Effects of Playing Mobile Games While Driving

Cristian-Cezar Postelnicu[1(✉)], Octavian-Mihai Machidon[2], Florin Girbacia[1], Gheorghe-Daniel Voinea[1], and Mihai Duguleana[1]

[1] Department of Automotive and Transport Engineering, Transilvania University of Brașov, Brașov, Romania
cristian-cezar.postelnicu@unitbv.ro
[2] Department of Electronics and Computers, Transilvania University of Brașov, Brașov, Romania

Abstract. The use of smartphones while driving is a growing phenomenon that has reached alarming proportions. Playing games is a particular type of activity performed by drivers on their smartphones and is the subject of this paper. The study that was con-ducted aimed at investigating the influence of playing games on a smartphone while driving in a virtual reality simulator. The driver's eye glance behavior has been analyzed for twelve subjects while driving in two environments, city and country (national) road. A reference set of data obtained by driving without the gaming distraction has been used for performing a comparison and drawing conclusions. The results have indicated increased accident risks when playing games, especially caused by loss of control of the vehicle and improper lane positioning due to the driver being distracted by the game played.

Keywords: Smartphone · Mobile gaming · Driving · Driving simulator · Accident risk · Driving performance

1 Introduction

Yesterday's ordinary devices have known a major evolution in the past decade by turning "smart" and thus getting into the spotlights of today's society. These gadgets and technologies are now more attractive to customers being Internet connected and having all sorts of high-tech features. This is the case of the smartphone, the next evolutionary step of the old-fashioned mobile phone good only for making calls and sending text messages.

Such smart gadgets have become a widespread technology today, among people of all cultures and ages. The users of smartphones are involved in a variety of activities beyond making calls and texting: using social network apps, taking pictures/selfies, playing games, or just surfing the net. Being able to provide a whole new range of attractive and fun features, smartphones also raise major challenges regarding issues like addiction, safety of use and other potential unintended consequences brought on by the "immersion" effect that these devices generate on users. For example, in a 2012 study, researchers at Tel-Aviv University (TAU) show that smartphones create the illusion of a "private bubble" around their users, which become more caught up in their mobile activity than their immediate surroundings [6].

N. Streitz and P. Markopoulos (Eds.): DAPI 2016, LNCS 9749, pp. 291–301, 2016.
DOI: 10.1007/978-3-319-39862-4_27

All the recent studies have shown that people use such devices in a variety of places: for example in [7] it is stated that 85 % of Americans who played smartphone or tablet-based games indicated that they would want to play games almost anywhere. However, these facts have serious consequences since the usage of smartphones or other similar devices has been shown to occur during driving – despite such activity being banned by law in most countries. This fact is the subject of several research groups worldwide, and a series of scientific surveys and articles have been published on this topic, analyzing the risks and consequences of using handheld devices while driving a car.

The use of smartphones while driving is a growing phenomenon that has reached alarming proportions. A recent AT&T study [8] has shown that 70 % of the people engage in a form of smartphone activity while driving. The most popular multi-tasking activities performed by drivers are texting (61 %) and sending emails (33 %), but the activities range vary from social media, taking selfies and using other mobile applications. Another alarming fact stated in the same study is that 62 % of drivers keep their smartphones within reach, intending to use them while driving.

A particular type of smartphone/tablet activity while driving is gaming. Mobile games are played everywhere and surveys have shown that about 4 % of mobile gamers do this while driving. This may look like a small percentage, but if we take into consideration that, based on a 2014 study [9], a total of 48 million Americans play mobile games on smartphones and tablets, it shows that the estimate number of people playing games while driving is quite worrying.

According to the US National Highway Traffic Safety Administration, distracted driving played a role in 12 % of the teenager's fatal car crashes accidents [10]. In 2012 alone, 3,328 were killed in distracted driving crashes [11]. For adults and older drivers, the main causes of car accidents are the loss of cognitive and motor functions [12], including visual-spatial attention, and speed of processing [13].

