Ambient information presentation: Effect of moving transverse lines on speed behaviour

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Abstract

Objective: The present study investigated the effect of virtual transverse lines, presented in the peripheral view of drivers, on the perceived speed and consequently on the driven speed. Background: The attention for the information processing within traditional communication between man and machine is limited. This could lead to a non-processing of relevant information and consequently to a dangerous misbehaviour of the human. Therefore, a concept for presenting information to the human/driver is proposed. In this, machines manipulate driving speed perception without any additional attentional demands. Hopefully, this leads to adequate behaviour changes even in mental-burdening situations. Method: Thirty eight subjects participated in the study to investigate the communication concept. They had to drive in a constant speed while their speed perception was manipulated with/by moving transverse lines in the peripheral view. The lines were decreasing, remaining the same, or increasing in flow speed and were either presented visually, auditory, or both. Results: The flow speed of the peripheral, visual and multimodal presented transverse lines led to ac-/decelerations of the simulated vehicle without awareness of the participants. Auditive presented transverse lines had no effect on the driving speed. Conclusion: The effect of virtual transverse lines on the driven speed gives a possibility to transfer information like "You have to accelerate!" or "You have to decelerate!" to drivers even in mental-burdening situations.

Introduction

The Interaction Framework (Abowd & Beale, 1991) describes the information transfer from the machine-to-human communication as one of the four fundamental components of the human-machine interaction. Machines use different languages and modalities for presenting information to the human. At this, the processing of the presented information requires the attention of the user within the traditional machine-to-human communication. There are different theories and discussions about the processing of information with respect to the attention (Broadbent, 1958), (Treisman, 1964), (Deutsch & Deutsch, 1963), but they all agree about a sequential processing with a limited capacity. This limitation could lead in mental-burdening situations to a non-processing of relevant information and subsequently to a dangerous misbehaviour of the human.

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However, the human information processing works in at least two different modi (e.g. Posner&Snyder, 1975). The controlled processing mode requires attention and accordingly inherits their limitations which lead to sequential processing with limited capacity. In contrast, the automatic processing mode requires barely or no attention and accordingly allows parallel processing without much limitation. Additionally, automatic processes are fast, unconscious, unavoidable and do not interfere with other processes. Automatic processes are described as solid stimulus-reaction linkages where stimuli or stimuli pattern invoke or control immediate motoric reactions (Heuer, 1990), without creating a mental information representation and consciously choosing an appropriate reaction. A communication concept which transmits information directly in automatic processes would allow a fast, unconscious, unavoidable and non-interfering information processing on the user side, even in mental-burdening situations. Therefore, the authors of this paper propose an ambient information presentation where machines manipulate or control the stimuli of automatic processes for transmitting or better communicating information to the human. The goal of the underlying research project is the investigation of the feasibility of this relatively new communication concept in a human-machine interaction.

Therefore, an automatic process from the vehicle-driver interaction was chosen where the driving speed is automatically adapted to the perceived speed. A possible subsequent use case would be the ambient communication of a required speed reduction in front of hazards (e.g. sharp curves) and in case of an inappropriate driving speed. In a vehicle, the primary stimulus for the perception of speed is the optical flow in the peripheral view of the driver (Gibson, 1958). Based on this, special road markings were developed (Figure 1a) which increase the optical flow rate in the peripheral view and consequently the perceived speed of the driver, which in turn leads to a reduction of the driving speed (Godley et al., 1999). These perceptual countermeasures (PCM) against speeding applied to real roads showed both strong (Denton, 1980), (Argent, 1980), (Drakopoulos&Vergou, 2003) and weak (Zaidel et al., 1986), (Maroney&Dewar, 1987), but almost significant speed-reducing effects. Motivated by and based on these findings, moving transverse lines for the upper and lower peripheral area on the windscreen (Figure 1b) were developed as a possible information presentation for manipulating the perceived and consequently the driven speed.

In a former study (Maier et al., 2012) it could already be observed that moving transverse lines have similar to PCMs a significant effect on the perceived speed in a speed producing task. Furthermore, the simultaneous presentation of moving lines in the upper and lower peripheral area with a flow speed greater than the vehicle speed was identified as an appropriate information presentation for increasing the perceived speed. At this, it was additionally observed that the difference between flow speed and vehicle speed was the key factor that influences the speed perception. This finding supports Gibson’s (1958) assumption that the alteration of the optical flow rate is a direct stimulus for the perception of speed. It was assumed that in a speed keeping task without a speedometer, a de-/increasing alteration of the flow speed of the presented transverse lines should lead to unconsciously ac-

/decelerations on the driver side and accordingly to a manipulation of the speed behaviour.

