Effects of phoning during driving

Kristina Stojmenova*, Vesna Marinko**, Mojca Komavec***, Jaka Sodnik*
*University of Ljubljana, Faculty of electrical engineering, Ljubljana, Slovenia
** Slovenian Traffic Safety Agency, Ljubljana, Slovenia
*Nervtech, Trzin, Slovenia
kristina.stojmenova@fe.uni-lj.si, vesna.marinko@avp-rs.si, mkomavec@nervtech.com, jaka.sodnik@fe.uni-lj.si

***Abstract*— Phone calling is a common task during driving. With the purpose of increasing awareness about its negative effects among drivers in Slovenia, the Slovenian Traffic Safety Agency in collaboration with University of Ljubljana and Nervtech, performed a user study which explored the effects of phoning during driving on the driving performance and the driver. The study was performed with participants aged from 22 to 67 years old with different driving experiences. To ensure driving safety, the study was performed in a high-fidelity motion-based driving simulator, which enabled a realistic and comparable driving experience for all participants. It was additionally equipped with sensors for observing cardiovascular, electrodermal and pupil activity. The detection response task (DRT) was also used for the assessment of the attentional effects of increased cognitive load from performing a phone call. The driving performance was observed through changes in speed, acceleration, lane deviation, reaction times and safety distance. The driver's state was observed through data on changes in galvanic skin response (GSR), skin temperature, response times, and pupil activity. The results for driving performance did not show any statistically significant changes in mean speed, however significant changes were found in mean acceleration and response times for trials with a phone call compared to trials with only driving. Also, the driver's mean galvanic skin response (skin conductance) increased and DRT response times and hit rates decreased statistically significantly.**

I. INTRODUCTION

When operating a vehicle, the driver's primary task is safe driving. Nevertheless, drivers often engage also in different secondary tasks while driving, such as interaction with in-vehicle information and infotainment systems or use of different mobile devices. When engaged in a secondary task, the driver can experience visual, tactile or cognitive distraction. Visual distraction is defined as distraction causing drivers to take their eyes off the road, whereas manual and cognitive distraction as taking hands off the wheel and mind off the road respectively [1]. Although humans are capable of performing two or more tasks at a time, when these tasks rely on the same attentional and cognitive resources, the performance of one (or all) of the tasks can be degraded. Since driving is mainly visual and manual task, performing additional tasks that require the same senses can affect the driving performance due to the use of same attentional resources. When using a mobile phone while driving, the driver is exposed to manual distraction by just holding the phone. Therefore the use of a mobile phone is forbidden by law in many countries. On the other hand, hands-free systems, which allow phoning without the manual distraction are allowed, and are already built-in in most of nowadays vehicles.

However, phoning does not cause only manual distraction, but it can also cause cognitive distraction. For demanding and complicated phone conversations, where the driver has to recall or memorize information, driver's cognitive load can increase significantly. Cognitive load theory proposes that the cognitive capacity in the working memory is limited, so if a task or set of tasks require too much capacity, the processing of data will be obstructed and cognitive overload would appear [2]. High levels of cognitive load increase also the processing of irrelevant tasks, and instead of focusing on driving, the driver could only focus on the phone call instead.

Since the use of mobile phones while driving by holding the phone or with the use of a hands-free system is very common in Slovenia, we were motivated to research the effects of phone calling while driving with Slovenian drivers. In the study, we observed the effects of bot h versions of using the phone, hand-held and using a hands-free system. In order to better understand the cause for distraction, we observed the effects on the driver and the driving performance.

II. METHODS

The study was performed in a high-fidelity Nervtech driving simulator [3]. It consists of a real car seat, a SimExperience AccuForce Pro V2 Simulation steering system [4] Fanatec club Sport pedals V3 inverted [5] and a Fanatec ClubSport Shifter [6]. It can be driven in an automatic or manual mode. To avoid additional manual distraction, all participants drove in automatic mode. The visuals were displayed on a triple-screen configuration, which covers 120° horizontal field of view (Fig. 1) and consists of three equal curved 48' HD Samsung TVs [7]. The simulation software used was from AVSimulations [8], and was run on a high-end gaming computer with an i7 - 8086K CPU and Nvidia GTX 1080 graphics card.

Figure 1. Simulation environment.

The driver's state (cardiovascular, electrodermal and pupil activity) was observed with the medical grade wristband E4 [9] and Tobii Pro 2 glasses eye tracker [10]. Additionally, using the detection-response task [11], we

observed also the effects of increased cognitive load on the driver.

