Calling safely through haptic biosignal transfer

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ABSTRACT
Talking on mobile phones while driving, be it hands-free or not, reduces driving safety dramatically. We developed a biosignal transfer system to create an empathic link between driver and caller. Our hypothesis is that this helps to caller to adapt to the driver and make the driving safer. We used electrodermal activity for measuring driver's arousal and a haptic vest for transferring biosignal information to the caller. Through a guessing game, we simulated constant and demanding discussion situations. A first pilot study shows, that GSR biosignal transfer can be quite easily manipulated to convey information about changes in driving challenge to caller, but the setup is also volatile to other stimulae such as enjoyment elicited by funny conversation.

Author Keywords
Biosignal transfer, driving safety, haptic communication

ACM Classification Keywords
Xxx

BACKGROUND
Safety is of paramount importance while driving. Road fatalities top 40 000 per year in the US alone, and globally it is estimated that road accidents kills close to one million people annually (http://www.factbook.net/EGRF_Exec_Summary.htm).

Road safety has been improving significantly over the last decades, but there is at least one new item that causes dangerous driving situations: talking on a phone while driving. In many countries, driving and talking on a phone without using a hands-free kit is banned. However, studies show that even hands-free calling can lower the drivers attention level and response intensity and hence, cause accidents [1]. However, driving with co-drivers apparently has no similar effect on attention. Our assumption is that co-drivers can moderate their interaction with a driver to varying driving situations. For instance, when a difficult driving situation emergers, they can adapt their behavior so that it is less demanding for the driver. This may help drivers to focus on the various driving tasks and reduce accidents.Our aim with the current study is to show how affective communication technology to help a caller understand the driver's situation. In turn, this would allow callers to adapt their behavior as they would do in face-to-face interaction. More specifically, we use biosignal communication in which the biosignals are used as communicative tools [2]. Biosignals such as electrodermal activity (EDA), electromyograms that measure muscle activity, electrocardiograms, and electroenecephalograms can be used to collect real-time information about subject's emotional responses and changes in cognitive performance (e.g., [3,4]). In the current work we focus on EDA. EDA reflects tonic and phasic changes in arousal and effort mobilization. It can be captured relatively easily with dry electrodes on the fingers. This makes it easy to implement in a car, as the sensors could be incorporated in the driving wheel. Moreover, it has proven to be a valuable signal when estimating emotions during driving [5].

For such new communication signals, it is not only important how to capture the signal, but also how to present it to the receiver. For this, two categories can be differentiated: (1) cognitive and (2) emotional presentation. For cognitive communication, the signal is presented solely as information from which the receiver has to deduce what is going on. For emotional communication, the presentation of the signal triggers the same emotion as the one the signal is communicating. In our case, we opted for cognitive communication through a haptic vest. We wanted to test a haptic communication channel as it would not interfere with other modalities that are often used more extensively.

In the next sections, we will describe a pilot experiment in which we implemented a communication system that utilized EDA to communicate effort mobilization and arousal between a caller and driver. We implemented the EDA feedback in realtime using a haptic vest to present the signal. Multiple participants used the system and gave us initial qualitative feedback.

EXPERIMENT SETUP

Our experiment consisted of a driving simulator, biosignal transmission system based on haptization, and phone calling system. A schematic overview of the general procedure can be found in Table 1. After preperation and practice, the driver drives dynamic driving tasks for 10 minutes. Then, both driver and caller will have a short reflection period, and subsequently repeat the driving task. We employed 20 different driving situations, half of which were easy and half of which werehard and very hard. Each driving condition lasted at least 1 minute. Psychophysiological, behavioral and self-report measures were captured to assess the impact of the biosignal transmission. The callers task waswas a word explanation game, similar to board game Alias.

Pre-experiement Preparation	Training	Driving task 1	Reflection	Driving task 2	Questionnaire interview
15 min	15 min	10 min	5 min	15 min	20 min

Table 1: Calling safely experiment procedure

We divided driving tasks in two parts, because we believed that there is a high learning curve and pause between the tasks would help drivers and callers to reflect on and improve their performance.

Driving simulator and scenario

We used a commercially available simulator in the experiment (see [6] for a detailed description). Each driving scenario was designed to last roughly 10 minutes. The scenario included challenging and driving tasks such as driving in fog, various objects in the road, pedestrians and cyclist on road, other cars creating unexpected situations, highway driving and city driving. These situations were intermixed with easy stretches. The scenario was designed to be effective stimulae for creating changing in driver's arousal. In practice there was always 1-2 minutes of easy driving followed by vroughly 0.5-1 minute episode of hard driving. Our hypothesis was that this hard driving episode would elicited higher arousal reflected by the EDA.

