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Driver distraction based lane-keeping assistance

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ABSTRACT

Driver assistance systems could be much more effective, if they were adaptive to the driver's state. Following the idea of a lane-keeping assistance system, which is adaptive to the use of in-vehicle information systems (IVIS), two field experiments were conducted. The first experiment concerned the influence of typical IVIS tasks on lane-keeping. Most IVIS tasks increased the lateral deviations, but in the majority of cases the drivers were still able to stay in their lane.

The second experiment concerned two questions: (1) how much lateral support would be needed and (2) how drivers accept this kind of support. The results show that all lateral support algorithms increased the lane-keeping performance with the algorithms providing a higher amount of assistance proving the most useful. All assistance systems were rated as helpful and were considered to increase driver safety, both by the drivers who did not have problems in lane-keeping without assistance.

In light of these results an adaptation of a lateral support system to the IVIS-use seems to be useful and worthwhile.

1. Introduction

Driver inattention is one of the major factors in traffic accidents. The National Highway Traffic Safety Administration estimates that in 25% of all crashes some form of inattention is involved (Wang, Knipling, & Goodman 1996). Distraction (besides drowsiness) as one form of driver inattention may be characterised as: "any activity that takes a driver's attention away from the task of driving" (Ranney, Mazzae, Garrott, & Goodman 2000). Naturalistic driving studies, like the "100-Car Naturalistic Driving Study" by Dingus et al. (2006), show in detail what kind of activities drivers engage in and what the likelihood of accidents for each kind of secondary task is. In almost 80% of crashes and 65% of near-crashes the driver was inattentive. In the majority of these cases the driver was occupied by a non-driving related task. The use of wireless devices and passenger related distractions are the most frequent causes of driver inattention.

Although in the last few years many European countries have prohibited the use of wireless devices while driving, it should not be expected that the amount of distraction in driving will necessarily decrease. Even without the distractions caused by mobile devices, the amount of distraction due to in-car information systems will increase. Multimedia devices, which allow the driver to select their favourite song out of thousands or the connection between the navigation system and Google search functions, provide plenty of opportunities to reduce the attention paid to the roadway. Even if new laws restrict the use of such in-car devices in the future, distraction will still be a problem in other forms, e.g. from roadside events or passengers in the car. Thus, OEMs and automotive suppliers will need to find a way to deal with this problem.

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One method that minimizes crashes rather than distractions is the development of new driver assistant systems. With the evolution of adequate lane tracking, lane departure warning systems which attract drivers' attention when lane departures occur were introduced recently onto the market. The naming is still not consistent with "Lane-keeping assistant" or "lateral control assistance" often being used. These systems track the lane markings in front of the vehicle and compute the time until the vehicle will cross the marking. If the driver does not show an intention of leaving the lane by using the indicator, the system will initiate a warning or start assistance.

Authors of several studies (Rimini-Döring, Altmüller, Ladstätter, & Rossmeier, 2005, Alkim, Bootsma, & Hoogendoorn, 2007) reported overall effects of lane departure warning systems. Alkim et al. (2007) reported a decrease in unintentional lane changes due to a lane-keeping assistant by 30–35% depending on the type of road. Different traffic and accident analyses (Abele et al., 2005; Alkim et al., 2007; McKeever, 1998) postulated a reduction of "head-on" and "left roadway" accidents by 25%, as well as a reduction of accident severity.

Subjective evaluations are rare. In Kozak et al. (2006) the different warnings were rated as helpful. The participants of the study by Alkim et al. (2007) judged the lane departure warning system as annoying but effective. Studies of the German EMPHASIS Project (Buld et al., 2002) showed that steering torques are less annoying than lane departure warnings in the form of a vibrating steering wheel.

It is debatable whether current warning algorithms are as good as they could be. An attentive driver does not need any lane-keeping support. But lane-keeping assistance systems do not yet account for the driver's state. If it was possible to recognize drivers' distraction reliably, the system could give just as much assistance as the driver needs. This would allow for a greater safety margin without annoying the driver with false alarms in normal driving situations. There are different concerns when estimating the driver's state online. Interpreting the driving task as a control loop as shown in Fig. 1 provides several possibilities for such estimations.

The perception of the driver could be assessed with driver monitoring systems. Pohl, Birk, and Westervall (2007) adjusted a lane-keeping assistant based on head-orientation and head-position. They concluded the system was useful to detect visual distraction, but the acceptance of this system remains unclear.

Another possibility is to monitor the use of the steering wheel and the pedals. Sensor data like steering wheel angle and lane position in combination with driver models might give hints of unusual driver behaviour. Based on vehicle sensor data, Torkkola, Massey, and Wood (2004) were able to distinguish between attentive and inattentive drivers by using self-learning algorithms. The accuracy was high, but a cross validation was missing. Furthermore, the algorithm was not used to adapt an assistance system.