Apart from the optical flow in the peripheral view, Evans (1970) and Bubb (1977) describe auditive information as a second important source for the perception of speed. Therefore, it was also assumed that a second auditive presentation besides the primary visual presentation would amplify the effect of transverse lines. Motivated by the successful application of rumble strips for reducing the speed in front of hazards, the sound caused by driving over them was chosen as an auditive presentation of transverse lines. It was assumed that a multimodal (visual and auditive) presentation would cause a stronger effect on the driven speed than the visual presentation.

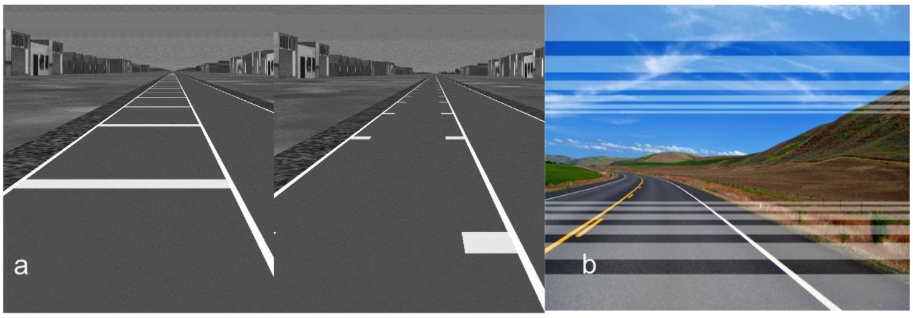

Figure 1: a.) Special road markings, from Godley et al. (1999), increase the optical flow rate in the peripheral view and consequently the perceived speed of the driver. b.) Moving transverse lines for the upper and lower peripheral area on the windshield as a possible information presentation for manipulating the perceived and consequently the driven speed.

Method

Participants

Thirty eight adults, aged between 19 and 48 years (M=25.66, SD=5.82, 14 women and 24 men) with normal or corrected vision but no glasses, participated in the study. They were all naive to the experimental hypotheses, get financial rewarded, and had a valid driver’s license. The recruitment was carried out with the aid of the participant-server from the Technische Universität Berlin.

Apparatus

Participants drove in a driving box (Figure 2a) with automatic gearbox and regular accelerator and brake pedals. The driving scene (Figure 2b) was generated by the driving simulation software included in the Lane-Change-Task (LCT) by Mattes (2003) and was projected 2m in front of the driver with a height of 2m and a length of 4m. The moving transverse lines were visually presented by an overlay projection (Figure 2c) with a second beamer and acoustically presented by loudspeakers under the driving seat. The stimuli were generated and controlled with the open source 3D content creation suite Blender. Speed and position of the simulated vehicle was readout with the help of the transmission control protocol/internet protocol TCP/IP logging function integrated in the LCT.

Stimuli

Transverse lines were presented to the upper half and lower fourth of the projected driving scene. Within the driving scene, they appear 30m in front of the vehicle and flow towards the driver with an initial speed similar to the current driving speed. Remaining flow rate was realized by keeping the initial speed as flow speed. In case of the decreasing flow rate the lines started with the initial speed, but the flow speed decreased every second down to 50% of the initial speed. Analogous to this, the flow speed increased every second up to 50% of the initial speed in case of the increasing flow rate. The transverse lines were visually presented as white lines with a length similar to the length of the projected driving scene, and within the scene they had a width of 0.6m when reaching the vehicle and a distance of 4.5m between the lines. The same lines were also used for the auditive presentation but they were set invisible and a sound was played every time when they reached the vehicle. The sound was similar to a sound caused by driving over a rumble strip and was received from the free online sound library Freesound.org. Multimodal presentation was realized by playing the aforementioned sound when a visible line reaches the border of the projection.

Task

In each round, participants were asked to drive a vehicle on the middle lane of a three-lane straight track. They had to adjust the vehicle speed to a visually presented given speed (100 km/h) within the first 35s (adjustment phase) with the help of a speedometer and to keep as good as possible the speed the following 45s (treatment phase) without a speedometer. In the treatment phase the participants got treated with a stimuli combination (flow rate x modality).

