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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, Taipei 10671, Taiwan; wtchang@mail.ntue.edu.tw; Tel.: +886-966-519-157

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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, gender, control device (joystick or handlebar), and task type on wayfinding proficiency using a virtual reality (VR) driving simulation were explored. The driving experiment model involved 96 randomly recruited participants, namely, 48 young people and 48 seniors (split evenly by gender in each group). Experiment results and statistical analyses indicated that, in a VR driving scenario, task type significantly affected VR driving performance. Navigational scores were significantly higher for the straight (easy/symmetrical straight route) task than those for the curved (difficult/asymmetrical curved route) task. The aging effect was the main reason for the significant and interacting effects of gender and control device. Interactions between age and gender difference indicated that the young group exhibited better wayfinding performance than the senior group did, and in the young group, males had better performance than that of females. Similarly, interactions between age and control device indicated that the handlebar control-device type resulted in better performance than the joystick device did 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, gender, 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 by using a computer at home.

Keywords: VR; aging effect; gender difference; control device; wayfinding strategy.

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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 [1]. It was demonstrated that the aging effect would cause individual differences in VR operation performance [2]. The elder group was not as well adapted to a virtual environment (VE) as the other age generation [2,3].

Gender could also trigger individual differences of VR task performance [4]. Some previous studies claimed that males tend to have significantly better performance than that of females on spatial-capacity tests [5], while others argued that the gender effect disappeared on mapping tasks [6]. Other studies proposed that cognitive mapping compression is crucial to the reason behind the gender effect on spatial capacity [7]. Discussions of the interactive effect between age and gender were rarely geared by previous research [8].

With three-dimensional (3D) VR driving simulators, researchers can create a safe and replicable stimulus, thereby enabling the empirical exploration of responses to interface designs and VR conditions [9]. To simulate real driving performance, it is important that the control device be as similar as possible to real-world circumstances [10]. It was found from the current electric-vehicle designs that seniors employed two main types of control device: a handlebar or a joystick (Figure 1a,b). Previous research seldom addressed differences in the operational performance of these two types of control devices. It is not known how the choice of control device may affect other factors such as age and gender.

(**a**) (**b**)

Figure 1. Two types of control device in this study: (**a**) Handlebar and (**b**) joystick control device.

Despite these VR simulation advantages of safety and convenience, previous studies argued that 3D VR simulations may provide little benefit in wayfinding tasks due to issues of task complexity [11]. There was an interactive effect between task type and individual difference. Individual differences appear only when the VR simulative route is relatively difficult [12,13]. In the context of string theory, the nature of symmetries or asymmetries allows one to clearly extract the fundamental degrees of freedom of a theory by choosing an appropriate gauge [14]. To plan the VR driving task on the basis of geometrical practice, it can be hypothesized that a driving route with simple straight or symmetrical features would have better task performance than a complicated curved or asymmetrical route.

In this study, we planned a navigational experiment to assess the differences between two popular control devices (handlebar and joystick) in relation to age, gender, and task difficulty (easy and difficult). Thus, the aim of the present study was to explore the correlation between factors that influenced the VR driving simulation.

The following specific results were hypothesized on VR-simulated task performance:

(1) there is an age effect;
(2) there is a gender effect;
(3) there is a control-device effect;
(4) there is a task-type effect; and
(5) there are interactions between navigation performance, age, gender, task type, and control device.

2. Materials and Methods

We conducted 2 × 2 × 2 × 2 mixed-design ANOVA with age (young and senior), gender (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.