Secondary tasks the driver is performing may also be taken as indicators of distraction. Dingus et al. (2006) showed in-vehicle information systems (IVIS) to be one source of inattention. Most of the tasks on an IVIS require visual attention which is likely to lead to a reduction of attention paid to the road ahead. Although IVIS use is only one source of distraction, it might show the usefulness of a driver state adaptive lane-keeping support.

Following the idea of adapting lane-keeping assistance to IVIS-interactions, two field experiments were conducted.

The first experiment was designed to evaluate the influence of typical IVIS tasks on lane-keeping performance. If driving performance decreases due to IVIS-use, an adaptation of lateral assistance each time the IVIS is used might be beneficial.

Naab (2000) concluded that driver assistance systems will only be accepted by the driver, if the system accounts for the personal driving style. Kompass and Huber (2007) summarized the idea in No. 3 of their 10 golden rules of driver assistance:

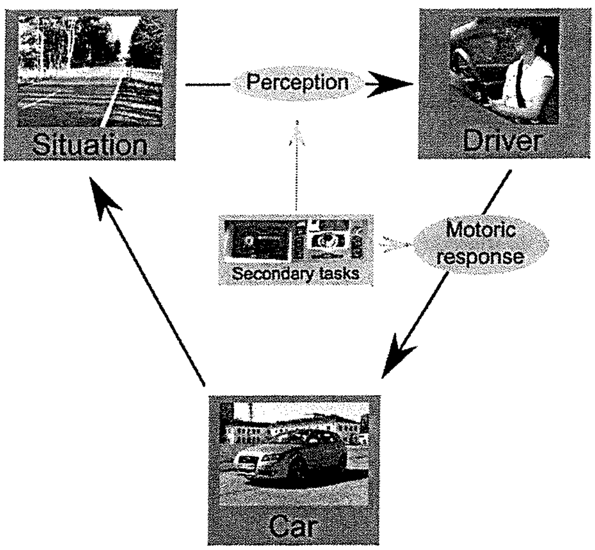

Fig. 1. Driving task as a control loop.

"Driver assistance should preserve a driver's sovereignty by being supportive, but not patronizing, in operating such system. The driver should not be inadvertently controlled by the driver assistance system". Although an adaptation of lane departure systems to the IVIS-interaction might be useful, it is not certain that all drivers would appreciate the assistance, especially those drivers who have no problems with lane-keeping.

The second experiment considers the acceptance and the need for an adaptive lane-keeping support due to the use of IVIS.

2. Experiment 1

The first experiment was designed to evaluate the influence of IVIS-use on lane-keeping performance. If typical tasks reduce drivers' ability to stay in the lane, a lateral assistance would be useful.

2.1. Participants

Thirty participants (12 female and 18 male) were recruited. The subjects were 23–59 years old and had driven at least 10,000 km in the last 12 months.

2.2. Experimental car

An Audi A6 was used as the experimental car. The car was equipped with the Audi Multimedia Interface. The control button of this IVIS was located between the driver's and the co-driver's seat. The display was in the middle console just under the dashboard. Fig. 2 shows the Audi A6 Cockpit.

2.3. Secondary task

Six typical tasks were executed while driving:

- Radio: Adjust the radio sound settings.
- CD: Skip to a specific song.
- Phonebook: Search for a name in the phonebook.
- Navigation – Point of interest: Search for a nearby gas station.
- Phone: Dial a specific phone number.
- Navigation: Enter a city in the navigation device.

Even those drivers who are experienced with the Audi Multimedia Interface do not know where every setting can be changed. It can happen that the driver has to search through the menu, because they do not know where to find the function. To simulate this, two more tasks were created. These tasks were not trained in the training phase.

- TV: Switch the TV mode to "PAL".
- Navigation – Sound: Adjust the volume of navigation announcements.

Fig. 2. Audi A6 Cockpit.

Probably not all drivers use these functions while driving. Recommendations in the IVIS instruction manual clearly advise not to do so, especially changing setup settings. Anyway, there will always be driver, who will ignore such guidelines. Thus, the experiment is designed as a worse case scenario.

For a better understanding Fig. 3a shows the IVIS control panel from the driver's perspective. The main functions (e.g. Navigation, CD/TV and Radio) are available through the eight so-called Hardkeys, which are located on the right- and left-hand side of the control panel. In each main menu special functions (e.g. sound settings in the radio menu) can be selected by the four so-called Softkeys, which surround the control button. These special functions differ between the main menus. The functions assigned to the Softkeys are shown in the corners of the display (e.g. in Fig. 3b the lower-right Softkey "Karte" opens a map in the navigation menu).

Most inputs are done with the control button. By turning the control button left or right you are able to scroll up and down in lists like in Fig. 3b and d. Pushing the button selects the highlighted item. For typing letters (Navigation) or digits (Phone) the so-called Speller is used (Fig. 3c). The symbols are arranged in a circle and can also be selected by turning and pushing the control button.