A. *Participants*

32 (16 female) participants, aged from 22 to 67 years old took part in the study. All of the participants had a valid driving license.
Prior to the study, participants were informed about the purpose of the study and asked to sign a consent form if they decided to participate. All of the recorded data was completely anonymized. Participants were given a gift card with value of 10€ for their participation.

B. *Tasks*

Before the start of the study, participants had a test trial to get familiar with the driving simulator.
After that all of the participants performed 3 trials:

- a reference trial,
- trial without a phone call,
- trial with a phone call.

The reference trial was added to collect more biometric data about the driver's state.
The trials without and with a phone call for counter-balanced. Half of the participants (16) performed the phone call using their mobile phone, and the other half performed the call using a hands free system.

The participant's primary task was driving safely. As a secondary task, in only one of the three trials, they had to drive and perform a phone call.

Additionally, the participants had to perform the detection-response task [11]. The DRT response times and hit rates indicate the effects of increased cognitive load on the driver's attention. It is a simple task, where the participant is presented with visual, tactile or auditory stimuli every 2-5 seconds and is asked to respond to it as fast as possible by pressing a button attached to his/her index finger. In this study we used the tactile DRT. With this version, the participant experiences tactile stimuli from a small vibrating tactor placed on his/her left shoulder collar bone.

C. *Variables*

The following dependent variables were observed:

- driving performance (speed, acceleration, reaction times), and
- driver state (galvanic skin response, DRT response times and hit rates).

III. RESULTS

The data analyses were performed with different statistical tests. For testing the normality, Shaprio-Wilk and Kolmogorov-Smirnov tests with were used for samples smaller than 2000 and larger than 2000 respectively. Levene's test was used for testing the homogeneity of variances. Based on the results from these tests, appropriate parametric and non-parametric tests and post-hoc test were used to further analyze the data.

A. *Driving performance*

1) *Speed*

The results for mean speed did not reveal any statistical differences. Although the lowest speed limit was 40 km/h, the results revealed that participants drove bellow the limit throughout all of the trials (Fig. 2 and Fig 3.).

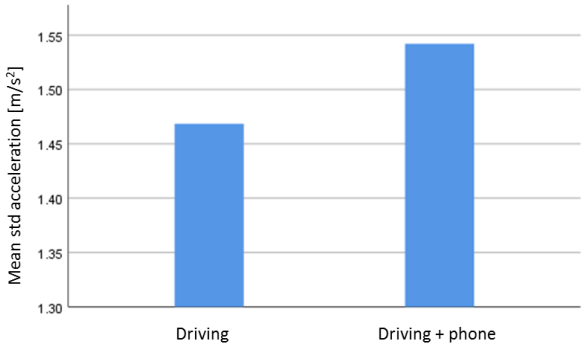

Figure 2. Mean speed values for trials without and with a phone call using a mobile phone.

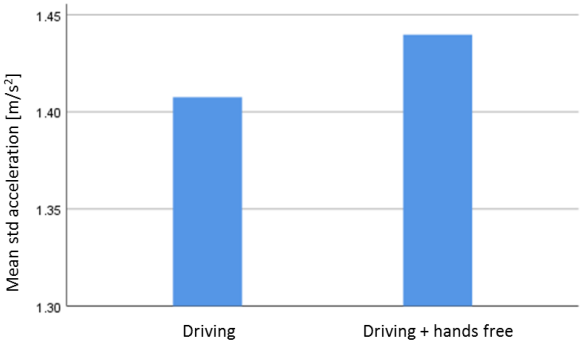

Figure 3. Mean speed values for trials without and with a phone call using a hands-free system.

2) *Acceleration*

The analysis showed that there were statistically significant differences in the mean standard deviation of acceleration for trials with a phone call compared to trials without the phone, $p<0.05$ (Fig. 4 and Fig. 5). Fig. 4 and Fig. 5 show the absolute values of accelerations and decelerations.

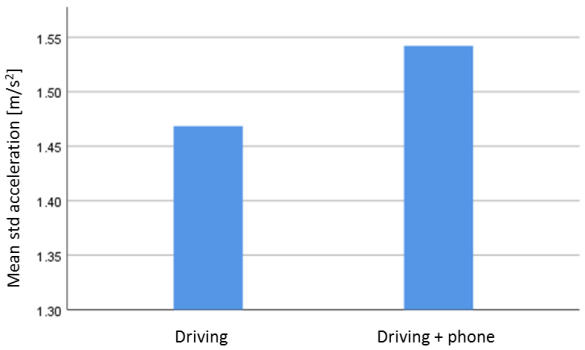

Figure 4. Mean STD acceleration for trials without and with a phone call using a mobile phone.

