Driver Interaction with Transport-Telematic Systems

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Abstract

Over the next few years it is expected that the number of in-vehicle telematic systems will increase rapidly, leading to an increased amount of information a driver has to deal with besides the primary task of driving. In the scope of the research project LIVES1 (Driver Interaction with Transport-telematic Systems), the research institutes CURE and FACTUM OHG have investigated, how these systems could be improved in order to optimise the transfer of information to the driver. This goes in line with research programme I2 – Intelligent Infrastructure of the Austrian Federal Ministry of Transport, Innovation and Technology in which this project was financed.

To be able to answer the two main research questions formulated by FACTUM namely:

- What is the best sensory modality with respect to the given information
- How does information, given simultaneously from different systems, effect the driver

CURE developed a driving simulator based on a Computer racing game. The driving simulator made it possible to investigate the effects on the driving behaviour using different modalities for information with different priorities of information and the effects when two information are submitted simultaneously.

During a one-day workshop with telematic experts the results of the simulator study were discussed also in order to get recommendation to formulated guidelines to increase safety while using telematic systems while driving. These guidelines focus on one hand on the optimal use of auditory, visual and haptic information for the driver and on the other hand on the simultaneous communication of more than one system.

1. Starting point

The main advantages of telematic systems are or should be the ability to increase both the safety and the comfort of the driving task. These advantages, however, might be compensated by additional perceptual and cognitive load, as the driving task is extended with the task of reacting correctly on the information, directions and warnings that these systems provide. This will especially be the case when the driver receives different information simultaneously from these systems.

1 German titel of the project: LIVES - LenkerInnenInteraktion mit VERkehrstelematischen Systemen
The private research institutes CURE (Center for Usability Research & Engineering) and FACTUM OHG (Transport- and Social Analyses) investigated in the Austrian study LIVES how the human machine interface (HMI) of different telematic in-vehicle systems should be designed in order to guarantee an optimal use of diverse systems. LIVES was carried out 2006 in the frame of the programme line “I2 – Intelligent Infrastructure” on the initiative of the Austrian ministry of transport, innovation and technology (BMVIT) The project LIVES dealt with the integration of these disjunctly developed systems. When these in-vehicle devices are not matched to one another, the driver may run the risk of being distracted by unimportant information during possibly critical situations.

2. Project structure

Two main research questions were the central point of this project:

- What is the best sensory modality with respect to the given information
- How does information, given simultaneously from different systems, effect the driver

The final goal was to develop guidelines for the optimisation of in-vehicle telematic systems in cars.

The first step of the project was a literature study about the main psychological theories with regard to physical and cognitive distraction and their effects on the driving task, situation awareness, mental workload, excessive demand, theory of multiple resources, adaptation to in-vehicle telematic systems, social feedback etc. Also a short summary of common in-vehicle telematic systems and about future trends was elaborated. Finally the literature was scanned about the use of different modalities for submitting information to drivers and how they are used in in-vehicle systems.

The next step was the establishment of hypotheses, based on the knowledge gathered from the literature study, in order to test the research questions formulated in the beginning of the project. For the testing of the hypothesis a macro simulation was developed by using a racing game software. On the computer a virtual test route was created in which different traffic situations were simulated where test persons had to fulfil tasks given by different telematic systems. So during their test ride the study participants received information, warnings and messages from different in-vehicle information and assistance systems submitted in different modalities. The main focus of the simulator test was on the simultaneous submission of the information through different modalities. The evaluation focused on how people react to the given information and how the primary task, the driving, was influenced. 19 test persons took part in the simulator test.

The evaluation of the data, collected with the help of permanent data logging during the test rides (speed, steering wheel movement) and video recording was done with statistical tests and behaviour observation.