To solve all IVIS tasks used in this experiment an optimal way can be described. The following steps have to be done to enter a city in the navigation device:

1. Press the Hardkey "NAV".
2. Select "Enter Destination" in a list (one row down).
3. Use the Speller nine times to enter the city.
4. Press the control button one time to confirm the city (zero rows).
5. Select "Downtown" in a list (one row down).
6. Confirm "Start Navigation" in a list (zero rows).

Table 1 shows the steps for each task. The digits behind "Speller" show the number of symbols to enter. The digits after "List" indicate the number of rows the driver has to scroll up or down in a list.

2.4. Design and dependent variables

A repeated measures design was chosen. Each participant drove down the same road eight times while performing the secondary tasks. On another run the drivers had to drive down the road with full attention on the roadway (baseline). In order to account for sequential effects, the order in which the conditions were presented was randomized for each participant.

As a dependent variable the maximum lateral deviation was recorded.

It was expected that all tasks would decrease the lane-keeping performance compared to the baseline, hence increasing the lateral deviation.

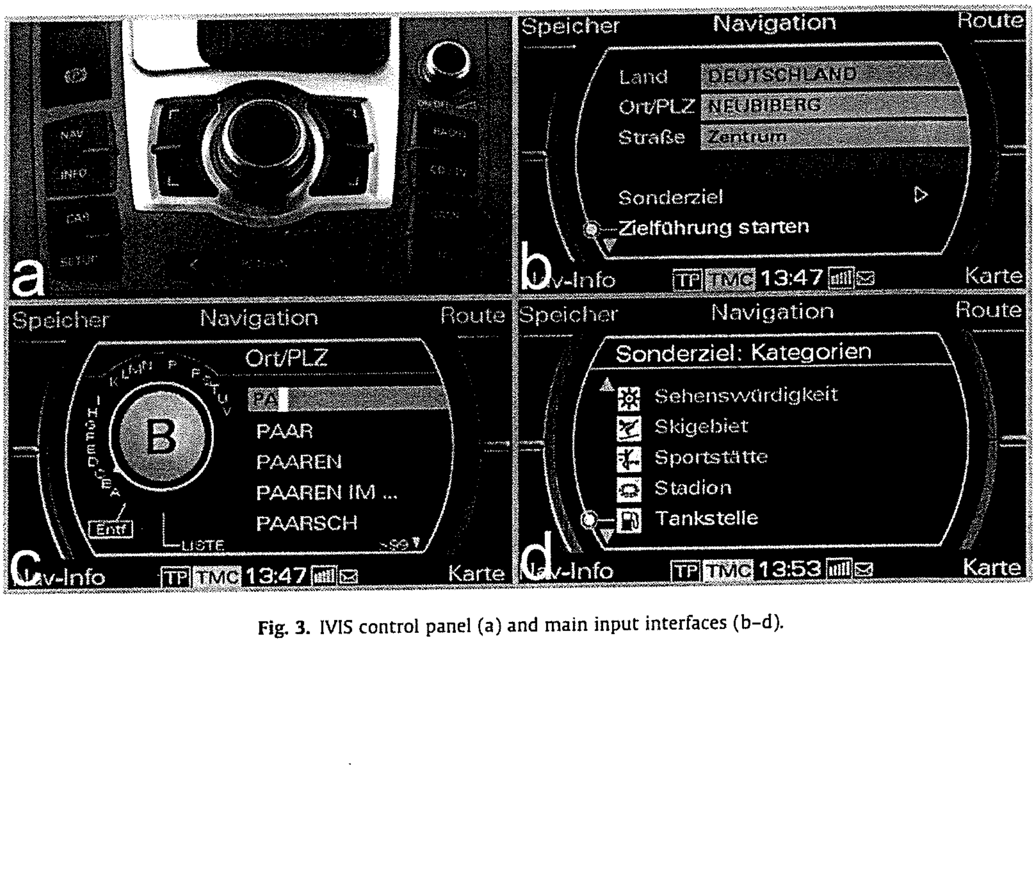

Fig. 3. IVIS control panel (a) and main input interfaces (b–d).

Table 1
Optimal steps to solve each task.

Task	Steps
CD	Hardkey → List (8)
Radio	Hardkey → Softkey → List (2) → Speller (1) → Hardkey → List (1) → Speller (1)
Phonebook	Hardkey → Softkey → List (3) → List (16)
Navigation - POI	Hardkey → List (4) → List (0) → List (29)
Phone	Hardkey → Speller (12)
Navigation	Hardkey → List (1) → Speller (9) → List (0) → List (1) → List (0)
TV	Hardkey → Softkey → List (1) → Hardkey → List (4) → List (5)
Navigation - Sound	Hardkey → Softkey → List (6) → List (1) → Speller (1)

2.5. Procedure

The participants received a training session of 30 min on a closed test track to become familiar with the car. To ensure each participant had the same level of ability in using the Multimedia Interface they also received a specific training for the above named six tasks.

