Transportation Research Part F 22 (2014) 76–85

Contents lists available at ScienceDirect

Transportation Research Part F

journal homepage: www.elsevier.com/locate/trf

Does driving experience in video games count? Hazard anticipation and visual exploration of male gamers as function of driving experience

Maria Rita Ciceri, Daniele Ruscio *

Department of Psychology, Università Cattolica del Sacro Cuore of Milan, Largo A. Gemelli 1, 20123 Milan, Italy

A R T I C L E I N F O

Article history:
Received 7 May 2013
Received in revised form 4 November 2013
Accepted 7 November 2013

Keywords:
Video games
Road exploration
Risk perception
Visual attention
Eyetracking
Novice drivers

A B S T R A C T

Risk perception and distribution of visual attention while driving are crucial elements for accident prevention and new-driver improvement. This study investigates how racing videogames could shape the visual exploration of virtual and real road in male pre-drivers. The visual performance of players of racing video games with and without driver's license was tested in virtual vs. real scenarios. Attention to specific elements of different types of road interactions was monitored using an eye-tracking system. Results showed that habitual use of racing video games was not found to foster a positive effect on users' distribution of visual attention, supporting visual patterns typical of novice drivers. Gamers without driving experience replicated the same patterns in a real road scenario, ignoring road signs and potential areas of interactions with other drivers, while experienced drivers gamers explored video games roads like real roads. The fact that the gamers' driving performance was not comparable to drivers in the virtual scenario suggests that there are other variables in the gameplay that create a less complex traffic scene, still the visual complexity of different real road interactions is kept in video game interactions, opening new perspectives towards gamers' visual exploration of the road.

1. Introduction

The role of risk perception and perceptual learning in pre-drivers are important topics in transportation research and are considered crucial issue to prevent road accidents (Barg, Keddem, Ginsburg, & Winston, 2009; Ciceri & Confalonieri, 2012; Deighton & Luther, 2007; Elliot & Baughan, 2003; Husband, 2010; Mann & Lansdown, 2009; Poulter & McKenna, 2010). Worldwide studies, reviews and police reports show that young male drivers experience more accidents in their first years of driving than any other category of drivers (Clarke, Ward, & Truman, 2005; OECD., 2006; Williams, 2003). The average collision rate for young male drivers does not begin to decline for at least six months after they begin driving (Mayhew, Simpson, & Pak, 2003) and as far as the Italian context the total accident rate for male start decreaseing only after five years since the achievement of the driving license (ACI-ISTAT, 2009, 2010, 2011, 2012) a period of time where drivers may learn from gradual and non-systematic driving experiences, while still being highly exposed to road accident (Bjornskau & Sagberg, 2005; Groeger, 2001; Kass, Cole, & Stanny, 2007; Underwood, 2005). For these reasons Italian legislator has recently ap-

* Corresponding author. Address: Laboratory of Communication Psychology, Università Cattolica del Sacro Cuore, Via Nirone 15, 20122 Milan, Italy. Tel.: +39 02 7234 5931.

E-mail address: daniele.ruscio@unicatt.it (D. Ruscio).

1369-8478/$ - see front matter
http://dx.doi.org/10.1016/j.trf.2013.11.001

proved a revision of the Traffic Code (Decreto Ministero Infrastrutture e trasporti 11.11.2011 no. 213, GU 23.12.2011) allowing controlled backed up guide session for 17 years old, in order to increase the amount of driving experience before getting the driving license.