During a one-day workshop the results of the evaluation were presented to Austrian telematic experts in order to discuss the outcomes of the simulator tests and to gather inputs for the final outcome of the project, i.e. the guidelines for optimum use of in-vehicle telematic systems. These guidelines focus on the one hand on the optimum use of auditory, visual and haptic information for the driver, and on the other hand on what aspects have to be considered with respect to the simultaneous communication deriving from more than one system.
3. Hypotheses

The identification of new requirements to drivers which might appear through the implementation of telematic systems into cars was one of the main focus of the project. Therefore, especially the effects on the driver and his/her behaviour while he/she gets simultaneous information from two systems were tested. Another focus was on the search for the optimum modality in which information should be submitted to the driver in order to distract him/her as little as possible.

In order to give answers to these questions a simulator study was conducted, in which the test persons drove through a virtual test route. During driving (primary task) the subjects received information (secondary task) from various systems with different modalities. The test persons had to remember or had to act correctly on the given. In the following the hypotheses which were tested are presented.

Based on the literature study several telematic in-vehicle systems and situations, were systems submit either information (traffic news) or warnings (too little distance to the car ahead etc.) to the driver, which suited the project objectives best, were selected. These information and warnings have different priorities with regard to the driving task and the driver's reaction in different situations. Three priority levels were defined:

1. Warnings which need an immediate reaction by the driver
2. Latent instruction - no immediate reaction of the driver is needed
3. General information - no immediate relevance for the driving task

One of the main question was: "What is the best way and the best modality to submit information or warnings in order not to distract or to overload the driver?" The following matrix was established, in which the priority levels are set in contrast to the three modalities acoustic, visual and haptic.

Table 1: Classification of information into priority levels and modalities

<table>
<thead>
<tr>
<th>type of information</th>
<th>modality</th>
<th>acoustic</th>
<th>visual</th>
<th>haptic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Warnings, high priority</strong></td>
<td></td>
<td>+</td>
<td>-</td>
<td>(-)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Suited well, it can be instinctively handled. Speech is not adequate.</td>
<td>Not adequate, modality is to slow to transfer the information in critical situation, is overlooked easily.</td>
<td>Hardly any literature, short breaking impulses lead to an erroneous interpretation of the driver and therefore was stated as dangerous</td>
</tr>
<tr>
<td><strong>Medium priority</strong></td>
<td></td>
<td>-</td>
<td>+</td>
<td>(+)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acoustic signals are experienced as hindering and therefore should not be used for this level.</td>
<td>Suitable. Drivers can partially decide themselves when they want to receive the information, Information should be place directly in the visual field of the driver</td>
<td>Pedal Feedback or vibration on the steering wheel helps the driver to adopt to the speed limit without nerving. Is better then acoustic feedback</td>
</tr>
<tr>
<td><strong>general information, low priority</strong></td>
<td></td>
<td>(+)</td>
<td>+</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Possible, but not optimal, driver is distracted from the driving situation.</td>
<td>Adequate, distract driver not directly. Driver can decide himself if and when he wants to receive information</td>
<td>Hardly any literature available</td>
</tr>
</tbody>
</table>

Legend:  
+ = Modality suits well for this priority level  
- = Modality is not adequate for this priority level  
? = Hardly any literature available
For the first level, the warnings, it become clear that acoustic signals (with the exception of speech) are the most appropriate ones. The driver can handle the signal instinctively. Visual as well as haptic signals are not adequate for this priority level, because they are either interpreted too slowly or lead to misunderstandings.

The visual information is seen as the best solution for the medium priority level, because messages of this type are not too penetrating for the situation (like acoustical signals). Haptic feedback, like it is used for example for ISA (Intelligent Speed Adaptation) systems, is also seen as adequate (4). If the driver is speeding above the limit the accelerator pedal gives a counter pressure which informs the driver about his/her erroneous behaviour.

For the general information on the third priority level the visual information were the most appropriate one. The reason for this is that the driver could decide him/herself when he/she wants to receive the information. Also acoustic signals are adequate, but have to be announced in some way in order not to distract the driver from the driving task. No literature was found for the haptic signals on this level.