After training on the test track the participants drove another 30 min in normal traffic before the measurement procedure started.

The experiment was carried out on a straight country road with a lane width of approximately 3.40 m. The participants had to drive down the road while performing the IVIS tasks. They were not instructed to perform the tasks as quickly as possible, but to perform them as they would normally in order to create a realistic scenario. During these tasks the lane deviation of the car was logged by a computer.

2.6. Results

The maximum lateral deviation is an indicator for the severity of the situation. The mean of the maximum lateral deviation was computed for each task. Fig. 4 shows the mean maximum lateral deviation and the standard deviation of the maximum lateral deviations for each IVIS task.

A repeated measures ANOVA showed significant differences between the conditions ($F = 17.901$, df = 8, $p < 0.001$). Bonferroni post hoc tests (adjusted p-value) revealed significant differences between the baseline and the conditions "Phonebook", "Navigation – Point of interest", "Phone", "Navigation", "TV" and "Navigation – Sound".

There are also significant differences between the tasks. "CD", "Radio" and "Phonebook" differ significantly from "Navigation", "TV" and "Navigation – Sound". In addition, the mean maximum lateral deviation of "Radio" differs to "Navigation –

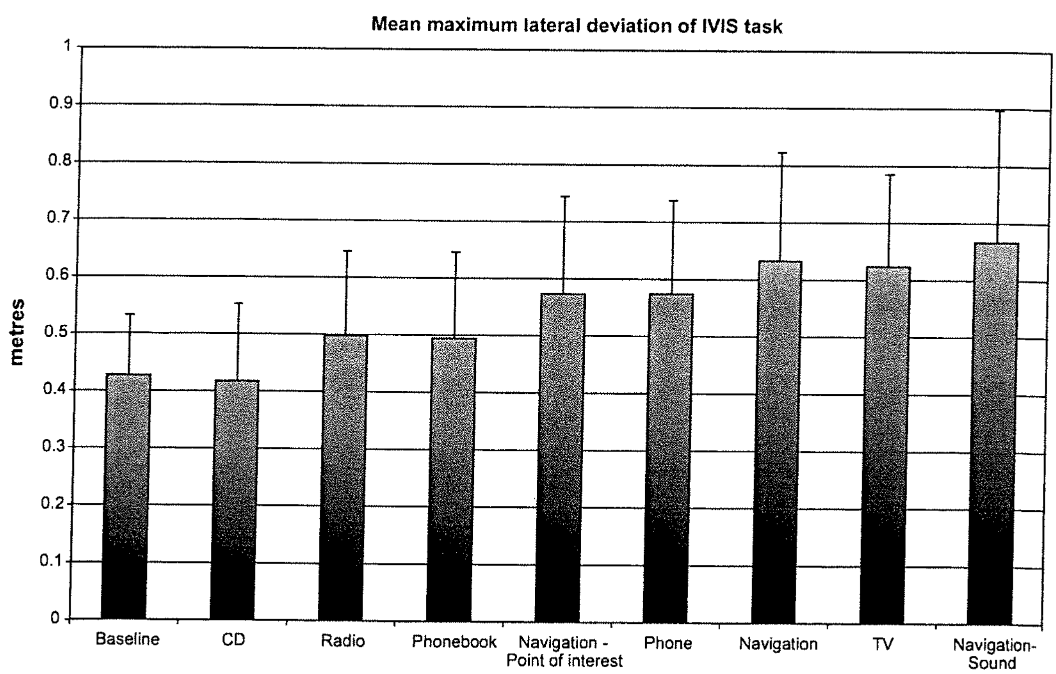

Fig. 4. Mean maximum lateral deviation for all eight IVIS tasks.

Point of interest" and "Phone". The difference between "Navigation – Point of interest" and "Navigation – Sound" is also significant.

The results for the comparison against the baseline condition are as expected. Nearly all IVIS tasks have a negative influence on the lane-keeping performance. All tasks but "CD" and "Radio" show a significant higher lane deviation compared to the baseline.

With regard to the different number of steps the driver has to do to solve each task (see Table 1), significant differences in the mean maximum lateral deviation are not surprising.

Table 2 shows the total number of lane departures (operationalized by a crossing of a lane marking's outer border with one part of the vehicle), the total number of participants who completed the task and the mean duration for completion of the tasks for all analysable runs.

Looking at the lane departures gives a better view of usefulness of lateral assistance. In most cases the drivers did not leave the road, but in 8 of 222 runs lane departures occurred. All at all this is a satisfying result. Although some tasks last sixty seconds most drivers were still able to keep the vehicle in the lane.

A question arising is whether the differences within a task are only due to familiarisation effects, so that more trained participants would not have had lane departures. First of all, if familiarisation with the task was a contributing factor, the differences between the trained (e.g. Navigation) and untrained tasks (e.g. TV) would be larger. Furthermore, as there was a training session on a closed test track, big differences in task familiarisation seem unlikely. As can be seen in Table 2 most participants solved all trained tasks except "Navigation". Observations of the unsolved "Navigation"-cases show the participants to be slower and close to task completion when the experimenter stopped the run. Thus, it is concluded that familiarisation effects can be neglected.