2 Related Work and Research Aim

To the best of our knowledge, our study is a pioneer one regarding the analysis of playing mobile games while driving a car. The lack of dedicated research papers on this topic might be explained due to it being included in wider studies targeting the effects of generic mobile use while driving. Some of such recent studies are described in [14–16]. All underline that mobile phone use while driving is associated with increased reaction times at unexpected events, increased vehicle distance from the central axis of the road, and ultimately representing significant safety risks to driving.

In [17], the authors analyze the impact of the most common activities performed with a mobile phone while driving a bicycle. Among them, it includes playing mobile games. This study acknowledges the lack of experiments and research papers regarding gaming while driving, and underlines the importance of analyzing this phenomena due to several media reports of accidents caused by it.

We consider that an explicit research study on gaming while driving is more than needed in this domain, for several reasons. First of all, as shown above, the mobile gaming market is experiencing a huge growth, leading to the development of a variety of attractive, challenging and thus addictive games. Second, a newly appeared research direction, detailed in [18], targets the development of "green" driving mobile apps, which are mobile phone applications which are supposed to be safely used by the driver. Some examples of such existing applications are: Car Tunes Music Player, DriveGain or goDriveGreen.

Furthermore, there are also attempts to develop "green" mobile games, particularly regarding competition between drivers (like FuelFit or Green Auto Rally), with the declared intent by the developers to promote safe and green driving. However this issue is controversial since there is no legal frame allowing such "exceptions" from the general ban on mobile phone use while driving. Also, this raises a storm of questions and risks that need to be properly addressed by research studies, trials and standardized design methodologies approved by the appropriate driving safety organizations and authorities.

Given this context, the research presented in this paper focuses on investigating the influence of playing games on a smartphone while driving in a virtual reality simulator. The eye glance behavior is being analyzed for a series of twelve subjects that are playing games on a touchscreen-based smartphone while driving in 2 types of environments: in a city and on a freeway. The data obtained is compared with a reference set of data – the same drivers and environments, but without the gaming distraction.

The study is part of the NAVIEYES Project [19] which aims to develop an intelligent assistant for mobile devices while driving. The project aims to identify the dangerous situations the driver may encounter, such as missing a traffic sign or lane crossing without watching, and to alert the driver when such events occurs.

3 Experiment Design

In this initial phase of our project we try to identify for how long a driver moves his eyes from the road, in this particular case to the mobile device. Thus, we asked the car drivers to play a game on a mobile device, an action which will distract them from the road, while in order to identify the actions performed by them during both driving and playing actions we used a Tobii eye-tracker, two webcams and the integrated software from the driving simulator. The general architecture of our experiment is presented in Fig. 1, while every component used for this setup is separately presented in the following chapters.

3.1 The Game to Be Played During Experiments

The game chosen for users to play is Splashy Fish (see Fig. 1), a very popular replica of Flappy Bird, game known to be a fun and very addictive one among nowadays mobile games players. The reason for which this game was chosen is the fact that it requires a single finger to control the fish inside the game, being thus extremely simple for the users and plausible to be played while driving. The users must actually tap the touchscreen in order to maintain the fish from colliding with obstacles from the environment.

