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THE IMPACT OF MOBILE PHONE USE ON YOUNG DRIVERS' DRIVING BEHAVIOUR AND VISUAL SCANNING OF THE ENVIRONMENT

ABSTRACT

Driver distraction has been identified as a contributing factor to road crashes, among which the most common is the use of mobile phones while driving. For this reason, the aim of this paper is to analyse the behaviour of young drivers while they use mobile phones (answering a telephone call, texting, and browsing the internet) and drive in a simulated urban environment. In total 28 volunteers participated in the study. Several variables were recorded for each participant: driving speed, acceleration, deceleration, and eye movement. The results show that the difference in driving speed, acceleration, and deceleration was relatively small for each task and for the control condition (no use of mobile phone). However, when looking at the total time required for conducting each task, participants spent 26.44% of the time looking at the phone when texting, 37.01% when browsing the internet, and 2.27% when talking on the phone. In addition, participants viewed on average 66.45% traffic signs when distracted, compared to 79.22% during undistracted driving. Based on the results, a proactive approach to reduce the problem related to the use of mobile phones while driving is proposed.

KEYWORDS

mobile phones; distraction; young drivers; driving simulator; eye tracking; road safety.

1. INTRODUCTION

Driver distraction can be caused by a number of internal or external sources (inside or outside the vehicle). In-vehicle distractions include eating, drinking, smoking, talking, use of embedded multimedia entertainment systems, etc. [1]. Drivers can, however, be ‘distracted’ by an activity or event to the extent that they no longer allocate sufficient attention to the driving task and their driving performance is compromised. In this sense, driver distraction occurs when drivers’ normal cognitive processes (i.e., attention-sharing) and adaptive strategies fail, and they are no longer able to adequately divide their attention between driving and secondary tasks, and thus cannot maintain driving performance at a satisfactory level. Distraction can occur either because the secondary task is so complex or compelling that drivers fail to allocate (or prioritise) sufficient attention to driving, or because the demands of the driving task are so high that they do not allow the performance of a secondary task at any level [2]. According to Young et al., there are four main types of driver distraction: (1) visual distraction which takes drivers' eyes off the road; (2) auditory distraction which directs the driver to ambient sounds or responding to a ringing mobile phone; (3) physical distraction when the driver removes his/her hands from the steering wheel; and (4) cognitive distraction which diverts drivers' attention from driving, or results in being lost in thought [3]. Of course, the worst scenario is a combination of the aforementioned distraction types. The risk of accident varies depending on the distraction type. However, it is estimated that car drivers spend about 25–30% of total driving time on distracting activities and that from 5 to 25% of car accidents may be attributed to driver distraction [4].

One of the main distractors in road traffic is mobile phone use. Since mobile phones have become indispensable in people's daily lives, most drivers are at some point tempted to check their phone while driving. According to the results of a survey conducted by the Croatian Association of Safety Managers in 2017, car drivers mostly use phones to talk while driving, to connect to GPS, and to send/read text messages [5]. Since more than 90% of information that drivers receive in road traffic is visual, mobile phone use weakens drivers' ability to process visual information and they become sluggish in performing basic control actions over the vehicle [6]. Overall, road safety statistics clearly indicate the problem of mobile phone use while driving. In 2015, the United States National Highway Traffic Safety Administration (NHTSA) reported that mobile phone use was a contributing factor in 442 fatal crashes (14% of all fatal distraction-affected crashes). For these distraction-affected crashes, the police crash report specified that the driver was talking on, listening to, or otherwise manipulating a mobile phone or performing other phone activity at the time of the crash [7]. In general, this type of distraction is associated with degraded driving performance and with a significant detriment of the cognitive performance (e.g. the reaction time), leading to a negative impact on road safety, mainly due to dual tasking: driving and using a mobile phone.

A vast body of literature has shown a negative effect of dual tasking (i.e., use of mobile phones for making calls and texting) on different driving performance measures such as: braking performance, maintaining headway distance, reaction and response time, etc. Strayer and Johnson reported that participants in a tracking task were slower to respond to targets and were also more susceptible to missing targets when engaged in a mobile phone conversation [8]. Slower response and more intense braking were also found by Hancock, Lesch and Simmons [9]. In addition, authors highlighted a critical 15% increase in non-response to the stop light in the presence of a mobile phone-related distraction task, which equates with increased stop light violations on the open road. They also underlined that response and braking patterns were influenced by drivers' age and gender – female and older drivers suffered a greater disadvantage concerning the presence of the distraction effect. Furthermore, Yan et al. demonstrated that driving performance, analysed through brake reaction time and driving speed fluctuation, was significantly impaired due to a normal conversation on a hands-free mobile phone [10]. Several other studies confirmed the same effect of hands-free mobile phone conversation on driving performance [11–13]. Consiglio et al. compared the impact of hands-free and handheld mobile phone conversation on the braking performance of distracted drivers upon the activation of a red lamp in a laboratory. They found that both types of mobile phone conversations (hands-free and handheld) resulted in slower reaction times in performing the braking task [14]. On the other hand, using a driving simulator, Saifuzzaman et al. concluded that although both handheld and hands-free calls impacted the car-following behaviour, headway time for hands-free phone conversation increased by 0.33 s, and for handheld mobile phone use by 0.75 s [15]. In addition, Tornros and Bolling found that handheld and hands-free calls to some extent differently affect driving performance depending on the environment in which the driver is driving [16]. The study was conducted using a driving simulator on which 48 participants drove a distance of 70 km on a route leading through the following types of environments: rural environment with a speed limit of 90 km/h, rural environment with a speed limit of 70 km/h, urban environment of low complexity, urban environment of medium complexity and urban environment of high complexity. During a handheld phone conversation speed reduced in all environments, whereas hands-free phone conversation had such an effect in only two environments: rural 90 and urban complex environments. Authors indicate that speed reduction as an effect of conversation is an attempt to compensate for the increased mental workload.