The following hypotheses for the systems which were tested were formulated, based on the matrix above:

If level-1 warnings are submitted acoustically, than they have less negative effect on the driving behaviour than if they are submitted visually.

Latent instructions of level 2 have less negative effect on the driving behaviour if they are submitted via the haptic channel than if they are submitted acoustically.

General information of level 3 has less negative influence on the driving behaviour if it is given visually than if it is submitted acoustically.

These hypotheses are also valid for combination of systems which submit information simultaneously. There is the assumption that information on the first level given by an acoustic signal in combination with an information on the second level submitted via the haptic channel do have less negative effects on the driving behaviour than if they are submitted visually (level 1 warning) and acoustically (level 2 information).

In order to test these general hypotheses five scenarios were developed. For these scenarios the driving task was defined as "primary task" while the secondary task consisted of the tasks given by the different telematic systems. In every scenario two systems submitted information/warnings/instructions to the test persons. The task of the test persons was to react correctly to these information/warnings/instructions. In order to test the following hypotheses the test persons drove through the test track twice while the modality in which the information in the different scenarios were submitted changed.

In the following, an overview about the scenarios, perceived hypotheses and the defined criteria for measurement of the driving behaviour is given. The primary task always consists of "correct driving".
3.1 Scenario 1: Turning left with simultaneous route guidance and traffic news

Scenario: Turning left at an intersection with right hand priority.

<table>
<thead>
<tr>
<th>Systems</th>
<th>Control situation</th>
<th>Test situation</th>
<th>Control situation</th>
<th>Test situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route guidance</td>
<td>Traffic sign</td>
<td>haptic</td>
<td>Traffic sign</td>
<td>acoustic</td>
</tr>
<tr>
<td>Information priority level 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traffic news</td>
<td>-</td>
<td>acoustic</td>
<td>-</td>
<td>acoustic</td>
</tr>
<tr>
<td>Information priority level 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The secondary task for the driver consists of reacting correctly to the route guidance information and to turn left while receiving simultaneously traffic news.

Hypotheses: Haptic route guidance in combination with acoustic traffic news have more positive effects on the driver's behaviour - test persons turn more often correctly - than an acoustic route guidance in combination with acoustic traffic news. Traffic news can be remembered better if the simultaneous Route Guidance information is submitted via the haptic channel, because two different input channels are used.

The measurement of the driving behaviour was carried out by comparing the driven speed, the steering wheel movements as well as the actual behaviour of the test person in the situations: approach to the crossing, behaviour as the one who has to give priority, accuracy of turning, conflict situations with other road users.

3.2 Scenario 2: ISA and traffic news

Scenario: Part of the test track with 30 km/h speed limit

<table>
<thead>
<tr>
<th>Systems</th>
<th>Control situation</th>
<th>Test situation</th>
<th>Control situation</th>
<th>Test situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISA Information priority level 1-2</td>
<td>Traffic sign</td>
<td>haptic</td>
<td>Traffic sign</td>
<td>acoustic/visual</td>
</tr>
<tr>
<td>Traffic news Information priority level 3</td>
<td>-</td>
<td>acoustic</td>
<td>-</td>
<td>acoustic</td>
</tr>
</tbody>
</table>

In the control situation the information about the speed limit was given by traffic signs. In the test situation the drivers were warned about their speeding by the in-vehicle system. Additionally, traffic news were submitted on this part of the test track.

Hypotheses: Haptic ISA warnings in combination with acoustic traffic news have a more positive effect on the driver's behaviour than acoustic/visual ISA warning in combination with acoustic traffic news. Speed limits are exceeded more often on course B when the ISA warning is submitted acoustically/visually than on course A where the information is submitted the haptic way. Traffic news are remembered better by simultaneous haptic ISA warning than by acoustical/visual ISA warning, because two different input channels are used.
The criteria for the assessment of the driving behaviour were: speed behaviour during this part of the test track (number of warnings etc.) and steering wheel movements.