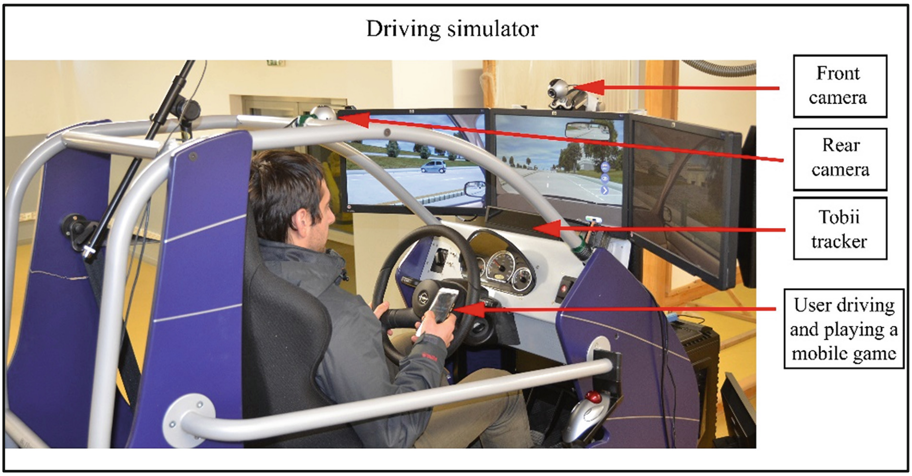

Fig. 1. Experimental setup

3.2 Driving Simulator

During the experiment a virtual driving simulator was used, EF-X by Eca-Faros (see Fig. 2), a very well-known simulator used in other several driving studies [1–5]. The simulator is composed from a right-hand drive vehicle structure equipped with the following Opel vehicle parts: steering wheel with force feedback, clutch, brake and acceleration pedals, manual gear shift, adjustable driver seat, control handles, instrument panel, handbrake, three LCD 19 inch monitors providing 120° horizontal field of

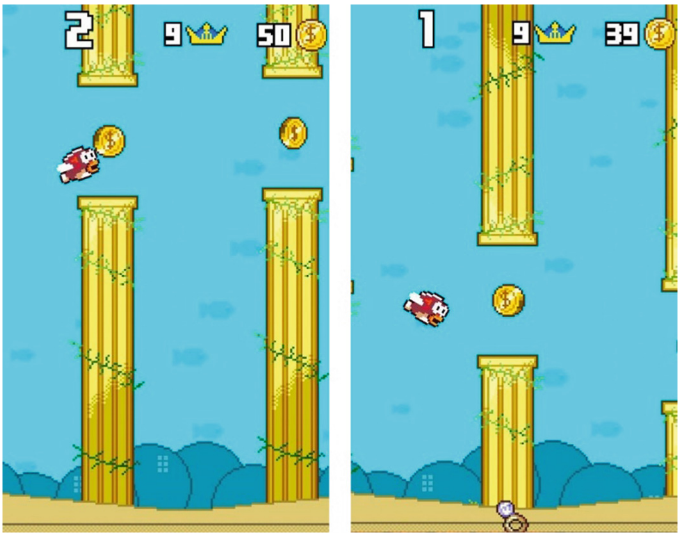

Fig. 2. Splashy fish game screenshots

view used for visual perception of the simulated 3D virtual environment, rear view mirror integrated in the virtual environment and an audio system (Fig. 3).

Fig. 3. EF-X Eca-Faros driving simulator

3.3 Tobii Eye-Tracker and User's Behavior

For this experiment the Tobii eye-tracker device was used in order to identify the time interval during which the user didn't properly looked at the road. The Tobii eyetracker is a device used to track user's eyes position relative to the position where the device is actually placed. As seen in Fig. 1 the device is placed in front of the user, below the middle display in a position where it doesn't affect the user's visibility to the road. The tracker is initially calibrated when the user enters the car and according to initial tests it fully tracks the user's eyes positions when he pays attention to the road. By analyzing the position where the user's held his hand while playing on the mobile device the tracker loses the eyes positions tracking thus triggering an event in the recording app. By analyzing the start and end timestamps we can compute the time interval during which the user didn't pay attention to the road properly, in other words the glance values.

Furthermore, in order to correctly validate the obtained results we placed two webcams on the simulator, one in front of the user and one behind the user. The front camera does actually monitor the user in order to check whether the eye tracker properly identified the glance behavior and also to further investigate exactly what the user does during the time interval when he is playing (or any other activity he performs). The rear camera is focused on the car's board and road path providing information related to speed and/or traffic signs violation.

3.4 Experiment Setup

Twelve subjects (age 20–31) with previous driving and gaming experiences were asked to participate in a series of tests. The current research tried to identify the direct effects of playing mobile games while driving. Thus, two types of possible situations found in real traffic were chosen in order to better evaluate the side effects, a city itinerary (50 km/h speed limit) and a country road (national road with 90 km/h speed limit). The experiment was divided for each of the proposed scenarios into two separate cases. Thus, in one case the drivers were asked only to drive and obey all traffic rules, while in the latter case the drivers were again asked to obey all rules but also to play the Splashy Fish game installed on their mobile device. Also, in order to compensate the fact that all users were knew to the virtual reality driving simulator they were all allowed a simulator accommodation time of 5 up to 10 min in one or both scenarios.