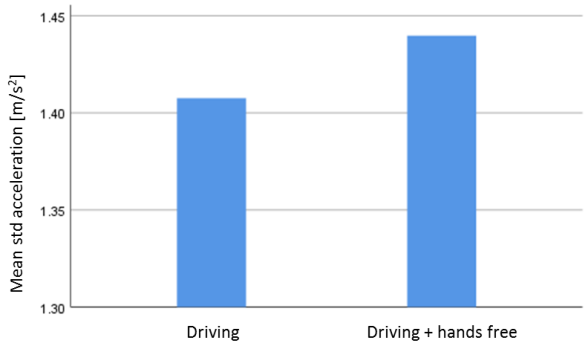

Figure 5. Mean STD acceleration for trials without and with a phone call using a hands-free system.

3) Reaction times

Reaction times were recorded three times in each trial. The analysis showed that the reaction times statistically significantly increased ($p<0.05$) for trials without a phone call compared to trials with a phone call for 61% when using a mobile phone (Fig. 6) and 71% when using a hands free system (Fig. 7).

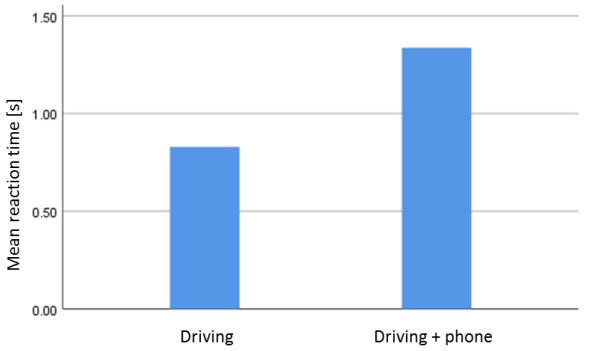

Figure 6. Mean reaction times for trials without and with a phone call using a mobile phone.

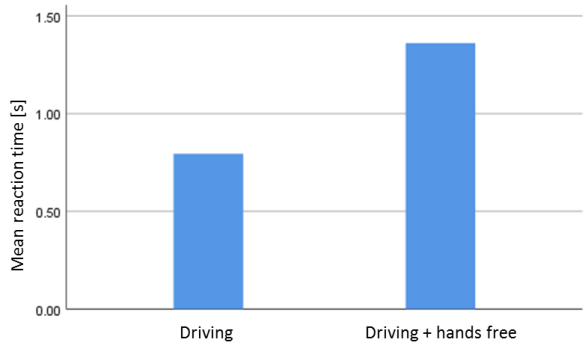

Figure 7. Mean reaction times for trials without and with a phone call using a hands-free system.

B. Driver state

1) Galvanic skin response

The galvanic skin response or the skin conductance was measured to assess changes in the electro dermal activity that could indicate stress. Although the galvanic skin response of drivers increased for the trials with a phone call, these changes were not statistically significant, $p>0.05$ (Fig. 8 and Fig. 9).

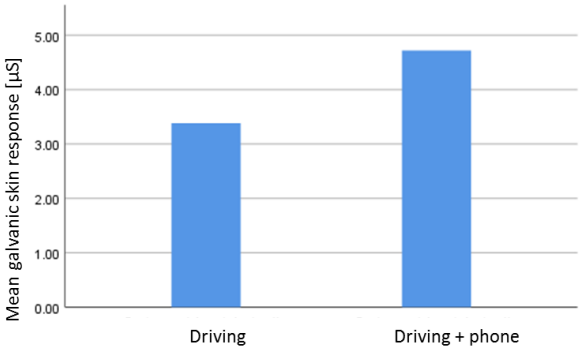

Figure 8. Mean galvanic skin response for trials without and with a phone call using a mobile phone.

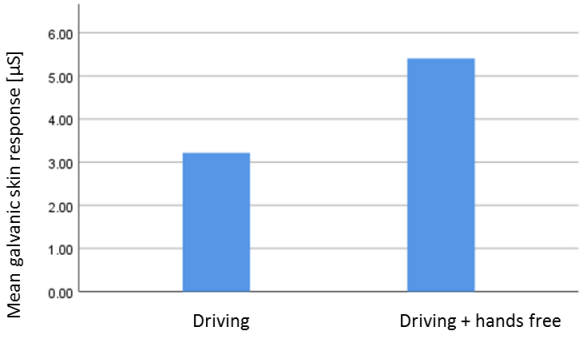

Figure 9. Mean galvanic skin response for trials without and with a phone call using a hands free system.

2) Detection response task

The DRT response times did not reveal any statistical differences in response times for trials without and with the phone call, $p>0.05$ (Fig. 10. and Fig.11).

