IDENTIFYING USER STRATEGIES FOR INTERACTION WITH IN–VEHICLE INFORMATION SYSTEMS WHILE DRIVING IN A SIMULATOR

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ABSTRACT: The study analyzes the efficiency of different strategies for interaction with in-vehicle information systems. N=24 drivers completed a test course in a motion-base driving simulator containing different critical situations. At predetermined points of the route an additional menu navigation task was offered to the driver. The driver could decide whether the actual situation was suitable to execute a task and when to interrupt it. The results show that drivers are able to adapt their secondary task behaviour to the situational demands. The anticipation of potential conflicts could be shown both in secondary task behaviour (complete task rejection or task delay in critical situations) as well as in driving behaviour (e.g. lower approaching speed in front of demanding situations). These strategies were successful to maintain driving safety. Adequate situational assessment prior to the start of the task and adequate monitoring of situational development during secondary task execution are identified as relevant processes for Situation Awareness in this context.

1 Introduction

Extended research has been done on the effects of dealing with in-vehicle information systems (IVIS) while driving. The overall result is that performance of an additional secondary task clearly reduces driving performance and safety. Typical effects are a decrease in lateral control (e.g. [1]) or delayed reaction times to sudden events (e.g. [2]). On the other hand also compensation strategies can be monitored, e.g. reduction of speed ([3] and [4]), an increase of safety margins [5] or fewer lane changes [6]. An often neglected fact is that drivers are also able to compensate additional workload by specific interaction strategies dealing with the secondary task. Like McCartt et al. [7] argue: "phone and driving tasks are paced by experimenters, but in the real world drivers decide when and where to use their phones and may adapt their phone use to varying traffic conditions" (p.92). This freedom of decision is often not given in typical experimental studies analyzing the potential risk of dealing with secondary tasks while driving. Some results from telephone interviews [8] and video observations [9] hint to specific compensation strategies, for example while using a cell phone. Some drivers do not use the phone in a moving vehicle at all, some use it only while they are waiting at a red traffic light, some even stop the car. While calling, drivers tend to drive more slowly, avoid lane changes, choose sections with lower traffic density for calling someone or ask a passenger to do the call. In demanding traffic situations drivers interrupt the conversation, or the remote caller is informed about the environmental conditions to adapt the conversation. While performing a secondary task, drivers try to divide the tasks into smaller chunks und look back to the road in adequate intervals [10].

2 Objectives

Compensation strategies in the interaction with IVIS while driving can be executed on the level of driving task as well as on the level of secondary task. The premise for those compensation strategies is to have Situation Awareness of the driving task. This concept was originally developed in aviation but has become more and more important also in the domain of driving. The most famous definition is the one by Endsley who defines Situation Awareness as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" [11; p. 792]. It is argued that a cognitive representation of the current and the future situation is formed on the base of knowledge in long-term memory which guides attention to the relevant cues in the environment. Due to the dynamics of the driving situation, this mental representation has to be continuously updated. According to a model of Adams, Tenney and Pew [12] this update is understood as a cyclical process, including an active search in the environment for information which may prove or disprove the activated schema and lead to modifications.

In the context of interactions with IVIS we postulate two different processes of Situation Awareness necessary for a situationally adaptive use of secondary tasks while driving:

1. An adequate assessment of the situation prior to the start of a secondary task for proper decisions if a secondary task can be performed in the current situation at all. In highly demanding traffic situations the driver should ignore an additional task or should delay the beginning of the task.
2. An adequate monitoring of situational development during secondary task execution in order to permanently compare the expected situational development with the actual one. In case of observed differences, the secondary task has to be interrupted.

We argue that the control process during secondary task execution is restricted to a subjectively relevant part of the environment. Therefore, the anticipative process of situational assessment prior to task execution is crucial for the proper control of situational development. It influences which of the cues in the environment will be monitored during secondary task execution.

In this paper we try to identify the two postulated processes of Situation Awareness in the driving task as well as in the interaction with secondary tasks while driving. Therefore, we examine anticipative compensation strategies in the decision process just before the beginning of a task as well as more reactive compensation strategies during secondary task execution and analyze their effects on driving safety.