In addition to mobile phone conversation while driving, research activities have also focused on the effect of texting on driving performance. In general, texting is one of the most detrimental uses of mobile phones while driving because it involves visual, manual, and cognitive distractions [17]. Rumschlag et al. conducted a driving simulator study to investigate a disruptive effect of texting on driving performance defined as lane excursions, or movement of the vehicle outside the directed driving lane (into the lane for oncoming traffic or onto the shoulder of the road). Overall, results show that 66% of drivers exhibited lane excursions while texting and driving [18]. Hosking, Young and Regan found in their driving simulator study that young drivers spent up to 400% more time not looking at the road while texting and driving compared to conditions in which they were not texting [19]. Furthermore, a meta-analysis of driving simulation studies concluded that reading and typing text messages while driving diverts attention away from the road, increases response time to hazards, and increases the risk of crashing [20].

Besides driving performance, several studies investigated how mobile phone use affects drivers' eye movements. Young et al. studied the impact of different mobile phone interfaces on driving performance and eye movements [21]. For this purpose, authors used a smartphone with a touch screen QWERTY keyboard and tactile numeric keypad phone. In total, 24 participants drove three test runs on a driving simulator. Half of the participants used a mobile phone with a numerical keypad (no QWERTY keypad) and half used a 'smartphone' with a touch screen interface and a virtual keyboard to carry out the text messaging tasks. Each of the three test runs comprised a 7-km tunnel segment and a 7-km freeway segment with the same road geometry. Furthermore, each test consisted of a different task related to the mobile phone: (1) a run without the use of mobile phone (control condition), (2) a run in which participants had to read text messages (read-only condition), and (3) a run in which participants had to read and send text messages (read-and-write condition). During test runs, authors recorded several driving performance and eye movement data: vehicle speed and speed variability, standard deviation of lane position, the percentage of drivers' total gaze time to the road centre (during text-messaging conditions), frequency and duration of glances to the phone, and ratings of subjective workload. Results show that reading and, in particular, writing text messages decreased the amount of time that drivers spent looking at the centre roadway (up to 29%), degraded their speed monitoring and increased their subjective workload compared to control conditions. In addition, the performance degradations were similar across numeric keypad and touch screen keyboard phones. In 2019, Desmet and Diependaele examined the effects of hands-free phoning on cognitive distraction with the use of eye tracking [22]. In total 30 participants made two consecutive trips (hands-free trip and a control trip) of about 14 km on a three-lane highway. During the hands-free trip, participants received a hands-free phone call. During the control trip, participants drove without engaging in any conversation. In both trips researchers recorded eye movements, i.e., frequency of fixation, fixation duration, saccade duration, and the horizontal and vertical densities of fixation. The results show that drivers fixated less on road signs, other vehicles, and the speedometer while making a hands-free call. Also, the visual scan pattern indicates that participants had a wider spatial distribution of eye fixations during a hands-free phone call. Overall, based on the results, authors highlight that drivers seem to fixate less on traffic-related information while making hands-free calls. The same year, Hashash, Zeid and Moacdieh evaluated the effect of browsing social media while driving on young drivers' performance and attention allocation using a driving simulator [23]. In total 26 students were recruited and asked to do three runs along a given path (6.8-km long urban environment). Each run represented one of the test conditions: (1) no use of mobile phone (control condition), (2) browsing through Facebook, and (3) texting. Each run also contained three events set at specific locations: a green light turning yellow then red as the participant approaches the traffic signal, a pedestrian crossing in front of the car, and a car braking suddenly in front of them. Recorded data were divided into three groups: driving performance – average speed, average lane position deviation, and average brake reaction time; eye tracking – number of fixations on the road, mean fixation duration on the road, fraction of time looking at the road, mean X and Y gaze position on the road, and spatial density; and subjective measures – participants rated three of the factors of the full NASA-TLX scale. The factors included their perception of mental demand, temporal demand, and effort on a scale from 1 (least demand or effort) to 20 (most demand or effort). Results show that both texting and browsing social media lead to performance decrements. However, texting while driving is more detrimental to performance compared to browsing social media. In terms of attention allocation, texting and browsing social media seem to be very similar, which confirms the need to raise awareness about the visual distraction caused by browsing social media.

The literature review clearly shows that mobile phones significantly affect driver performance. However, most of the studies focused only on investigating a specific use of mobile phones, such as texting, conversing, or browsing (social media), with few of them using eye tracking. In addition, most of the simulator studies simulated open-road environment (for example freeway road segments) which is in most cases less demanding than urban environments in terms of visual complexity, number of different road users, and number of conflicting situations. Therefore, the aim of this study is to compare the impact of several types of mobile phone use (handheld mobile phone conversation, texting, and internet browsing) on young drivers' driving performance (driving speed, acceleration, and deceleration) and eye movement (number of gazes on the mobile phone, the duration of gaze, and the number of viewed traffic signs) in urban environment. The reasons for the aim of the study are the following: (1) handheld phone conversation, texting, and internet browsing are three most detrimental uses of mobile phones while driving; (2) young drivers are especially prone to the use of mobile phones while driving [19, 24, 25]; (3) urban environments are complex areas in which, although the driving speed is lower, a number of conflicting and risky situations occur due to the number of different road users and high concentration of information, which may ultimately increase drivers' mental workload, especially for young inexperienced drivers [26–28]. The main objective of the study is to determine which type of mobile phone use by young drivers represents the worst-case scenario for road safety and as such, the study is a valuable contribution to the existing body of literature.

