Taylor & Francis
Taylor & Francis Group

Occupational Therapy In Health Care

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/iohc20

The Effectiveness of a Digital Game-Based Intervention on Hazard Perception and Visual Skills in Novice Drivers: A Single Blind, Randomized Controlled Trial

Berkan Torpil & Mehmet Kaan İldiz

To cite this article: Berkan Torpil & Mehmet Kaan İldiz (19 May 2023): The Effectiveness of a Digital Game-Based Intervention on Hazard Perception and Visual Skills in Novice Drivers: A Single Blind, Randomized Controlled Trial, Occupational Therapy In Health Care, DOI: 10.1080/07380577.2023.2212303

To link to this article: https://doi.org/10.1080/07380577.2023.2212303

Published online: 19 May 2023.

OCCUPATIONAL THERAPY IN HEALTH CARE
https://doi.org/10.1080/07380577.2023.2212303

The Effectiveness of a Digital Game-Based Intervention on Hazard Perception and Visual Skills in Novice Drivers: A Single Blind, Randomized Controlled Trial

Berkan Torpil[a] and Mehmet Kaan İldiz[b]

[a]Occupational Therapy Department, Faculty of Gülhane Health Sciences, University of Health Sciences Turkey, Ankara, Turkey; [b]Occupational Therapy Department, Faculty of Health Sciences, Atlas University, İstanbul, Turkey

ABSTRACT

Novice drivers show poorer performance than experienced drivers in terms of visual skills and hazard perception. This study aimed at evaluating the effectiveness of a digital game-based intervention on hazard perception and visual skills in novice drivers. Forty-six novice drivers (6 men, 40 women) were randomized to the intervention group ($n = 23$; 20.79 ± 0.81 years) or control ($n = 23$; 20.65 ± 0.93 years) group. The intervention group received a game-based intervention in addition to a hazard perception training, whereas the control group received only the hazard perception training. Hazard perception and visual skills were assessed in both groups before and after the 14-day interventions. Between-group comparisons revealed significantly greater improvements in visual short time memory, visual closure, visual discrimination, figure-ground and total scores in the game-based group than in the control group ($p < 0.05$ for all). Our results showed that 14 days of game-based intervention enhanced hazard perception and visual skills in novice drivers. Using game-based interventions in driving rehabilitation is recommended to improve hazard perception and visual skills of novice drivers.

ARTICLE HISTORY
Received 29 November 2022
Accepted 6 May 2023

KEYWORDS
Game; hazard perception; novice drivers; visual skills

Introduction

Road traffic crashes lead to the annual global death rate of 1.35 million people (World Health Organization, 2018). Younger road users are over-represented in crash statistics and traffic crashes are the leading cause of death for 5–29 years old (World Health Organization, 2018). For younger drivers, the risk of injury or death rapidly decreases in the months following a license, suggesting that both age and experience are

CONTACT Berkan Torpil berkantorpil@gmail.com Occupational Therapy Department, Faculty of Gülhane Health Sciences, University of Health Sciences Turkey, 06018 Etlik, Keçiören, Ankara, Turkey.

contributing factors to crash risk (Mayhew et al., 2003). Adolescents demonstrate cognitive changes associated with brain maturation as they develop into adulthood, while also transitioning from a novice to a more experienced driver by practicing on the road (Foy et al., 2016; Moran et al., 2019). Research have argued that one of the main reasons for the young drivers' high crash rate is that the hazard perception and visual skills are not as developed as experienced drivers (Gharib et al., 2020; Moran et al., 2019).

Hazard perception in driving refers to a driver's ability to anticipate potentially dangerous situations on the road (Gharib et al., 2020; Moran et al., 2019). Visual skills include many skills such as figure-ground perception, color discrimination, visual proximity, visual discrimination, visual attention, depth perception, visual-spatial perception (Hammill & Colarusso, 2005).The young driver must be able to recognize the hazards quickly, control the vehicle on the road while watching other vehicles, check the mirrors frequently, and focus on other objects such as pedestrians in order to avoid a crash (Brown & Groeger, 1988). Many studies have shown that visual skills and hazard perception in driver-oriented skills components can be associated with traffic crashes (Gharib et al., 2020; Horswill et al., 2009; Horswill & Mckenna, 2004).

