# MEET THE DRIVER NEEDS BY MATCHING ASSISTANCE FUNCTIONS AND TASK DEMANDS

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ABSTRACT: Test drivers drove in fog as well as with clear visibility. They were assisted with informing, warning or intervening Driver Assistance Systems or drove without assistance. Driving data and acceptance judgments show the best safety and acceptance values for the Info-Assistant. The Info-Assistant allowed the consistent driving behavior, the safest headway parameters and the shortest danger exposure. Acceptance evaluation showed that the Info-Assistant provided the most relief and maintained control over driving at the same time. Paying attention to task demands gives some useful information about the user needs. Matching of task difficulty and assistance functionality seems to be a useful step within the development of Driver Assistance Systems.

## 1 Introduction

Advanced Driver Assistance Systems (ADAS) are supposed to increase traffic safety. Although a lot of systems are available the take rate with 1% of all cars is low [1]. Therefore positive consequences for traffic safety are small and should be enhanced. Maybe car drivers don't know the advantages or the functionality of these systems. At the same time with the introduction of active systems (such as lane departure warning) there will be more and more systems that involve the driver and need his understanding of their functioning. This requires more precise knowledge about the cooperation of driver, car and ADAS than with passive systems (ABS e.g.). The development of ADAS motivated by economic or technical aspects doesn't seem to be very useful. Instead, the development process should focus on the driver and his needs to get some assistance. This assistance needs arise mainly from the difficulty of the driving task since task difficulty is a main determinant of driver behavior [2]. According to the Information Processing Approach (e.g. [3]) the difficulty can consist in perceiving the relevant information, deciding or executing the action correctly. ADAS could then assist through information, warning or intervention. For example, if perception in fog is difficult an ADAS could inform you about relevant things in your near environment, could warn you and facilitate your decision or could brake by itself. It would be useful to know if matching of the functionality of ADAS (informing, warning, intervening) with task difficulty (perception, decision, action execution) results in better driving performance and system acceptance. Traffic safety could profit because systems would be more efficient and then maybe more systems would be used because of the better acceptance. Therefore this knowledge could be useful for the development process of future ADAS.

## 2 Method

We examined this question with the Dynamic Driving Simulator of the DLR. 16 test persons participated aged between 24 and 39 years (mean = 30.1 years , STD = 4.85 years). Participation was voluntarily and compensated. Before the experiment each driver completed a training session in the simulator. In the experiment the subjects had to drive on a straight road for 10 minutes and repeatedly approached a lead car which drove with a constant speed of 50 km/h. After at least 20 seconds each lead car pulled off the road and the participants had the chance to drive unaffected until they approached the next lead car. The distances between the cars within one trial varied between 900 und 1600m. The order of the distances varied from trial to trial to inhibit that the drivers build some expectations about the appearance of the next car.

As independent variables we varied the task difficulty and the functionality of assistance. Task difficulty was varied by creating two different perceptional conditions. In the easy task condition the drivers had clear visibility conditions. In the difficult task they drove in fog. In both conditions they were instructed to drive safely and as fast as possible. To prevent any velocity reduction especially in the difficult condition which might reduce task difficulty we additionally motivated the test persons to drive fast by time measurements. The assistance functionality was varied by supporting the drivers either by an informing, warning or braking Assistant or let them drive without assistance. The experiment was designed as a within-subjects design. Thus each driver drove in clear visibility with either an informing, warning or braking Assistant or without assistance and each driver drove in fog with either an informing, warning or braking Assistant or without assistance.

To let the test drivers familiarize themselves with the Assistants and to minimize any carry-over effects each trial was performed twice and just the second trial was used for the analysis. Half of the participants started with the easy task, the other half started with the difficult task. The order of the assistance conditions within the difficulty condition was counterbalanced.