2. METHODOLOGY

The following research equipment was used for this research: a driving simulator and eye-tracking glasses. With the research equipment we collected data related to driving speed, acceleration, deceleration, and the participants' eye movement. A more detailed description of the methodology is provided in the following section.

2.1 Research equipment

Carnetsoft B. V. driving simulator (*Figure 1*) consisting of a driver section (driver seat with pedals, steering wheel, and shifter) and three interconnected displays, 30″ in size, 5760x1080 resolution, and 30 Hz frame rate was used in this study. The hardware consisted of a computer with NVidia GeForce GTX 1080 Ti graphics processing unit (GPU) and 3GB of video memory, Intel Core i7 7700K central processor unit (CPU) with four cores, eight threads and frequency of 4.20GHz, 32GB of RAM, 250GB SSD for storage, and Windows 10 Pro 64-bit operating system. The simulator provides an interactive display of reality with a 210° environment with over six channels (left, middle, and right views plus three rear-view mirrors).

Figure 1 – Carnetsoft B. V. driving simulator used in the study

Tobii Pro Glasses 2 were used to record participants' eye movements. The glasses are equipped with cameras, a recording unit and a computer unit with installed software that records, captures and stores collected data (*Figure 2*). The glasses have four eye-tracking cameras (two cameras per eye) and four sensors (gyroscope and accelerometer). The camera installed at the front of the glasses records the space in front of the participant with a 1920* 1080-pixel HD resolution and a viewing area of 160° horizontally and 70° vertically, while the remaining cameras that record eye movement are placed in the eyeglass lenses [29].

Figure 2 – Elements of a Tobii Pro Glasses 2 eye-tracking system [29]

2.2 Scenario design

The scenario was designed as a two-way street with a road surface 6.8 m wide (each roadway lane 3.4 m wide) in a typical urban environment. The scenario was divided into two parts. The first part passed through a rural area 2.37 km long and was designed as a 'warm up' run during which participants adapted to the simulator. This part has not been taken into account during further data processing. The second part represented the testing part with a total length of 10.74 km which was divided into six identical parts or 'laps'. In each part, participants had a different task (elaborated in more detail in Section 2.3).

Since the scenario represented a typical urban environment, the speed limits varied from 40 km/h, 50 km/h to 60 km/h. The speed limit of 40 km/h was set in front of each major curve, 50 km/h at the very beginning of each lap because it announced driving through an urban area, while the limit of 60 km/h was set in an urban area on a straight road section. Within each part (lap) of the scenario, there were two three-way intersections and two four-way intersections. At three-way intersections drivers had the right of way. At the first four-way intersection a stop sign was installed, and the second contained a pedestrian crossing. There were also two sharp curves marked with chevron signs. The entire scenario included 15 cm wide middle and edge road markings and 66 traffic signs (placed in the direction of travel). The number and percentage share of traffic signs by each sign category is presented in *Table 1*. Additionally, both sides of the roadway contained a 1 m wide red bicycle line.

Random traffic (both cars and pedestrians) was present (cars were only present in the opposite direction). Also, the scenario included the sound of traffic in the environment and the sound of the participant's car. The road environment consisted of houses, buildings, street lighting, parked vehicles, and trees typical for urban setting. Other distractions were not present in the scenario. The scenario simulated daytime conditions with sunny weather.

Table 1 – The proportion of traffic signs in the scenario

Traffic sign category	Dimensions [cm]	Number of traffic signs	Percentage [%]
Danger signs	90×90×90	18	27.3
Mandatory signs – stop	60	6	9.1
Mandatory signs	60	24	36.3
Information signs	60×60	6	9.1
Chevron signs	60×60	12	18.2
TOTAL	-	66	100

2.3 Procedure

The testing room was set up at the Department of Traffic Signalling, Faculty of Transport and Traffic Sciences, University of Zagreb (Croatia). Before conducting the test, each participant had gotten acquainted with the research equipment and research procedure. Researchers instructed the participants that their driving knowledge and ability are not being evaluated and that they can freely stop the testing at any time, especially if they feel side effects such as simulator sickness. The participants signed a consent to take part and filled in a short questionnaire related to personal information such as age, gender, date of obtaining the driver's license, self-assessment of their driving ability, frequency of driving, and other comments and possible problems related to their visual system. In addition, participants filled out a questionnaire aimed at determining their attitudes, habits, and opinions regarding the use of mobile devices while driving and its risk. Before the beginning of the simulation run, the researchers explained the methodology to the participants and told them that they would have to perform some mobile phone-related tasks while driving.

As already mentioned, the scenario was divided into six identical sections. In three of the six identical parts participants had to complete a specific task related to mobile phone use, while in the other three parts they did not use mobile phones. The mobile phone-related tasks consisted of: (a) writing a message (texting); (b) answering a telephone call (conversing); and (c) browsing the internet. All participants drove the same scenario, with a random order of tasks in the scenario. Also, they used their own mobile phones so the impact of 'learning' to work on a new phone was eliminated. *Figure 3* shows the way one of the participants used a mobile phone while driving.

Figure 3 – View from the driver's perspective of using a mobile phone while driving

2.4 Variables and data analysis

During the entire run, driving speed, acceleration, deceleration, and eye movements (number of gazes on the mobile phone, the duration of the gaze, and the total number of traffic signs viewed) were measured. The above data were extracted from Carnetsoft B. V. 'Data Analysis' software and Tobii Lab, and analysed using ANOVA. In addition to the ANOVA system, Bonferroni post-hoc analysis was used. The Bonferroni test attempts to prevent data from incorrectly appearing as statistically significant by making an adjustment during comparison testing, and it is often applied as a post-hoc test in many statistical procedures such as ANOVA and its variants (ANCOVA, MANOVA), multiple t-tests, Pearson's correlation analysis and in several non-parametric tests (Mann-Whitney U test, Wilcoxon signed rank test, and Kruskal-Wallis test) [30]. Statistical significance was set at 5% and 95% confidence intervals, respectively.