Task difficulty might explain differences in lane departures and maximum lane deviation between the tasks. Table 1 indicates that the steps of the tasks are similar but not the same. Comparing trained and untrained tasks the cognitive load appears to differ. Whether there is a difference between "List" and "Speller" is debatable. Furthermore, the amount of steps to solve each task, i.e. the visual demand of the tasks, is not equal. This is clearly observable by the mean task duration in Table 2. To get a better insight in the influence of task duration, an analysis of the mean maximum lateral deviation was carried out for the first 10 s of each task. Fig. 5 shows the mean maximum lateral deviation and the standard deviation of the maximum lateral deviations for the first 10 s of each IVIS task.

A repeated measures ANOVA showed significant differences between the conditions ($F = 6.251$, $df = 8$, $p < 0.001$). Bonferroni post hoc tests (adjusted p-value) revealed significant differences between the baseline and all eight IVIS tasks. As it was found in the analysis of the whole runs, there were no significant differences between the tasks.

The result that there are no differences between the tasks in the first 10 s here argues for task duration as the main problem. However, without another experiment it is not possible to distinguish whether the differences in the whole runs are due to different demands of cognitive capacity or due to visual demands in form of longer tasks.

In any case is the observation of a lack of differences between the tasks in the mean maximum lateral deviation in the first 10 s interesting when considered in conjunction with another fact: the time the driver used the IVIS before the lane departures occurred. One lane departure happened just 5 seconds after starting the task. Two occurred between 10 and 20 s, another 4 between 20 and 40 and one after 43 s. Although lane departures in this experiment are rare and as a result of this floor effect a statistical analysis is neither meaningful nor possible, it demonstrates two things:

1. Lane departures might occur as soon as IVIS is first used.
2. Lane departures occurred in this experiment only in 4 of 8 tasks. However, due to the fact that the cognitive and visual demands in the first 10 s of each task are similar, lane departures might also happen when the driver is doing other IVIS tasks. The "missing" lane departures in these tasks are presumably a floor effect.

With regard to the idea of adjusting a lateral support system when the IVIS is used, a few questions arise. A lateral support system may have prevented the lane departures in this experiment. However, most drivers obviously did not leave the lane, although an increase of maximum lateral deviation was measured. How do these drivers react to lateral support? According to Kompass (2007) they might feel patronized by the system.

Table 2
Total number of lane departures, total solved tasks and mean task duration for analysable runs.

Task (analysable runs)	Total lane departures	Total solved tasks	Mean duration in sec
Baseline (30)	0	30	59.1
CD (28)	0	28	14.1
Radio (30)	0	30	27.1
Phonebook (30)	0	30	31.0
Navigation - Point of interest (25)	0	23	43.3
Phone (27)	2	26	42.6
Navigation (26)	2	14	59.2
TV (29)	1	8	57.9
Navigation – Sound (27)	3	2	61.1

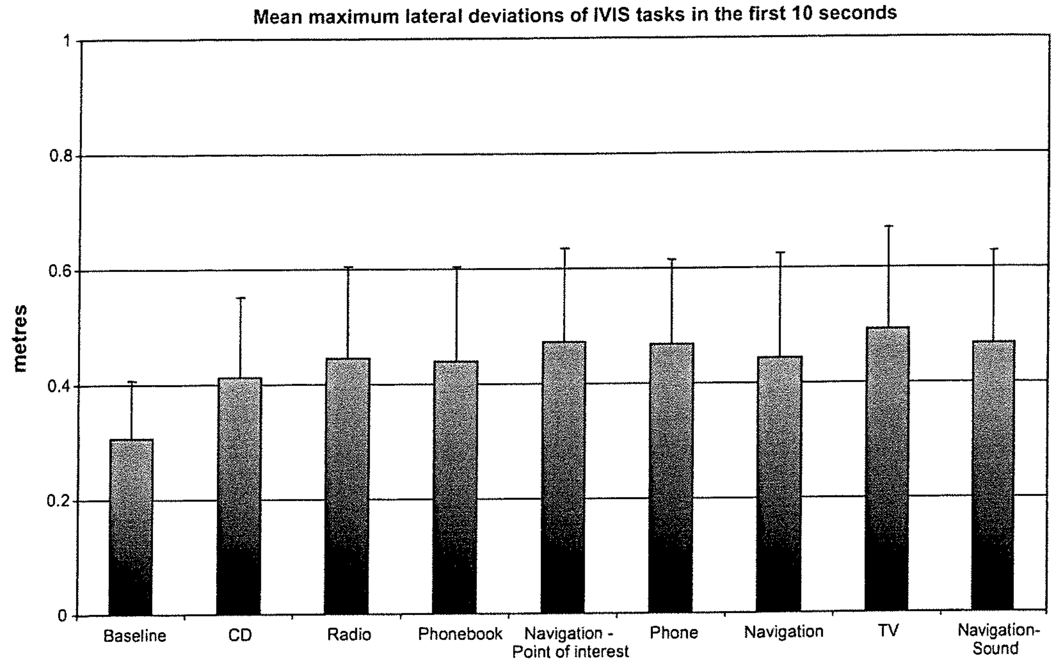

Fig. 5. Mean maximum lateral deviation for the first 10 s for all eight IVIS tasks.