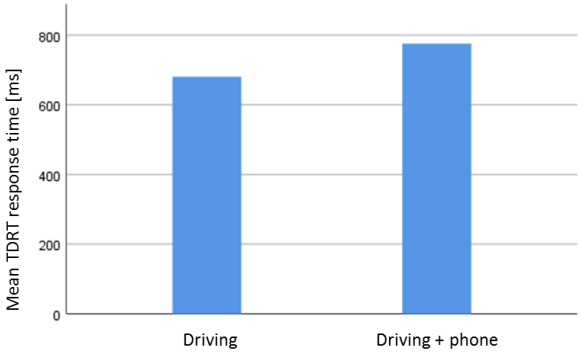

Figure 10. Mean DRT response times for trials without and with a phone call using a mobile phone.

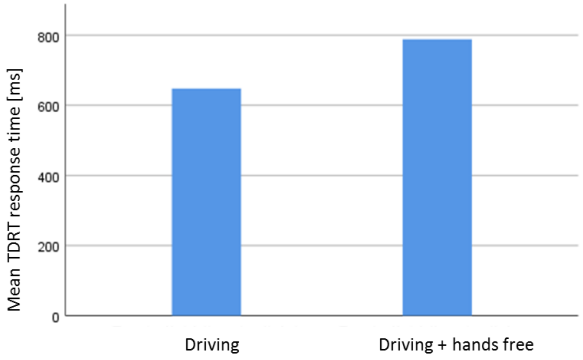

Figure 11. Mean DRT response times for trials without and with a phone call using a hands free system.

However, the results for the DRT hit rates, which show how the success rate of performing the detection response task, showed that the hit rates decreased significantly for trials with the phone call compared to trials without, $p<0.05$. The success rate decreased for 41% for trials with a phone call using a mobile phone (Fig. 12) and for 32% for trials using a hands free system (Fig. 13).

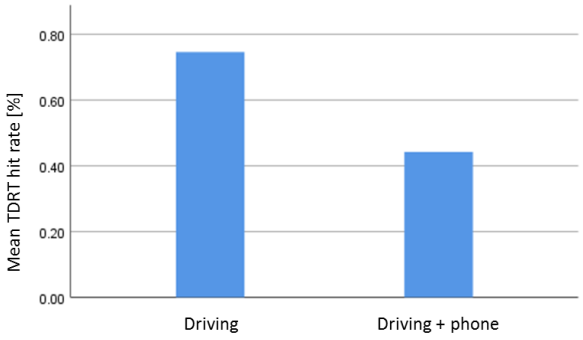

Figure 12. Mean DRT hit rates for trials without and with a phone call using a mobile phone.

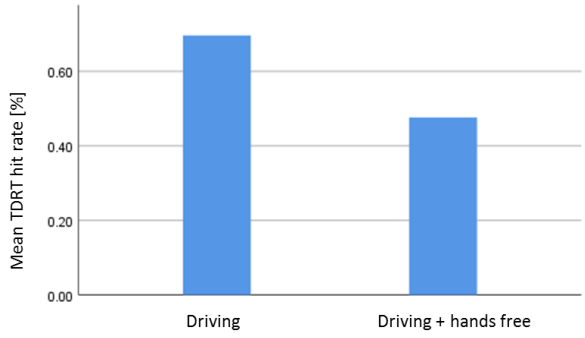

Figure 13. Mean DRT hit rates for trials without and with a phone call using a hands free system.

Discussion and conclusions

The aim of the study was to determine the extent to which the use of mobile telephones while driving affects the driver and their driving performance, by focusing on several different segments. The telephone conversation (using a mobile phone and hands-free) was observed consideration as a potential distraction from the primary task of driving.

Based on the results and statistical analysis of the collected data, we can conclude that the effect of a telephone conversation on driving is undoubtedly present and that the effects for most parameters are statistically significant. This means that phoning results into the reduction of driving skills and consequently, increased level of potential dangerous driving.

One the most important conclusions from this study is the significant increase in reaction times of drivers regardless of the type of system used for performing the phone call. Although hands-free systems eliminate the manual distraction, the results showed that response times increased in trials with this system. This is in line also with the results for hit rates of the detection response task, which indicated significant decrease in performance of the task with the introduction of the phone call. The detection response task shows the attentional effects of increased cognitive load, further indicating the biggest negative effect of phoning is the cognitive distraction.

The results from this and previous similar studies have shown that the use of mobile phones decreases the driving performance and affects the driver cognitively; therefore its use should be avoided while driving.

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