2.5 Participants

The participants were recruited through researchers' personal contacts. A total of 28 volunteers holding a valid driver's license participated in the study and all of them successfully completed the testing procedure without any problems (such as simulator sickness etc.). Sample size was restricted due to the COVID-19 pandemic, but overall, it is in line with other similar studies [10, 21, 23]. Of a total of 28 participants, 17 men (60.71%) and 11 women (39.29%) participated in the study. The average age of the participants was 26 years ($\bar{x}$=26.82; min=18.69; max=33.58; SD=3.35), and their driving experience averaged seven years ($\bar{x}$= 7.13).; min=0.05; max=14.26; SD=3.67).

More than half (60.71%) of participants assessed their driving ability as "moderately experienced driver". Ten of them (35.71%) stated that they do not use mobile phones while driving, and if they are forced to, they use them in a hands-free manner. A total of 57.14% of participants choose to use the hands-free mode, and 42.86% the handheld mode. As many as 78.57% of participants claim that mobile phones have a significant impact on road safety, but although they are aware of the dangers, 42.86% of them still use them while driving. When looking at the three most detrimental uses of mobile phones while driving, the results of the questionnaire presented in *Figure 4* indicate that browsing the internet and texting is very or moderately distracting to most of the participants. When it comes to conversing on mobile phones, the majority of participants (54%) stated that it is very distracting. However, almost 40% stated that talking on a mobile phone does not have a distractive impact.

3. RESULTS

3.1 Driving speed

The ANOVA results show that there is a significant statistical difference between the participants' driving speed depending on the way the mobile phone was used while driving, Wilks' Lambda=0.439, F=10.669, p<0.05 (p=0.000).

In the control condition, i.e., scenario parts where the mobile phone was not used, the participants drove on average 45.41 km/h (SD=6.02). It can be noticed that, on average, the participants

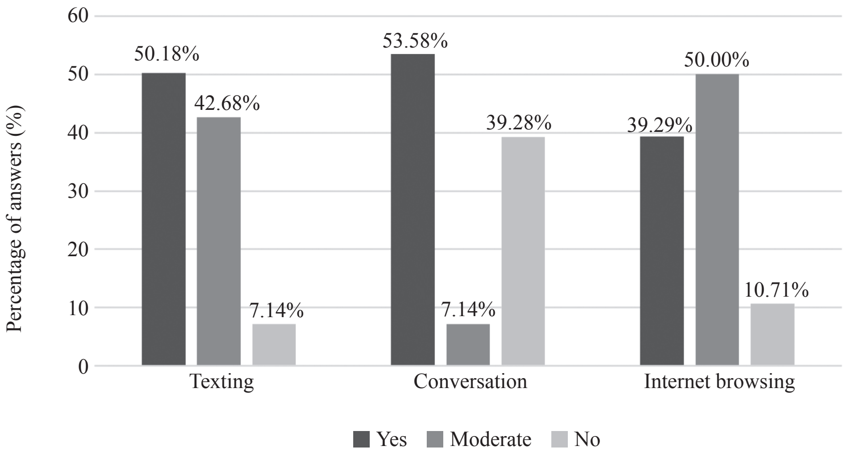

Figure 4 – Distractive effect of different mobile phone uses while driving, based on the questionnaire replies

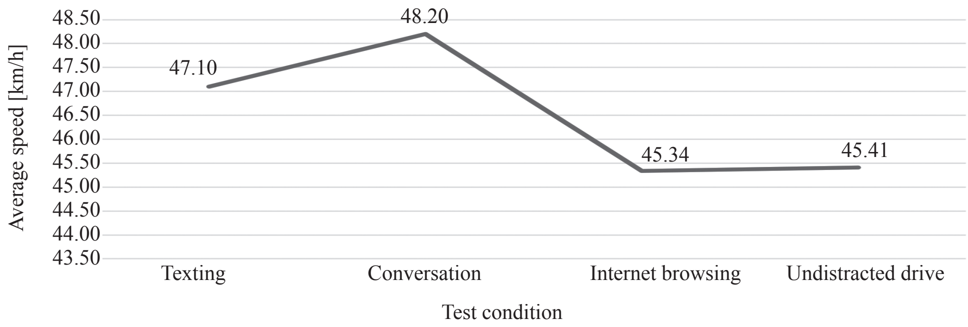

Figure 5 – Average driving speed per each condition

drove at the same speed as when browsing the internet – 45.34 km/h (SD=10.29). When they interfered with driving by writing messages and phoning, the average speed was slightly higher, 47.10 km/h (SD=9.59), and for telephone conversations 48.20 km/h (SD=7.76). The difference is shown in *Figure 5*.

3.2 Acceleration and deceleration

In contrast to driving speed, ANOVA results show that there is no significant statistical difference between acceleration depending on how mobile phones were used while driving, Wilks' Lambda=0.836, F=1.640, p>0.05 (p=0.205). The obtained data show that the average acceleration in undistracted driving was 0.71 m/s^2 (SD=0.22). Although the obtained values are approximately the same, during the telephone conversation the participants achieved the highest average acceleration of 0.76 m/s^2 (SD=0.29). Participants achieved the lowest acceleration while browsing the internet and texting. The results are shown in *Figure 6*.