Another question is how much lateral support is needed when doing an IVIS task. Perhaps an adaptation of the support would be of little use, because the standard assistance is already sufficient.

A second field experiment was conducted to answer these questions.

3. Experiment 2

The second experiment was designed to answer two questions:

1. Would drivers, who are able to keep to the lane while performing an IVIS task, appreciate lateral assistance? Or do they feel patronized by the system, like Kompass (2007) would predict?
2. How much assistance is needed and appreciated?

3.1. Driver assistance devices

An Audi A3 was used as the experimental car. The car was equipped with electrical power steering. This steering gives the opportunity to apply steering torques on the steering wheel with a force of up to 3 N m, which guide the driver back to the centre of the lane. A CCD camera behind the rear-view mirror tracked the lane markings. Based on lane position, yaw angle, steering angle, lateral and longitudinal speed a possible lane crossing was predicted. Three different assistance algorithms were implemented, which differed in the amount of lateral assistance. The definition of where the assistance started is complex. It was not just dependent on a "time to line crossing" or a "distance to line crossing" value, but also on the lateral speed and the yaw rate. For a better understanding an approximation in the form of a distance to line crossing is given here.

3.1.1. Standard assistance

The system applies noticeable steering torques towards the centre of the lane when the distance to a lane marking becomes smaller than approximately 25 cm. This assistance is comparable to common lane departure warning systems.

3.1.2. Early assistance

The system applies noticeable steering torques towards the centre of the lane when the distance to a lane marking becomes smaller than approximately 40 cm.

3.1.3. Continuous assistance

The system applies continuous steering torques towards the centre of the lane.

Fig. 6 shows a schema of the different assistance algorithms.

3.2. Participants

Thirty participants (5 females and 25 males) were recruited. The subjects were 31–65 years old and had driven at least 10,000 km in the last 12 months.

3.3. Secondary task

The phone dialling task was chosen as the secondary task. This was useful, because by changing the numbers dialled, each participant could do different tasks with the same cognitive and visual demands repeated five times. To ensure that the task was distracting enough, phone numbers with 25 digits were created. Again the phone function of the Audi Multimedia Interface was used. As it was done in the first experiment, the input interface was realized by the Speller. The display was located in the middle console just under the dashboard. The control button for dialling was located on the right side of the display. The phone number was attached to the dashboard on the right side of the control button. Fig. 7 shows the cockpit of the experimental car.

Fig. 6. Assistance algorithms: green: standard, yellow: early, blue: continuous.

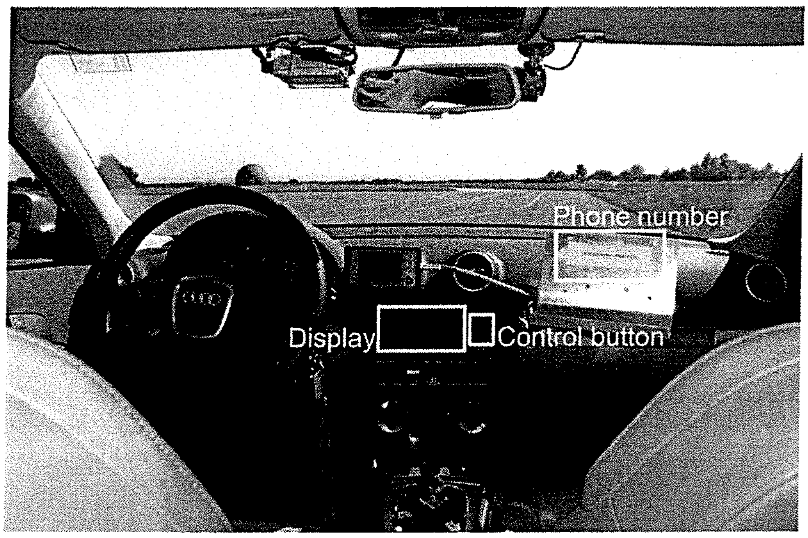

Fig. 7. Cockpit of the Audi A3.

3.4. Design and dependent variables

In order to take interindividual differences in lane-keeping performance into account, a repeated measures design was chosen. The independent variable was the amount of assistance. Each participant drove the same country road five times in the following conditions:

3.4.1. Baseline

The participants drove down the road without any secondary task.

3.4.2. No assistance

The participants drove down the road, while executing the secondary task. There was no lane-keeping assistance.