However, non-drivers can have a direct experience of the road and the traffic regulation system (Twisk, Vlakveld, Mesken, Shope, & Kok, 2013; Walke, Butland, & Connell, 2000; Waylen & McKenna, 2002; Waylen & McKenna, 2008; Zakrajsek et al., 2013). Pre-drivers are particularly active users of the street as pedestrians and cyclists, (Gatersleben & Haddad, 2010) and it is possible for them to actively explore the road and interact with complex traffic environment when driving in interactive playful simulations of video games (Beullens, Roe, & Van den Bulck, 2011). Modern racing video games can simulate whole cities as well as complex road interactions in which the virtual driver must explore cities, drive in different traffic situations and interact with other cars in a highly realistic urban environment (Fischer et al., 2009; Metzger & Flanagin, 2008; Vorderer & Bryant, 2006). Beginning in early childhood, adolescents play video games for hours every week (Durkin, 1995, 2006), and racing video games represent the 5.8% of the top sellers video games in the US market (ESA., 2013). Italian video games market represents €0.6bn in revenue, and racing video games represent the 10.3% of the market. Italian gamers are for 71% male aged 15–30 and 88% of Italian adolescent aged 14–19 years spend a mean of half an hour playing video games every day (AESVI, 2011; ISFE, 2012; Rivoltella, 2006).

Gaming and virtual experiences interact both directly and indirectly with cognitive and emotional processes that regulate visual attention and risk perception (Ciceri, 2004; Ciceri, 2005; Feldman, 2011; Underwood, Crundall, & Chapman, 2011). Perception and action in video games and virtual words are embodied and merged in coordinating actions and cognitions (Carberry & De Rosis, 2008; Knoblich & Flach, 2003; Lakoff & Nunez, 2000), allowing the gamer to act and immerse in flow experiences (Klasen, Weber, Kircher, Mathiak, & Mathiak, 2012) and experimenting directly with their body scheme the possible actions and interaction the video game require to be performed, like they are actually inside these virtual scenarios (Zlatev, Racine, Sinha, & Itkonen, 2008). The effects of this virtual interaction are real (Gorini, Gaggioli, & Riva, 2007; Juul, 2011) and lead to empowerment of perception, visuo-motorial skills and eye-hand coordination (Imamizu, Higuchi, Toda, & Kawato, 2007; Whiteley, Spence, & Haggard, 2008). In particular video games increase selective visual attention (Green & Bavelier, 2003), speed of visual processing (Anderson, 2013; Dye, Green, & Bavelier, 2009), improve target localization (Achtman, Green, & Bavelier, 2008; Green & Bavelier, 2007) and quicken decision making and cognitive control (Bailey, West, & Anderson, 2010; Barlett, Anderson, & Swing, 2009). All skills and abilities that are crucial and essential for driving (Groeger, 2001). On the other hand video games can have negative effects, and lead to risky behaviors, especially for adolescents (Chein, Albert, O'Brien, Uckert, & Steinberg, 2011; Dumas, Ellis, & Wolfe, 2012). Many experimental studies have been made about the influence of video games on specific behavior and on social abilities like attitude toward violence (Anderson, 2002b; Anderson, 2003; Anderson & Bushman, 2001; DeWall, Anderson, & Bushman, 2011; Dill & Dill, 1998; Fleming & Rick wood, 2001; Gentile & Trad. Media violence, 2003; Villani, 2001), empowerment of complex cognitive functions (Adachi & Willoughby, 2013; Basak, Boot, Voss, & Kramer, 2008; Bavelier & Davidson, 2013; Jenkins 2002; Pillay, 2003), and transfer of skills and effective learning in serious games (Breuer & Bente, 2010; Cerri, Clancey, Papadourakis, & Panourgia, 2012; Coleman 2001; Durkin & Barber 2002; Mitgutsch, Rosenstingl, & Wimmer, 2012; Ritterfeld, Cody, & Vorderer, 2009). As video games are able to impact gamer's risky driving attitudes and complex social behaviors (Vingilis et al., 2013), we want to know if also specific visual behaviors that affect driving abilities can be influenced by habitual use of racing video games. Does virtual driving experience in games support functional strategies of road exploration? Do gamers possess visual strategies that are useful for real driving?