For deceleration, the ANOVA results show that there is a significant marginal statistical difference between the deceleration level depending on the way the mobile phone was used while driving, Wilks' Lambda=0.726, F=3.139, p< 0.05 (p=0.043). The largest deceleration was recorded again during the telephone conversation, -1.22 m/s^2 (SD=0.79), while the lowest was during internet browsing (-1.02 m/s^2) as shown in *Figure 7*.

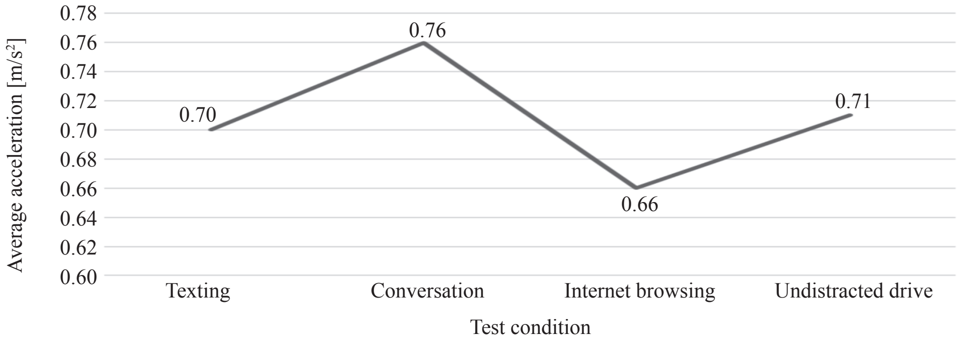

Figure 6 – Average acceleration per each condition

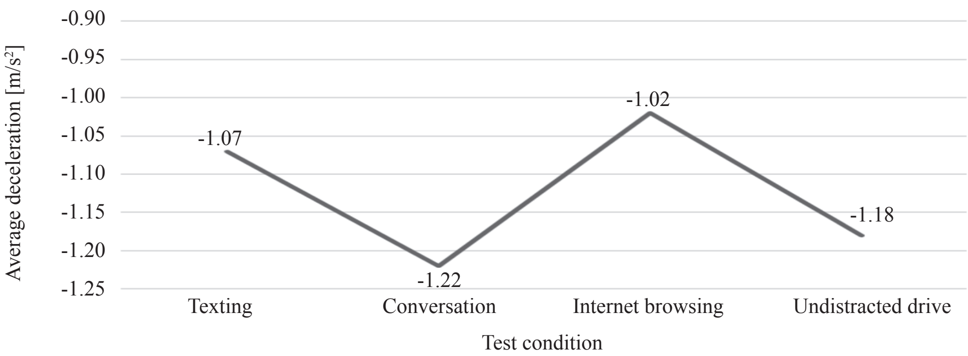

Figure 7 – Average deceleration per each condition

3.3 Eye movement

Using Tobii Pro glasses, we collected data related to the number of gazes on the mobile phone, the duration of the gaze and the number of traffic signs viewed by the participants. When comparing the number of gazes on the mobile phone while conducting a specific task, the results show that internet browsing demanded the highest visual attention, i.e., participants on average looked 44 times at the mobile phone. When texting, participants looked at the phone on average 32 times, and when answering a call only two times (when answering and when ending the call). The duration of each gaze was on average 1.11 s when texting, 1.29 s when browsing the internet, and 1.20 s when answering the phone. When looking at the total time for conducting each task, participants spent 26.44% of the time looking at the phone when texting, 37.01% when browsing the internet, and 2.27% when talking on the phone.

Furthermore, when distracted by the use of the mobile phone, participants viewed on average 66.45% (SD=20.45%) of traffic signs located in the scenario. In undistracted parts of the scenario, the participants viewed on average 79.22% (SD=17.05%) of traffic signs.

4. DISCUSSION AND CONCLUSION

Overall, the results of the study show that drivers drove statistically faster when they were distracted by the use of the mobile phone. Specifically, the highest average speeds were recorded when participants were distracted by a telephone conversation (48.20 km/h) and texting (47.10 km/h). On the other hand, the average speed during internet browsing and undistracted driving was almost the same, 45.34 km/h and 45.41 km/h respectively. These results are to some extent contrary to the previous findings [31–33], which may be due to the fact that speed limitations in this study were relatively low (40 km/h to 60 km/h) and that we focused only on young drivers. Several studies have shown that young drivers often misjudge situations, overestimate their own abilities, and do not accurately perceive their driving speed, i.e., tend to overspeed [34–36]. However, it must be noted that a meta-analysis of the effects of mobile phone use on driving performance indicated that young drivers are less affected by mobile phone tasks than older drivers [37]. Additional studies are needed in order to further evaluate the impact of different mobile phone uses on driving speed since personal characteristics play an important role in speed adaptation [33]. Although the difference in average speed is relatively small (less than 5 km/h), it still may significantly increase the risk of accidents.

In addition to speed, we conducted an analysis of acceleration and deceleration, and the results related to the achieved speeds. At higher speeds, drivers accelerated and decelerated more intensively. Overall, participants accelerated at the lowest rate while browsing the internet and texting, probably because the tasks were complex and demanded more attention. The highest acceleration was recorded during a telephone conversation, which may be due to the fact that the drivers were visually focused on the road. The highest deceleration was also recorded during a telephone conversation ($-1.22\ m/s^2$), while the lowest was during internet browsing ($-1.02\ m/s^2$). Overall, the deceleration in each condition was in the range of $-0.85\ m/s^2$ up to $-1.8\ m/s^2$, which is considered safe [38, 39].