3 Method

3.1 Driving task

To examine different compensation strategies in interactions with IVIS, a study in a driving simulator with motion system of the WIVW (Wuerzburg Institute for Traffic Sciences GmbH, for more information see www.wivw.de) was conducted. The 1.25 h test course consisted of sections with rural roads and urban areas. Within this course, eight specific situations, including a potential conflict, were realized (e.g. a vehicle parking out from a parking zone in front of the subject's vehicle, a pedestrian crossing the road just in front of the subject's vehicle, a broken-down car on a rural road, curvy sections etc.). Each of these situations was realized three times varying in the salience of environmental cues pointing to the specific conflict (good, medium, hard to predict; not further discussed in this paper). For all these situations, it was characteristic that the conflict could possibly be anticipated by the driver. Figure 1 shows the driving simulator of the WIVW (left) and a screenshot of a simulator scene of a typical urban situation (right).

N=24 subjects participated in the study: one control-group with a baseline driving condition (n=8 subjects) and one dual task group which performed an additional menu navigation task while driving (n=16 subjects). The mean age of subjects was 36 years (sd=10.1 years) with n=12 female and n=12 male drivers. The two groups did not differ in relevant trait factors like driving experience, age or gender. They were all well trained in simulator driving.

Fig.1. The driving simulator with motion system of the WIVW (left) and a screenshot of a typical driving scene (right).

3.2 Menu navigation task

In the dual task condition, the driver had to perform a secondary task while driving. The presentation of this task was the following: At predetermined points of the route, the driver was offered the choice to perform an additional task. This offer was given either just before a critical situation (e.g. just after a parked car started to indicate but was still standing) or in a non-critical situation (on road segments between the critical situations). The offer was signalled by a question mark shown in the Head-Up Display on the front scene (see figure 2 left).

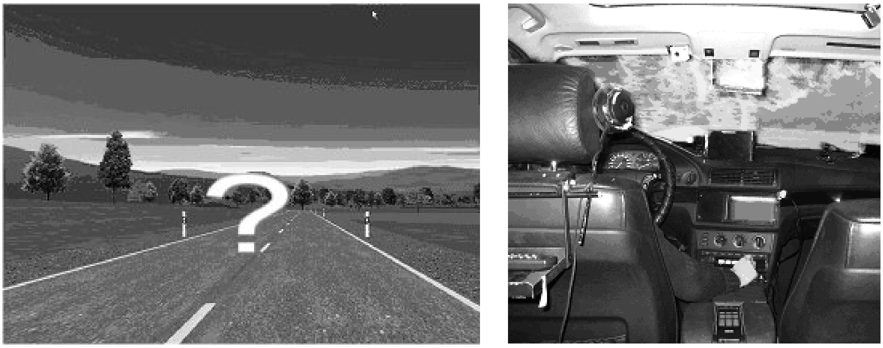

Fig.2. Screenshot of the HUD for offering a secondary task (left) and the menu selection task (right).

The offer given, the driver had to decide within 3 seconds whether the situation was suitable for the secondary task or not, according to the situational demands (‘decision phase’). To start the secondary task, the driver had to pull a joystick on the middle console of the vehicle to the right (see figure 2 right). Then a “start display” was presented on a visual display located at a lower position on the middle console of the vehicle (‘start phase’). To reject the offer, nothing must be done. After 3 seconds the question mark disappeared and the driver had to wait for the next opportunity to perform a task.

The task itself was a hierarchical menu navigation task simulating the interaction with a typical in-vehicle information system. The task could be interrupted at any point within the menu navigation. The driver was instructed to navigate to a specific menu function (e.g. “control average fuel resumption”; ‘instruction phase’). To navigate within the menu, the joystick was used. After reaching the correct function the driver confirmed the selection and the task was finished (‘performance phase’). For limiting the time for task performance until the next task was offered, menu navigation was stopped automatically after 15 seconds. The driver was instructed to interrupt the secondary task and return to the driving task whenever the driving task required full attention. To motivate the subjects to execute tasks at all, they received rewards for every completed task but also penalties for severe driving errors.