Procedure

At first the participant seated, adjusted their seat, and got instructed about the procedure and the tasks. Then participants had a practice session where they adjusted the vehicle speed to a given speed and kept the speed with the presence of a speedometer. A 3x3 two-factorial within-subject design was used in this study. First independent variable was the presentation modality with the levels: visual, auditive and multimodal, and the second independent variable was the flow rate with the levels: decreasing, remaining and increasing. The combination of the levels of the two factors resulted in 9 treatments. Accordingly, within the actual investigation participants drove 10 randomized rounds on the same straight track, one round for each of the 9 treatments and one round for a baseline measurement. For motivational reasons, at the end of each round participants were asked about the difficulty of the task and their subjective estimation of their final speed. The experiment was completed by filling out a questionnaire about demographic information (age, gender, driver’s license, etc.).

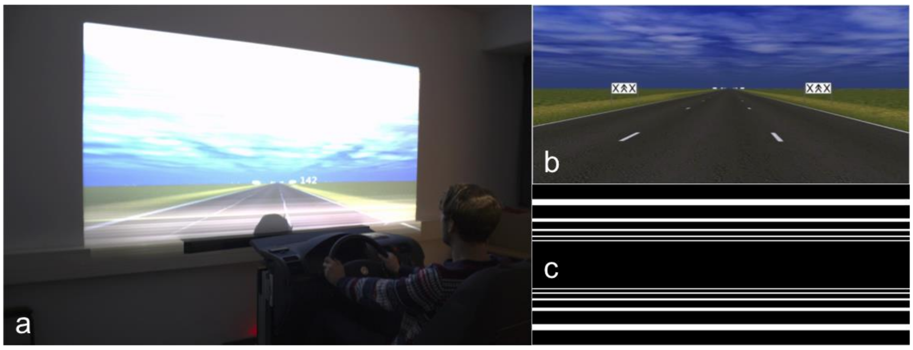

Figure 2: The experimental apparatus, a.) driving box at the Technische Universität Berlin, b.) driving scene from the Lane-Change-Task (Mattes, 2003), c.) overlay projection of moving transverse lines.

Results

The speed of the vehicle was captured every second in the treatment phase for each of the 9 treatment rounds and the baseline round. Figure 3 shows driving speed increased when flow rate decreased and decreased when the flow rate increased, but only when the transverse lines were presented either visual or multimodal. Mean differences were defined by the mean speed difference between treatment and baseline in the last 10s of the treatment phase. Plotting the mean differences as a function of the flow rate for each modality (Figure 4) show that there was only an effect on the driving speed when the transverse lines were visually (included in multimodal) presented, an auditive presentation had no effect at all. The mean differences caused by visually presented transverse lines (Figure 5) show that a decreasing flow rate increases the speed about 5.5km/h (SEM=4.21), a remaining flow rate decreases the speed about 2.7km/h (SEM=3.76), and an increasing flow rate decreases the speed about 7.2km/h (SEM=2.94) on average.

A two-factorial repeated-measures ANOVA revealed a significant main effect of flow rate on the driving speed ($F(2, 74) = 7.492$, $p = 0.001$), but no significant effects either of the modality ($F(2, 74) = 0.017$, $p = 0.984$) or of the interaction between modality and flow rate ($F(4, 148) = 1.837$, $p = 0.125$). Bonferroni-corrected post hoc analyses on the flow rate showed only significant differences between the decreasing and the increasing flow rate ($p = 0.002$), but no significant differences either between decreasing and remaining flow rate ($p = 0.305$) or increasing and remaining flow rate ($p = 0.075$).

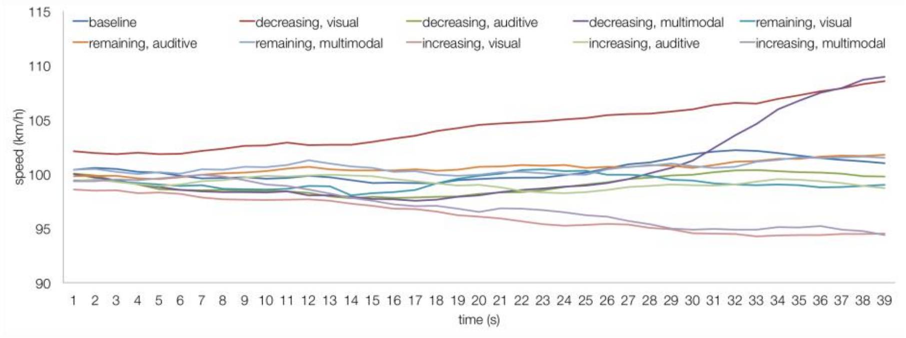

Figure 3: Mean trajectories of the treatment phase for each treatment, driving speed in-/decreased when moving transverse lines with a de-/increasing flow rate where whether visual or multimodal presented to the drivers.