There are many methods of assessment and intervention for hazard perception and visual skills including videos, static images, driving simulation, and in a vehicle on a real-world driving environment (Moran et al., 2019). Driving in the real-world environment and a driving simulation environment have disadvantages such as low accessibility and high cost (Betz et al., 2014; Moran et al., 2019). However, the rapid advancement of technology and the inclusion of mobile applications in recent years have brought different approaches to rehabilitation (Connolly et al., 2012). One of these is the digital game-based approach (Connolly et al., 2012), which some researchers state is important due to its immerse effect, low cost and high availability (Backlund et al. 2010; Ferguson, 2007; Schaffer & Fang, 2019). Such studies include applications on the smartphone and digital games in driver education that have the potential for learning the traffic rules and compliance. It can be argued that since digital games and platforms are used intensively by young people, therefore digital games might be used in driver studies (Li, 2015; Voinea, 2020). However, to our knowledge, we have not found any study using digital games on the development of hazard perception. The current study was planned to examine the effectiveness of hazard perception training and digital game-based intervention approach on hazard perception and visual skills in young novice drivers.

Methods

Design

This single-blinded, randomized, controlled trial (RCT) investigated changes in the hazard perception and visual skills of novice drivers after digital game-based interventions. The study was designed according to the CONSORT statement, which provides a standardized method for RCT design (Schulz et al., 2010). Approval for the study was carried out after obtaining the ethical approval number 21/25 by the Gülhane Scientific Research Ethics Committee of the University of Health Sciences Turkey.

The study consists of two groups of novice drivers (game-based group and control group) and a 14-day 60 min a day intervention procedure. Evaluation was made on the first and last day (approximately 60 min). Hazard perception training was given to all participants for two days 60 min a day. In addition, digital game-based intervention was applied to the intervention group, which was 60 min a day for 12 days. The pre- and post-intervention evaluations were made by the second author (M.K.İ) of the study, and the first author (B.T.) was blinded to the evaluation process.

Participants

Novice drivers were recruited by the researchers in the occupational therapy department of a University of Health Sciences Turkey, a public university between February and April of 2021. Inclusion criteria included: (1) age between 18 and 25 years (due to the legal legislation for obtaining driver license age of Turkey is 18 years or older); (2) driving license for a maximum of one year; (3) at least high school graduate; and (4) ability to understand and follow verbal instructions. Exclusion criteria were: (1) any chronic disease or auditory and visual issues; and (3) experienced playing the "Subway Surfers" game with a mobile device (e.g. smart phone, iPad, tablet). Fifty participants were screened and two were excluded due to having played Subway Surfers. The remaining 48 participants were randomized to either the game-based group or the control group by using a computer-generated randomization technique. Written informed consent was obtained from all participants prior to the study. However, two other participants were later excluded because they could not adhere to the frequency of the study intervention. Therefore, the study was completed with a sample of 46 novice drivers (see Figure 1 for the Consort diagram).

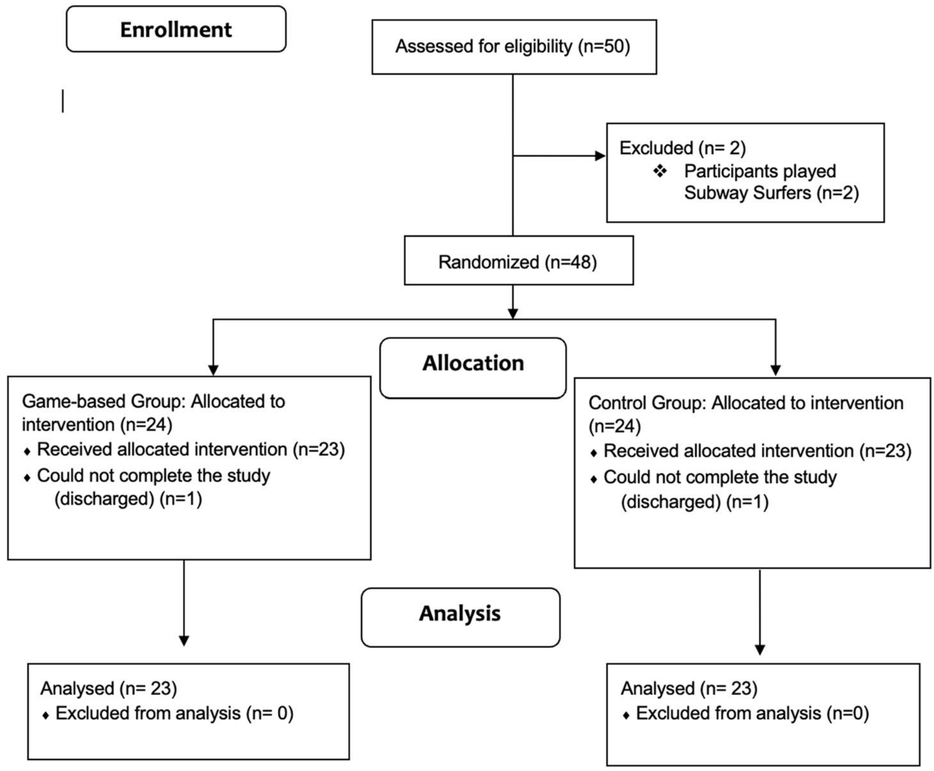

Figure 1. Consort diagram.

