Article

The Effects of Age, Gender, and Control Device in a Virtual-Reality Driving Simulation

Wen-Te Chang

Department of Arts and Design, National Taipei University of Education; wtchang@mail.tea.ntue.edu.tw

* Correspondence: wtchang@mail.ta.ntue.edu.tw; +886-9366-519-157

Abstract: The application of Virtual Reality in a driving simulation is not novel, yet little is known about the use of this technology by senior populations. The effects of age, sex, control device (joystick or handlebar), and task type on wayfinding proficiency using a virtual reality (VR) driving simulation were explored. The driving experimental model involved 96 randomly recruited participants, including 48 young people and 48 seniors (split evenly by gender in each group). The experimental results and statistical analyses indicate that in a VR driving scenario task type significantly affected VR driving performance. Navigational scores were significantly higher for the straight (easy) task than for the curved (difficult) task. The aging effect was the main reason for significant and interacting effects of sex and control device. It was found that interactions between age and sex difference indicated that the young group exhibited better wayfinding performance than the senior group, and in the young group males had better performance than females. Similarly, interactions between age and control device indicated that the handlebar control device type resulted in better performance than the joystick device in the young group, but no difference was found in the senior group due to age or learning effects. Findings provide an understanding of the evaluation of the interface designs of navigational support systems, taking into consideration any effects of age, sex, control device, and task type within three-dimensional VR games and driving systems. With a VR driving simulator, seniors can test drive inaccessible products, such as electric bicycles or cars, using a computer at home.

Keywords: VR, Aging Effect; Gender difference; Control Device; Wayfinding Strategy

1. Introduction

The application of Virtual Reality (VR) in a driving simulation is not novel, yet little is known about the use of this technology by senior populations. VR wayfinding tasks may be more difficult for seniors than for young people (Mateus et al., 2013; Mott et al., 2014). Previous research shows that cognitive-related responses while using VR, including use of home-automation systems for wayfinding, vary with age (Polich, 2007; de Tommaso, et al., 2016). With three-dimensional (3D) VR driving simulators, researchers can create a safe and replicable stimulus, thereby enabling empirical exploration of responses to interface designs and VR conditions (Kemeny, 2014). Despite this advantage, previous studies have argued that 3D VR simulation may provide little benefit in wayfinding tasks, due to issues of task complexity and personal differences (Mustikawati, Yatmo, & Atmodiwirjo, 2018).

To simulate real driving performance, it is important that the control device be as similar as possible to real-world circumstances. It was found from the current electrical vehicle designs for the seniors employed two main types of control device: a handlebar or a joystick (Figure 1-a & Figure 1-b). Previous research has seldom addressed differences in the operational performance of these two types of control device. It is not known how the choice of control device may affect other wayfinding factors such as sex, task difficulty, etc.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 May 2020 doi:10.20944/preprints202005.0074.v1

Peer-reviewed version available at Symmetry 2020, 12, 995; doi:10.3390/sym12060995

In this study, we planned a navigational experiment to assess the differences between two popular control devices (handlebar and joystick) in relation to age and sex. Through a navigation experiment on the differences between control device (handle/ joystick) in relation to age, sex, and task difficulty (easy and difficult) was carried out. The study results are expected to benefit VR interface design and research for the aged.

The following specific results were hypothesized:

(1). There will be an age effect.

(2). There will be a sex effect.

(3). There will be a control device effect.

(4). There will be a task type effect.

(5). There will be interactions among navigation performance, age, sex, task type, control device, or wayfinding strategies.

a. Handlebar control device b. Joystick control device

Figure 1. The two types of control device in this study: (a) handlebar control device and (b) joystick control device

2. Materials and Methods

A 2 x 2 x 2 x 2 mixed-design ANOVA was conducted, with age (young and senior), sex (female and male), and control device (handlebar and joystick) as the between-subject factors, and two task types (straight and curved) as the within-subject factors.