Each driving scenario lasted for 10 min while the users were supposed to obey all traffic rules. The order of the four scenarios (city with/without playing and country with/without playing) were randomly defined for each user in order to avoid possible prediction or accommodation with the environment/scenario. Even if the starting point was the same the users were allowed to drive at their will, except for the city scenarios when the users were asked to turn at least once to the right and at least once to the left just to be sure they won't follow just a straight path through the city.

The parameters investigated in this experiment are the number of improper lane positions, speed infractions, turn signals missed, number of points succeeded while playing the game and of course the fact that the driver crashed or not during the test. For each parameter related to driving the experiment investigated how many times the action was performed and the total duration of them. The experiment also investigated the total number of glances from the road and their average.

4 Results, Evaluation and Discussion

4.1 City Scenario Results and Evaluation

In Table 1 the results obtained by the twelve users for the city scenarios are presented. By comparing the results we found that no significant statistical differences were between the two cases, "normal" and "playing", for total number of improper lane position (L) $t(22) = 0.566$ $p > 0.05$ and for the total number of turn signals missed (T) $t(22) = 0.201$ $p > 0.05$. Also, for the total time of speed infractions (St) $t(16) = 1.94$ $p > 0.05$ no significant differences were found even if the numbers related to speed infractions were three times lower in the case of "playing" compared with "normal" one (St-normal = 14 vs. St-playing = 4). Statistical significant differences were found for the total time of improper (Lt) lane position $t(13) = 2.48$ $p < 0.05$ and for the total number of speed infractions (S) $t(17) = 2.12$ $p < 0.05$. Thus, it results that users had almost the same number of improper lane positions (average L-normal = 2.5 vs. average L-playing = 3), but the total time while they were not properly positioned on their lane had a significant increase during playing test (average Lt-normal = 2.33 s vs. average Lt-playing = 6.75 s). Also, there was a single user that had a crash during City scenario, which happened due to improper lane positioning (User 6). Probably such higher numbers for improper lane positioning are due to the fact that users were not properly accommodated with the simulator and the sensitivity of the steering wheel, but values are comparable for both "normal" and "playing" scenarios. The intriguing part is related to the fact that the total time during which they were running improperly on the lane is a lot higher during the "playing" scenario, proving the fact that the drivers experience a control loss when they are performing an extra action while driving. Surprisingly is also the fact that both number of speed infractions (S) and the total time of speed infractions are lower during the "playing" case, probably the users realizing the fact that they are in a more dangerous situation when performing a supplementary action while driving.

By visually analyzing the images recorded during this City scenario the authors found that users were mostly tempted to play during the waiting time at red light. Basically there was no danger during this case but a few of them still continued to play after the traffic lights were turning green, thus setting the car in motion again with a small delay, however the exact amount of time couldn't be measured accurately. It is also worth mentioning that Lt and St time intervals were automatically measured by the simulator software without decimals thus leading to a small loss in accuracy.

Table 1. Results obtained from the conducted experiment – City scenario (L – number of improper lane position, Lt – improper lane position time, S – number of speed infractions, St – speed infractions time, T – number of turn signals missed, G – number of glances, Ga – glances average time, C – states if the user crashed).

User	City scenario													
	Normal						Playing							
	L	Lt [s]	S	St [s]	T	C	L	Lt [s]	S	St [s]	T	G	Gt [s]	C
1	2	1	2	4	1	No	2	5	1	2	0	61	2.73	No
2	5	7	0	0	3	No	6	11	0	0	3	57	2.52	No
3	3	4	1	1	0	No	3	3	0	0	1	70	2.35	No
4	4	3	2	2	1	No	7	15	0	0	1	65	2.25	No
5	2	2	0	0	1	No	0	0	0	0	0	76	2.6	No
6	4	3	1	1	1	No	7	18	0	0	2	45	2.90	Yes
7	4	3	1	2	2	No	5	12	1	1	2	72	2.35	No
8	0	0	0	0	0	No	1	1	0	0	1	45	2.25	No
9	1	1	0	0	1	No	2	5	0	0	0	64	2.60	No
10	2	2	2	3	1	No	2	4	0	0	1	80	2.12	No
11	0	0	1	1	0	No	1	1	0	0	3	75	1.95	No
12	3	2	0	0	2	No	0	0	1	1	0	60	2.35	No
Avg	2.5	2.33	0.83	1.17	1.08	–	3	6.75	0.25	0.33	1.17	64.17	2.41	–
Total	30	28	10	14	13	–	38	81	3	4	14	770	–	–