Measurements

Motor-free visual perception test-3 (MVPT-3)

MVPT-3 was developed by Colarusso and Hammill (1972). It is a test that evaluates the visual perception skills of individuals between the ages of 4–94, independent of motor performance (Colarusso & Hammill, 1972). The first 14–65 questions are prepared for 10 years and older. Each correct answer given in the test is recorded on the score sheet as one point and zero points for a wrong answer. Turkish validity and reliability of MVPT-3 was made by Metin and Neriman (Cronbach's α: 0.85) (Metin & Neriman, 2012). The MVPT is a frequently used scales in the assessment of visual skills by therapists working in the field of driving rehabilitation and in driving studies (Dickerson, 2013; Dickerson et al., 2014; Holowaychuk et al., 2020).

Trail Making Test-B

The Trail Making Test-B (TMT-B) test has been used to evaluate the visual scanning speed, visual-motor perception and function, planning ability, organizational ability, and abstract thinking ability (Reitan, 1958). The time to complete the consolidation (in seconds) establishes the score of the test. Turkish validity ICC value of the test performed by Cangöz et al. was determined as 0.93 (Cangöz et al., 2009). Türkiye normative values of TMT-B in healthy young adults were determined as 67 s on average (Türkeş et al, 2015). While the Trails Making Test B is used commonly in driving evaluations (Dickerson, 2014), the test is also preferred in studies on young drivers for such as driver screening and hazard perception (Betz & Fisher, 2009; Sasaki et al., 2017).

Hazard Perception Test. The Hazard Perception Test (HPT) (Scialfa et al., 2011) is a test in which the hazards are answered by touching the mouse or touch screen through the video clip containing different traffic events to evaluate the hazard and risk perception of the person while driving (Horswill & McKenna, 2004). Hazard perception tests have been incorporated into licensing procedures in the United Kingdom and in some states in Australia, and the validity of such tests has been demonstrated by means of correlations with crash risk (Mckenna & Horswill, 1999; Scialfa et al., 2011). HPT includes 35 different one-minute video clips (with two used as practice) with a driving hazard scenario that requires the driver to identify. The participant must click with a mouse in distress or touch the screen if there is a touchscreen. The scoring of the test is calculated with the online test tool; A higher score is obtained when the participant reacts in the first segment (when potential hazard begins) and the score drops if the test taker reacts more slowly and/or clicks in the wrong situation. It has the highest score of 5 and the lowest score of 0 for each video.

Interventions

Hazard perception training

Studies on hazard perception training used a variety of intervention methods including interactive computer programs, videos, simulation, static images, or during a test drive in a real driving environment or combination of approaches (McDonald et al., 2015; Moran et al., 2019). In the current study, we created our Hazard Perception Training program by using the information in the literature. The two-day hazard perception training was given to all novice drivers individually. This tutorial was created using 30 slides and 15 videos. The training program included what can be done about situations that pose a hazard in the driving environment, how this situation can be predicted and the issues that need attention. With the images from the driving environment on the slide, what to do in the hazardous situation was discussed interactively with the participants. In the video part of the training, discussions included what hazardous situations may be encountered in case of stopping and continuing the video in a certain part of the scenarios, and what measures should be taken regarding these situations.

Digital game-based intervention

Digital game-based intervention was implemented through the application with free access on the mobile device. Since at least 720 min of training is required to demonstrate the effectiveness of game-based and virtual reality interventions (Torpil et al., 2021), this study's program was 720 min, consisting of 12 consecutive days and 60-minute sessions.

The game called "Subway Surfers" was used with a mobile device (e.g. smart phone, iPad, tablet) that participants chose according to their preferences. Whether the participant played the game or not was followed by telephone every day.

Subway Surfers is a mobile application with the main purpose is that the character can overcome various obstacles and escape in an endless way with the highest score and the longest time. The main functions offered to the user in the game are the character's jump, bend and change direction. In order to achieve these, it is necessary to perform some finger movements by touching the touch screen mobile device. These skills vary according to the finger used, as well as flexion and adduction for the thumb, as well as adduction and abduction for those who play the application with the index finger, as well as flexion and extension movements of the finger. Along with skills such as visual skills, attention, coordination, visual motor skills, rapid decision making, rapid response, praxis, risk perception of the obstacles encountered and making benefit calculations in order to gain more points are among the basic skills required to achieve a higher success in the game. A basic mechanic of the game is that the pace of the game accelerates as the start time of the game progresses. This pace increases in direct proportion to the score and the lengthening of the right to play, and as time progresses, this difficulty remains constant at a certain level and continues until the player loses the right to play. Responding quickly to the obstacles encountered in the game and providing correct escape plans brings the main success in the game. At the same time, keeping track of points in the progress in the game is as important as avoiding threats. The basic score of the game is how long the player has traveled, the length of progression on the road and how many points used to take that path.