3.4.3. Standard assistance

The participants drove down the road, while executing the secondary task. The lane-keeping assistant was switched to "standard".

3.4.4. Early assistance

The participants drove down the road, while executing the secondary task. The lane-keeping assistant was switched to "early".

3.4.5. Continuous assistance

The participants drove down the road, while executing the secondary task. The lane-keeping assistant was switched to "continuous". The conditions were randomized, to prevent any sequential effects.

The maximum lateral deviation was considered as the dependent variable. The hypotheses were that the biggest lane deviations would be found in the "No assistance" condition and that with increasing lateral assistance the maximum deviations would decrease.

After each assisted condition the participants were asked to rate the influence of the system on driving safety on a scale from 1 to 5 (1 = decreases safety to 5 = increases safety). High safety ratings for all algorithms were hypothesized.

The subjects also rated if the system disturbs (1) or helps (5) in lane-keeping.

The hypothesis was formulated that the "standard assistance" and "early assistance" settings would be considered helpful. It was also hypothesized that those participants who had not experienced problems in lane-keeping without assistance would rate the "continuous assistance" as more disturbing.

3.5. Procedure

All drivers had driven for approximately four hours in normal traffic with the "standard" and the "continuous" algorithm before the measurement procedure took place. They were also accustomed to the secondary task.

To allow lane departures without risk a straight country road with a lane width of 3.20 m was chosen. The subjects had to drive down the road five times while performing the secondary task under different forms of assistance. They were not instructed to perform the task as quickly as possible, but to do as they would normally to create a realistic scenario. The lane deviation was logged by a computer.

3.6. Results

3.6.1. Objective results

For all runs the maximum lateral deviation was extracted. Fig. 8 shows the mean of these maxima for each condition.

A repeated measures ANOVA showed significant differences between the conditions ($F = 10.086$, $df = 4$, $p < 0.001$). Bonferroni post hoc tests (adjusted p-value) revealed significant differences between "Baseline" and "No assistance", "No assistance" and "Early assistance" and "No assistance" and "Continuous assistance".

The significant higher lateral deviations in the "No assistance" condition when compared to the "Baseline" indicate the effectiveness of the implemented distraction in the form of the dialling task. Although a smaller car with a different location of the control panel was used, the results are similar. The mean maximum lateral deviation in the phone task of the first experiment was 0.57 cm compared to the "No assistance" condition in the second experiment with 0.59 cm. A t-test showed no significant difference ($t = 0.328$, $df = 56$, $p = 0.744$).

As expected, lateral assistance was helpful to the drivers. Although the difference between "No assistance" and "Standard assistance" is not significant, a downwards trend is observable.

"Early assistance" and "Continuous assistance" clearly differ from driving without any lane-keeping support. The maximum lane deviation is significantly smaller than in the "No assistance" condition.

Table 3 shows the total number of lane departures of the analysable runs per condition. As it was done in the first experiment, a lane departure was counted when one part of the vehicle crossed the outer border of a lane marking.

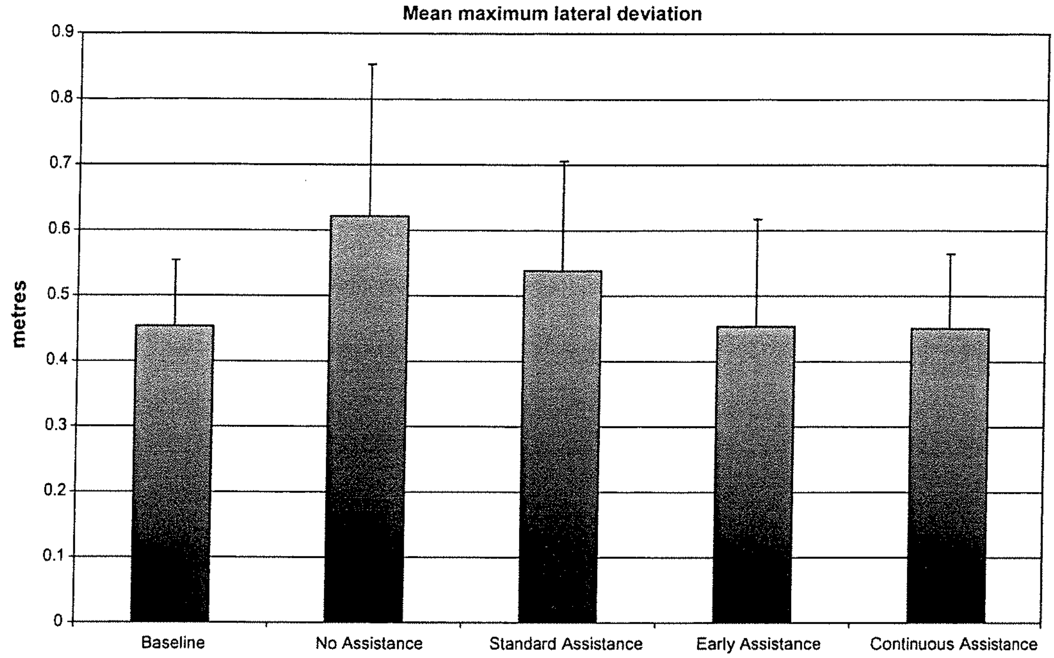

Fig. 8. Mean maximum lateral deviation for each assistance condition.