The different Assistants were supposed to support different parts of the driving task. The Info-Assistant is supposed to support the perception of the headway to a lead car since it always shows a topview of the road and a possible lead vehicle in a head-up display. The Warning-Assistant gives an auditive and visual signal depending on the collision risk (based on the Time-To-Collision) and is supposed to facilitate the decision to brake. ). The Brake-Assistant brakes if the collision risk is imminent to prevent any collision and gives some visual and auditive feedback. Figure 1 shows the three Assistants.

Fig.1. Info-Assistant, visual feedback of the Warning-Assistant and visual feedback of the Brake-Assistant, trial with clear visibility

The three Assistants were activated at different times. The design emerged from preliminary expert tests. The Info-Assistant was always present and started to display the lead car very early to give the driver enough time for the next steps to take. The Warning-Assistant was active when a certain threshold for the time-to-collision was reached. It warned early enough to allow the driver a moderate braking action but it warned late enough not to anticipate the driver’s decision to brake. The Brake-Assistant intervened as the latest when the time-to-collision was small. It braked early enough to avoid a collision but late enough to allow the driver braking by himself.

## 3 Results

Three of the ten approaching events of each trial were chosen because then the distance to the next lead car was large enough and there were no missing data. For each of this three events the driving behavior before the approaching (phase 1) and during the approaching process (phase 2) was examined. Phase 1 lasted 7 seconds and ended when the lead car was 6 seconds (time headway) away. Phase 2 lasted at least 20 seconds depending on the driving behavior and ended when the lead car left the road to the right. The activities of the Assistance Systems started during phase 2, the always present Info-Assistant just showed an empty road in phase 1. The results were analyzed using a Two-Way Analysis of Variance with repeated Measurements with the factors task difficulty (clear visibility and fog) and Assistance System (without assistance, Info-Assistant, Warning-Assistant and Brake-Assistant).

First I will focus on phase 1 and start with the speed behavior. As desired there were no velocity differences between difficulty conditions and Assistance Systems in phase 1. Thus the drivers didn’t reduce the task difficulty of the fog condition by reducing the velocity. Also no Assistance System induced a lower or higher velocity either. A meaningful variable of the speed behavior is the speed variability. It describes how much the drivers changed their speed and showed a main effect of the task difficulty ($F(1,14) = 14.97$, $p < .05$). With clear visibility velocity changed more. Mean deceleration showed the same effect which means that there was more braking activity under clear visibility conditions. A reason might be that the lead car in the clear visibility condition was already visible in this phase and the drivers started decelerating. Furthermore speed variability showed a main effect of the Assistance System ($F(3,42) = 5.37$, $p < .05$) with the Info-Assistant leading to the most constant speed behavior. Again, mean deceleration was responsible which was the lowest with the Info-Assistant. Driver behavior in phase 1 is also useful to examine possible behavioral adaptations since drivers in this phase drove unaffected by any lead car. Therefore we compared the mean velocity of the first event with the mean velocity of the third event and found no differences ($F(1,13)= 0.396$, $p= 0.54$). Thus there were no short term behavioral adaptations.

Phase 2 showed no velocity differences between the visibility conditions or the Assistance Systems as well. As instructed the test persons drove with similar velocity in clear visibility as well as in fog. This time speed variability in fog was higher than with clear visibility conditions ($F(1,14) = 8.92$, $p< .05$). This again resulted from the deceleration behavior which showed the same main effect. In phase 2 braking in fog was more severe than in clear visibility and the drivers decelerated to a lower velocity. The speed variability depended also on the Assistance System ($F(3,42) = 3.06$, $p< .05$). The Info-Assistant allowed the smoothest speed behavior. Especially in fog drivers reduced their speed with the Info-Assistant not to the same extent as with the other Assistants. Figure 2 shows speed variability as a measure of driving behavior.