2.1 Participants

Participants were randomly assigned to one of the between-subject factors (sex and control device). For the driving experiment (N = 96), we recruited participants for the young (n = 48) and senior (n = 48) groups, both evenly balanced by sex (24 females and 24 males). The young group comprised university students from the design school of Ming-Chuan University, Taiwan, and ranged in age from 19–30 years (mean = 20.96, SD= 2.6). All of the senior participants were retirees, recruited from the Activity Center of the Elderly, North Branch of Taoyuan County, Taiwan, and were selected for participation based on the criterion that they reported daily use of a smart phone. Their ages ranged from 60–83 years (mean = 66.60, SD= 5.8). All participants were paid approximately US$7 per hour for their participation.

2.2 Task type

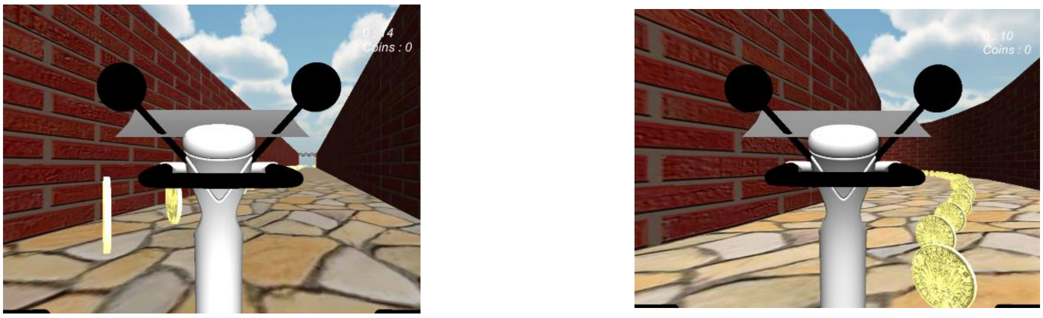
Two task types (straight track and curved track) were developed. The task was to collect coins that appeared to be floating on the track by driving a simulated motorcycle along a 300m VR track at a speed of 100 m/min. The simulation allowed only forward motion towards the end goal and did not allow backwards motion. Participants were asked to collect as many coins as possible along the course, from a maximum of 100. The participants' total numbers of coins collected were used as an indicator score of navigational proficiency. Task types were as follows:

(1). Easy: straight track (see Figure-2a), coins spread randomly.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 May 2020 doi:10.20944/preprints202005.0074.v1

Peer-reviewed version available at Symmetry 2020, 12, 995; doi:10.3390/sym12060995

(2). Difficult: curved track (see Figure-2b), four curves, coins spread randomly.



a. Straight track (easy task) b. Curved track (difficult task)

Figure 2. The experimental scene and navigational task types i.e., (a) straight track and (b) curved track tasks.

2.3 VR Control Device

Two VR control-device types (handlebar and joystick) were assessed:

(1). Handlebar: The handlebar had the form and appearance of motorcycle handlebars (Figure-1a, Yamaha game handlebar). Two hands were needed for operation. The user twisted the right handgrip to accelerate (10%), and used the brake to stop.

(2). Joystick: The joystick was similar to the popular game control device (Figure-1b, Rockfire QF-8000US game joystick). One hand was needed for operation. The user controlled the direction and speed by pointing the stick in the desired direction.

2.4 Procedure

Unity software was used to construct an interactive VR interface. All of the navigational settings were run on a Microsoft operating system and displayed on an all-in-one computer with a 23-inch LCD. The resolution was 1024 x 768 pixels and the frame rate was 85 Hz. The activities of the participants were monitored throughout the experiment.

In an initial practice session, the specifications of the experiment and the task to be performed were verbally explained to the participants, who were asked to interact with the control device by conducting several practice tasks. No time constraint was imposed during the warm-up session. The session ended when the participant reported confidence in having a basic understanding of the interface. One week after the practice session, participants returned for testing. They completed the two aforementioned designated object wayfinding tasks (straight and curved tracks). Testing sessions generally lasted approximately 30 min and 1 h for the young and senior groups, respectively.