### 3.3 Scenario 3: Driving on a parking space with additional information

Scenario: Before the start of the test ride the test persons got the directive to stop at all signed parking places during the test track (three parking places).

<table>
<thead>
<tr>
<th>Systems</th>
<th>Course A</th>
<th>Course B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control situation</td>
<td>Test situation</td>
</tr>
<tr>
<td>Route guidance</td>
<td>Traffic sign</td>
<td>acoustic</td>
</tr>
<tr>
<td><em>Information priority level 2</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additional information</td>
<td>-</td>
<td>visual</td>
</tr>
<tr>
<td><em>Information priority level 3</em></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

While in the control situation the parking place was marked with a traffic sign (turn left), the test persons received information by the route guidance system in the test situations. Shortly before the subjects turned into the parking space they received the additional information that they should park on the right side.

Hypotheses: Acoustical Route Guidance to the parking place in combination with additional visual information is better perceived than visual Route Guidance in combination with additional, acoustical information. Acoustical Route Guidance works better on the behaviour of the driver because more visual attention is needed in order to oversee the crossing situation, consequently less driving errors are made during the turning.

For the assessment of the driving behaviour the following criteria were used: Comparison of the driven speed, movement of the steering wheel, and the behaviour criteria approach to the crossing, behaviour as the one who has to give priority, driving into the parking place, conflict situations with other road users, parking on the right side of the parking place.

### 3.4 Scenario 4: Pedestrian warning and route guidance

Scenario: On the whole test track several pedestrian crossings were created. On three of these crossings a pedestrian moved from the right side to the left.

Course A: - Route Guidance haptic

Course B: Pedestrian warning visual - Route Guidance acoustic

<table>
<thead>
<tr>
<th>Systems</th>
<th>Course A</th>
<th>Course B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control situation</td>
<td>Test situation</td>
</tr>
<tr>
<td>Pedestrian warning</td>
<td>-</td>
<td>acoustic</td>
</tr>
<tr>
<td><em>Information priority level 1</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Route Guidance</td>
<td>Traffic sign</td>
<td>visual</td>
</tr>
<tr>
<td><em>Information priority level 2</em></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the control situation the test persons were not warned at all about the appearance of the pedestrian and the next turning was announced by a traffic sign. In the test situations the subjects received a warning that there will be a pedestrian crossing and they received simultaneously the information that they should turn at the next crossing.
Hypotheses: Acoustical pedestrian warning in combination with haptic route guidance is more effective than visual pedestrian warnings in combination with acoustic route guidance. The interaction with pedestrians is more intensive with acoustic warning than with visual warning because more visual attention is needed to overcome the situation where the pedestrians are crossing.

The measurement of the driving behaviour was carried out by logging the driven speeds and the steering wheel movements as well as the behaviour which the test person set in the situation: reaction to pedestrians (conflict, evasion, hitting a pedestrian), behaviour at the next crossing (correct turning, conflict situations with other road users).

3.5 Scenario 5: ACC and traffic news

Scenario: On three parts of the test track it was not allowed to overtake a car which appeared in front of the test persons and which was moving with a very low speed.

<table>
<thead>
<tr>
<th>Systems</th>
<th>Course A</th>
<th>Course B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control situation</td>
<td>Test situation</td>
</tr>
<tr>
<td></td>
<td>Test situation</td>
<td>Control situation</td>
</tr>
<tr>
<td></td>
<td>Test situation</td>
<td>Test situation</td>
</tr>
<tr>
<td>ACC</td>
<td>Traffic sign</td>
<td>Traffic sign</td>
</tr>
<tr>
<td>Information priority level 1-2</td>
<td>visual</td>
<td>acoustic</td>
</tr>
<tr>
<td>Traffic news</td>
<td>-</td>
<td>acoustic</td>
</tr>
<tr>
<td>Information priority level 3</td>
<td>-</td>
<td>acoustic</td>
</tr>
</tbody>
</table>

In the test situation the study participants immediately received a warning when the distance to the car ahead was too small. Additionally traffic news were submitted on these parts of the test track.

