,1
	s	0,6	0,3	0,4	0,8	0,7	0,5
	n	7	6	9	6	9	8

Test subjects group II
Percentage reaction failures (f) and number of tests (n)

picto-gramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	f	46%	27%	--	40%	20%	7%
	n	13	15	12	15	20	15
simple	f	18%	10%	18%	50%	20%	11%
	n	11	10	11	8	5	9
complex	f	36%	45%	18%	40%	18%	11%
	n	11	11	11	10	11	9

Test subjects group III, omission of reaction failures
Average reaction time ($\bar{x}$), standard deviation (s), number of tests (n);

picto-gramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	$\bar{x}$	3,8	3,5	3,3	2,0	2,0	1,8
	s	0,5	0,5	0,5	0,5	0,5	0,4
	n	13	16	20	12	19	18
simple	$\bar{x}$	3,8	3,6	3,5	2,1	2,3	2,0
	s	0,5	0,01	0,3	0,5	0,8	0,4
	n	7	2	4	7	5	8
complex	$\bar{x}$	3,9	3,6	3,4	2,5	2,5	2,3
	s	0,5	0,4	0,5	0,9	1,1	0,5
	n	7	10	10	7	7	7

Test subjects group III
Percentage reaction failures (f) and number of tests (n)

picto-gramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	f	19%	6%	5%	20%	5%	--
	n	16	17	21	15	20	18
simple	f	--	50%	--	13%	--	--
	n	7	4	4	8	5	8
complex	f	30%	23%	9%	13%	--	13%
	n	10	13	11	8	7	8

Test subjects group IV, omission of reaction failures
Average reaction time ($\bar{x}$), standard deviation (s), number of tests (n);

picto-gramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	$\bar{x}$	3,5	3,3	3,0	2,0	1,8	2,0
	s	0,6	0,4	0,5	0,9	0,3	0,6
	n	11	16	19	13	18	19
simple	$\bar{x}$	3,6	3,2	3,0	2,4	1,9	2,6
	s	0,7	0,3	0,5	0,6	0,4	1,5
	n	9	6	7	9	5	7
complex	$\bar{x}$	3,4	3,5	3,4	2,3	2,0	2,3
	s	0,4	0,7	0,6	1,0	0,7	0,6
	n	9	8	8	9	7	8

Test subjects group IV
Percentage reaction failures (f) and number of tests (n)

picto-gramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	f	15%	11%	10%	7%	10%	--
	n	13	18	21	14	20	19
simple	f	10%	14%	--	10%	17%	--
	n	10	7	7	10	6	7
complex	f	25%	27%	--	10%	30%	--
	n	12	11	8	10	10	8

All test subjects, omission of reaction failures
Average reaction time ($\bar{x}$), standard deviation (s), number of tests (n);

pictogramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	$\bar{x}$	3,7	3,4	3,1	1,9	1,9	1,8
	s	0,6	0,5	0,6	0,6	0,6	0,5
	n	45	59	69	51	74	68
simple	$\bar{x}$	3,7	3,4	3,1	2,2	1,9	2,1
	s	0,6	0,4	0,4	0,7	0,6	0,8
	n	32	21	28	27	18	28
complex	$\bar{x}$	3,6	3,5	3,3	2,4	2,3	2,1
	s	0,5	0,5	0,5	0,8	0,8	0,6
	n	33	33	33	28	29	33

All test subjects
Percentage reaction failures (f) and number of tests (n)

pictogramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	f	20%	14%	5%	16%	10%	1%
	n	56	69	73	61	82	69
simple	f	11%	16%	7%	23%	10%	3%
	n	36	25	30	35	20	29
complex	f	25%	28%	13%	24%	19%	11%
	n	44	46	38	37	36	37