Data analysis

Data were analyzed with SPSS version 26.0 (IBM Corp., Armonk, NY) statistical software package program. Data are presented as mean with standard deviation. Normality of the data was analyzed using Kolmogorov-Smirnov test. Differences between groups were analyzed with chi-square test for nominal data. Comparisons between the groups were conducted using Mann-Whitney U test. Pre- to post-intervention changes within the groups were analyzed with Wilcoxon signed-rank test. Furthermore, Quade's rank analysis of covariance test was applied for controlling the effect of baseline differences for variables. Significance was evaluated at levels of .05. Effect size was calculated using the means and standard deviations of the groups. Effect size benchmarks were determined as <.30, .30-.80, and >.80 and considered small, moderate, and strong, respectively (Cohen, 1992).

Results

Mean ages of the game-based group ($n = 23$; 3 man, 20 woman) and control group ($n = 23$; 3 man, 20 woman) were 20.79 ± 0.81 years (range, 19–22 years) and 20.65 ± 0.93 years (range, 19–22 years) respectively. All of these novice drivers were high school graduates none were involved in any crashes.

There is no statistically significant difference in all parameters between pre-intervention groups ($p > 0.05$) (Table 1).

Within-group analysis showed a significant increase in TMT-B, HPT, MVPT-3 visual closure-1, visual discrimination and total score ($p < 0.01$) in visual short time memory-1 in the study group ($p < 0.05$), and TMT-B, HPT and MVPT total score ($p < 0.01$) in visual closure-1 in the control group ($p < 0.05$). Comparisons of the changes over time for hazard perception and visual skills within groups, as well as effect sizes, are shown in Table 2. Between-group analysis showed a significant increase in TMT-B, HPT, MVPT-3's visual short time memory-1, visual closure-1, visual discrimination, figure-ground and total score in the study group ($p < 0.05$ for

Table 1. Comparisons of the pre-intervention TMT-B, HPT and MVPT-3 scores between the groups.

	Game-based Group Mean ± SD	Control Group 1 Mean ± SD	Comparisons p
TMT-B	63.07 ± 24.54	63.70 ± 22.26	.818
HPT	97.60 ± 30.34	95.08 ± 26.33	.510
MVPT-3			
Visual Short Time Memory-1	7.39 ± 0.78	7.21 ± 0.73	.330
Visual Closure-1	11.13 ± 1.17	10.82 ± 1.07	.340
Visual Discrimination	9.04 ± 1.18	9.08 ± 1.23	.901
Spatial Orientation	3.43 ± 1.37	3.21 ± 0.95	.290
Figure-ground	2.43 ± 1.16	2.39 ± 1.03	.810
Visual Closure-2	3.60 ± 1.11	3.43 ± 1.03	570
Visual Short Time Memory-2	4.17 ± 0.83	4.13 ± 0.69	768
Total Score	54.21 ± 3.55	53.30 ± 5.58	.509

TMT-B, Trail Making Test-B; HPT, Hazard Perception Test; MVPT-3, Motor-Free Visual Perception Test-3.

Table 2. Comparisons of the groups pre-intervention and post-intervention TMT-B, HPT and MVPT-3 scores results.

	Game-based Group				Control Group			
	Pre-Intervention Mean ± SD	Post-Intervention Mean ± SD	p	Effect size d	Pre-Intervention Mean ± SD	Post-Intervention Mean ± SD	p	Effect size d
TMT-B	63.07 ± 24.54	41.81 ± 15.81	<.001**	1.03	63.70 ± 22.26	60.51 ± 20.64	<0.01**	0.14
HPT	97.60 ± 30.34	118.00 ± 30.80	<.001**	0.66	95.08 ± 26.33	98.56 ± 24.01	<0.01**	0.13
MVPT-3								
Visual Short Time Memory-1	7.39 ± 0.78	7.78 ± 0.59	<0.05*	0.56	7.21 ± 0.73	7.30 ± 0.63	0.414	0.13
Visual Closure-1	11.13 ± 1.17	11.95 ± 1.10	<0.01**	0.72	10.82 ± 1.07	11.08 ± 0.94	<0.05*	0.25
Visual Discrimination	9.04 ± 1.18	9.86 ± 1.21	<0.01**	0.68	9.08 ± 1.23	9.21 ± 1.08	0.180	0.11
Spatial Orientation	3.43 ± 1.37	3.82 ± 1.46	0.131	0.27	3.21 ± 0.95	3.39 ± 0.78	0.102	0.20
Figure-ground	2.43 ± 1.16	2.91 ± 0.59	0.061	0.52	2.39 ± 1.03	2.43 ± 0.84	0.564	0.04
Visual Closure-2	3.60 ± 1.11	4.00 ± 1.04	0.120	0.37	3.43 ± 1.03	3.52 ± 1.03	0.317	0.08
Visual Short Time Memory-2	4.17 ± 0.83	4.30 ± 0.97	0.512	0.14	4.13 ± 0.69	4.17 ± 0.71	0.655	0.05
Total Score	54.21 ± 3.55	57.65 ± 4.59	<.001**	0.83	53.30 ± 5.58	54.13 ± 4.87	<0.01**	0.15