4 Results

In a first step, compensation strategies in the secondary task (ST) were analyzed by the following parameters of the menu task:

- Mean number of rejected tasks [%]
- Mean preparation time before starting menu navigation (start phase + instruction phase), only for executed tasks [sec]
- Mean execution time for menu navigation (limited to max. 15 sec), [sec]
- Number of tasks with minimum one interruption (delay times between two steps within the menu system > 3 sec), [%]

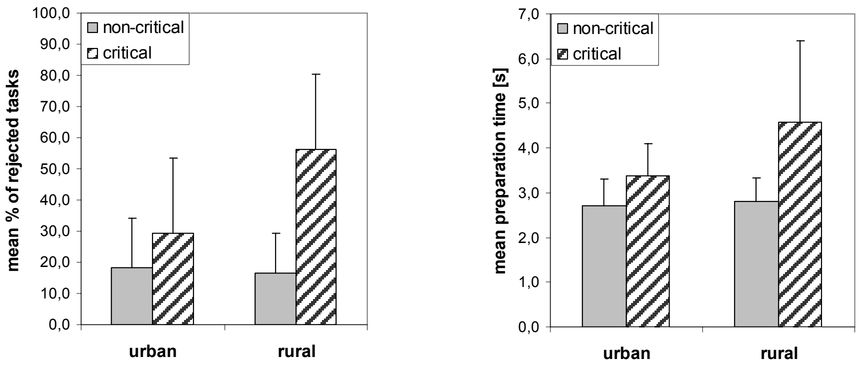

Fig.3. Mean % of rejected tasks (left), mean preparation time (right), for urban and rural, critical vs. non-critical situations.

The percentage of rejected tasks was generally higher in critical situations (43% vs. 17%; see figure 3 left), especially on rural roads (in front of curves and the broken-down vehicle; significant main effects “criticality” F[1;14]=74.737, p<.000 and “road type” F[1;14]=6.217, p=.026 and significant interaction; F[1;14]=33.023; p<.000). Drivers seemed to anticipate these demanding situations and therefore avoided any additional load of dual task performance. If drivers decided to execute a task in critical situations (after all over 50% of tasks) they try to await how the situation will develop (see figure 3 right). This resulted in longer mean preparation times until the menu system was started in front of critical situations (significant main effects “criticality“ F[1;14]=54.613, p<.000 and „road type“ F[1;14]=8.399; p=.012 and significant interaction F[1;14]=5.109; p=.042).

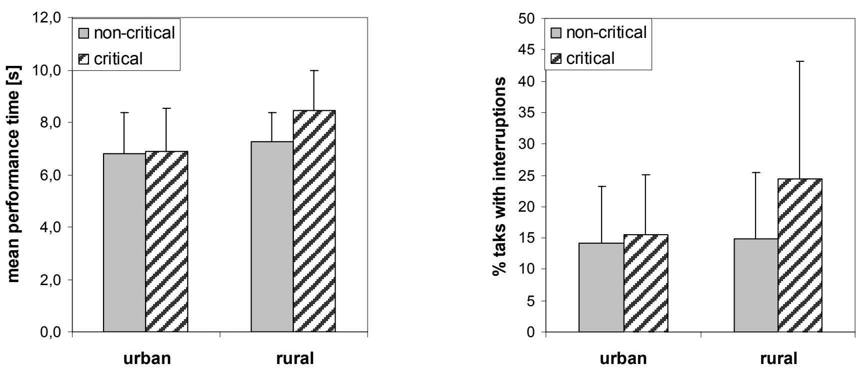

Fig.4. Mean performance time (left) and % tasks with interruptions (right), for urban and rural, critical vs. non-critical situations.

The execution time for menu navigation was also longer in critical situations, especially on rural roads (significant main effects “criticality“ F[1;13]=9.756; p=.008 and „road type“ F[1;13]=27.214; p<.000 and significant interaction F[1;13]=28.016; p<.000; see figure 4 left). This can be referred to a greater number of necessary interruptions during ST execution in these situations. The results for task interruption didn't reach significance ("criticality" F[1;14]=2.671, p<.124, „road type" F[1;14]=3.877; p=.069 and interaction F[1;14]=2.011; p=.178).

Figure 5 shows the relevant driving parameters in the different phases of ST execution, separated for straight and curvy roads. In both conditions, speed is continuously reduced, beginning with the decision phase until the end of ST execution. This implies that driving behaviour is first of all directed by the driving task, but then adapted to the requirements of ST execution.

The parameters SDLP/second and steering wheel_sd/second (due to variable phase durations standardized to sd/second) show an increase in steering activity at the beginning of the secondary task which may be interpreted as an attempt to get an optimum lane position, anticipating that during ST execution lateral control will be worse. During the execution of the secondary task, steering activity was then reduced which can be interpreted as a distraction effect of the secondary task that lead to a disregard of lateral control in the driving task. After the ST execution, often larger steering corrections could be observed in order to adjust the accumulated lane position error during the ST execution.