Hypotheses: Visual distance warning in combination with acoustic traffic information has a more positive effect on the driver's behaviour than acoustic ACC warning in combination with acoustic traffic news: According to literature, visually submitted information works better for information on priority level 2 than acoustic information. It is as expected that there are no interferences with acoustically submitted traffic news. Traffic news are remembered better when ACC-warning is visual than acoustic because two different input channels are used.

The criteria for the assessment of the driving behaviour were: speed behaviour and the movement of the steering wheel during this part of the test track, as well as the distance to the car in front (number of warnings etc.) and overtaking manoeuvres.

4. Procedure

In order to test the above formulated hypotheses a driving simulator based on a 3D development environment (BLENDER - open source) was developed, in which the test persons had to drive along a virtual-reality test route. Every test person had to drive along the test course the course twice. While driving the drivers were confronted with the above described situations. The modality in which the information was submitted by the telematic systems to the drivers changed during the two test rides. The following table gives an overview about the scenarios and the combinations of submitted information:

**Simulator set-up**

A customary steering wheel for racing games was used as well as two pedals (acceleration and breaking pedal as in a car with automatic gearing). A simple engine noise reflecting the driven speed was heard.
The picture of the test track was projected with two beamers on a white wall. The test person sat approximately two meters away from the wall.

Traffic signs were virtualised in order to guide the test person through the course, and speed limits as well as overtaking bans were announced with the help of traffic signs. Random generated traffic volumes but also virtualised cars and pedestrians based on the behaviour of the test person appeared during the test rides.

Data about deviation from the optimum driving line, control of pedals (speed) and steering wheel movements (deviation from the zero position) were logged during the whole test ride. In addition, all test rides were filmed with two video cameras.

Picture 1: View from the back of a study participant

5. Evaluation

The sample was distributed in the following way:

Table 3: Sampling distribution

<table>
<thead>
<tr>
<th>Gender</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 30 years</td>
<td>4</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Between 30 and 49 years</td>
<td>5</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>50 years and older</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>11</td>
<td>8</td>
<td>19</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Experiences with car racing games</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>No</td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Yes</td>
<td>2</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>No</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>11</td>
<td>8</td>
<td>19</td>
</tr>
</tbody>
</table>

5.1 Statistical evaluation for speed and steering wheel movements

In order to make the data of the test persons and for each situation comparable only the data logged ten seconds before and after each scenario (test situation and control situation) was taken for the statistical evaluation. Mean speeds for the various situations and standard deviations of the steering wheel movements were used to calculate significance’s between the control situation and the two test situations and within the test situations (Mann Whitney U-Test).
5.2 Behaviour observation with the help of the video recording material

In order to evaluate differences in the behaviour of the test persons in each situation the recorded material was seen through with the help of a standardised observation sheets. In these sheets specific criteria were defined (as described above) which cannot be identified in the logged data, e.g. overtaking where the test persons were not allowed to overtake, conflicts with other road users, etc.

Furthermore, on the three parking places the test subjects were asked about the traffic news which they received during the test- and control-situations. The answers to these questions were also evaluated.

6. Results

In the following the main results concerning the five scenarios in which the hypotheses were tested are presented.

6.1 Scenario 1: Turning with Route Guidance and traffic news

The hypothesis is confirmed partially. The average speed driven in connection with haptic route guidance is lower in the control and in the test situations than with acoustically forwarded route guidance (though not significantly so). Also the standard deviation of the steering wheel movements in course B (haptic route guidance) is lower, which is taken as an indicator for lower workload. Additionally, the acoustically submitted traffic news together with haptic route guidance were remembered better than together with acoustic route guidance.