Finally, eye-tracking results show that different usage of mobile phones demands different visual attention. Internet browsing and texting demanded the highest number of gazes at the phone, due to the pure complexity of the task. Specifically, drivers needed to focus on the phone in order to properly and correctly fulfil the tasks. As reported by Collet, Guillot and Petit in their literature review, a number of studies have indicated that the use of mobile phones affects visual information processing [40]. Several studies have shown that under highly loaded conditions, the driver's functional field of view reduces [41–43], and that some of the cues related to driving may not get to be visually processed and perceived [44]. This is why participants viewed the lowest number of traffic signs when they were distracted compared to when they were not, although most of the signs were in their central field of view. Of course, just viewing a sign does not mean that it will be perceived, but without fixating the gaze on the sign, drivers have a lower chance of correctly and timely identifying and understanding its meaning and thus the risk of improper and untimely reaction increases.

According to the obtained results, it can be concluded that from the safety perspective, the most critical uses of mobile phones while driving are internet browsing and texting. If we take a plastic example of just a 3-second drive at a continuous speed of 47.10 km/h, which is the average speed at which participants drove while texting, 26.44% of the overall driving time (0.79 seconds) drivers will be distracted and not look at the road. This would result in 10.3 m of travelled distance without the "eyes on the road", which in an urban environment may be crucial for performing a safety manoeuvre like braking and stopping. The situation is even worse with internet browsing. Although the average driving speed was the lowest compared to all the other conditions, drivers were distracted 37.01% of the total time, which would result in almost 14 m of travelled distance without "eyes on the road". On the other hand, during a phone conversation drivers would most of the time visually focus on the situation in front of them and thus for this specific case it would mean that less than a meter of travelled distance would be without "eyes on the road". Of course, the use of mobile phones does not result just in a visual distraction, but rather in a combination of visual, manual, cognitive, and auditory distraction, which means that any use of mobile phones while driving will increase the driver's mental workload. The increase of mental workload can significantly impair driving performance, perception, and reaction time and thus the overall road safety [45–47].

Although this study provided valuable results, it has certain limitations. They are primarily related to the driving simulator since a fixed-base simulator does not provide a completely realistic, real-life driving feeling and external validation of the results is an often-mentioned issue even though the method has many advantages. Another limitation is related to the potential 'familiarity' effect. The scenario consisted of six identical sections, and although the tasks were randomised for each participant, they may have learned about the route which could, according to Yanko and Spalek [48], lead to mind-wandering and poor driving performance. Finally, the sample size in this study was relatively small (28 participants) due to the COVID-19 pandemic. In general, a relatively small sample size increases the likelihood of a Type II error skewing the results, which decreases the power of the study. However, the sample size is in line with other simulator studies examining the impact of mobile phones on driving behaviour [10, 21, 23]. Based on the findings and limitations of the study, we recommend that future research focuses on investigating in more depth how different mobile phone tasks affect driving performance and visual scanning of the environment. Such research should include a broader range of participants since personal characteristics, such as age, gender, cultural background, driving experience, personality etc., impact the level of distraction, i.e., the way specific distraction will affect the driver. Such studies should also investigate how different weather (sun, rain, fog etc.) and visibility conditions (day, night, dusk, dawn) impact the level of distraction by mobile phones.

Finally, since the study further proved that the use of mobile phones while driving significantly affects young drivers' behaviour, especially in terms of their visual scanning of the environment, we propose implementing measures and programmes aimed at educating young drivers about the negative effects of mobile phone use on road safety. The results of the questionnaire related to different uses of mobile phones while driving and their risks indicate that in some cases, such as phoning while driving, participants to a large extent (40%) do not even perceive the action as risky and distracting. Therefore, we propose that the educational programmes should be based on personal contact which includes empathy, emotions, and mutual understanding with real-life examples. It has been highlighted that programmes which include personal contact and stories of victims injured in road traffic accidents may be more effective in increasing awareness, especially of young drivers [49, 50].

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UTJECAJ UPOTREBE MOBILNIH TELEFONA TIJEKOM VOŽNJE NA PONAŠANJE I VIZUALNO "SKENIRANJE" OKOLINE MLADIH VOZAČA

Distrakcija vozača identificirana je kao jedan od faktora koji doprinosi nastanku prometnih nesreća, među kojima je najčešća upotreba mobitela tijekom vožnje. Iz tog razloga, cilj ovog rada je analizirati ponašanje mladih vozača prilikom korištenja mobitela (javljanje na telefonski poziv, slanje poruka i pregledavanje interneta) i vožnje u simuliranom urbanom okruženju. U istraživanju je sudjelovalo ukupno 28 volontera. Za svakog ispitanika mjereni su različiti parametri: brzina vožnje, akceleracija, deceleracija i pokreti očiju. Rezultati pokazuju kako je razlika u brzini vožnje, akceleraciji i deceleraciji bila relativno mala za svaki "zadatak" kao i za kontrolni uvjet (vožnja bez korištenja mobitela). Međutim, gledajući ukupno vrijeme potrebno za izvođenje svakog zadatka, sudionici su proveli 26,44 % vremena gledajući u mobitel prilikom slanja poruka, 37,01 % prilikom pregledavanja interneta i 2,27 % kada su razgovarali na mobitel. Osim toga, sudionici su u prosjeku pogled usmjerili na 66,45 % prometnih znakova kada su koristili mobitel, u usporedbi sa 79,22 % tijekom vožnje bez korištenja mobitela. Na temelju rezultata predlaže se proaktivan pristup smanjenju problema vezanog uz korištenje mobitela tijekom vožnje.

KLJUČNE RIJEČI

mobiteli; distrakcija; mladi vozači; simulator vožnje; očni pokreti; cestovna sigurnost.

REFERENCES

[1] Jovović I, Peraković D, Husnjak S. The impact of using modern information and communication equipment and services on driving safety. *Promet – Traffic&Transportation.* 2018;30(5): 635-4. doi: 10.7307/ptt.v30i5.2783.