4.2 Country Road Scenario Results and Evaluation

Table 2 shows the results obtained for Country road scenarios for both "normal" and "playing" cases. First of all, in this scenario a total number of three users crashed during the "playing" test. For each of them we stopped the test when the event occurred.

Table 2. Results obtained from the conducted experiment – Country road scenario (abbreviations are the same as in the previous table).

User	Country road scenario													
	Normal						Playing							
	L	Lt [s]	S	St [s]	T	C	L	Lt [s]	S	St [s]	T	G	Gt [s]	C
1	9	7	0	0	0	No	12	20	0	0	0	81	1.65	No
2	1	0	1	1	0	No	3	2	0	0	0	90	1.45	No
3	2	1	1	1	0	No	2	2	0	0	1	60	1.56	No
4	8	5	0	0	0	No	6	13	1	1	0	40	2.14	Yes
5	0	0	0	0	0	No	2	2	0	0	0	73	1.65	No
6	3	3	3	2	1	No	0	0	1	1	0	55	1.58	No
7	4	2	2	3	1	No	5	7	0	0	0	103	1.33	No
8	5	4	1	1	0	No	4	9	0	0	0	52	1.75	Yes
9	2	2	0	0	0	No	9	16	0	0	0	53	1.92	Yes
10	3	1	1	2	0	No	2	5	1	1	1	115	1.15	No
11	1	1	2	1	1	No	4	6	0	0	0	97	1.41	No
12	0	0	1	0	0	No	3	7	0	0	0	64	1.53	No
Avg	3.17	2.17	1	0.92	0.25	–	4.33	7.42	0.25	0.25	0.17	73.58	1.59	–
Total	38	26	12	11	3	–	52	89	3	3	2	883	–	–

Also, only by analyzing the total number of speed infractions we can see that while playing on the mobile device users tend to slow down a bit having only 3 speed infractions compared with 12 when no other action was involved. The speed infraction time seems to be lower average St-playing = 0.17 s while average St-normal = 0.92 s (see Fig. 5). Again, similar with the City scenario in the Country road scenario the average Lt-playing = 7.42 s is significantly higher compared with average Lt-normal = 2.17 s (see Fig. 4).

In this scenario there are no significant statistical differences for total number of lane improper position $t(22) = 0.911$ $p > 0.05$ and for the total number of turn signals missed $t(22) = 0.484$ $p > 0.05$ (see Fig. 6 for average and range interval). Significant statistical differences were found for total lane improper position time $t(14) = 2.781$ $p < 0.05$, for number of speed infractions $t(22) = 2.462$ $p < 0.05$ and for the total speed infractions time interval $t(15) = 2.111$ $p < 0.05$.

The authors also found relevant to compare the number of glances and the average glance time, and significant statistical differences were found for the glance time values $t(16) = 8.472$ $p < 0.05$, while for the total number of glances there were no significant statistical differences $t(16) = 2.007$ $p > 0.05$. For the glance test values for users #4,