2.5 Data analysis

As an indicator of navigational performance, the numbers of coins collected were scored and analyzed using MANOVA. Interactive effects were further analyzed to identify the correlative effects among the factors.

Previous studies indicated that wayfinding scores significantly correlated with turns and hesitation frequency (Coluccia & Iouse, 2004), but here, backtracking frequency and search time did not vary with task difficulty. Thus, backtracking frequency, wrong turns, and hesitation frequency were not analyzed. Each task was confirmed by the research staff when the task was completed.

3. Results

3.1 Overall results

Peer-reviewed version available at *Symmetry* **2020**, *12*, 995; doi:10.3390/sym12060995

Table 1 presents the means and standard deviations of navigational scores by split data of age, task type, sex, and control device. Navigational proficiency scores (collected coins) were significantly higher for the straight/easy track than for the curved track (F (1, 88) = 52.11, p < .001). The main effects of age were noted to be significant (F (1, 88) = 71.10, p < .001). The results indicated that the young group navigated significantly better than did the senior group. Other between-subject factors, including sex (F (1, 88) = 1.62, p >.05), and control device (F (1, 88) = 1.44, p >.05), were not significant.

Table 1. Means and Standard Errors of Navigation Times

The Young group							The Senior group						
			Task type							Task type			
Gender	control	N	straight		curve		Gender	control	N	straight		curve	
male	handlebar	12	74.58	(12.14)	78.13	(18.32)	male	handlebar	12	67.42	(9.04)	70.63	(13.55)
	joystick	12	55.46	(9.19)	30.00	(17.63)		joystick	12	56.71	(11.31)	26.13	(14.83)
female	handlebar	12	65.46	(14.79)	72.58	(16.86)	female	handlebar	12	60.71	(11.62)	48.88	(24.80)
	joystick	12	56.33	(4.11)	27.29	(20.27)		joystick	12	60.63	(9.40)	40.79	(29.11)

3.2 Interactive effects

The data revealed three two-way interactive effects, but the three-way and four-way interactive effects were not significant. The first two-way interactive effect found was between task type and age (F (1, 88) = 56.32, p < .001). A significant difference between the two tasks was evident in the navigational scores of the senior group, whose navigational performance was better on the straight track than on the curved track. There was no significant difference between the two tracks in the navigational scores of the young group. Task type significantly affected the navigational performance of the senior group, but not that of the young group.

The second two-way interactive effect found was between sex and age (F (1, 88) = 7.06, p < .01). A significant effect was evident in the navigational scores of the young group: males' scores were higher than those of females. No significant effect of sex was found in the navigational scores of the senior group.

The third two-way interactive effect found was between control device and age (F (1, 88) =7.44, p < .01). In the young group, the control device significantly affected navigational scores: the handlebar device scored higher than the joystick. Nevertheless, no significant difference was found in the navigational scores of the senior participants related to the control device. Thus, the young group scored higher than the senior group, and the type of control device significantly affected the navigational performance of the young group but not of the senior group.

4. Discussion

4.1 Age and task type difference

The experimental results showed that the navigational proficiency scores of the young group were significantly higher than those of the senior group (young group = 67.3; senior group = 44.2). Thus, our first hypothesis that there would be an age effect was supported by the study results. Our hypothesis that there would be a task-type effect was also supported by the study results. One possible explanation for this is that the hippocampal formation (HPC) and related structures in the medial temporal lobe of the brain are necessary for encoding cognitive maps (Parslow et al., 2004). The HPC is one of the first structures to show atrophic changes with age (Raz et al., 2004). In addition, a decline in sensory abilities is common in aging; thus, place learning may be impaired when there are HPC and sensory changes due to aging effects (Davis & Weisbeck, 2015). These results are consistent with previous studies that addressed statements of individual difference (Polich, 2007; Dowiasch et al., 2015) and task-type effects (Coluccia & Iouse, 2004).