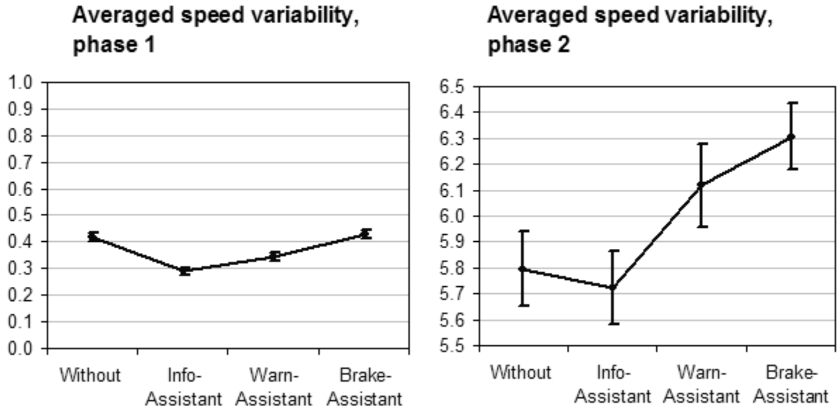


Fig.2. Speed variability in phase 1 and 2 [m/s]

This speed behavior can result in safe or unsafe traffic situations that are especially in phase 2 a matter of interest. An important safety indicator is the time-to-collision (TTC) that contains the time until a possible collision occurs and measures therefore how dangerous a situation is. Traffic situations with less than 4 seconds TTC are considered to be dangerous. The proportion of the dangerous time (TTC) to the time of the whole phase describes how long danger existed. This time-exposed TTC shows a main effect of task difficulty ($F(1,14) = 26.94$, $p< .001$), which means that the danger in fog existed for a longer period of time than with clear visibility. Other safety indicators showed the same effect. Distance headway or time headway describe how closely the driver followed the lead car. In fog the mean time headway and the mean distance headway were smaller than with clear visibility. Furthermore the time-exposed TTC depended on the interaction of visibility condition and Assistance System ($F(3,42) = 5.34$, $p< .05$). With the Info-Assistant in fog drivers were not as long exposed to the danger than with the other Assistance Systems.

Distance headway and time headway were the safest for the Info-Assistant as well. However, the duration of lane exceedences was the longest with the Info-Assistant (F(1.5, 21.1) = 4.95, p< .05) but happened mainly with clear visibility. Figure 3 shows time-exposed TTC and lane exceedences as measures of traffic safety.