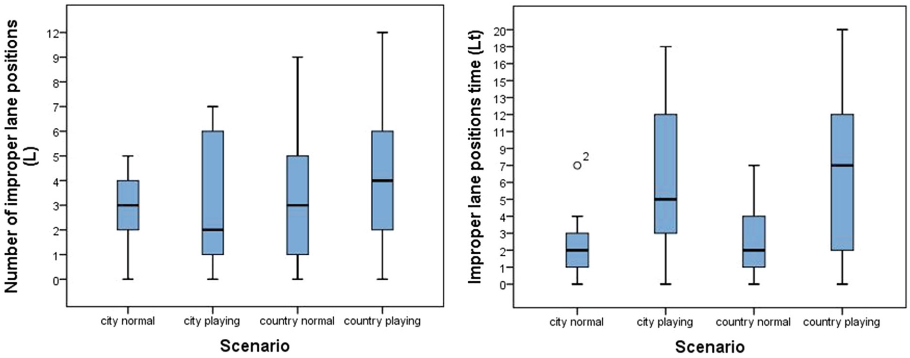

Fig. 4. Number of improper lane positions and improper lane positions duration for all cases

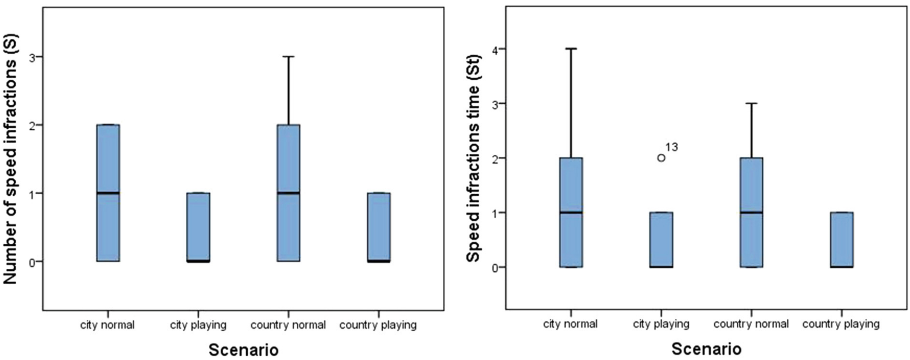

Fig. 5. Number of speed infractions and speed infractions duration for all cases

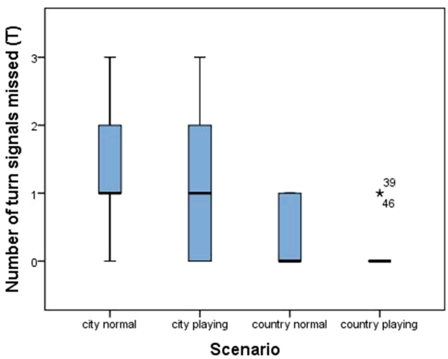

Fig. 6. Number of turn signals missed

#8 and #9 have been excluded from evaluation since they didn't manage to finish the Country road scenario. Values for user #6 were included since he did crash at the end of the test at 9 min 45 s out of the 10 min allocated for test.

4.3 Discussion

It can be stated that the most frequent side-effect underlined by our tests is the control loss of the vehicle's direction since the lane improper position parameter presents the most significant differences with higher values in the "playing" case and for both City and Country road scenarios. This seems to be only related to the time they are actually improperly positioned (Lt-normal vs. Lt-playing values) on the lane. Furthermore, in the Country road scenario it seems that the users "felt" the possible danger and the number of speed infractions are lower in the "playing" case compared with the "normal" case with significant statistical differences. In terms of values this is also valid for the City scenario. Another plausible explanation for this phenomena is the natural occurring driving reflex of speeding down when having the attention distracted from the road by a certain event in the cabin.

A surprisingly fact is that two of the users that crashed during the tests contacted us a couple of days after the experiments to inform us that they were very impressed after their experiences with gaming while driving and as a result they are committed to pay much more attention and be more responsible when driving in real world. They stated that somehow the fact that they crashed so easily should give some insights not just for them but for everyone and especially due to the fact that they didn't crash because of the speed but because of improper lane positioning which is directly a consequence of not properly paying attention to the traffic and road.

5 Conclusions and Future Work

The study described in this paper has clearly shown that playing games does represent a very dangerous activity when driving a car and it should definitely not be performed by any driver. This statement should also involve other smartphone activities like talking, text messaging, taking photos, etc. From our experiments it results that improper lane positioning could be as dangerous as speed infractions and could lead to real life accidents.