Figure 1: Driving simulator consisting of a driving wheel and paddles, a screen and projector, and speakers.

Biosignal transfer

Biosignal transfer was divided in to three parts: (1) biosignal capture by using a NeXus-10 portable device and dry electrodes on the left hand (see Figure 2), (2) EDA signal manipulation, (3) signal haptization through haptic vest.

EDA signal manipulation was based on two minute running window. Each new datapoint was scaled by subtracting the mean and dividing by the standard deviation over the last two minutes [7]. For practical purposes, values outside [-3, +3] were not allowed and put at -3 or +3 respectively. Finally, the signal was scaled to [0, 1] using a min-max procedure with -3 as minimum and +3 as maximum.

Figure 2: Biosignal (EDA) capturing through two dry electrodes strapped around the lower phalanx of the index and ring fingers.

The haptic vest was a proprietary design by Philips Research. It includes 64 vibrators divided throughout the torso and arms. Vibrator intensity could be adjusted in real time. See [8] for specific details of the vest.

During pilot tests, we tested many different activation patterns on the vest. Finally, we decided to use a haptization procedure were front torso vibrators were employed so that increasing EDA resulted in motor activity higher up the torso. Always four motors in a row were active at the same time starting from the lowest vibrators and ending to the vibrators highest up in the front torso near the neck. This vibrator algorithm was thought to be intuitive and tested so that different states were fairly easy to distinguish from each others. We also tested sonification instead of haptization, but decided to use haptization because sonification causes noise to the discussion.

Calling procedure

Before the experiment, both driver and caller received an instruction sheet and point scoring table. The instruction sheet and point scoring table were unique for driver and caller. The scoring table and instructions highlighted the fact that there were two focus points in this experiment: (1) driving safely and (2) guessing words quickly. In addition drivers instructions and point scoring table had emphasis on driving fairly fast without exceeding speed limits. We added fast driving completion as a requirement in order to increase driving challenge and normalize the driving task between subjects.

The calling assignment included word list (compound words) and instruction to explain these words as fast as possible without using the word itself and without compromising driving safety. Each explained word contributed one point, each skipped or missed word contributed one negative point, and each minor driving mistake contributed three negative points and major driving mistake seven negative points. The points were used only to illustrate that driving safely has significantly higher emphasis.

Data capture

Our plan was to use multiple data capturing methods: biosignal recording, system log, audio log, video log, questionnaires and interviews. Our principal analysis method would have been to analyze whether our primary subject group with biosignal transfer qualified better in road safety than our control group. We would have performed this by analyzing system log. In addition it would have been possible to analyze the subjective questionnaire and interview data whether subjects considered that this kind of system has any benefits. Furthermore, biosignal data and video data could have been used to analyze unique driving situation and whether responses in the haptization scenarios were different than without haptization.

RESULTS

We conducted a pilot study with four dyads to get some initial feedback about the system and experimental setup. Below we shortly describe the qualitative results we obtained.

Taken at face validity, all drivers showed showed increased EDA during the difficult driving situations. This was in line with out hypothesis and shows that EDA is probably a usefull signal to communicate the driving situation. Furthermore, all callers were able to recognize the changes in EDA as presented by the haptic vest. Moreover, the callers reported feeling connecting and close to the driver which is in line with earlier studies that show physiological signals to be intimate communication channels.

However,during the pilot studies it became evident that it is hard for callers to focus on two items simultaneously: (1) explain words, (2) adapt explanation based on haptization. This was primary reason why we decided to postpone the experiment. We need to figure out new calling assignment, which would be less cognitively demanding to the caller. Also we noticed that discussion in a gaming setup can easily elicit other responses than those related to factual guessing or driving. It often happened that subjects were laughing because a word explanation was funny. Laughing had significant impact to the arousal level.

DISCUSSION

It is hard to draw sound conclusions based on pilot tests only. It is probable that biosignals can be used to transmit information about drivers state, but it is a demanding engineering task to design a data collection procedure, which is stable and insensitive to the probable artifacts. Furthermore, haptization is very interesting modality for using together with biosignal transfer. Further research is needed to investigate the effects of our proposed system on calling safety.

Instead of improving calling safety, the experiment setup could be also used as a basis for a game, which is not only about word explaining, but more about how to learn to be sensitive about changes in other person context and cognitive and emotional states. In this kind of game, it would be possible to use also other signals to convey information about the changing context.

The use of biosignals as communicative tools presents an interesting and promising approach for communication. Although there are many open issues still to be resolved the power of interpersonal physiological closed-loops [9] is of great potential for future affective communication technology.

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