Table 3
Total number of lane departures and analysable runs per condition.

Condition (analysable runs)	Total lane departures
Baseline (27)	0
No assistance (29)	3
Standard assistance (22)	0
Early assistance (23)	0
Continuous assistance (20)	0

The results show lane departures only when the driver is not getting any kind of lateral assistance while dialling the phone number. Again it remains unclear whether the number of lane departures is biased by a floor effect.

Based on the objective results of the second experiment, it is concluded that there were no lane departures when using lateral assistance. However, only "Early assistance" and "Continuous assistance" show a significant decrease in the mean maximum lateral deviation. From this perspective an adaptation of a lane-keeping assistance due to the IVIS use seems to be beneficial.

3.6.2. Subjective results

The participants rated the impact on driving safety of all assisted conditions on a scale from 1 (reduces safety) to 5 (increases safety). Table 4 shows the descriptive statistics and the p-value of a t-test against 3 (midpoint of the scale).

All assistance algorithms are rated as safety increasing when the drivers are using the IVIS. Pairwise comparisons show that the participants also consider the "early" and "continuous" algorithms to increase the safety more than the standard assistance.

Table 5 shows the descriptive statistics and the p-value of the t-test against 3 (midpoint of the scale) for the rating of helpfulness (1 = assistance disturbs to 5 = assistance helps).

The three systems were rated as helpful to the same degree.

Table 4
Descriptive statistics and p-values of safety rating.

	Mean	Std. dev.	p
Standard assistance	3.62	0.740	0.001
Early assistance	4.10	0.944	0.000
Continuous assistance	4.38	0.973	0.000

Table 5
Descriptive statistics and p-values of helpfulness rating.

	Mean	Std. dev.	p
Standard assistance	4.27	0.647	0.000
Early assistance	4.15	1.089	0.000
Continuous assistance	4.27	0.913	0.000

To test the hypothesis that drivers who have better skills in lane-keeping find the "Continuous assistance" patronizing, the correlation between the maximum lateral deviation in the "No assistance" condition (as an estimation of the driver's lane-keeping performance) and the helpfulness rating of the "Continuous assistance" was calculated. The correlation was not significant ($p = 0.485$). Altogether 22 subjects rated the system as helpful (5), three categorized it as a little bit disturbing (2) and four participants were indifferent (3).

Based on these results, there does not seem to be an acceptance problem due to too much lateral assistance while using the IVIS. Drivers who are able to perform secondary tasks without leaving the lane as well as drivers, who have problems with lane-keeping, rate the lateral support as helpful. Furthermore, the "early" and the "continuous" system were considered to increase safety more compared to the "standard" assistance.

4. Discussion and conclusions

Following the idea of an increased lateral support due to the use of IVIS, two field experiments were conducted. The first one concerned the influence of typical IVIS tasks on lane-keeping. Most of the tasks increased the lateral deviations, but in most cases the drivers were still able to stay in their lane. The number of lane departures found here might be low, but these few events still showcase the usefulness of lateral support.

The second experiment concerned the questions, how much lateral support would be needed and whether drivers would accept this kind of assistance. It was shown that all the lateral assistance algorithms increased the lane-keeping performance with the "early" and the "continuous" system proving the most useful when compared to the "standard" assistance. All assistance systems were rated as helpful and safety increasing, even though the drivers did not seem to have problems in lane-keeping without assistance.

Based on these results, it may be argued that it is useful and beneficial to adapt a lane departure warning system based on driver use of an in-vehicle information system.

However, the use of IVIS as an indicator of driver distraction is only one possibility. Looking at the 100-car naturalistic driving study (Dingus et al. 2006), IVIS tasks are only one little piece in the puzzle of distraction. There should be further investigations using driver monitoring and driver models, which allow for the detection of unusual lateral and longitudinal control behaviour.

The concept of adapting driver assistance systems to the driver's state seems to be useful, but there could also be negative outcomes. If the support systems are working properly and increase safety margins, the driver might rely too much on the system. Smiley (2000) reported such behavioural adaptation for different assistance systems. Rudin-Brown and Noy (2002) discussed such findings concerning lane departure warning. Mercedes Benz. (2008), on the other hand, reported in an official press release a reduction of serious truck accidents by 50% due to the use of lane departure warning and proximity control. The problems due to behavioural adaptation have to be kept in mind and require further studies.

From this point of view, a driver state-based adaption of lane-keeping assistance systems is useful and recommended. Further studies at the Human Factors Institute of the Bundeswehr University will focus on further ways to detect a distracted driver online.

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