As future work, we are planning to extend our research aiming it to identify and analyze the appearance and consequences of the speed decrease pattern that takes place when drivers are playing games, an effect shown in this current study. Also, we plan on identifying which type of activity (talking, texting, taking photos, etc.) is more distracting for the driver and the degree in which it impairs his driving ability and control of the vehicle.

Acknowledgements. This paper is supported by the Romanian Government, specifically MEN – UEFISCDI authority under the program PNII "Partnerships in priority areas", under the project number 240/2014 - NAVIEYES, supporting the collaboration between the company Route 66 and University Transilvania of Brașov.

References

1. Hughes, G.M., Rudin-Brown, C.M., Young, K.L.: A simulator study of the effects of singing on driving performance. Accid. Anal. Prev. **50**, 787–792 (2013)
2. Rudin-Brown, C.M., Edquist, J., Lenné, M.G.: Effects of driving experience and sensation-seeking on drivers' adaptation to road environment complexity. Saf. Sci. **62**, 121–129 (2014)
3. Beanland, V., Lenné, M.G., Underwood, G.: Safety in numbers: target prevalence affects the detection of vehicles during simulated driving. Atten. Percept. Psychophys. **76**(3), 805–813 (2014)
4. Edquist, J., Rudin-Brown, C.M., Lenné, M.G.: The effects of on-street parking and road environment visual complexity on travel speed and reaction time. Accid. Anal. Prev. **45**, 759–765 (2012)
5. Rosenbloom, T., Eldror, E.: Effectiveness evaluation of simulative workshops for newly licensed drivers. Accid. Anal. Prev. **63**, 30–36 (2014)
6. Hatuka, T., Toch, E.: Smart-spaces: smartphone's influence on perceptions of the public space. Toch Research Group, Tel-Aviv University (2012). http://www.aftau.org/site/News2?page=NewsArticle&id=16519
7. Business wire site. http://www.businesswire.com/news/home/20131003005397/en/Goo-Survey-Majority-Americans-Play-Browser-Based-Games#.VH4gYzHF-ao
8. Smartphone Use Behind the Wheel Survey. AT&T, May 2015
9. Big fish games site. http://www.bigfishgames.com/blog/2014-global-gaming-stats-whos-playing-what-and-why/
10. CNN site. http://edition.cnn.com/2013/11/06/tech/mobile/selfies-while-driving/
11. Distracted driving site. http://www.distraction.gov/
12. Regan, M.A., Lee, J.D., Victor, T.W.: Driver Distraction and Inattention: Advances in Research and Countermeasures, vol. 1. Ashgate Publishing, Ltd., Burlington (2013)
13. Anstey, K.J., Wood, J., Lord, S., Walker, J.G.: Cognitive, sensory and physical factors enabling driving safety in older adults. Clin. Psychol. Rev. **25**(1), 45–65 (2005)
14. Leung, S., Croft, R.J., Jackson, M.L., Howard, M.E., Mckenzie, R.J.: A comparison of the effect of mobile phone use and alcohol consumption on driving simulation performance. Traffic Inj. Prev. **13**(6), 566–574 (2012)
15. Yannis, G., Papathanasiou, E., Postantzi, E., Papadimitriou, E.: Impact of mobile phone use and music on driver behaviour and safety by the use of a driving simulator. In: Proceedings of the 3rd International Conference on Driver Distraction and Innatentio, 17pp (2013)
16. Zhao, N., Reimer, B., Mehler, B., D'Ambrosio, L.A., Coughlin, J.F.: Self-reported and observed risky driving behaviors among frequent and infrequent cell phone users. Accid. Anal. Prev. **61**, 71–77 (2013)
17. De Waard, D., Lewis-Evans, B., Jelijs, B., Tucha, O., Brookhuis, K.: The effects of operating a touch screen smartphone and other common activities performed while bicycling on cycling behavior. Transp. Res. Part F Traffic Psychol. Behav. **22**, 196–206 (2014)
18. Nykänen, A.: Testing of mobile apps intended for use while driving. In: AstaZero Researchers Day – Emerging Trends in Active Safety for Road Vehicles Symposium, 14 April 2015
19. NaviEyes research project site. http://navieyes.unitbv.ro