[2] Young K, Regan, M. Driver distraction: A review of the literature. In: Faults IJ, Regan M, Stevenson M, Brown J, Porter A, Irwin JD. (eds.). *Distracted driving.* Sydney, NSW: Australasian College of Road Safety; 2007. p. 379-405.

[3] Young K, Regam M, Hammer M. *Driver distraction: A review of the literature*. Monash University Accident Research Centre. Report number: 206, 2003.

[4] European Road Safety Observatory. *Driver distraction – Summary, 2018*. 2018. Available at: https://ec.europa.eu/transport/road_safety/sites/default/files/pdf/ersosynthesis2018-driverdistraction-summary.pdf.

[5] Hrvatska udruga menadžera u sigurnosti. [*Dan bez mobitela u prometu*]. 2017. Available at: https://danbezmobitelauprometu.uhms.hr/istrazivanja/. Croatian.

[6] Babić D, Ščukanec A, Babić D. The impact of road familiarity on the perception of traffic signs - Eye tracking case study. *The Proceedings of the 10th International Conference: "Environmental Engineering", 27-28 April 2017, Vilnius, Lithuania*; 2017. p. 1-7.

[7] National Highway Traffic Safety Administration (NHTSA). *Distracted driving 2015 – Summary of statistical findings.* Report number: DOT HS 812 132, 2017. Available at: https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812381.

[8] Strayer DL, Johnston WA. Driver to distraction: Dual-task studies of simulated driving and conversing on a cellular telephone. *Psychological Science*. 2001;12(6): 462-466. doi: 10.1111/1467-9280.00386.

[9] Hancock PA, Lesch M, Simmons L. The distraction effects of phone use during a crucial driving maneuver. *Accident Analysis and Prevention*. 2003;35(4): 501-514. doi: 10.1016/s0001-4575(02)00028-3.

[10] Yan W, et al. Effects of hands-free cellular phone conversational cognitive tasks on driving stability based on driving simulation experiment. *Transportation Research Part F: Traffic Psychology and Behaviour.* 2018;58: 264-281. doi: 10.1016/j.trf.2018.06.023.

[11] Charlton SG. Driving while conversing: Cell phones that distract and passengers who react. *Accident Analysis and Prevention*. 2009;41(1): 160-173. doi: 10.1016/j.aap.2008.10.006.

[12] Rosenbloom T. Driving performance while using cell phones: An observational study. *Journal of Safety Research*. 2006;37(2): 207-212. doi: 10.1016/j.jsr.2005.11.007.

[13] Beede KE, Kass SJ. Engrossed in conversation: The impact of cell phones on simulated driving performance. *Accident Analysis and Prevention*. 2006;38(2): 415-421. doi: 10.1016/j.aap.2005.10.015.

[14] Consiglio W, Driscoll P, Witte M, Berg WP. Effect of cellular telephone conversations and other potential interference on reaction time in a braking response. *Accident Analysis and Prevention.* 2003;35(4): 495-500. doi: 10.1016/s0001-4575(02)00027-1.

[15] Saifuzzaman M, Haque MM, Zheng Z, Washington S. Impact of mobile phone use on car-following behaviour of young drivers. *Accident Analysis and Prevention*. 2015;82: 10-19. doi: 10.1016/j.aap.2015.05.001.

[16] Törnros J, Bolling A. Mobile phone use – Effects of conversation on mental workload and driving speed in rural and urban environments. *Transportation Research Part F: Traffic Psychology and Behaviour.* 2006;9(4): 298-306. doi: 10.1016/j.trf.2006.01.008.

[17] Alosco ML, et al. Both texting and eating are associated with impaired simulated driving performance. *Traffic Injury Prevention*. 2012;13: 468-475. doi: 10.1080/15389588.2012.676697.

[18] Rumschlag G, et al. The effects of texting on driving performance in a driving simulator: The influence of driver age. *Accident Analysis and Prevention.* 2015;74: 145-149. doi: 10.1016/j.aap.2014.10.009.

[19] Hosking SG, Young KL, Regan MA. The effects of text messaging on young drivers. *Human Factors*. 2009;51: 582-592. doi: 10.1177/0018720809341575.

[20] Caird JK, et al. A meta-analysis of the effects of texting on driving. *Accident Analysis and Prevention.* 2014;71: 311-318. doi: 10.1016/j.aap.2014.06.005.

[21] Young KL, et al. Effects of phone type on driving and eye glance behaviour while text-messaging. *Safety Science*. 2014;68: 47-54. doi: 10.1016/j.ssci.2014.02.018.

[22] Desmet D, Diependaele K. An eye-tracking study on

the road examining the effects of handsfree phoning on visual attention. *Transportation Research Part F: Traffic Psychology and Behaviour*. 2019;60: 549-559. doi: 10.1016/j.trf.2018.11.013.

[23] Hashash M, Zeid MA, Moacdieh NM. Social media browsing while driving: Effects on driver performance and attention allocation. *Transportation Research Part F: Traffic Psychology and Behaviour*. 2019;63: 67-82. doi: 10.1016/j.trf.2019.03.021.

[24] Cazzulino F, et al. Cell phones and young drivers: A systematic review regarding the association between psychological factors and prevention. *Traffic Injury Prevention*. 2013;15(3): 234-242. doi: 10.1080/15389588.2013.822075.

[25] Jannuscha T, et al. Smartphone use while driving: An investigation of young novice driver (YND) behaviour. *Transportation Research Part F: Traffic Psychology and Behaviour*. 2021;77: 209-220. doi: 10.1016/j.trf.2020.12.013.