TMT-B, Trail Making Test-B; HPT, Hazard Perception Test; MVPT-3, Motor-Free Visual Perception Test-3.
**$p < 0.01$; *$p < 0.05$.

Table 3. Comparisons of the post-intervention TMT-B, HPT and MVPT-3 scores between the groups.

	Game-based Group Post-Intervention Mean ± SD	Control Group Post-Intervention Mean ± SD	p
TMT-B	41.81 ± 15.81	60.51 ± 20.64	0.003**
HPT	118.00 ± 30.80	98.56 ± 24.01	0.009**
MVPT-3			
Visual Short Time Memory-1	7.78 ± 0.59	7.30 ± 0.63	0.003**
Visual Closure-1	11.95 ± 1.10	11.08 ± 0.94	0.002**
Visual Discrimination	9.86 ± 1.21	9.21 ± 1.08	0.037**
Spatial Orientation	3.82 ± 1.46	3.39 ± 0.78	0.066
Figure-ground	2.91 ± 0.59	2.43 ± 0.84	0.037*
Visual Closure-2	4.00 ± 1.04	3.52 ± 1.03	0.095
Visual Short Time Memory-2	4.30 ± 0.97	4.17 ± 0.71	0.301
Total Score	57.65 ± 4.59	54.13 ± 4.87	0.011*

TMT-B, Trail Making Test-B; HPT, Hazard Perception Test; MVPT-3, Motor-Free Visual Perception Test-3.
**$p < 0.01$; *$p < 0.05$.

Table 4. Comparisons of post intervention scores when controlling the effect of baseline scores.

	Game-based Group Post-Intervention Mean ± SD	Control Group Post-Intervention Mean ± SD	F	p
TMT-B	41.81 ± 15.81	60.51 ± 20.64	32.90	<0.001**
HPT	118.00 ± 30.80	98.56 ± 24.01	17.25	<0.001**
MVPT-3				
Visual Short Time Memory-1	7.78 ± 0.59	7.30 ± 0.63	20.99	<0.001**
Visual Closure-1	11.95 ± 1.10	11.08 ± 0.94	10.82	<0.01**
Visual Discrimination	9.86 ± 1.21	9.21 ± 1.08	13.81	<.001**
Spatial Orientation	3.82 ± 1.46	3.39 ± 0.78	12.54	<0.01**
Figure-ground	2.91 ± 0.59	2.43 ± 0.84	2.53	0.119
Visual Closure-2	4.00 ± 1.04	3.52 ± 1.03	7.15	0.010
Visual Short Time Memory-2	4.30 ± 0.97	4.17 ± 0.71	3.02	0.089
Total Score	57.65 ± 4.59	54.13 ± 4.87	1.05	0.311

Notes: Quade's rank analysis of covariance test was used, to control for the significant difference observed between the groups in the baseline values.

all). Comparisons of the post-intervention for hazard perception and visual skills between groups, are shown in Table 3.

The game-based intervention was significantly more effective for TMT-B, HPT, MVPT-3 visual closure-1, visual discrimination and total score after controlling for differences between groups in their baseline values (Table 4).

Discussion

The current study was conducted to examine the effectiveness of digital game-based intervention approach on visual skills and hazard perception in novice drivers. It was determined that the 14-day intervention program improved visual skills and hazard perception in young novice drivers.

With the widespread availability of distribution platforms such as computers, iPads, tablets, and smartphone game apps, digital games have gained mainstream attraction (Connolly et al., 2012). Authors reported that the use of digital games in rehabilitation has many benefits (Connolly et al., 2012; Li et al., 2014). Researchers stated that the use of these games is effective in reducing various psychosocial problems; creating a solution to the problem of accessibility in rehabilitation; increasing visual, cognitive, physical skills; and gaining time and cost (Connolly et al., 2012; Li et al., 2014; Schaffer & Fang, 2019). On the other hand, it is also used in education due to its contribution to learning processes (Acquah & Katz, 2020). Various videos or simulation environments are used to improve driving skills and have a positive effect on driving skills (Moran et al., 2019). In the current study, the digital game-based intervention approach positively affected the visual skills and hazard perception; skills which are important for driving. We believe the skills are developed because the game has an immerse effect, includes intense visual skills, fast decision making and actions that require fast action. We also believe that it will be important to use digital games in driving studies to increase visual skills in novice drivers and to improve the hazard perception.