Test subjects group I, homogenised group
Average reaction time ($\bar{x}$), standard deviation (s), number of tests (n);

picto-gramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
	$\bar{x}$	3,6	3,5	3,2	2,0	2,2	1,5
-	s	0,5	0,7	0,6	0,5	1,1	0,3
	n	10	14	12	11	16	11
	$\bar{x}$	4,0	3,0	3,0	3,0	1,3	1,9
simple	s	0,7	0,1	0,4	1,6	0,4	0,5
	n	6	3	6	6	3	4
	$\bar{x}$	3,6	3,8	3,7	3,3	3,1	2,6
complex	s	0,7	0,9	1,1	1,7	1,8	1,6
	n	8	7	6	7	5	8

Test subjects group II, homogenised group
Average reaction time ($\bar{x}$), standard deviation (s), number of tests (n);

picto-gramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
	$\bar{x}$	4,5	3,9	2,9	3,3	2,7	1,7
-	s	0,6	0,8	0,3	1,7	1,4	0,4
	n	11	12	10	13	17	12
	$\bar{x}$	4,2	3,4	3,6	4,3	1,9	2,4
simple	s	0,7	0,4	0,9	1,3	0,3	1,2
	n	9	8	9	6	4	7
	$\bar{x}$	4,2	4,1	3,4	3,6	2,9	2,1
complex	s	0,8	1,0	0,7	1,6	1,0	0,5
	n	9	10	9	8	9	8

Test subjects group III, homogenised group
Average reaction time ($\bar{x}$), standard deviation (s), number of tests (n);

pictogramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	$\bar{x}$	4,1	3,6	3,3	2,3	2,3	1,9
	s	0,6	0,7	0,6	1,1	1,0	0,4
	n	8	12	14	9	13	12
simple	$\bar{x}$	3,9	5,0	3,6	2,7	2,6	2,3
	s	0,5	-	0,3	1,3	1,0	0,3
	n	6	1	3	6	3	5
complex	$\bar{x}$	4,3	4,0	3,5	3,2	3,0	2,4
	s	0,7	0,7	0,5	1,5	1,4	0,5
	n	7	9	7	4	4	5

Test subjects group I, homogenised group, omission of reaction failures
Average reaction time ($\bar{x}$), standard deviation (s), number of tests (n);

picto-gramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	$\bar{x}$	3,6	3,2	3,0	2,0	2,0	1,5
	s	0,5	0,2	0,2	0,5	0,9	0,3
	n	10	12	11	11	15	11
simple	$\bar{x}$	3,8	3,0	3,0	2,0	1,3	1,9
	s	0,6	0,1	0,4	0,4	0,4	0,5
	n	5	3	6	4	3	4
complex	$\bar{x}$	3,4	3,3	3,0	2,6	1,8	1,8
	s	0,4	0,3	0,4	1,5	0,2	0,5
	n	7	5	4	5	3	6

Test subjects group I, homogenised group
Percentage reaction failures (f) and number of tests (n)

picto-gramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	f	--	14%	8%	--	6%	--
	n	10	14	12	11	16	11
simple	f	17%	--	--	33%	--	--
	n	6	3	6	6	3	4
complex	f	13%	29%	34%	29%	40%	25%
	n	8	7	6	7	5	8

Test subjects group II, homogenised group, omission of reaction failures
Average reaction time ($\bar{x}$), standard deviation (s), number of tests (n);

picto-gramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	$\bar{x}$	4,1	3,6	2,9	1,8	1,9	1,7
	s	0,5	0,6	0,3	0,3	0,5	0,4
	n	6	10	10	7	13	12
simple	$\bar{x}$	3,9	3,4	3,2	2,7	1,9	1,9
	s	0,6	0,4	0,3	1,3	0,3	0,3
	n	7	8	7	2	4	6
complex	$\bar{x}$	3,8	3,2	3,2	2,2	2,6	2,1
	s	0,7	0,3	0,3	0,6	0,7	0,5
	n	6	5	8	4	8	8

Test subjects group II, homogenised group
Percentage reaction failures (f) and number of tests (n)

picto-gramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	f	45%	17%	--	46%	24%	--
	n	11	12	10	13	17	12
simple	f	22%	--	22%	67%	--	14%
	n	9	8	9	6	4	7
complex	f	33%	50%	11%	50%	11%	--
	n	9	10	9	8	9	8