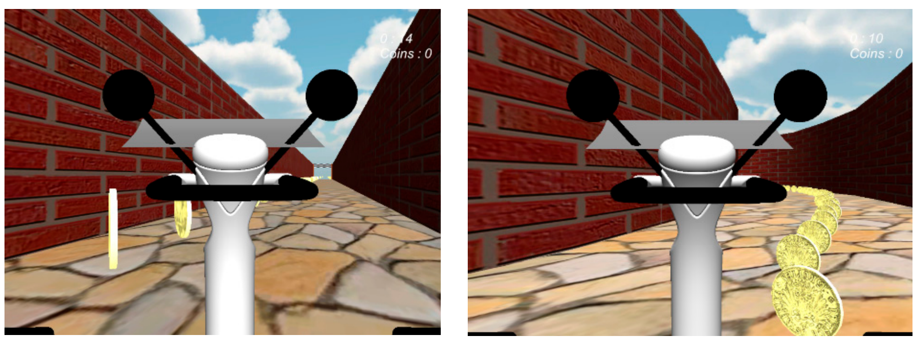
2.1. Participants

Participants were randomly assigned to one of the between-subject factors (age, gender 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 gender (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 to 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 on the basis of the criterion that they reported daily use of a smart phone and computer. Their ages ranged from 60 to 83 years (mean = 66.60, SD = 5.8). All participants were paid approximately USD 7 per hour for their participation.

2.2. Task Types

Two task types (simple/symmetrical straight track and difficult/asymmetrical 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 300 m 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, with a maximum of 100. The participants' total number of coins collected was used as an indicator score of navigational proficiency. Task types were as follows:

(1) Easy: straight track (see Figure 2a)—coins spread along an invisible continued symmetrical straight line with four turns of sixty degrees.
(2) Difficult: curved track (see Figure 2b)—coins spread along an invisible continued asymmetrical curved line with four turns.



(**a**) (**b**)

Figure 2. Experiment scene and navigational-task types. (**a**) Straight-track (easy) and (**b**) curved-track (difficult) tasks.

2.3. VR Control Device

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

(1) 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 the brake to stop.
(2) Joystick: Similar to popular game control devices (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 × 768 pixels and 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 multivariate ANOVA (MANOVA). Interactive effects were further analyzed to identify the correlative effects among the factors. Analysis was conducted using IBM SPSS Statistics 22.0 software (SPSS, Inc., Chicago, IL, USA). A p-value < 0.05 was considered significant.

Previous studies indicated that wayfinding scores were significantly correlated with turns and hesitation frequency [11]. 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

Table 1 presents the means and standard deviations of navigational scores by split data of age, task type, gender, and control device. Navigational-proficiency scores (collected coins) were significantly higher for the straight/easy track than those for the curved track/ difficult ($F(1, 88) = 52.11$, $p < 0.001$, $\eta_p^2 = 0.372$). The main effects of age were noted to be significant ($F(1, 88) = 71.10$, $p < 0.001$, $\eta_p^2 = 0.447$). Results indicated that the young group navigated significantly better than the senior group did. Other between-subject factors, including gender ($F(1, 88) = 1.62$, $p > 0.05$, $\eta_p^2 = 0.018$), and control device ($F(1, 88) = 1.44$, $p > 0.05$, $\eta_p^2 = 0.016$), were not significant.

Table 1. Means and standard errors of navigation times**.**

Young Group							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

Data revealed three two-way interactive effects, but three- and four-way interactive effects were not significant. The first two-way interactive effect found was between task type and age ($F(1, 88) = 56.32$, $p < 0.001$, $\eta_p^2 = 0.390$) (see Table 2). 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.

Table 2. Multivariate ANOVA (MANOVA) for independent variables affecting virtual-reality (VR) task performance (dB).

		SS	df	MS	F	Pr	Partial η2
Within-subject contrasts	Task type (A)	7937.449	1	7937.45	52.11	***	0.372
	A×B	173.47	1	173.47	1.14		0.013
	A×C	13.81	1	13.81	0.09		0.001
	A×D	8580.06	1	8580.06	56.32	***	0.390
	A×B×C	13.81	1	13.81	0.09		0.001
	A×B×D	409.79	1	409.79	2.69		0.030
	A×C×D	260.17	1	260.17	1.71		0.019
	A×B×C×D	814.69	1	814.69	5.35		0.057
	Error(factor1)	13405.37	88	152.33			
Between-subject effects	Gender (B)	586.25	1	586.25	1.62		0.018
	Control device (C)	521.73	1	521.73	1.44		0.016
	Age (D)	25680.31	1	25680.31	71.10	***	0.447
	B×C	32.99	1	32.99	0.09		0.001
	B×D	2548.44	1	2548.44	7.06	**	0.074
	C×D	2688.76	1	2688.76	7.44	**	0.078
	B×C×D	877.66	1	877.66	2.43		0.027
	Error	31785.74	88	361.20			

Note: SS = sum of square; df = degree of freedom; MS = mean square; Pr = probability. ** < 0.01; *** < 0.001.