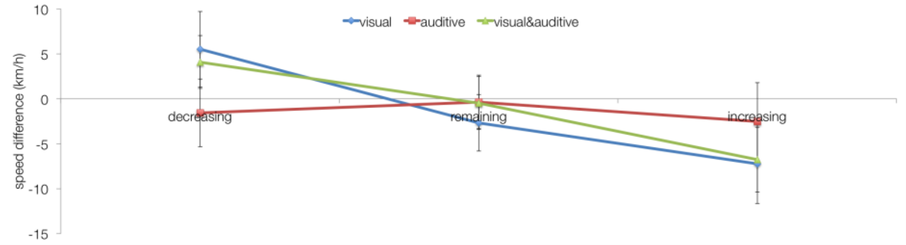

Figure 4: Mean speed differences between treatment and baseline drive as a function of the flow rate for each modality show that there was only an effect on the driving speed when the transverse lines were visually (included in multimodal) presented, an auditive presentation had no effect at all.

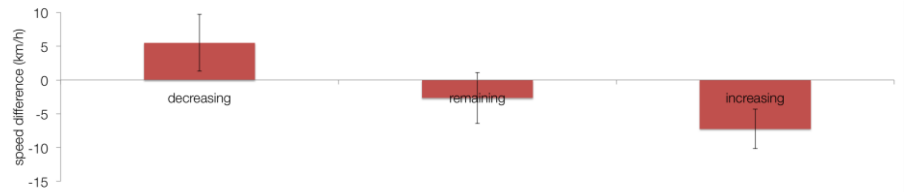

Figure 5: Mean speed differences between treatment and baseline drive caused by visually presented transverse lines show that a decreasing flow rate increases the speed about 5.5km/h (SEM=4.21), a remaining flow rate decreases the speed about 2.7km/h (SEM=3.76), and an increasing flow rate decreases the speed about 7.2km/h (SEM=2.94) on average.

Discussion

Results of the present study indicate that driving speed in-/decreases when moving transverse lines with a de-/increasing flow rate are visually presented in the peripheral view of the driver. Drivers tried to keep a given speed as good as possible without a speedometer over a period of 45s and unknowingly ac-/decelerated when transverse lines with a de-/increasing flow rate were presented. These results follow Gibson's (1958) assumption, that the alteration of the flow rate in the peripheral view is the direct stimulus for speed perception. Results also indicate that moving transverse lines with a constant flow rate gently decrease the driving speed. That could be explained by the additional texture in the peripheral view that increases the optical flow rate just by presence and therefore increases the perceived speed. Unfortunately, only the mean differences between the decreasing and the increasing flow rate were significant and not between remaining and de-/increasing flow rate. An explanation would be that participants chose their speed not only based on their perceived speed. As their task was to keep the speed as good as possible they started to work against their feeling because they found out that the stimulus influences their speed perception. An evidence for this were frequent statements where participants described that they had to force themselves not to ac-/decelerate against their feeling. The participants effort to correct biased perception could have cushioned the effect between the flow rate levels. A suggestion would be, that in future experiments it is important to take the focus away from keeping the speed as perfect as possible. When participants really adjust their speed like they feel we should found stronger effects caused by the alteration of the flow rate.

Furthermore, results show that an auditive presentation of moving transverse lines with an altering flow rate has no effect at all on the perceived speed. Neither an amplifying effect for the visual presentation realized as multimodal presentation nor a stand-alone effect as auditive presentation could be found. It seems in the first instance that the results contradict the assumption of Evans (1970) and Bubb (1977), that auditive information are a second but important source for the perception of speed. Another explanation would be that the sound of driving over a rumble strip was simply unsuitable as a source for the perception of speed. The success of rumble strips applied on real roads probably based more on discomfort for the drivers and not on a modified perception of speed. A better auditive source for manipulating the perception of speed in future experiments is probably the sound of the engine and the tires. Concerning this, it was observed that people in high class vehicles, reducing the exterior sound of the engine and the tires to a minimum, frequently underestimate their driving speed (Evans, 1970).

This study indicates that moving transverse lines visually presented in the peripheral view of the driver in-/decrease the driving speed by changing their flow rate. Drivers unknowingly ac-/decelerated in response to the altering stimulus. Therefore, an ambient information presentation for requesting a speed reduction to drivers in front of hazards (e.g. sharp curve and inappropriate speed) by manipulating the feeling for speed was found. With that, a machine-to-human communication was presented which manipulates ambient stimuli within the surrounding of the human for transferring information without binding attention. That would theoretically allow an information transfer to the user even in mental-burdening situations.

Acknowledgement

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