An attempt to mitigate driver distraction with advisory information and auditory warnings

- Benefits of ADAS integration and different warning types effects on driving performance

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ABSTRACT

Distraction often occurs when attention is on something else besides the primary task of driving. Driver distraction affects driver performance negatively and reduces driver situation awareness that can lead to accidents. An ecologically designed advisory information interface was designed integrating several Advanced Driver Assistance Systems (ADAS), forward collision warning (FCW), lane departure warning (LDW), and curve speed warning (CSW) to support driver situational awareness during normal driving. The prototype was tested during three conditions, baseline (no warnings), auditory warnings and advisory information (and auditory warnings). Results show significantly improved driver performance and significantly less triggered warnings for both warning conditions compared to baseline. Advisory information (and auditory warnings) was slightly better in longitudinal control compared to the auditory warnings condition. Participants held significantly better distances to vehicles in front and indicatively had less CSW warnings triggered compared to auditory warnings. Subjective results however show that the Chinese drivers preferred auditory warnings and felt that advisory information was irritating and would be distracting to have when driving in real traffic. Both warning types had safety advantages compared to the baseline condition without warnings.

INTRODUCTION

Driver inattention and distraction

Driver inattention and distractions have been identified as major problems in driver related accidents. Driver inattention is a broader term that describes the width of distractions that can cause accidents, consisting of fatigue, driver-related inattention (checking blind-spot or mirrors), non specific eye-glances (not looking at anything in particular) and secondary task engagement (Tay & Knowles, 2004; Neale et al, 2005). Driver distraction on the other hand occurs when the driver has attention on something else besides the primary task, usually by engaging in secondary tasks inside or outside of the vehicle (Stutts et al, 2005). How does driver distraction affect driver performance? Well a report by the Swedish governments identified several driver performance deficiencies when being distracted by engaging in the secondary task of mobile phones usage. They concluded that distracted drivers had problem maintaining correct lane position; impaired ability to keep appropriate and predictable speed; longer reaction times; missing traffic light signals; resulting in harder and later braking; reducing the functional field of view; longer or shorter following distances to vehicles in front; higher acceptance towards gaps in traffic stream that are not large enough; increased mental workload; harder to detect and respond to unexpected events; encourages people to look straight ahead rather than scanning around and reduces situational awareness (Charlotte et al, 2007).

Distraction explained from a control theory perspective

In an effort to further understand how distraction causes problems Sheridan (2004) has a framework that describes the interaction of elements that can cause distraction. The model is based on ideas of control theory (Figure 1). The model shows the blocks **I**, **S** and **D** that represent the input-output transfer functions of the active human driver, while I, S, and D represent output variables from these blocks. I* (driver goal modification e.g. a sudden need to return home), S* (Any disturbance to sensing, internal and external) and D* (Mental workload induced by internal devices, such as mobiles, etc.) represent the corresponding distraction variables. The output of **V** relative to the environment is the system state and the vehicle distraction is V* (a disturbance or constrain in the driver's ability o steer or break). The G & G' represents the secondary motor loop for necessary control sensor orientation. Block **A** represents the human body mechanisms that effect activation, e.g. alertness and energy with the A* (extraneous disturbances to activation, e.g. tiredness) distractions (Sheridan, 2004).

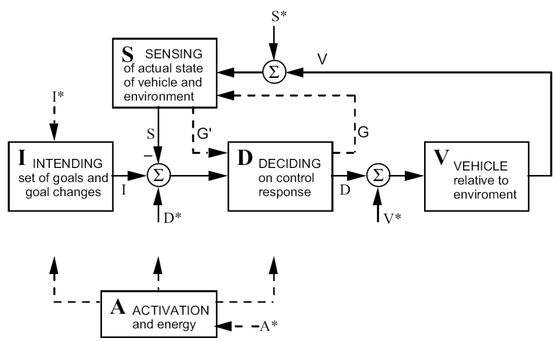

Figure 1: Distraction from a control theory perspective (Sheridan, 2004)