The second two-way interactive effect found was between gender and age ($F (1, 88) = 7.06$, $p < 0.01$, $\eta_p^2 = 0.074$). 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 gender was found in the navigational scores of the senior group.

The third two-way interactive effect found was between control device and age ($F (1, 88) =7.44$, $p < 0.01$, $\eta_p^2 = 0.078$). 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 senior participants related to the control device. Thus, the young group scored higher than the senior group did, 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

Experiment 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. 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 [15]. The HPC is one of the first structures to show atrophic changes with age [16]. 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 [2,17]. These results are consistent with previous studies that addressed statements of individual difference [18–20] and task-type effects [11].

The straight-track task resulted in significantly higher scores than those of 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 was by previous research [12]. As Coluccia, Iosue, and Brandimonte [21] stated, task-difficulty effects need to be considered 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 showed 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).

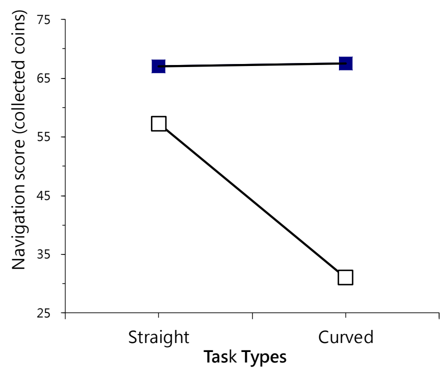


Figure 3. Effects of age (■, young group; □, senior group) and task type on navigation scores.

This phenomenon seems to correspond to our fifth hypothesis that there would be an interaction between navigation performance, age, gender, task type, and control device, as supported by the results of both this research and previous studies [1,22]. A possible reason is another correlative effect, such as familiarity, a learning effect [23,24] for the task types, or since the young group adapted to the task types (symmetrical straight route and asymmetrical curved route) faster than the elder group did, which might have eliminated any task effect in the young group [10].

4.2. Age and Gender Differences

As the statistical analyses indicated, there was no significant effect of gender (males = 57.48; females = 53.98). Thus, the second hypothesis that there would be a gender effect was not supported by the results. However, significant interaction between age and gender was revealed. The significant interactive effect was seen in the navigational scores of the young-group split data: males scored higher than females did (males = 72.69; females = 61.90). However, no significant effect of gender was found among senior participants (males = 42.27; females = 46.06), as shown in Figure 4. The young group scored higher than the senior group did. Thus, there was a significant effect of gender on navigational performance in the young group, but not in the senior group [2].

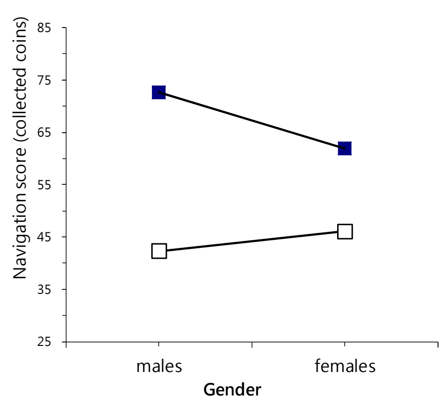


Figure 4. Effects of age (■, young group; □, senior group) and gender on navigation scores.

This result partially aligns with previous claims that males may perform better than females in VR wayfinding tasks [5,13], 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 gender effect to be eliminated, while gender difference remains significant in the young [4]. Additionally, males under

30 years of age may be sociologically positioned to generally be confident in, and familiar with, VR simulations, and thus better able to direct motion in an unfamiliar VR simulation as compared to any other group, whether based on gender or age [8,22].

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 the 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).