Visual attention and risk perception, are among the main causes of road accidents (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006; Lee, 2008; Reyes & Lee, 2008; Ruscio, 2012; Summala, 1996; Vorderer & Klimmt, 2006) and can be studied by analyzing eye movement and gaze fixations (Endsley, 1995; Konstantopoulos, Chapman, & Crundall, 2012; Martens, 2004). Previous research has shown that non-drivers and novice drivers approach the road with visual strategies that differ from those used by experienced drivers in terms of time efficacy and efficiency of gaze performance (Chapman, Underwood, & Roberts, 2002; Jackson, Chapman, & Crundall, 2009; Martens & Fox, 2007b; Underwood, Chapman, Brocklehurst, Underwood, & Crundall, 2003). Through driving experience, novice drivers adapt to a more functional attentional resource allocation (Konstantopoulos, Chapman, & Crundall, 2010; Martens & Fox, 2007a; Shahar, Alberti, Clarke, & Crundall, 2010; Underwood, Crundal, & Chapman, 2002). Evidence shows that an exploration of the visual field can be organized to alter drivers' gaze orientation and configuration of saccades and fixations around salient points to enable safe driving (Crundall, Underwood, & Chapman, 1999).

The aim of the present study is to test visual attention of a particular category of pre-drivers that are male gamers of racing video games, and understand how visual skills acquired playing regularly video games are used for exploring the road. The main objectives are: (1) test gamer's selective visual attention and target localization for potential dangers, road signs and specific areas of interactions while driving; (2) test if gamer visual attention to target elements in the game scenario is adopted also in real scenarios. More specifically we hypothesize that: (a) gamer's real driving experience may influence visual exploration of the road, as reported in literature; (b) gamer's visual strategies for anticipate potential dangers in a video game scenario could be adopted also in real life scenario; (c) attentional resource allocation would be dependent on the road complexity, both in video game and in real roads, hypothesizing that similar road injunctions would require similar levels of visual attention.

2. Method

2.1. Design and variables

To test and compare the visual attention and distribution of eye movements while driving, three variables in interaction were considered: (1) driving experience of the gamer (between) comparing a group of young male gamers with a driver's license vs. young male experienced driver gamers, (2) real road vs. virtual road (within), to compare the distribution of attention both in video game and in a real scenario; (3) type of road interaction (within), in order to compare and measure the visual performance in different road configurations (Underwood, 2007).

Two experimental videos were constructed: one with seven road interactions in a reality-based driving scenario and one with the same road interactions in a virtual scenario from a video game. Both videos included five minutes of ordinary urban driving from the driver's perspective facing a sequence of the seven more common road interactions in the Italian urban roads (ACI-ISTAT, 2012): (1) roundabout, (2) traffic light, (3) give way, (4) right of way, (5) crossbuck, (6) right turn and (7) stop. The order of the video was randomized, and, inside each video, the sequence of the road interactions was randomized for each gamer, too. In the real video, the gamer had to face road interactions recorded from real driving in an urban area near the city of Milan, Italy. In the other video, the gamer had to face road interactions recorded from a driving session in a virtual European urban city from the video game Crash Time II (Synetic, 2009) chosen specifically for its likelihood of suburban roads and its matching of the European traffic sign system and traffic regulation. In term of salient elements for driving, both videos presented the same structure for each road interaction, and the vehicles moved across the road interaction with average urban speed, without exceeding urban speed limit of 50 km/h. The road interactions were selected according to the presence of the same vertical and horizontal road signs in the scene, as can be seen in Fig. 1. The two videos were presented to the gamers of the two groups who differed in real driving experience, and their gaze data and fixations were recorded by an eye-tracking system.