The, **I** block**,** is the intending block, that generates an ordered sequence of near-term driver goals e.g. to follow a given lane, maintaining the speed, keeping a certain distance to leading car, etc. No matter the additional task to driving the main basic intention will always be to drive safely. The **S** block, is the Sensing block and represents all what the nervous system does, through visual, auditory or tactile receptors to extract information from the environment about the situation in relation to the intention. The output variables G & G' represent command of the head, eye-muscles, ears for better understanding of the environment and send it to **D** as a zone of situation awareness that allows **D** to set an appropriate vehicle action. The **D** block, is the decision block containing the cognitive processing of relevant sensed information from S in relation to I to determine appropriate action. This block contains a mental model that can predict near-future states of the vehicle in relation to objects in the environment (Sheridan, 2004). This could be seen as a form of situation awareness (Endsley et al, 2003). The **V** block, is the vehicle block that describes the physical dynamics of the vehicle in relation to the roadway environment. The **A** block, activation block represents biochemical and neurological functions, e.g. the nervous system that keeps the body awake, alert, motivated and more (Sheridan, 2004).

Sheridan (2004) continuous to describe competition of the same resources, when an appropriate criteria is met driver can make clean switches between **S**, sensing or **D**, deciding resources or both to other tasks allowing one to be unattended for a short period of time. An example is if the vehicle appears to be under control and no problems are predicted in the near-future then a goal of a secondary task may be given higher priority and vehicle control loops are opened briefly. If and when a hazard is predicted or sufficient time for the secondary task intention has passed, another goal may be present, e.g. a following vehicle may be bumped to top priority and the vehicle control loop will be reclosed.

To measure if a distraction actually degrades safety depends on the switching criteria and sampling strategy as well as on unexpected events when a driver is distracted and attention is not on the primary task of driving. Periodic sampling can be safe but is receptive to failure if unexpected events occur (Sheridan 2004).

Advanced Driver Assistance Systems

Advanced Driver Assistance Systems (ADAS) are used in vehicles to actively assist the driver when driving. Most ADAS today provide warnings that alert the drivers of critical situations. The warnings are often binary does not provide sufficient information on the type of threat and changes over time. Binary warning have an advantage of simplicity, however by being simple and not graded they lack the ability to support the full range of driver and situations (Lee et al, 2006).

Situational awareness

Situation awareness (SA) is known 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" (Endsley et al., 2003, pp. 13). To achieve SA there are three levels that need to be fulfilled. The first level is about understanding relevant information, internal and external of the environment. The second level is about understanding the perceived meaning of the information from the first level in relation to relevant goals and objectives. The third level explains the ability to project near future status and actions with the understanding of the first and second level (Endsley, 1995; Endsley et al, 2003). Factors that affect how SA is obtained and used are individual factors and task/system factors. The individual factors are goals and objectives as well as the driver's information processing mechanism, which is influenced by their abilities, experiences and training. The task/system factors are the systems capability of providing the needed information in a way that supports the driver and SA. Task/system factors need to provide means to obtain situation awareness, and should also support the driver's information processing in an unobtrusive way.

Ecological interface design

Ecological interface design (EID) is a theoretical framework for interface design and is based on skill, rule and knowledge (SRK) based taxonomy of cognitive control. The EID approach is used to design for lower cognitive levels to not contribute to the difficulty of the task. It is equally important that three levels of cognitive control are supported (Vicente & Rasmussen, 1992). SRK is used to describe the different mechanisms that people use when processing information. Cognitive control can have a skill based behavior and be automated (routine events), or be rule-based behavior and follow a set of cue-action mappings (unfamiliar but anticipated by designers) or knowledge based behavior dealing with problem solving operations (unfamiliar and unanticipated events). The skill and -rule based behaviors can be grouped together since perceptual processing is fast and effortless. However knowledge based behavior is analytical problem solving based on symbolic representation and is slow and complex and more error-prone due to limitations in our working memory (Vicente & Rasmussen, 1992). Ecological interface design has been used in complex system and automotive setting and has shown positive results improving decision making (Kruit, et al, 2005), helps support and sustain situation awareness (Wang et al, 2002), it was found to be less cognitively demanding compared to other approaches (Lee et al, 2006) and also improving response ability (Wong et al, 1998).

In this paper we explore a proposed EID prototype (Alvarado Mendoza et al, 2009), that has been used on Swedish drivers with the same setup (Lindgren et al, 2008a) and used in a comparison study between Swedish and Chinese drivers (Lindgren et al, 2009). This paper focuses on the Chinese driver's data and how warning types can mitigate distraction. The interface consists of several ADAS that are integrated to enhance the driver's situational awareness with information and auditory warnings. The main purpose of the warning modalities is to mitigate distraction and promoting attentive driving by supporting situational awareness. It is interesting to see how increased situation awareness affects driver performance. The situation awareness is gained with an ecologically designed interface supporting lower cognitive levels and unobtrusively supports the driver in the primary task.