In the studies on hazard perception, researchers stated that four methodologies are frequently used, which include video, static image, driving simulations and test drive methodologies in real driving environment (Backlund et al., 2010; Li, 2015; Moran et al., 2019). Most studies have found that novice drivers have worse hazard perception than experienced drivers (Gharib et al., 2020; Moran et al., 2019). Moran et al. (2019) states driving(?) simulators and vehicle drives in the real-world environment are the most natural method to test the hazard perception by using cognitive skills during "driving." However, their use is largely limited to research due to time and cost problems related to testing (Moran et al., 2019). In the this study, we used the game-based approach to improve visual skills and hazard perception in novice drivers as the rapid introduction of technology, mobile applications have an important place in activities of daily living, their accessibility, and their cost and time efficiency. We believe the use of the digital game-based intervention approach improves the hazard perception in novice drivers due to its immerse effect, intensive visual skills and rapid decision-making effect. In addition, this intervention can be a solution to time and cost problems in hazard perception development and/or studies. Thus, this study is important in terms of showing the benefits of mobile applications.

Researchers recognize visual skills as important in many aspects of driving, particularly recognizing warnings and hazard perception (Gharib et al., 2020; Muela et al., 2021; Zheng et al., 2020). When problems arise in visual field and visual skills problems, risk of crash increases and driving cessation may be warranted (Gharib et al., 2020; Muela et al., 2021; Wood et al., 2018; Zheng et al., 2020). Moreover, novice drivers react more slowly in visual skills than experienced drivers (Wood et al., 2018) and this situation may negatively affected the hazard perception (Gharib et al., 2020; Wood et al., 2018). In our study, it was determined that a 14-day intervention positively affected visual memory, visual closure, visual discrimination, visual scanning speed, shape-ground separation and reaction speed in the game-based group. The game used in this intervention may have had a positive effect on visual skills due to the fact that the game includes visual stimuli and is played using visual praxis skills.

On the other hand, it was observed that some visual skills developed positively in the control group. This situation is likely due to the content of the hazard perception training given to both groups for two days affects visual skills. However, when the effect level of the treatment in the control group is examined, it is seen that it has a weak effect. Since the game-based approach applied in the intervention group has a moderate or high effect on visual skills, this approach can be preferred as an active method in treatment.

Limitations

There are several limitations to this study that deserve comment. First, our limitation is that not evaluating in a real driving environment leads to the fact that its real effect on driving is not fully known. Second, because Trail Making Test A and Trail Making Test B are often used together, it may be a limitation that we only use Trail Making Test B in the current study. Making evaluations in real driving environment or simulation environment would offer more effective information for generalization. Another limitation is whether the intervention occurred or not because it was based on the statements of the participants. Failure to compare with experienced drivers also creates an additional limitation in terms of interpretation of the effect level of the intervention. In further studies, the effectiveness of the intervention with experienced drivers could be compared. Another limitation is that the long-term effect of the intervention is not known which would be important to investigate the long-term impact of digital games on novice drivers. Finally, a limitation is that novice driver participants had significantly more female participants and therefore we were unable to conclude efficacy in a larger male population. It will be important to investigate the effects of digital games on people in more detail as well as individuals with chronic conditions such as cerebral palsy and traumatic brain injury.

Conclusion

Novice who completed 14 days of HPT and digital game-based intervention showed greater improvement in hazard perception and visual skills on novice drivers. The digital game-based intervention approach and HPT provides support for hazard perception interventions and visual skills interventions in novice drivers, and it is appropriate for research and clinical interventions targeting hazard perception and visual skills in young novice drivers.

Author disclosure statement

The results of the study are presented honestly, clearly, and without falsification, fabrication, or inappropriate data manipulation. The authors have declared no conflicts of interest in the current study.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this paper.

Ethical approval

Ethical Approval obtained from University of Health Sciences Turkey Gülhane Scientific Research Ethics Committee (Ref: Go 21/25).

Funding

The author(s) reported there is no funding associated with the work featured in this article.