Test subjects group III, homogenised group, omission of reaction failures
Average reaction time ($\bar{x}$), standard deviation (s), number of tests (n);

pictogramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	$\bar{x}$	3,9	3,5	3,2	2,0	2,1	1,9
	s	0,5	0,5	0,4	0,4	0,5	0,4
	n	7	11	13	8	12	12
simple	$\bar{x}$	3,9		3,6	2,2	2,6	2,3
	s	0,5		0,3	0,5	1,0	0,3
	n	6		3	5	3	5
complex	$\bar{x}$	3,9	3,7	3,5	2,6	3,0	2,4
	s	0,6	0,4	0,5	1,0	1,4	0,5
	n	5	7	7	3	4	5

Test subjects group III, homogenised group
Percentage reaction failures (f) and number of tests (n)

pictogramme		Encounter situations (Lumination pattern 1)			Incident situations (lumination pattern 2)		
		80°	50°	20°	80°	50°	20°
-	f	13%	8%	7%	11%	8%	--
	n	8	12	14	9	13	12
simple	f	--	(100%)	--	17%	--	--
	n	7	1	3	6	3	5
complex	f	29%	22%	--	25%	--	--
	n	6	9	7	4	4	5

Enclosure: The phase model of the transport and traffic (unsafety) process

1. Introduction

Both the transport and traffic process, that can result in accidents, and the crash process can be regarded as a chronological complex of successive, increasingly critical combinations of circumstances and events.

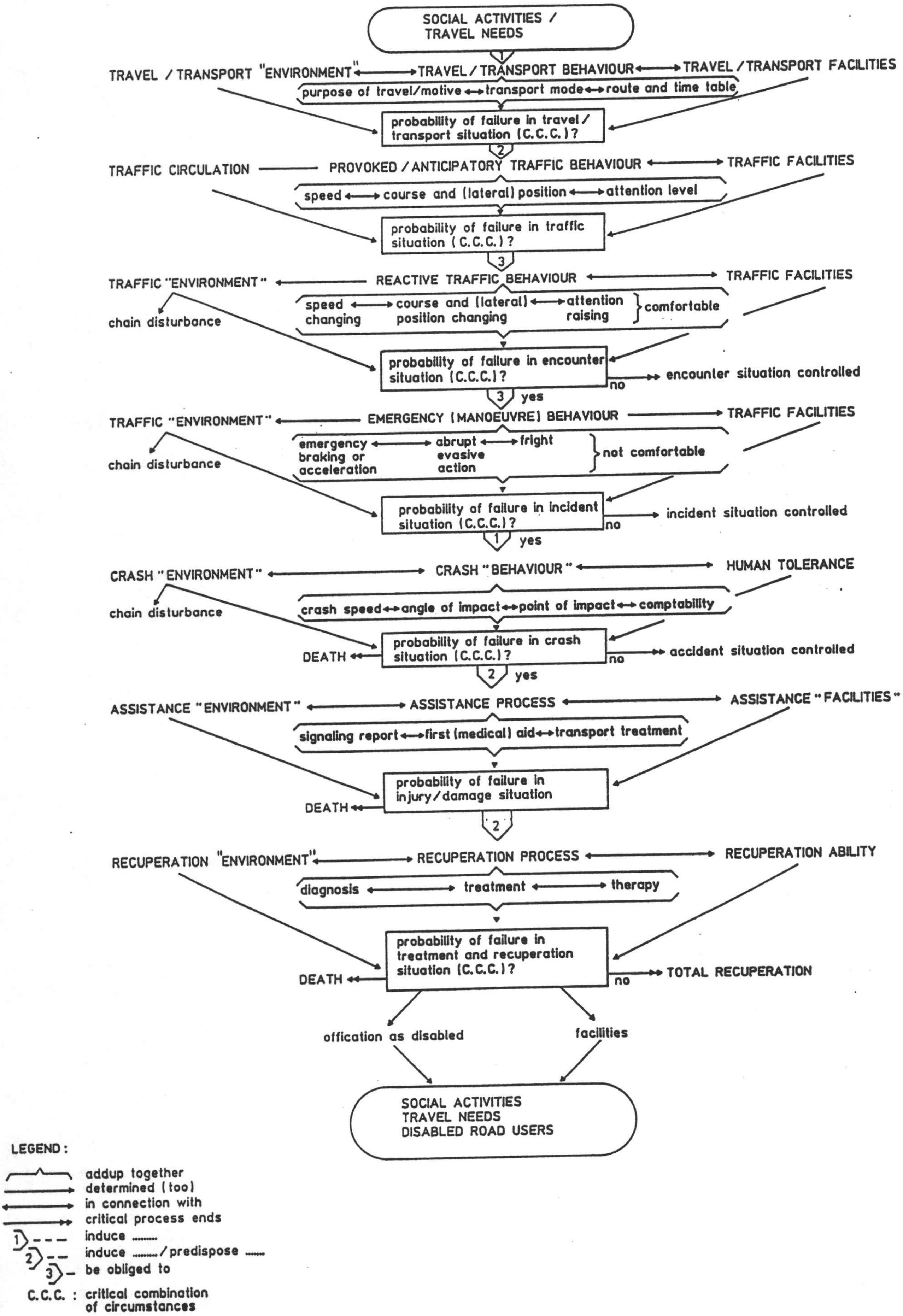
These eventually result in injury and damage, followed by a "recuperation process", in which critical circumstances again can occur. In theory a halt can be called to this "accident process" in any of the phases it comprises of.