METHOD

Participants

The simulator study included 16 participants – 8 women and 8 men – ages 27 to 43 years (M = 34,3, SD = 5) were recruited from the city of Dalian in China. They drove an annual mean distance of 14438 kilometers (SD = 13171 kilometers). All participants had a valid driving license and were required to have normal vision (or corrected to normal vision using lenses) since wearing eyeglasses could degrade eye-tracking quality.

Equipment

The experiments were carried out at the IT Sino European Usability Center at Dalian Maritime University in China. A medium-fidelity, fixed-base driving simulator was used. The view of the road was projected by a 1024x768 mega pixel monitor and generated by a PC-computer running the STISIM Drive software developed by System Technology Incorporated. The projected area was approximately 200 cm wide by 100 cm high and approximately 180 cm from the driver's seat. In the dashboard instrumentation a PC steering wheel, gas pedal, and brake pedal were integrated. During all driving the simulator was set up to run with an automatic transmission.

Experimental design

The STISIM Drive II simulation by Systems Technology Inc (www.systemstech.com) was used to develop driving scenarios and record simulator data. In the experiment three ADAS were included: Forward Collision Warning (FCW), Curve Speed Warning (CSW) and Lane Departure Warning (LDW). The participants drove on a double-lane trafficked rural road scenario during three conditions – Baseline, critical auditory warnings and advisory information and critical auditory warnings. The Baseline Scenario was divided in two (having one in the beginning and one in the end). The Baseline scenarios were 22 kilometers (around 15 min) and the warning scenarios were 44 kilometers (around 30 min) long. The speed limit was 90 km/h (55 mph) and participants' primary task was to drive normally and follow speed. However, drivers were allowed to overtake slower vehicles if finding this necessary. All scenarios used daytime dry-pavement driving conditions with good visibility. In the scenarios there were three kinds of incidents, braking cars, sharp curves and wind gusts. The baseline scenarios had three of each incident whilst the warning conditions had six incidents. The scenarios were randomized to reduce scenario learning effects and the baseline scenario was divided to balance the simulator learning effects.

Warning timing and modality

Critical warnings

The auditory critical warnings were output from two speakers hidden behind the dashboard. The ADAS all had short tonal beeping alarms provided by an automotive manufacturer which represent the type of warning that is implemented in vehicles today. The FCW warning was triggered when time to collision to a lead vehicle was less than 2 seconds. The driver had approximately 1 second to steer or break to avoid the accident. The timing was set based on pilot testing and literature study (Green, 2000) that reports that response time to unexpected but common signals in good daylight condition is about 1.3 seconds. In simulator driving these reaction times are reduced by 300 milliseconds (McGehee et al, 2000). CSW on the other hand was presented to the driver only if the drivers speed was over 80km/h or more. In a speed of 90km/h this gave drivers 2 seconds to perceive the sharp curve sign and slow down to a speed under 80 km/h. The LDW was triggered if the simulated vehicles position was less or equal 2 cm from the lane markings. The LDW was based on lateral position and the warning could be triggered at anytime during the scenario and not only when the wind gust situations occurred.

Advisory warnings
The advisory warnings were presented on a 7" graphical display (Figure 2). The display was mounted at a 16 degree horizontal viewing angle from the driver (Stevens et al, 2002). The interface was designed using ecological interface design and user centered approach (Alvarado Mendoza et al, 2009). The FCW (see Figure 3) was represented the front area that represented 130 meters ahead. When a car was within this front area they were represented by a yellow area that lit up. The CSW was presented only if the driver drove to fast, approximately 70km/h at 120 meters entering the curve. Additionally, an area below the curve sign indicated how close to the curve the driver was. The warning appeared only if the driver drove to fast, and if the driver was decreasing speed the symbol faded away to show that there was no danger. The LDW was presented as lane markings on left and right side of the vehicle. The lane markings were not visible when the driver was within the lane markings, but when drivers drove within 45 cm of the lane markings they began to fade in. When the drivers were 5 cm from the lane markings the lane markings were fully lit up and if a driver noticed the lane markings lighting up and steered back then the lane markings faded out again. The blind spot areas were designed for. However, due to simulator software limitations, they were chosen to be inactive during this study.