ORCID

Berkan Torpil http://orcid.org/0000-0002-0322-5163
Mehmet Kaan İldiz http://orcid.org/0000-0003-0429-3915

References

Acquah, E. O., & Katz, H. T. (2020). Digital game-based L2 learning outcomes for primary through high-school students: A systematic literature review. *Computers & Education*, *143*, 103667. https://doi.org/10.1016/j.compedu.2019.103667

Backlund, P., Engström, H., Johannesson, M., & Lebram, M. (2010). Games for traffic education: An experimental study of a game-based driving simulator. *Simulation & Gaming*, *41*(2), 145–169. https://doi.org/10.1177/1046878107311455

Betz, M. E., Dickerson, A., Coolman, T., Schold Davis, E., Jones, J., & Schwartz, R. (2014). Driving rehabilitation programs for older drivers in the United States. *Occupational Therapy in Health Care*, *28*(3), 306–317. https://doi.org/10.3109/07380577.2014.908336

Betz, M. E., & Fisher, J. (2009). The Trail-making Test B and driver screening in the emergency department. *Traffic İnjury Prevention*, *10*(5), 415–420. https://doi.org/10.1080/15389580903132819

Brown, I. D., & Groeger, J. A. (1988). Risk perception and decision taking during the transition between novice and experienced driver status. *Ergonomics*, *31*(4), 585–597. https://doi.org/10.1080/00140138808966701

Cangöz, B., Karakoc, E., & Selekler, K. (2009). Trail Making Test: Normative data for Turkish elderly population by age, sex and education. *Journal of the Neurological Sciences*, *283*(1–2), 73–78. https://doi.org/10.1016/j.jns.2009.02.313

Cohen, J. (1992). A power primer. *Psychological Bulletin*, *112*(1), 155–159. https://doi.org/10.1037//0033-2909.112.1.155

Colarusso, R. P., & Hammill, D. D. (1972). *Motor-free visual perception test*. Academic Therapy Pub.

Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education*, *59*(2), 661–686. https://doi.org/10.1016/j.compedu.2012.03.004

Dickerson, A. E. (2013). Driving assessment tools used by driver rehabilitation specialists: Survey of use and implications for practice. *The American Journal of Occupational Therapy: Official Publication of the American Occupational Therapy Association*, *67*(5), 564–573. https://doi.org/10.5014/ajot.2013.007823

Dickerson, A. E., Meuel, D. B., Ridenour, C. D., & Cooper, K. (2014). Assessment tools predicting fitness to drive in older adults: A systematic review. *The American Journal of Occupational Therapy: Official Publication of the American Occupational Therapy Association*, *68*(6), 670–680. https://doi.org/10.5014/ajot.2014.011833

Ferguson, C. J. (2007). The good, the bad and the ugly: A meta-analytic review of positive and negative effects of violent video games. *The Psychiatric Quarterly*, *78*(4), 309–316. https://doi.org/10.1007/s11126-007-9056-9

Foy, H. J., Runham, P., & Chapman, P. (2016). Prefrontal cortex activation and young driver behaviour: A fNIRS study. *PloS One*, *11*(5), e0156512. https://doi.org/10.1371/journal.pone.0156512

Gharib, S., Zare-Sadeghi, A., Zakerian, S. A., & Haidari, M. R. (2020). The neural basis of hazard perception differences between novice and experienced drivers-An fMRI study. *Excli Journal*, *19*, 547–566.

Hammill, D. D., & Colarusso, P. (2005). *Motor-free visual perception test* (3rd ed.). Academic Therapy.

Holowaychuk, A., Parrott, Y., & Leung, A. W. (2020). Exploring the predictive ability of the Motor-Free Visual Perception Test (MVPT) and Trail Making Test (TMT) for on-road driving performance. *The American Journal of Occupational Therapy: Official Publication of the American Occupational Therapy Association*, *74*(5), 7405205070p1–7405205070p8. https://doi.org/10.5014/ajot.119.040626

Horswill, M. S., & McKenna, F. P. (2004). Drivers' hazard perception ability: Situation awareness on the road. In S. Banbury & S. Tremblay (Eds.). *A Cognitive Approach to Situation Awareness* (pp.155-175). Aldershot, UK: Ashgate.

Horswill, M. S., Pachana, N. A., Wood, J., Marrington, S. A., McWilliam, J., & McCullough, C. M. (2009). A comparison of the hazard perception ability of matched groups of healthy drivers aged 35 to 55, 65 to 74, and 75 to 84 years. *Journal of the International Neuropsychological Society: JINS*, *15*(5), 799–802. https://doi.org/10.1017/S1355617709990312

Li, Q. (2015). Can driving in games translate to driving in real life? A study of game-based traffic education. In *Developments in Business Simulation and Experiential Learning: Proceedings of the Annual ABSEL Conference* (Vol. 42).