The straight-track task resulted in significantly higher scores than the curved-track task (straight track = 62.2; curved track = 49.30). Thus, the fourth hypothesis that there would be a task-type effect was also supported by the study results, as it has been by previous research (Coluccia, Bosco, & Brandimonte, 2007). As Coluccia, Iosue, and Brandimonte (2007) stated, task-difficulty effects need to be taken into account in any analysis of navigational performance. Individual differences appear only when the task is relatively difficult.

It was hypothesized that the task-type effect would be interactively affected by age and other variables. Our results show a significant interactive effect between age and task type, as shown in Figure 3. Split data for the young group showed no significant difference in either task type (straight track = 67.04; curved track = 67.55). For the senior group, however, navigational performance was significantly better for the straight track (straight track = 57.28; curved track=31.05). This phenomenon seems to correspond to our fifth hypothesis that there would be an interaction among navigation performance, age, sex, task type, control device, and wayfinding strategies, as supported by the results of both this research and previous studies (Mateus et al., 2013; Mott et al., 2014). A possible reason is another correlative effect, such as familiarity or a learning effect (Darken & Sibert, 1996) for the control device or, since the young group was more familiar with the control device than the senior group, that might have eliminated any task effect in the young group.

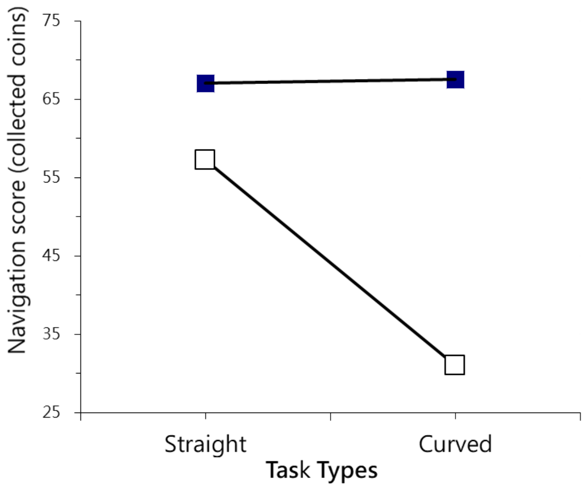


Figure 3. Effects of age (■young group, □senior group) and task type on navigation scores

4.2 Age and sex differences

As the statistical analyses indicated, there was no significant effect of sex (males = 57.48; females = 53.98). Thus, the second hypothesis, that there would be a sex effect, was not supported by the results. However, a significant interaction between age and sex was revealed. The significant interactive effect was seen in the navigational scores of the young group split data: males scored higher than females (males = 72.69; females = 61.90). However, no significant effect of sex was found among the senior participants (males = 42.27; females = 46.06), as shown in Figure 4. The young group scored higher than the senior group. Thus, there was a significant effect of sex on navigational performance in the young group, but not in the senior group.

This result partially aligns with previous claims that males may perform better than females in VR wayfinding tasks (e.g., Lawton, 1996; Chen, Chang, & Chang, 2009), but that this difference may disappear due to other interactive effects. A possible reason is that the decline in sensory abilities caused by aging causes the sex effect to be eliminated, while the sex difference remains significant in the young (de Tommaso et al., 2016). Additionally, males under 30 years of age may be sociologically positioned to be confident in, and familiar with, VR simulations generally, and thus better able to direct motion in an unfamiliar VR simulation, as compared to any other group, whether based on sex or age.