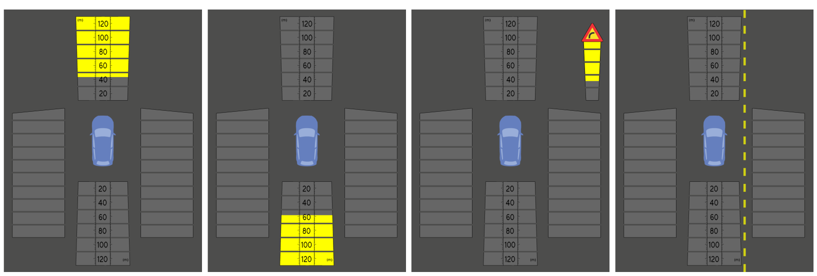

Figure 2: Advisory display (FCW, Rear area after take over, CSW and LDW)

Procedure
The participants arrived and got informed about their confidentiality and filled out a demographics questionnaire. When ready they were shown the simulator and participants had a 5-minute practice run to become familiar with the simulator. They were also informed that there could be differences on the effectiveness of the simulation engine break from reality. When the participants were ready the eye-tracking system was calibrated. All the participants started with a baseline condition with no warnings. After the baseline, they drove one of the two warning conditions and received instructions about the warnings. The orders of these warning conditions were counterbalanced to avoid training effects. Before the auditory warning condition the participants were instructed that they would receive three different types of warnings, if they approached another vehicle to fast and close, or entered a curve to fast, or if they crossed the lane markings without using the turn signals. The auditory warnings were not described any further, since these critical warnings often occur very rarely. In real driving that could mean that drivers would rarely experience the warnings until they found themselves in a critical situation. However, for the advisory information participants were shown screenshots of the different situations that might occur in the display. The warnings were explained so that the drivers would not try to drive differently to explore the display capabilities. After each of the warning condition

participants were asked to fill in a questionnaire about the respective warning experience. After both warning conditions participants drove a last baseline scenario without warnings. The participants were interviewed briefly on their experience. The whole procedure lasted around 2 hours and participants received 30$ for participating in the study.

Dependent measures

Simulator measures

Driver performance was measured in terms of number of collisions and road excursions, longitudinal control (Speed, minimum time to collision) and lateral control (standard deviation of lateral position), this was all recorded via the simulator software. Minimum time to collision was measured to analyze safety margins with vehicles in-front. Lane deviation was measured to see the effects the advisory and auditory warnings had on lateral control. In addition to the simulator measures, a program was used to record the number of critical warnings triggered, this was done during all the conditions. During baseline the warnings were activated but recorded silently.

Eye-movement

The eye movements were recorded with FaceLAB v.4.5 from seeing machines, Australia. The eye-tracker system was mounted on the dashboard. The system had two cameras and with their video signals a 3D head position and gaze direction was measured at a rate of 60 Hz.

Subjective measures

The participant ratings were collected with a 7-point Likert-scale questionnaire. The questionnaire contained questions on how easy it was to perceive and understand the presented information, if it helped them to notice dangers in the driving environment, whether they found he system irritating, or believed that the information improved their driving, if they were more aware of the surrounding traffic environment and if they would have wanted the type of warning information in their own vehicles.

Data analysis

The data average speed, minimum time to collision and standard deviation of lateral positions were calculated from the simulator recordings with excel. One participant was excluded from the minimum time to collision analysis due to data errors. The data was analyzed with some predefined limitations. Data below 30km/h was excluded because the display warnings were idle in those speeds. Lateral deviation data not exceeding one meter was used, basically to exclude voluntary overtakes as being mistaken as poor lateral control. The eye-movement data was analyzed using Visual Demand Measurement (VDM) tool (Victor & Larsson, 2004) in terms of percent road center (PRC). PRC is defined as the percentage of gaze points that fall within a road center area (Victor et al, 2005).

RESULTS

A One-way repeated measure ANOVA that included warning condition as the within-subject variable was used to analyze the simulator results. An α-value of .05 was used as the criterion for statistical significance.

Longitudinal control

Average speed

Statistical analysis showed no significant difference in average speed.

Minimum time to collision

In terms of minimum time to collision (MTTC) analysis a significant main effect was found between the conditions in terms of MTTC, $F(2, 28) = 7.75$, $p<.005$. Subsequent test of within-subject contrasts showed that participants drove with significantly larger MTTC in the advisory condition than in the baseline condition, $F(1, 14) = 14.28$, $p = .005$. Participants also drove with larger MTTC in the critical condition compared to the baseline condition and in the advisory condition compared to the critical condition (Figure 3). However these results were only indicative and not significant (baseline vs. critical $p = .057$, critical vs. advisory $p = .070$.