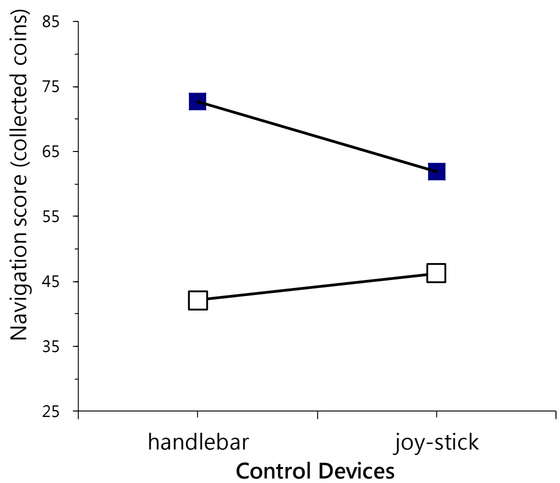


Figure 5. Effects of age (■, young group; □, senior group) and control device on navigation scores.

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 the 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 [20]. The second is the issue of familiarity. The young generation may become familiar with the control device quicker than senior people can. Previous studies argued that familiarity may interactively affect other effects [25,26]. 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.

4.4. Limitations

This experiment did not include a task type with various complicated VR settings, such as more applications based on string theory [23,27,28], as an example of a more difficult task that is beyond ordinary human spatial comprehension. In addition, a previous study indicated that the feelings of reality and immersion experienced by users familiar with VR environments might obscure comparisons of VR performance [2,25]. A future enhancement of the present study would be to include other kinds of control devices, such as one developed especially for seniors [13], and/or VR features such as field of view [29,30] to further pinpoint interactions between VR characteristics, gender, navigational-support mode, and wayfinding strategies [5,31].

5. Conclusions

Our experiment results and statistical analyses indicated that, in a VR driving scenario, task type significantly affected VR driving performance. Navigational scores were significantly higher for the symmetrical straight (easy) route than for the asymmetrical curved (difficult) route. The aging effect was the main reason for the significant and interacting effects of gender and control device. Interactions between age and gender difference indicated that the young group exhibited better wayfinding performance than that of the senior group, and in the young group, males had better performance than females did. Similarly, interactions between age and control device indicated that the handlebar control-device type resulted in better performance than the joystick device did 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 of aging, gender differences, control device, and task type, in 3D VR games, including VR driving systems. With a VR driving simulator, seniors can test-drive inaccessible products, such as electric bicycles or cars, by using a computer at home.

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References

1. 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.
2. Stevic, A.; Schmuck, D.; Matthes, J.; Karsay, K. Age Matters': A panel study investigating the influence of communicative and passive smartphone use on well-being. *Behav. Inf. Technol.* **2019**, 15, doi:10.1080/0144929X.2019.1680732.
3. Wiemeyer, J.; Kliem, A. *The frequent wayfinding-sequence* ion and rehabilitation—A new panacea for elderly people? *Eur. Rev. Aging Phys. Act.* **2011**, *9*, 41–50.
4. 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.
5. Lawton, C.A. Strategies for indoor way-finding:the role of orientation. *J. Environ. Psychol.* **1996**, *16*, 137–145.
6. O'Laughlin, E.M.; Brubaker, B.S. Use of landmarks in cognitive mapping: Gender differences in self-report versus performance. *Personal. Individ. Differ.* **1998**, *24*, 595–601.
7. Malinowski, J.C.; Gillespie, W.T. Individual differences in performance on a large scale, real world wayfinding task. *J. Environ. Psychol.* **2001**, *21*, 73–82.
8. Kothgassner, O.D.; Goreis, A.; Kafka, J.X.; Hlavacs, H.; Beutl, L.; Kryspin-Exner, I.; Felnhofer, A. Agency and Gender Influence Older Adults' Presence-Related Experiences in an Interactive Virtual Environment. *Cyberpsychol. Behav. Soc. Netw.* **2018**, *21*, 318–324.
9. Kemeny, A. From Driving Simulation to Virtual Reality. In Proceedings of the Laval Virtual VRIC '14, Laval, France, 9–11 April 2014; pp. 1–5.
10. Haeger, M.; Bock, O.; Memmert, D.; Hüttermann, S. Can Driving-Simulator Training Enhance Visual Attention, Cognition, and Physical Functioning in Older Adults? *J. Aging Res.* **2018**, 9, doi:10.1155/2018/7547631.
11. Coluccia, E.; Iosue, G. Gender differences in spatial orientation: A review. *J. Environ. Psychol.* **2004**, *24*, 329–340.
12. Coluccia, E.; Bosco, A.; Brandimonte, M.A. The role of visuo-spatial working memory in map drawing. *Psychol. Res.* **2007**, *71*, 359–372.
13. 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. *J. Environ. Psychol.* **2009**, *29*, 220–226.
14. Wondrak, M.F.; Bleicher, M. Constraints on the String T-Duality Propagator from the Hydrogen Atom. *Symmetry* **2019**, *11*, 1478, doi:10.3390/sym11121478.