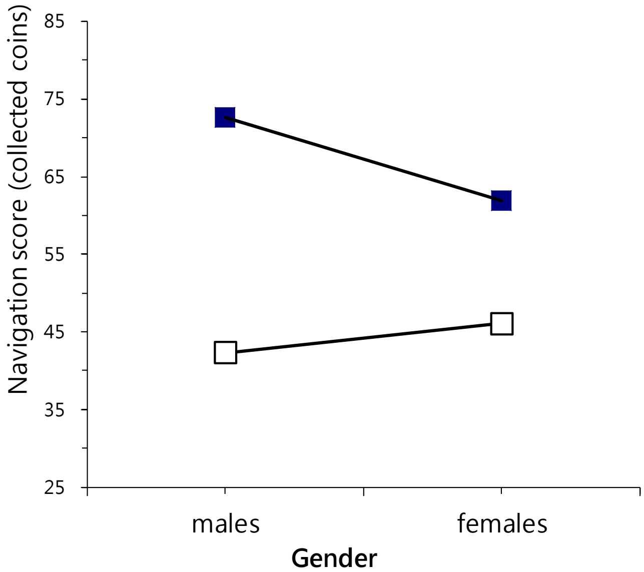


Figure 4. Effects of age (■young group, □ senior group) and gender on navigation scores

4.3 Age and control devices

No significant effect of the control device was found (handlebar = 57.38; joystick = 54.08). Thus, the third hypothesis, that there would be a control-device effect was not supported by the research results. However, a significant interaction between age and control device was found, as shown in Figure 5. Handlebar-device scores were significantly higher than joystick scores in the youth group (handlebar = 72.69; joystick = 61.91), yet no significant difference was found in senior participants for a control-device effect (handlebar = 42.07; joystick = 46.26). These data imply that the navigational performance of the young group was better than that of the senior group, and that there was a significant effect of control device on the navigational performance of the young group but not on the senior group. There are two possible reasons. The first is similar to the argument regarding a decline with age as noted in the previous section: the effect of the control device was eliminated by the age effect in the senior group, but was still present in the young group (Dowiasch et al., 2015). The second is the issue of familiarity; the young generation may get familiar to the control device quicker than the senior people. The previous studies have argued that familiarity may interactively affect other effects (Darken & Peterson, 2002). The results of this study imply that to overcome any effect of familiarity, a control device developed especially for the senior group might provide a better operating experience.

Note that this experiment did not include a task type with a different VR setting, such as third axis height differnce, as an example of a more difficult task that is beyond ordinary human spatial comprehension. In addition, a previous study pointed out that the feelings of reality and immersion experienced by users familiar with VR environments might obscure comparisons of VR performance (Stavropoulos et al., 2017). A future enhancement of the present study would be to include other kinds of control devices, such as one developed especially for seniors (Chen, Chang, & Chang, 2009) and/or VR features such as field of view (Choi, 2011; Walch et al., 2017) to further pinpoint the interactions among VR characteristics, sex, navigational support mode, and wayfinding strategies (Lawton, 1996; Gramann et al., 2005).

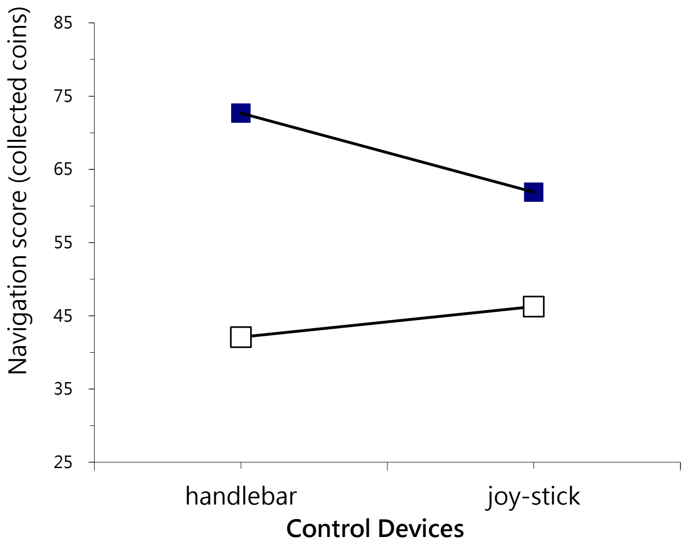


Figure 5. Effects of age (■young group, □ senior group) and control device on navigation scores