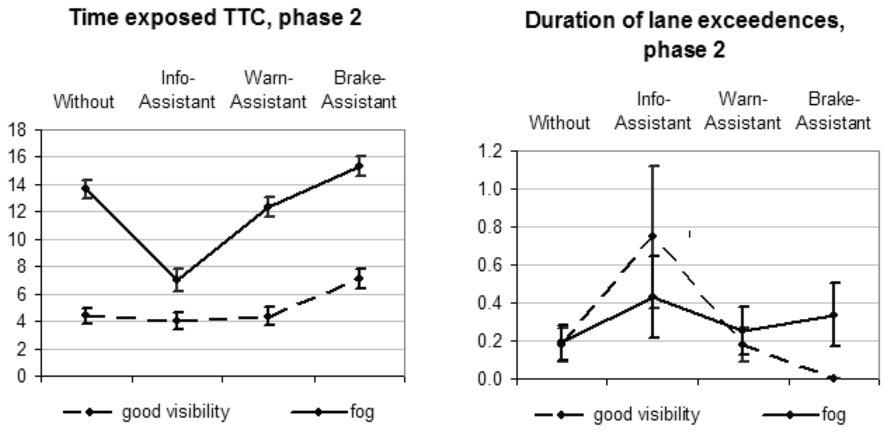


Fig.3. Time-exposed TTC and duration of lane exceedences

Acceptance was measured with questionnaires after each trial. Driver judged the speedometer in the trial without assistance instead of an Assistant System. With judging the content of the Assistant drivers evaluated how useful information about the distance to the lead car is compared to a collision warning or a collision-dependent intervention. Results showed an interaction of task difficulty and Assistance System (F(3,42)= 4.67, p< .05). With clear visibility information about the distance made no sense, but in fog it's usefulness was similar to a warning or intervention. Evaluations of the user interface tended to depend on the interaction of both factors (F(3,42) = 2.61, p= .064). The user interface of the Info-Assistant performed poorly with clear visibility but as good as the other Assistants in fog. The relief through the use of assistance showed an interaction, too (F(3,42) = 2.9, p< .05). The test drivers evaluated whether distance keeping to the lead vehicle was easier or more difficult when using the Assistant. The Info-Assistant made this task easier, especially in fog. Control over driving is another important variable and describes how the use of an Assistant changes the own control over driving. It was evaluated dependent on both factors (F(3,42) = 4.85, p< .05), which means that the Info-Assistant in fog reduced the control least of all. However, the distraction through assistance showed a main effect (F(1.7,23.8) = 9.94, p< .001) with the Info-Assistant distracting most. Figure 4 shows the important evaluations.

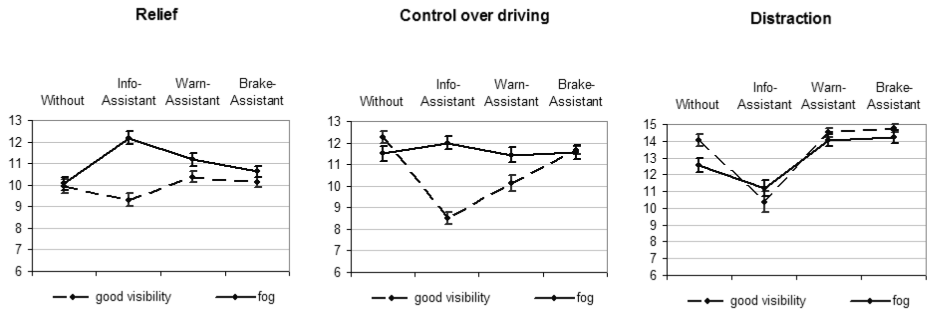


Fig.4. Evaluation of relief, control over driving and distraction. A score of 15 means the best evaluation

# 4 Discussion

In the experiment the participants drove on a straight road with good or bad visibility conditions and therefore different task difficulties. They were supported by one of three Assistance Systems that differed in the kind of functionality or they drove without assistance. Following our instruction they drove in both task difficulty conditions with the same velocity. Thus the drivers didn't reduce task difficulty of the fog condition and they experienced a more difficult driving task in the fog condition than with clear visibility. Task difficulty further resulted in different driving behavior. In phase 1 deceleration was stronger with clear visibility since they already saw the lead car, whereas in phase 2 they had to decelerate stronger in fog. The difficult fog condition resulted also in less safe traffic situations. Drivers then had lower safety margins and dangerous time periods were longer. More relevant than task difficulty effects are the effects of the different Assistance Systems. No Assistance System tempted the drivers to drive faster. The test persons drove more consistent with the Info-Assistant than with the other Assistants since they didn't have to decelerate so much. In phase 2 the Info-Assistant especially in fog generated less deceleration. Thus the Info-Assistant allowed a very smooth driving behavior with early and weak decelerations. The Info-Assistant also resulted in the best traffic safety values especially in fog. Dangerous time periods with the Info-Assistant were shorter. Distance and time headway were safer. Acceptance evaluation in the fog condition didn't differ between the Assistance Systems regarding the delivered content (distance information, collision warning or collision-dependent intervention) and the user interface. The major subjective advantages of the Info-Assistant consisted in the usefulness. The Info-Assistant allowed the most control over driving which corresponds with the better anticipative abilities in driving behavior. In addition the Info-Assistant facilitated distance keeping most which corresponds with higher traffic safety in driving behavior. However, drivers evaluated the Info-Assistant as most distractive which is supported by the time of lane exceedences. Since the Info-Assistant doesn't result in more variation in the lateral position than the other Assistance Systems, the distractive effect should be of more subjective than objective nature. Overall the

Info-Assistant shows the best driving behavior, the highest traffic safety and the best acceptance evaluations.