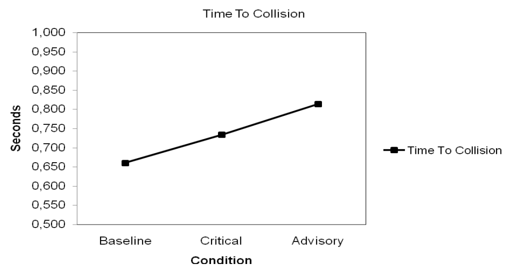

Figure 3: Minimum time to collision

Lateral control - Standard deviation lane position

During the simulator study 20 excursions took place in baseline condition, 5 in the critical warning condition and 7 in the advisory warning condition. A significant main effect was found between the conditions in terms of standard deviation lane position (SDLP), $F(2, 30) = 27.77$, $p<.001$. Subsequent test of within-subject contrasts showed that participants drove with significantly larger SDLP in the baseline condition than in the critical condition, $F(1, 15) = 34.65$, $p = .001$ as well as the advisory condition $F(1, 15) = 40.58$, $p = .001$. No significant differences were found between the two warning conditions (Figure 4).

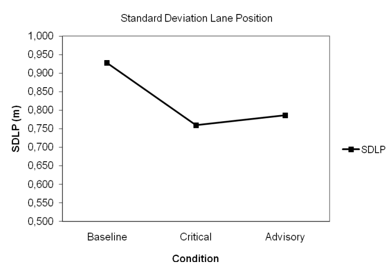

Figure 4: Standard deviation lane position

Number of triggered warnings

Forward collision warning

In terms of the FCWs no significant main effect was found between the conditions. Subsequent test of within-subject contrasts however, showed that participants triggered significantly more FCW's in the baseline condition compared to the critical condition, $F(1, 15) = 6.03$, $p = .05$, as well as compared to the advisory condition, $F(1, 15) = 4.95$, $p = .05$. No significant differences were found between the two warning conditions (Figure 5).

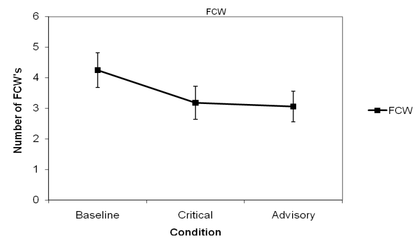

Figure 5: Forward collision warnings triggered

Lane departure warning (Right)

There was a significant main effect found between the conditions in the number of LDW-Right triggered, $F(2, 30) = 9.59$, $p<.001$. Subsequent test of within-subject contrasts showed that participants triggered significantly more LDW-R's in the baseline condition than in the critical condition, $F(1, 15) = 14.58$, $p = .005$ as well as the advisory condition $F(1, 15) = 9.89$, $p = .01$. No significant differences were found between the two warning conditions (Figure 6).

Lane departure warning (Left)

A significant main effect was found between the conditions in the number of LDW-L's triggered, $F(2, 30) = 37.93$, $p<.001$. Subsequent test of within-subject contrasts showed that participants triggered significantly more LDW-L's in the baseline condition than in the critical condition, $F(1, 15) = 40.82$, $p = .001$ as well as the advisory condition $F(1, 15) = 39.39$, $p = .001$. No significant differences were found between the two warning conditions (Figure 7).

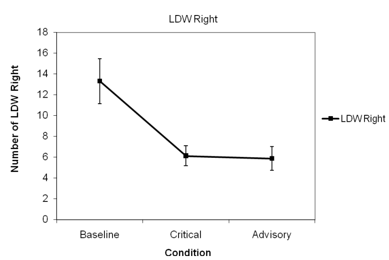

Figure 6: LDW triggered Right

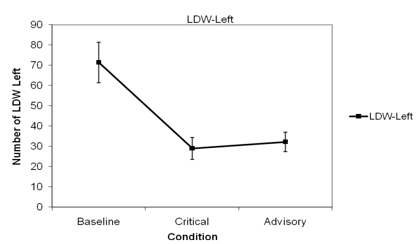

Figure 7: LDW triggered Left

Curve speed warning

In terms of CSW's (Figure 8) no significant main effect was found between the conditions. Subsequent test of within-subject contrasts however, showed that participants triggered fewer CSW's in the advisory condition compared to the critical condition. This difference was not significant but strongly indicative, $F(1, 15) = 3.57$, $p = .078$.