To get an oversight of traffic unsafety, is it necessary to order or structure the transport and traffic process from a traffic safety point of view. Such an order and structure of the "accident process" has been found in a conceptual model referred to as phase model of the transport and traffic unsafety process (see figure e.1).

The phase model is based on the following principles.

1. The transport and traffic unsafety process is a dynamic process, i.e. it is a chronological complex of successive critical circumstances and events. Each state observed is a "snapshot" and has a history, a "memory" and a follow-up. The follow-up is determined by the memory, the road user's goal and his behaviour alternatives.
2. It is a model of a process that becomes increasingly critical once a phase is reached where critical states cannot be overcome. In each phase of the process a critical situation can arise which unleashes a chain of critical states which are increasingly difficult to control: the time and room for observing, deciding and acting becomes less and less.
3. Each phase involves different critical combinations of circumstances, different relationschips between behaviour and environment. The transition from one phase into the next is a greater or lesser discontinuity, i.e. in a particular phase the road user has behaviour alternatives which differ from those in the previous and the next phase.

Figure e.1: Phase model of the transport and traffic (unsafety) process



2. Description

The phase model of the transport and traffic unsafety process describes the nature of the traffic process insofar as there are critical changes in state with increasing losses in relation to the goal. In it the individual road user is central as the elementary system. Other road users are regarded as part of the individual road user's traffic environment. External control mechanisms, operated by the "collective decision-makers", are designed to influence the internal control mechanism of the individual road user. The points at which this takes place are the critical combinations of circumstances in the various phases which entail a risk of failure for individual road users.

Figure e.1 shows the phases of the transport and traffic unsafety process split up according to discontinuities in critical states and thus by the nature of the behaviour alternatives a road user has to bring an "accident process" once started, or a critical state, under control. These phases are described in the following.

Travel/transport situation

A decision to engage in an activity at another location, e.g. to visit relatives, makes it necessary to travel. The nature of the travel goal, the motive for travelling, the mode of transport chosen, the route, and the timetable together determine the travel behaviour. The circumstances in which a road user travels are referred to as the travel/transport situation. These circumstances can in themselves entail a risk of failure or a potential loss. Two examples: a timetable that is too tight, a journey to an important meeting - result: fast driving and attention already on the meeting. These risks in or as a result of travel behaviour are only manifested in the next phase, at the manoeuvring. The transport or travelling circumstances preordain, as it were, the start of a chain of fresh risks of failure for the road user.