5. Conclusions

Our experimental results and statistical analyses indicate that in a VR driving scenario task type significantly affected VR driving performance. Navigational scores were significantly higher for the straight (easy) task than for the curved (difficult) task. The aging effect was the main reason for significant and interacting effects of sex and control device. It was found that interactions between age and sex difference indicated that the young group exhibited better wayfinding performance than the senior group, and in the young group males had better performance than females. Similarly, interactions between age and control device indicated that the handlebar control device type resulted in better performance than the joystick device in the young group but no difference was found in the senior group due to age or learning effects.

Our results can be used to evaluate VR technology in a driving simulation with the interface designs of navigational support systems, taking into consideration aging, sex differences, control device, and task type, in 3D VR games, and including VR driving systems. With a VR driving simulator, seniors can test drive inaccessible products, such as electric bicycles or cars, using a computer at home.

Funding: Financial support of this research study by National Science Council under the grant NSC 101-2628-H-130-002-MY2 is gratefully acknowledged.

References

1. Chen, C.-H.; Chang, W.-C.; Chang, W.-T. Gender differences with regard to wayfinding strategies, navigational support design, and task difficulties for user wayfinding. *Journal of Environmental Psychology*, 2009, 29 (2), 220-226.
2. Choi, G. The Impacts of Wayfinding Affordance on User Experience in Virtual Worlds. *International Journal of Computer Information Systems and Industrial Management Applications*, 2011, 3, 912-923
3. Coluccia, E.; Iosue, G. Gender differences in spatial orientation: A review. *Journal of Environmentsal Psychology,* 2004, 24(3), 329-340.
4. Coluccia, E.; Bosco, A.; Brandimonte, M. A. The role of visuo-spatial working memory in map drawing. *Psychological Research,* 2007, 71, 359-372.

Peer-reviewed version available at *Symmetry* **2020**, *12*, 995; doi:10.3390/sym12060995