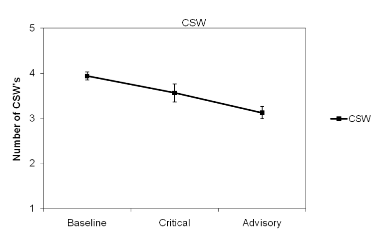

Figure 8: Curve speed warnings triggered

Eye-movements

A mixed ANOVA failed to reveal any significant differences among the three conditions in terms of percentage road centre (PRC).

Subjective ratings

There was no significant difference in the subjective results between the two warnings conditions (Figure 9). However, it is noticeable that they overall thought that the critical auditory warnings helped more detecting dangers and improved their driving than the visual display. They found the visual display more irritating. In addition, many of the participants mentioned that they found the visual display irritating and distracting when having conversations with them during the interviews.

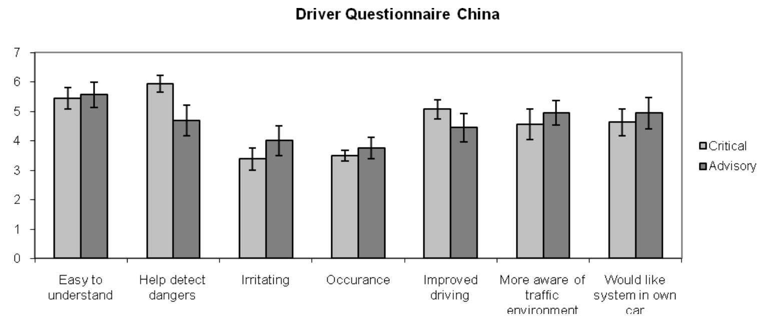

Figure 9: Subjective ratings – Critical and advisory

DISCUSSION

Method discussion

The *simulator environment* was a typical Nordic environment scenario with Swedish road users and scenery. This was mentioned by the participants, they felt that the environment complexity was did not depict a typical Chinese environment. The *advisory information timings* were set during pilot testing. However after seeing the results from the study test leaders noticed that much of the advisory information was given too late in comparison to the auditory warnings. In some occasions the auditory warnings would sound before the driver noticed the advisory information. The advisory information timings are as important as the critical warning timings to have the preferred effects on safety without annoying the driver or increase distraction instead of mitigating it.

Longitudinal control

In the longitudinal control, difference in *average speed* was not found to be significant. This shows that neither the visual nor the auditory information showed any evidence of behavioral adaptation (Östlund et al, 2004) suggesting that no increased workload was imposed by the warning designs. As for the *minimum time to collision* there was a significant difference between both warnings conditions compared to the baseline condition. Drivers had significantly better distances to vehicles in front in the warning conditions. The advisory information showed an indicative difference compared to the auditory warnings suggesting further improvement of distances to vehicles in front. The reason for this might be increased situation awareness by the visually continuous information, compared to the auditory warnings that only warn the drivers to keep safety margins.

Lateral control

Standard deviation of lane position had a significant difference between both warning conditions and baseline. There were a total of 32 excursions and over 60 % of them occurred during baseline condition. There was no significant difference between the warning conditions. The assumption here is that drivers ignored the visual display advisory warnings and guided themselves using the auditory warnings. The reason for this is the lane departure warning timings. Since the visual display dynamically faded the yellow lane markings in the display depending on the distance to the real lane markings driver sometimes did not clearly have time to see the advisory warning before an auditory warning was triggered.

Number of triggered warnings

The overall results of the number of triggered warnings showed both warning conditions had less triggered warnings than baseline condition. There was no significant main effect between conditions in terms of FCW, but within-subject contrast showed that participants triggered more FCW's in the baseline condition than the warning conditions. This correlates with the longitudinal control results that keeping distances to vehicle in front may result in less critical situations. The LDW-left and right showed significant main effect between the warning conditions and baseline condition. There were significantly more LDW's left and right triggered in the baseline compared to the two warning conditions. There was no difference found between warning conditions, suggesting that they were equally effective, another assumption could be that the advisory information was give to late making the drivers make vehicle adjustments only to the auditory warnings. There was no significant main effect found between the conditions, however within-subject contrasts showed that participants triggered strongly indicatively fewer CSW's in the advisory compared to the critical condition. When driving the advisory (and auditory) warning condition, test leaders often noticed that participants started to slow down when receiving the advisory warning of a sharp curve but did not make it in time before the auditory warning was triggered and recorded.