[26] Rudin-Brown CM, Edquist J, Lenné MG. Effects of driving experience and sensation-seeking on drivers' adaptation to road environment complexity. *Safety Science*. 2014;62: 121-129. doi: 10.1016/j.ssci.2013.08.012.

[27] Cox JA, Beanland V, Filtness AJ. Risk and safety perception on urban and rural roads: Effects of environmental features, driver age and risk sensitivity. *Traffic Injury Prevention*. 2017;18(7): 703-710. doi: 10.1080/15389588.2017.1296956.

[28] Cabrera-Arnau C, Curiel RP, Bishop SR. Uncovering the behaviour of road accidents in urban areas. *Royal Society Open Science*. 2020;7(4): 191739. doi: 10.1098/rsos.191739.

[29] Tobii Pro. 2021. Available at: https://www.tobiipro.com/.

[30] Dunn OJ. Multiple Comparisons among Means. *Journal of the American Statistical Association*. 1961;56(293): 52-64.

[31] Fitch GM, Grove K, Hanowski RJ, Perez MA. Compensatory behavior of drivers when conversing on a cell phone. *Journal of the Transportation Research Board*. 2014;2434: 1-8. doi: 10.3141/2434-01.

[32] Törnros JEB, Bolling AK. Mobile phone use—Effects of handheld and handsfree phones on driving performance. *Accident Analysis and Prevention*. 2005;37: 902-09. doi: 10.1016/j.aap.2005.04.007.

[33] Oviedo-Trespalacios O, Haque MM, King M, Washington S. Self-regulation of driving speed among distracted drivers: An application of driver behavioral adaptation theory. *Traffic Injury Prevention*. 2017;18: 599-605. doi: 10.1080/15389588.2017.1278628.

[34] Hussain Q, et al. Drivers' estimation of their travelling speed: A study on an expressway and a local road. *International Journal of Injury Control and Safety Promotion*. 2019;26(3): 216-224. doi: 10.1080/17457300.2019.1618342.

[35] Ben-Bassat T, Shinar D. Effect of shoulder width, guardrail and roadway geometry on driver perception and behavior. *Accident Analysis and Prevention*. 2011;43(6): 2142-2152. doi: 10.1016/j.aap.2011.06.004 PMID: 21819845.

[36] Bos JE, van den Berg-Kroon L, Houben M, Kuiper O. Incar speed estimations with real, virtual, and no view. *Displays*. 2019;58: 66-70. doi: 10.1016/j.displa.2019.01.001.

[37] Caird JK, Willness CR, Steel P, Scialfa C. A meta-analysis of the effects of cell phones on driver performance. *Accident Analysis and Prevention*. 2008;40(4): 1282-1293. doi: 10.1016/j.aap.2008.01.009.

[38] Almeida R, Vasconcelos L, Bastos Silva A. Design consistency index for twolane roads based on continuous speed profiles. *Promet – Traffic&Transportation*. 2018;30(2): 231-239. doi: 10.7307/ptt.v30i2.2573.

[39] Altamira A, et al. Acceleration and deceleration patterns on horizontal curves and their tangents on two-lane rural roads. *Presented at the 93rd Transportation Research Board Meeting, 12–16 January 2014, Washington* DC, USA; 2014. p. 15.

[40] Collet C, Guillot A, Petit C. Phoning while driving I: A review of epidemiological, psychological, behavioural and physiological studies. *Ergonomics*. 2010;53(5): 589-601. doi: 10.1080/00140131003672023.

[41] Weltman G, Egstrom GH. Perceptual narrowing in novice drivers. *Human Factors*. 1966;8: 499-905. doi: 10.1177/001872086600800604.

[42] Atchley P, Dressel J. Conversation limits the functional field of view. *Human Factors*. 2004;46: 664-673. doi: 10.1518/hfes.46.4.664.56808.

[43] Langer P, et al. Hand-free mobile phone conversation impairs the peripheral visual system to an extent comparable to an alcohol level of 4–5 g 100 ml. *Human Psychopharmacology*. 2005;20: 65-66. doi: 10.1002/hup.654.

[44] Barkana Y, et al. Visual field attention is reduced by concomitant hand-free conversation on a cellular tele-phone. *American Journal of Ophthalmology*. 2004;138: 347-353. doi: 10.1016/j.ajo.2004.04.016.

[45] Matthews G, et al. Driving in states of fatigue or stress. In: Fisher DL, Rizzo M, Caird J, Lee JD. (eds.) *Handbook of Driving Simulation for Engineering, Medicine, and Psychology*. Boca Raton, FL, USA: Taylor and Francis; 2011. p. 29-11.

[46] De Waard D, Brookhuis K. On the measurement of driver mental workload. In: Rothengatter T, Carbonell Vaya EE. (eds.) *Traffic and Transport Psychology: Theory and Application*. Amsterdam: Pergamon; 1997. p. 161-171.

[47] Galante F, et al. Validity of mental workload measures in a driving simulation environment. *Journal of Advanced Transportation*. 2018;(4): 1-11. doi: 10.1155/2018/5679151.

[48] Yanko MR, Spalek TM. Route familiarity breeds inattention: A driving simulator study. *Accident Analysis and Prevention*. 2013;57: 80-86. doi: 10.1016/j.aap.2013.04.003.

[49] Topolšek D, Babić D, Fiolić M. The effect of road safety education on the relationship between driver's errors, violations and accidents: Slovenian case study. *European Transport Research Review*. 2019;11(18): 1-8. doi: 10.1186/s12544-019-0351-y.

[50] Shell DF, Newman IM, Cordova-Cazar AL, Heese JM. Driver education and teen crashes and traffic violations in the first two years of driving in a graduated licensing system. *Accident Analysis and Prevention*. 2015;82: 45-52. doi: 10.1016/j.aap.2015.05.011.