5. Coluccia, E.; Iosue G.; Brandimonte M. A. The relationship between map drawing and spatial orientation abilities: A study of gender differences. *Journal of Environmental Psychology*, 2007, 27, 135-244.
6. Darken, R. P.; Sibert, J. L. Navigating large virtual spaces. *The International Journal of Human-Computer Interaction*, 1996, 8(1), 49-72.
7. Darken, R.; Peterson, B. Spatial orientation, wayfinding and representation. In K. Stanney, (Eds.), *Handbook of Virtual Environmentss: Design, Implethe maletation and Applications*. Mahwah, New Jersey: Lawrence Erlbaum Associates. 2002.
8. Davis, R.L.; Weisbeck, C. Search Strategies Used by Older Adults in a Virtual Reality Place Learning Task. *Gerontologist*, 2015, 55 (1), 118-127.
9. de Tommaso, M.; Ricci, K.; Delussi, M.; Montemurno, A.; Vecchio, E.; Brunetti, A.; Bevilacqua, V. Testing a novel method for improving wayfinding by means of a P3b Virtual Reality Visual Paradigm in normal aging. *Springer Plus*, 2016, 5,1297, DOI 10.1186/s40064-016-2978-7,12p.
10. Dowiasch, S.; Marx, S.; Einhauser, W.; Bremmer, F. Effects of aging on eye movements in the real world. *Frontiers in Human Neuroscience,* 2015, 9, 12. https ://doi.org/10.3389/fnhum.2015.00046
11. Gramann, K.; Muller, H. J.; Eick, E. M.; Schonebeck, B. Evidence of separable spatial representations in a virtual navigation task. *Journal of Experimental Psychology: Human Perception and Performance*, 2005, 31 (6), 1199-1223.
12. Hilton, C.; Miellet, S.; Slattery, T. J.; & Wiener, J. Are age-related deficits in route learning related to control of visual attention? *Psychological Research*, 2019, Feb 18, 2019, 12p, https://doi.org/10.1007/s00426-019-01159-5
13. Kemeny. A. From Driving Simulation to Virtual Reality. *Laval Virtual VRIC'14*, Apr., 2014, pp.1-5, Laval, France.. <hal-01142689>
14. Kitchin, R. M. Exploring spatial thought. *Environments and Behavior*, 1997, 29, 123-156.
15. Kyllonen, P. C.; Lohman, D. F.; Woltz, D. J. Componential modeling of alternative strategies for performing spatial tasks. *Journal of Educational Psychology*, 1984, 76, 1325-1345.
16. Lawton, C. A. Strategies for indoor way-finding:the role of orientation. *Journal of Environmental Psychology*, 1996, 16, 137-145.
17. Lynch, K. T*he image of the city, Cambridge*, MA: Harvard University Press, 1960.
18. Mateus, C.; Lemos, R.; Silva, M.F.; Reis, A.; Fonseca, P.; Oliveiros, B.; Castelo-Branco, M. Aging of low and high level vision: from chromatic and achromatic contrast sensitivity to local and 3D object motion perception. *PLoS ONE*, 2013, 8(1), e55348.
19. Mott, K.K.; Alperin, B.R.; Holcomb, P.J.; Daffner, K.R. Age-related decline in differentiated neural responses to rare target versus frequent standard stimuli. *Brain Res*, 2014, 1587, 97–111.
20. Mustikawati, T.; Yatmo, Y.; Atmodiwirjo, P. Wayfinding beyond signage: rethinking the role of spatial objects and object relations. *IOP Conference Series: Earth and Environmental Science*, 2018, 195, 8p. doi: 10.1088/1755-1315/195/1/012083.
21. Parslow, D. M.; Rose, D.; Brooks, B.; Fleminger, S.; Gray, J. A.; Giampietro, V.; Morris, R. G. Allocentric spatial memory activation of the hippocampal formation measured with fMRI. *Neuropsychology*, 2004, 18, 450–461.doi:10.1037/0894-4105.18.3.450
22. Polich, J. Updating P300: an integrative theory of P3a and P3b. *Clin Neurophysiol,* 2007, 118(10), 2128–2148.
23. Raz, N.; Rodrigue, K.; Head, D.; Kennedy, K.; Acker, J. Differential aging of the medial temporal lobe: A study of a five-year change. *Neurology*, 2004, 62, 433–438. doi:10.1212/01. wnl.0000106466.09835.46
24. Sadeghian, P.; Kantardzic, M.; Lozitskiy, O.; Sheta, W. The frequent wayfinding-sequence fws; methodology: Finding preferred routes in completing. *International Journal of Human-Computer Studies*, 2006, 4(4), 356-374.

25. Stavropoulos, V.; Wilson, P.; Kuss, D.; Griffiths, M.; Gentile, D. A multilevel longitudinal study of experiencing virtual presence in adolescence: the role of anxiety and openness to experience in the classroom. *Behaviour & Information Technology*, 2017, 36(5), 524-539, DOI: 10.1080/0144929X.2016.1262900
26. Wagner, J.; Yao, Q.; Alexander, K.; Pidgeon, P. Assessment of an Automotive Driving Simulator to Educate Novice Drivers, The Chronicle for DE Professionals, 2013, pp. 19-32, Mechanical Engineering.
27. Walch, M.; Frommel, J.; Rogers, K.; Schüssel, F.; Hock, P.; Dobbelstein, D.; Weber, M. Evaluating VR Driving Simulation from a Player Experience Perspective, *CHI EA '17: Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, May 2017, pp.2982–2989, https://doi.org/10.1145/3027063.3053202
28. Yang, Y.; Merrila, E.C. Cognitive and personality characteristics of masculinity and femininity predict wayfinding competence and strategies of men and women, *Sex Role*s, 2017, 76, 747–758.