However, all test persons followed the track correctly when they received the route guidance acoustically. At the same time, three subjects did not turn when the information was submitted the haptic way.

6.2 Scenario 2: ISA and traffic news

The haptic ISA warning seems to provide less workload for the driver; the steering wheel movement rate was lower than when the warning was submitted acoustically/visually (both in combination with acoustic traffic news). However, in the behaviour observation it turned out that almost all test persons reacted to the haptic as well as to the acoustical/visual ISA warnings immediately, there was no difference in reaction time.

6.3 Scenario 3: Driving into a parking space with additional information

Within the control situation, where the test persons had to follow the traffic signs, they obviously needed the highest attention, suggested by the fact that they drove more slowly than in the test situations (significantly for the visual route guidance). Also more errors happened while using the visual route guidance, as not all subjects turned into the parking place. Due to these results the conclusion was that visually submitted information produces more workload for the drivers. The hypothesis suggesting this can be confirmed.

6.4 Scenario 4: Pedestrian warning and route guidance

The average speed as well as the standard deviation from the steering wheel movements were (significantly) lower when the pedestrian warning was submitted acoustically than when it was submitted visually. Furthermore there were more conflicts and accidents with pedestrians when the warning was submitted visually in combination with acoustic route
guidance. So the hypothesis that acoustic warning in combination with haptic route guidance works better than visual warning in combination with acoustical route guidance was confirmed.

6.5 Scenario 5: ACC and traffic news

The standard deviation of steering wheel movements was in one test situation significantly higher when ACC warning was submitted acoustically compared to the visual version. Furthermore, more overtaking manoeuvres were made when the warning was acoustic. Thus, the hypothesis was confirmed that visual warning on this level in combination with acoustic traffic news works better than when both types of information are submitted acoustically.

The results of hypotheses tests were transferred back to the matrix in which the information given on different priority levels was combined with the three modalities. In the next table the comparison between the literature results and the results of the simulator study are compared. Green fields mark those results of the simulator study which confirm the results from the literature study, yellow those combinations of priority level and modality which were not tested and red those results which does not give a clear answer.

Table 4: Classification of information into priority levels and modalities

<table>
<thead>
<tr>
<th>Type of information</th>
<th>Modality</th>
<th>According to literature: Modality suits well for this priority level</th>
<th>According to literature: Modality is not adequate for this priority level</th>
<th>According to literature: Modality should not be used for this priority level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warnings, high priority</td>
<td>Acoustic</td>
<td>Confirmed by the results of the simulator study</td>
<td>Confirmed by the results of the simulator study</td>
<td>Was not tested within these project</td>
</tr>
<tr>
<td></td>
<td>Visual</td>
<td>Confirmed by the results of the simulator study</td>
<td>Confirmed by the results of the simulator study</td>
<td>Confirmed by the results of the simulator study</td>
</tr>
<tr>
<td></td>
<td>Haptic</td>
<td>Confirmed by the results of the simulator study</td>
<td>Confirmed by the results of the simulator study</td>
<td>Confirmed by the results of the simulator study</td>
</tr>
<tr>
<td>Medium priority</td>
<td>Acoustic</td>
<td>Confirmed by the results of the simulator study</td>
<td>Confirmed by the results of the simulator study</td>
<td>Confirmed by the results of the simulator study</td>
</tr>
<tr>
<td></td>
<td>Visual</td>
<td>Confirmed by the results of the simulator study</td>
<td>Confirmed by the results of the simulator study</td>
<td>Confirmed by the results of the simulator study</td>
</tr>
<tr>
<td></td>
<td>Haptic</td>
<td>Confirmed by the results of the simulator study</td>
<td>Confirmed by the results of the simulator study</td>
<td>Confirmed by the results of the simulator study</td>
</tr>
<tr>
<td>General information, low priority</td>
<td>Acoustic</td>
<td>Confirmed by the results of the simulator study</td>
<td>Confirmed by the results of the simulator study</td>
<td>Results of the simulator study are not clear in this respect</td>
</tr>
<tr>
<td></td>
<td>Visual</td>
<td>Confirmed by the results of the simulator study</td>
<td>Confirmed by the results of the simulator study</td>
<td>Results of the simulator study are not clear in this respect</td>
</tr>
<tr>
<td></td>
<td>Haptic</td>
<td>Confirmed by the results of the simulator study</td>
<td>Confirmed by the results of the simulator study</td>
<td>Results of the simulator study are not clear in this respect</td>
</tr>
</tbody>
</table>