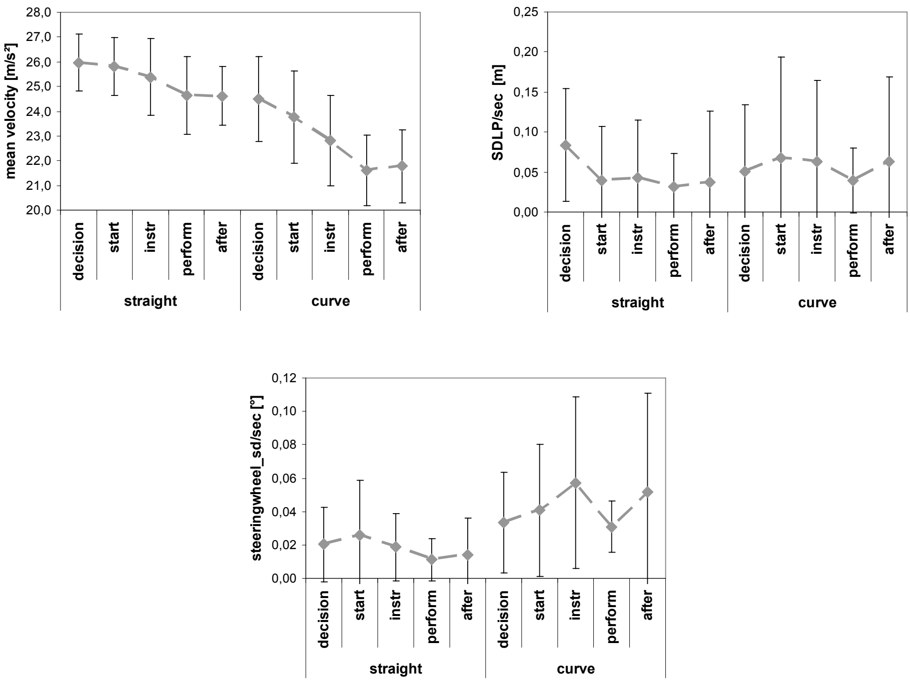

Fig.5. Mean velocity, mean standard deviation of lateral position (SDLP) per second and mean standard deviation of steering wheel activity per second in different phases of the secondary task execution on straight and curvy rural sections. Decision=decision phase, start=start phase, instr=instruction phase, perform=task performance phase, after=phase 2.5 s after ST performance.

For analyzing the effects on driving safety, we defined performance strategies in the interaction with IVIS in critical situations based on the following groups:

- Rejection of a task (not performing the task at all)
- Delayed beginning of the task (beginning of the task after a critical point; defined separately for each of the situations; e.g. the moment when the other vehicle is just parking out)
- Execution of the task without any interruptions
- Interruption of the secondary task, implicating a return to the driving task after the secondary task was started

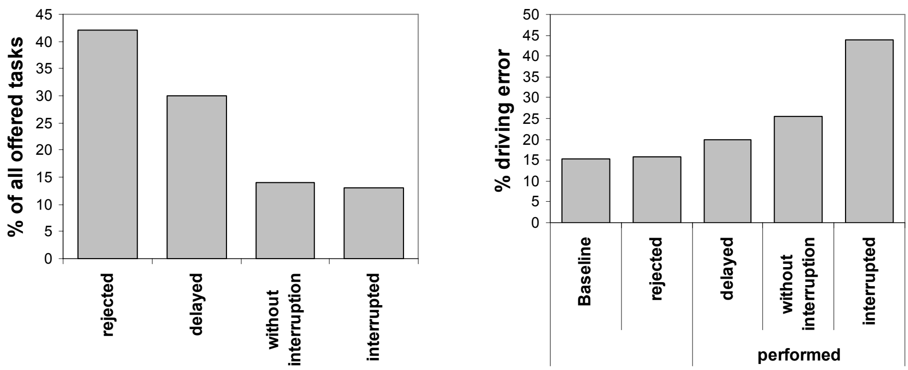

Fig.6. Percentage of different performance strategies for secondary task offers in critical situations (left), percentage of situations with driving errors of all critical situations; separately shown for the different performance strategies.