Li, J., Theng, Y. L., & Foo, S. (2014). Game-based digital interventions for depression therapy: A systematic review and meta-analysis. *Cyberpsychology, Behavior and Social Networking*, *17*(8), 519–527. https://doi.org/10.1089/cyber.2013.0481

Mayhew, D. R., Simpson, H. M., & Pak, A. (2003). Changes in collision rates among novice drivers during the first months of driving. *Accident; Analysis and Prevention*, *35*(5), 683–691. https://doi.org/10.1016/s0001-4575(02)00047-7

McDonald, C. C., Goodwin, A. H., Pradhan, A. K., Romoser, M. R., & Williams, A. F. (2015). A review of hazard anticipation training programs for young drivers. *The Journal of Adolescent Health: Official Publication of the Society for Adolescent Medicine*, *57*(1 Suppl), S15–S23. https://doi.org/10.1016/j.jadohealth.2015.02.013

McKenna, F. P., & Horswill, M. S. (1999). Hazard perception and its relevance for driver licensing. *IATSS Research*, *23*, 26–41.

Metin, Ş., & Neriman, A. R. A. L. (2012). Motor beceriden bağımsız görsel algı testi-3: Geçerlik güvenirlik çalışması. *Çankırı Karatekin Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *4*(2), 57–72.

Moran, C., Bennett, J. M., & Prabhakharan, P. (2019). Road user hazard perception tests: A systematic review of current methodologies. *Accident; Analysis and Prevention*, *129*, 309–333. https://doi.org/10.1016/j.aap.2019.05.021

Muela, I., Chica, A. B., Garcia-Fernandez, P., & Castro, C. (2021). Visual attention in realistic driving situations: Attentional capture and hazard prediction. *Applied Ergonomics*, *90*, 103235. https://doi.org/10.1016/j.apergo.2020.103235

Reitan, R. M. (1958). Validity of the Trail Making Test as an indicator of organic brain damage. *Perceptual and Motor Skills*, *8*(3), 271–276. https://doi.org/10.2466/pms.1958.8.3.271

Sasaki, T., Yamada, K., Kojima, T., Kanaya, K., Abe, T., & Hirao, Y. (2017). Development of a video-based hazard detection task: Preliminary study in younger drivers. *Asian Journal of Occupational Therapy*, *13*(1), 47–54. https://doi.org/10.11596/asiajot.13.47

Schaffer, O., & Fang, X. (2019, July). Digital game enjoyment: A literature review. In *International Conference on Human-Computer Interaction* (pp. 191–214). Springer.

Schulz, K. F., Altman, D. G., & Moher, D. (2010). CONSORT 2010 statement: Updated guidelines for reporting parallel group randomized trials. *Annals of İnternal Medicine*, *152*(11), 726–732. https://doi.org/10.7326/0003-4819-152-11-201006010-00232

Scialfa, C. T., Deschênes, M. C., Ference, J., Boone, J., Horswill, M. S., & Wetton, M. (2011). A hazard perception test for novice drivers. *Accident; Analysis and Prevention*, *43*(1), 204–208. https://doi.org/10.1016/j.aap.2010.08.010

Torpil, B., Şahin, S., Pekçetin, S., & Uyanık, M. (2021). The effectiveness of a virtual reality-based intervention on cognitive functions in older adults with mild cognitive impairment: A single-blind, randomized controlled trial. *Games for Health Journal*, *10*(2), 109–114. https://doi.org/10.1089/g4h.2020.0086

Türkeş, N., Can, H., Kurt, M., & Dikeç, B. E. (2015). A study to determine the norms for the trail making test for the age range of 20-49 in Turkey. *Turkish Journal of Psychiatry*, *26*(3), 189–196.

Voinea, G. D., Postelnicu, C. C., Duguleana, M., Mogan, G. L., & Socianu, R. (2020). Driving performance and technology acceptance evaluation in real traffic of a smartphone-based driver assistance system. *International Journal of Environmental Research and Public Health*, *17*(19), 7098. https://doi.org/10.3390/ijerph17197098

Wood, J. M., Black, A. A., Mallon, K., Kwan, A. S., & Owsley, C. (2018). Effects of age-related macular degeneration on driving performance. *Investigative Ophthalmology & Visual Science*, *59*(1), 273–279. https://doi.org/10.1167/iovs.17-22751

World Health Organization. (2018). *Global status report on road safety 2018*. https://wwwwho.int/violence_injury_prevention/road_safety_status/2018/en/.

Zheng, X., Yang, Y., Easa, S., Lin, W., & Cherchi, E. (2020). The effect of leftward bias on visual attention for driving tasks. *Transportation Research Part F: Traffic Psychology and Behaviour*, *70*, 199–207. https://doi.org/10.1016/j.trf.2020.02.016