15. 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.
16. 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.
17. Davis, R.L.; Weisbeck, C. Search Strategies Used by Older Adults in a Virtual Reality Place Learning Task. *Gerontologist* **2015**, *55*, 118–127.
18. Yang, Y.; Merrila, E.C. Cognitive and personality characteristics of masculinity and femininity predict wayfinding competence and strategies of men and women. Sex. Roles. **2017**, *76*, 747–758.
19. Polich, J. Updating P300: An integrative theory of P3a and P3b. *Clin. Neurophysiol.* **2007**, *118*, 2128–2148.
20. Dowiasch, S.; Marx, S.; Einhauser, W.; Bremmer, F. Effects of aging on eye movements in the real world. *Front. Hum. Neurosci.* **2015**, *9*, 12, doi:10.3389/fnhum.2015.00046.
21. Coluccia, E.; Iosue, G.; Brandimonte, M. A. The relationship between map drawing and spatial orientation abilities: A study of gender differences. *J. Environ. Psychol.* **2007**, *27*, 135–244.
22. 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*, e55348.
23. Darken, R.P.; Sibert, J.L. Navigating large virtual spaces. Int. J. Hum. Comput. Interact. 1996, 8, 49-72.
24. Mustikawati, T.; Yatmo, Y.; Atmodiwirjo, P. Wayfinding beyond signage: Rethinking the role of spatial objects and object relations. *IOP Conf. Ser. Earth Environ. Sci.* **2018**, *195*, 8, doi:10.1088/1755-1315/195/1/012083.
25. Hilton, C.; Miellet, S.; Slattery, T.J.; Wiener, J. Are age-related deficits in route learning related to control of visual attention? *Psychol. Res.* **2019**, *2019*, 12, doi:10.1007/s00426-019-01159-5.
26. Kim, B. Effects of visual and spatial working memory improvement training program on elderly driving behavior. *Indian J. Public Health Res. Dev.* **2018**, *9*, 683–689.
27. 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. *Behav. Inf. Technol.* **2017**, *36*, 524–539, doi:10.1080/0144929X.2016.1262900.
28. Becker, K.; Becker, M.; Schwarz, J. *String Theory and M-Theory: A Modern Introduction*; Cambridge University Press: Cambridge, UK, 2007; ISBN 978-0-521-86069-7.
29. Choi, G. The Impacts of Wayfinding Affordance on User Experience in Virtual Worlds. *Int. J. Comput. Inf. Syst. Ind. Manag. Appl.* **2011**, *3*, 912–923.
30. Walch, M.; Frommel, J.; Rogers, K.; Schüssel, F.; Hock, P.; Dobbelstein, D.; Weber, M. Evaluating VR Driving Simulation from a Player Experience Perspective. In Proceedings of the CHI EA '17: Conference Extended Abstracts on Human Factors in Computing Systems, Denver, CO, USA, 6–11 May 2017; pp. 2982–2989, doi:10.1145/3027063.3053202.
31. Gramann, K.; Muller, H.J.; Eick, E.M.; Schonebeck, B. Evidence of separable spatial representations in a virtual navigation task. *J. Exp. Psychol. Hum. Percept. Perform.* **2005**, *31*, 1199–1223.