Subjective measures

Subjective measures showed no significant difference between warning conditions. The participants preferred the auditory warnings more than the visual advisory information and they found the advisory information more irritating. However, eye-tracking analysis showed no significant difference in percent road center, suggesting that there was no increased distraction and objective results support this assumption as well. The participants felt irritated because they misunderstood the visual information as being warnings, since they said that they did not need the visual aid to support their driving. It is interesting to see that even though they felt that the auditory warnings were better, they drove slightly better with the advisory information. A reason for this might be the difference in their real traffic environment and the simulated environment complexity. Chinese traffic environment is much more complex and they felt that having a display where you had to look away from the real traffic environment would be very distracting and unsafe. The auditory warnings however, were seen as means of bringing attention to potential problems, more of advisory information for them. Chinese drivers are very used to having sound as a means of communication in traffic, e.g. they honk to make other traffic users aware of them. Chinese drivers probably have good vehicle control and situation awareness because of the high complexity in their normal traffic environment every day. Unexpected events are not that unexpected when people do as they want and do not follow regulations, compared to Sweden where the regulations are usually followed and violations are rarely seen (Lindgren et al, 2008b).

Situation awareness

Driver situation awareness has to be achieved and sustained by routinely identifying objects in the environment (Endsley, 1995). A difference between auditory and advisory information is that advisory information continuously supports the driver in achieving and sustaining situation awareness by continuously providing information of the driver environment. Advisory information is also used to positively change driver behavior by increasing safety margins, as seen in this study. An auditory warning on the other hand has limited information about the environment and its continuous changes. The auditory warning brings attention to a critical situation where the driver needs to make an action to avoid danger. Individual differences in driver abilities, experiences and ability to achieve and sustain situation awareness could affect how the outcome of a critical situation. By having advisory information and situation awareness fewer risks might be taken and less critical situation would be encountered. Especially, since achieving driver situation awareness would suggest that it is less likely to be surprised by unexpected events, because potential dangers already are indentified in the driver environment. The advisory information could mitigate distraction and inattention by making the driving environment changes and hazards available earlier to the driver, thus supporting the switching criteria by focusing on the primary task of driving (Sheridan, 2004), ultimately also supporting attentive driving.

Driver Distraction from a control theory perspective

The sensing blocks situational awareness range is limited by the G & G's capacity to scan the environment and drivers experience in forming situation awareness (Sheridan, 2004). E.g. when a driver intends to overtake, the driver gets feedback from the sensing block (G & G' commands the sensory components in the human) to decide whether to overtake or not. Then if the driver finds the situation appropriate (by looking around to see if there are any hazards) for an overtake moves the **V**, vehicle which again gives new impressions to the sensing block continuously throughout the overtaking. If the sensing block sees no threats nor the driver predicts any near-future threats and the decision block and vehicle block will finish the overtake and finish the intention blocks goal of overtaking. As mentioned the sensing is limited to the human capacity of perceiving the environment (by looking around to identify the surroundings) while driving (having to look at the road) to form situational awareness. The main purpose of the intention block is to drive safe, making this assumption, then an increase of situation awareness would make drivers less risk taking and cautious to objects in the environment, which was seen with both warning conditions, however slightly more with the advisory information. Further studies in real driving environments are needed to validate the assumption of how increased situation awareness may mitigate distraction and the benefits of different warning types would translate to real driving.

CONCLUSIONS

Both warning conditions had positive effects on driver performance making driver more attentive when driving. However, advisory information showed better longitudinal control and increased safety margins compared to the auditory warnings, suggesting increased situation awareness, with increased safety behavior. Findings clearly show the safety advantages with both warning types compared the baseline condition without warnings. The results from this study suggests that further research is needed on advisory information timings and how they might be improved to further increase the safety advantages of advisory information. Increased situation awareness resulted in less risk taking and increased attentive driving. Drivers can with advisory information and auditory warnings see driving environment changes and hazards earlier. Letting the driver switch full attention to the primary task of driving earlier and thus could mitigate usual distraction and inattention problems, e.g. shortening reaction times due to attentive driving making unexpected events less likely in normal driving.

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