Additionally, general results show that

- None of the test persons could accomplish all tasks or reacted correctly to all given information
- None of the test persons could answer all question concerning the traffic news correctly

This underlined that simultaneous communication should be avoided whenever possible, as it may lead to an overload situation for the driver. Hence, it is recommended to delay the communication of less important information until a higher-priority warning has been resolved.
7. Workshop and resulting guidelines

The results were presented to Austrian telematic experts during a one-day workshop. Additionally to the comments which were collected with respect to the results also feedback about the matrix, future trends and recommendations for the formulation of the guidelines were obtained.

Finally, the results from the literature study at the beginning of the project, the results of the simulator study and the recommendations produced by the experts were used to formulate guidelines for the optimum use of in-vehicle telematic systems. These guidelines were compared to international guidelines (5-7) so that at the end 14 LIVES-recommendations were the outcome of the project:

1) Information and warnings have to be as simple as possible; they should include clear instructions for the drivers, what kind of actions have to be taken; it has to be clear for the driver what he/she has to do.

According to the priority of an information different modalities could be assigned. Within a modality further classification for the use of it have to be done:

- **Acoustic modality:** general information: sounds and speech
  warnings: sounds\(^2\), earcons and analogue signals

- **Visual modality:** general information: symbols, pictures, text and maps
  latent information: symbols and pictures in the visual field of the driver

- **Haptic modality:** latent information
  warnings: exception driver monitoring systems

Based on this classification further recommendations were established.

2) For warnings which need an immediate reaction - priority level 1 - acoustic signals should be used:
   a) But no speech should be used because information is interpreted too slowly.
   b) Simple tones, earcons and analogue signals are the best possibility to attract attention for a risky situation.

3) Haptic signals can be exceptionally used for warnings (priority level 1). These exceptions are for instance related to exceeding of limits (speed, distance to the car ahead).
   a) But the driver must not be scared by the haptic signal, so that he/she is not reacting correctly.
   b) It is recommended that the user should train the handling of the haptic signal before using it in real traffic.

4) For latent information (priority level 2) visual signals could be used.
   a) Symbols and pictures should be placed in the direct visual field of the driver.
   b) Visual information which is not directly in the visual field is detected too late for this priority level.
   c) More complex visual presentation should be avoided as it needs more attention and may draw attention away from the road.

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\(^2\) Sounds - noises, tones: random mapping, the signal has no direct link to the content of the information

Earcons - mnemonic mapping, the signal has a semantic link to the content of the information (e.g.: train noise = information that one is soon arriving a railroad crossing)

analogue signals -analogue mapping, the signal is according to the content of the information modified along a dimension (tone gets higher if a hindrance is approaching)
5) Latent information (priority level 2) could also be submitted in a haptic way
   a) But the driver must not be scared by the haptic signal, so that he/she is not reacting
correctly.
   b) It is recommended that the user should train the handling of the haptic signal before
using it in real traffic.

6) The visual channel is appropriate for general information (priority 3).
   It has to be taken care of that the submitting of the information does not last longer
than two seconds so that such information does not distract the driver.