Critical states in travel behaviour influence not only speed, direction and lateral position on the road and the alertness of the road user, they also can make all the subsequent phases more critical. A road user in a hurry has e.g. less peripheral perception and may overlook traffic that crosses his path. In the event of an encounter with other traffic he is more likely to accelerate in an attempt to pass in front than to brake.

Traffic situation
The traffic behaviour of a road user, provoked by travel and traffic circumstances (in particular vehicle, traffic and road characteristics), takes the form of speed, direction and lateral position on the road and in the traffic flow, and alertness. The provoked and anticipatory traffic behaviour can be regarded as a continuous change of state (in speed, course and lateral position): following the road, following a stable traffic flow.

Encounter situation
Every change in state can result in a change in the risk of failure: encounters with other road users, but also instability of a traffic flow, discontinuities in the path of the road, etc. A lot of the risks in these encounter situations can be overcome by timely and adequate reaction: braking or accelerating, deviating to the left or right, and increasing one's alertness are the opportunities available to the road user for reactive traffic behaviour.

Incident situation
The absence of a timely and/or adequately reaction in the encounter situation, owing to misjudgement of the situation or lack of information or experience, results in an increase in the risk of failure. The time for acting becomes very short and the opportunities in many cases very limited: we can speak of an incident. The only way of preventing an accident then is for the road user to carry out an emergency manoeuvre: abruptly swerving, an emergency stop and a call on "survival" reflexes are the types of emergency manoeuvre behaviour available. If the emergency manoeuvre is successful, so that the vehicle remains on the carriageway without hitting anything, we call this a "conflict" - a near miss. Often, however, fresh risks of failure occur during, or as a result of, the emergency behaviour.
A chain reaction may affect other road users if e.g. during an emergency manoeuvre a vehicle crosses to the other side of the road (obstructing oncoming traffic) or comes to a halt on its own side (obstructing following traffic). This effectively starts a new "accident process", now for the other road users.

Crash situation
Every year in the Netherlands alone at least one million emergency manoeuvres are unsuccessful (if they took place at all). High speed at the start of the manoeuvre, inadequate time, not enough distance (including the danger of skidding) produce risks of failure which, if they materialize, inevitably result in a crash (accident).
Fortunately not all of the 1 million yearly Dutch accidents are serious. Nevertheless, the number of registrated (!) casualties

mounts up to 1600 deaths and some 50.000 injuries per year.
Determinative for the severeness of an accident are the collision speed, the angle of impact and the point of impact. Together these make up the crash behaviour of the vehicle (and to some extent of the occupants or riders) and the object collided with. A chain reaction can also take place here. The risk of damage and injury, the damage and injury pattern, does not depend solely on the crash behaviour of the vehicle and object. Crash circumstances, such as characteristics of vehicle exterior and interior and the resilience of occupants and riders have a considerable influence, as does the wearing of seat belts, crash helmets, etc.

Injury and damage situation
After the crash phase comes the injury and damage situation. This begins with the discovery and the reporting of the accident, followed by first aid (including emergency medical aid), removal of the injured to a hospital and finally treatment. We need not concern ourselves here with the recovery and repair of damaged vehicles. During the entire aid process risks of failure occur which may affect the damage and injury pattern. These generally occur in the timespan between the crash phase and treatment. In some cases the outcome is serious (permanent) damage. The absence of actions needed to save life or incorrect first aid, the stagnation in the removal of victims owing to inaccessibility of the scene of the accident or traffic congestion can entail risks of failure or critical combinations of circumstances which determine the ultimate effects.

Treatment and recuperation situation
The treatment and recuperation situation comprises the medical diagnosis, the therapy, and the after-care. In this situation again possible failures manifest themselves, e.g. as a result of an incorrect diagnosis, or an insufficient organisation in the traumatologic department of a hospital. If the recovery is not complete, permanent effects occur (that may sometimes manifest themselves only after years and often were not confirmed in the diagnosis).
We shall not consider rehabilitation, the social care and training of those handicapped in road accidents, in detail here. They do, however, have to be able to make use of travel facilities so that they can carry out their activities as they did before becoming handicapped.