Figure 6 left gives the percentages of how often the different performance strategies were selected related to all offered secondary tasks in the defined critical situations. In most cases the task was rejected completely (43%). In 30% the beginning of the task was delayed until the critical event had happened. Further 14% of the tasks were performed without any interruptions straight through the critical situation. In 13% of the tasks the task was interrupted after the beginning of the task.

To prove the efficiency of the different strategies, driving errors were defined as decelerations > 8 m/s², critical safety margins < 1 m or critical TTC < 1 sec. Figure 6 right gives the results for the different strategies compared to the errors in the baseline condition without secondary tasks. If the task was rejected or delayed, there was no important increase in driving errors compared to the baseline condition (baseline-rejected Chi²=0.019; p=.890; baseline-delayed Chi²=1.765; p=.184). If the secondary task was performed straight through the critical situation there was a visible increase in driving errors (baseline-without interruptions: Chi²=3.596; p=.058). The highest percentage of driving errors occurred if the task had to be interrupted after it was started (baseline-interrupted: Chi²=20.748; p<.000). Evidently, the interruption of the secondary task was not successful to avoid driving errors.

5 Conclusions

Results show that drivers are able to adapt their secondary task behaviour to the situational demands. The anticipation of potential conflicts can be shown both in secondary task behaviour (task rejection or task delay) as well as in driving behaviour (lower approaching speed or preparation of proper lane positions in front of demanding situations like curves). These strategies seem to be very successful in maintaining an adequate driving safety. We observed less driving errors in critical situations when no secondary task was offered (baseline), when the secondary task was rejected or when the beginning of the task was delayed.

During the execution of a secondary task, drivers try to further adapt their behaviour to the situational development. They further reduce speed, e.g. on curvy sections and interrupt a task if the situation gets critical. In contrast to anticipative strategies, the control of situational development after the beginning of the task seems to be much more difficult. The results show that drivers who didn't' use anticipative strategies and performed the menu task straight through the critical situation, had a higher risk of driving errors, e.g. colliding with a suddenly braking preceding vehicle.

Also an interruption of ST performance was not a successful strategy in this study. In fact, the interruption of the task is an indicator of an adequate monitoring of the situational development during ST execution. But we believe that the success of this strategy is largely based on the time criticality of situations. Most situations in this study were so time-critical that an interruption of the menu navigation after starting the task could only be performed reaction-based but not anticipation-based. In less time critical situations a timely interruption of the secondary task execution should be successful to avoid negative effects on driving safety.

The still high number of executed tasks in critical situations indicates the potential problems of the interaction with in-vehicle information systems while driving. Drivers tend to perform secondary tasks also in situations where the load of the driving task is already very high and then may have problems to maintain driving safety. First of all, we explain this finding with an inadequate assessment of the situation's potential risk. In further analyses on the influence of situation's predictability in the study, varied by the availability of environmental cues pointing to the specific conflict, it could be shown that the less easy it was to predict the situation's criticality the higher the number of executed tasks was in this situation. This result indicates special problems for a situationally adaptive use of in-vehicle tasks in real traffic situations with low predictability. Another explanation would be that motivation for secondary task may have been very high (drivers got rewards in the form of bonus points for every completed task; the subject with the highest number of points at the end received a gratification) despite the instruction that primary task should be prioritized (they received a deduction of points for severe driving errors, e.g. crossing the lane). For real traffic this indicates a special risk for tasks with high relevance for the driver (e.g. important job-related phone calls). Furthermore, drivers may have underestimated the associated risk of secondary tasks in general. Results from a special questionnaire on the general attitudes of the drivers towards the use of secondary tasks while driving indicate that drivers who rated secondary tasks less distracting, rejected fewer tasks in the study.

In summary, the results show the importance of the two postulated processes of Situation Awareness for situationally adaptive interactions with IVIS while driving. The adequate situational assessment prior to ST execution is crucial to avoid overload due to the additional load of a secondary task in already demanding driving situations. Monitoring of situational development during ST execution is also necessary but much more difficult for maintaining Situation Awareness in interactions with IVIS.

The specific experimental setting, in which the driver decides whether and how to interact with a secondary task, allows a realistic assessment of driver interaction strategies with in-vehicle information systems. It permits analysis of specific compensation strategies and of their effects on driving performance and safety. Not only can possible distraction effects of an additional task be explored, but also the conscious decisions for the neglect of the driving task and their correlation to Situation Awareness.

6 Acklowledgements

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7 References

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