7) The acoustic channel is, however, more appropriate for general information (priority 3)
   a) Speech could be used for submitting such information, also if much information has
   to be submitted to the driver.
   b) The volume of the acoustic signals should be low, so that surrounding noises from
outside the car could easily be heard.

8) Information that is submitted frequently and consist of the same information should not
be submitted acoustically, in order to avoid irritation (same repeated tone, same speech
message etc.).

9) There should be the possibility that priority level 3 information can be turned off in order
not to interfere with information of higher priority.

   For submitting simultaneous information the following recommendations were
established:

10) The simultaneous submission of information to the driver should, if possible, generally
be avoided. The possibility to receive information from two different sources is limited
and distract the driver from the primary task the driving.

   If the submitting submission of information could not be avoided following
recommendations should be considered:

11) For certain priority level 3 information speech could be used. But one should not submit
more messages from this area simultaneously. Priorities have to be set, submission
should happen consecutively.

   For detailed information there should be the possibility that the driver gets a short visual
message that the information is available, so that he/she can decide when the
information will be submitted (this should not be done while driving) The simultaneous
submission of information.

12) Information with lower priority should be submitted in such a way that
information/warnings of higher level priority can be understood without any problems.
   a) If information of higher priority is submitted acoustically, all other
information can be displayed visually with simple symbols and pictures, but not
in the direct visual field of the driver, otherwise there is the possibility that the driver
is distracted from the information of the lower priority level.
   b) If higher priority information is displayed visually, the submission of all other
information should be avoided. Visual information on a higher priority level needs
all the attention of the driver to interpret the information while concentrate on the
driving situation. So no other additional information should distract the driver in this
situation.

   It is possible to submit the information with the same content multi-modal so that two
or more modalities are used and strengthen the information. This can reduce the
reaction time of the driver.
13) The use of different modalities, especially acoustic and visual, for the simultaneous submission of the same information is possible without disadvantages.

14) The use of acoustic and visual information in combination with haptic submission of the same information is possible for priority level 2 warnings. There, the acoustic and visual signals support the understanding of the haptic signal.

8. Conclusion

The aim of this project was on the one hand to give recommendations for which modality should be used to submit information to the driver while considering the priority level of the content. On the other hand, the goal was to look how simultaneous information submitted to the driver influences his/her driving behaviour. This was done in the light of the fact that more and more in-vehicle telematic systems are today implemented in cars in order to inform, warn and help the driver. Conclusions were drawn as a result of simulator tests as well as from comments by experts in different settings.

Research work in this project provided indications for what modalities should be used for different kinds of information and warnings in order to address the driver in the best way, without interfering too much with the driving task. Acoustic information can be used when low priority information is submitted, as it is usually not too much disturbing. However, this modality also should be used when the driver should (urgently) be warned, because information forwarded via this channel is interpreted very fast. Visual information should mainly be used for low and medium priority information. Like for the acoustic modality it is essential to consider how visual information should be prepared for the driver. Low-priority information can be presented in detail (like maps). The higher the priority becomes the more simple the information should become (symbols). The haptic modality can with advantage be used for the medium priority level.

Simultaneous submission of information should be avoided unless two different modalities are used to submit the same information. If different types of information become relevant simultaneously a “workload manager” or “dialogue manager” could help, that "decides" what information should be presented to the driver first and what information could be suppressed for the moment and provided later, under better preconditions. Although such technical solutions are much sought for, their development must be based on socio-scientific findings, such as the guidelines described in this project. With the help of this research, solutions for both individual systems and combinations of systems can be developed.

However, more research within this field has to be done. For instance, there is hardly any literature according to haptic information which may be seen as a good possibility for in-vehicle telematics, as this channel is to used so far. More information also has to be gathered about technical solutions to avoid simultaneous submission of information ("dialogue manager"). Furthermore, recommendations and directives for HMI application should be continuously adjusted. Not least, clear instructions for the use of telematic systems, and for training for their use, should be given.

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