Our study shows that the longitudinal control in a perceptually difficult driving task is best assisted by an Assistant that provides early information about a lead car. The Warning-Assistant which gave a warning about some danger with the request to brake or the Brake-Assistant which intervened in case of an emergency resulted in less safe traffic situations and these Assistants were also less accepted. This happened despite the fact that these systems also gave the driver enough time to brake, thus didn’t induce any time pressure. Apparently it is most useful for the driver in this situation to get some information about future events which allows the driver to anticipate his behavior. With the different Assistance Systems we also tried to vary different Levels of Automation. The Info-Assistant represents the lowest level since it just gives some relevant information about the environment and the driver has to deal with the consequences. The Brake-Assistant represents the highest Level of Automation since it acts for the driver. The study shows that the highest degree of automation is not always desirable. One has to consider also the task difficulty.

On the other hand we do not know if the drivers really used the Assistance Systems as they were intended to use. For example it is quite possible to use the Brake-Assistant as a warning when the start of the system’s activity is used as a hint to start with braking. Similarly it is possible to use the Info-Assistant as a warning when one specific status of the display is used to start braking. We hope to get some insights into this issue when we evaluate the interviews where we asked the participants how they used the systems. Another weakness of the study is that the functionality of the Assistance Systems is confounded with the kind and number of the used sensory channels. The Info-Assistant just uses the visual channel, the Warning-Assistant additionally uses the auditory channel. The Brake-Assistant uses the visual, auditory and the haptic channel. However, the used channel results from the functionality of the assistance. One cannot combine each functionality with each channel, e.g. an intervention must use the haptic channel and can’t be visual. This restriction means that we can’t be sure that the advantages of the Info-Assistant only result from it’s informing character, maybe the used channel is also responsible. However, we found no differences in the acceptance evaluations regarding the used channels. As another possible weakness the functionality of the Assistance Systems is confounded with the different times they started to be active. Again this results from their functionality. The Info-Assistant has to be active early to allow the driver all the other steps to take. A warning as early as this information would have been considered as a false alarm since the lead car was far ahead. A braking at this early time would be completely senseless. There exists no common point in time to start the activity of the different functionalities. The functionality cannot be separated from the starting point. In other words – the starting point is in addition to the functionality part of the Assistance System. One might argue that the smoother and safer driving behavior of the Info-Assistant results from it’s earlier activity. Of course it allowed an earlier reaction of the driver but this earlier reaction wouldn’t have happened if the drivers hadn’t thought that an anticipative behavior is useful. Finally we have to consider that the identified effects of the Assistance Systems may change with longer use. We found no short-term adaptations in terms of velocity changes after the participants had used each system at least 20 times. Longer term adaptations can usually be measured only after a familiarization period. Possible determinants of behavioral adaptations are the influence of the system on the way the driving task is performed, the drivers' possibilities to change their behavior and the presence of competitive motives for changing behavior [4]. Maybe it can be hypothesized that a lower Level of Automation changes the way a task is performed to a less extent and therefore induces less behavioral adaptations than higher Levels of Automation. But this has to be examined in a long-term study.

## 5 Acknowledgements

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## 6 References

[1] Mercer-Untersuchung, Automobile Sicherheitstechnik. Available under: http://www.presseportal.de/story.htx?nr=553838&action=bigpic&att=28898, accessed May 2006

[2] Fuller, R. (2005). Towards a general theory of driver behaviour. Accident Analysis and Prevention, 37, pp. 461-472

[3] Timpe, K.-P., Giesa, H.-G. & Seifert, K.: Engineering Psychology. in: C.D. Spielberger (Ed.): Encyclopedia of Applied Psychology (Elsevier, 2004, Volume I), pp. 777-786

[4] Saad, F. et al. (2004). Literature review of behavioural effects. EU project AIDE, project IST-1-507674-IP, Deliverable 1-2-1