2.2. Participants

Forty young male users of driving video games participated voluntarily in this study. Two groups of gamers were systematically created, one with and one without real driving experience. Male pre-drivers were chosen for their habitual use of racing video games among a preliminary wider sample of pre-drivers recruited without monetary compensation in high schools and in local Universities for the study. The Italian version of the Sensation Seeking Scale VI (Galeazzi, D'Incerti, & Franceschina, 2003) was administer along with an ad hoc questionnaire built in order to control the participants' exposure level to video games, as well as their beliefs and attitude towards driving, racing video games, and particular dangers of the road. The first group included 20 male gamers aged 23–30 years ($M = 25.8$, $SD = 2.0$), normal SSS ($M = 2.73$, $SD = 5.53$), who were regular drivers (12,000 km/year) with more than five years of driving experience ($M = 6.91$, $SD = 1.70$). The second group included 20 male gamers aged 15–18 years ($M = 16.9$, $SD = 0.5$), normal SSS ($M = 2.43$, $SD = 4.58$), who were non-drivers who had never attended any driving lessons. All of the participants selected were intensive users of commercial games, and in particular they were habitual user of games that simulate an urban city scenario, such as the *Burnout* racing video game series (Criterion Games), the *Need for Speed* series (Electronic Arts), the *Test Drive* series (Infogrames) and others "drive'em up" racing games. In the previous six months, on average, they had played racing video games at least twice a week and for more than one hour a week. (*Mode* = "3 times a week, 1 h per session") for a sample's total mean usage estimated between 10 and 15 h a week, an amount of hours considered enough to classify participants as habitual gamers of racing video games (Vingilis et al., 2013), playing similarly or more than the average game usage of their Italian peers (AESVI, 2011) and yet exclude any pathological use of video games (Gentile et al., 2011). Pre-drivers were particularly confident about their driving skills. On a seven-point Likert scale, the selected pre-drivers believes that playing video games can

Fig. 1. Vertical and horizontal sign in real and virtual interactions. In the roundabout selected, the same sign were present.

improve their reaction to potential driving dangers in real driving (M = 5.07, SD = 1.94), and agree more than the experienced driver that being good at racing video games, means being good in real driving $F(1,39) = 4.400$, $p = .037$.

2.3. Procedure

Each participant was shown the two videos while seating in a static driving placement, consisting of a steering wheel and brake/accelerator pedals. This procedure allow to study visual search when driving of inexperienced drivers without exposing them to dangerous situations and has successfully already been use for studying visual attention (Underwood et al., 2011). They were encouraged to use the steering wheel and car pedals, pretending to be the actual drivers for the video as it facilitates immersion in the video stimulating the interaction of the motor cortex with the visual system performance (Pascha, Bianchi-Berthouze, Van Dijkc, & Nijholt, 2009; Seung & Jin, 2009; Thin, 2011). The participants were not informed that their gaze was being recorded in this phase, in order to avoid possible side effects of conscious gaze modifications.

Videos were run on an Acer Aspire 5930G (Intel Core Duo 2.26 GHz, 4 GB DDR2 e NVIDIA GeForce 9600M GT 512 MB RAM) connected to a 24-in. high-definition monitor. An Eyetracker Tobii x120 (drift: <0.3°, accuracy: 0.5°, 120 Hz) was placed under the monitor. The eye tracker system allowed for an automatic nine-point calibration procedure, without the need to measure the concrete geometry of the setup. No mobile devices or cables were connected to the driver, so as to provide a more naturalistic driving experience. After the experimental session, participants were debriefed and informed that their gaze was being recorded. Consent form was signed by all participants and the study was approved.

2.4. Calculation

In order to test target location and selective attention to the main important areas of the driving sight (Green, 2002), four Areas of Interest (AOIs) in every road interaction were selected for the statistical analysis: (1) vertical signs, (2) horizontal signs, (3) space of interaction with other users of the street approaching the intersection, and (4) rearview mirror. The frequency of the drivers' fixations inside each AOI (fixation count FC) (Underwood et al., 2003) plus the duration of each fixation (fixation length FL) were calculated using Tobii Studio 2.0 eye-tracking software. The variance of fixation locations along the horizontal and vertical meridian was also calculated for all road interactions, as visual search tends to spread wider for more demanding roadways (Underwood, Chapman, Bowden, & Crundall, 2002). Analyses were conducted on the three seconds preceding the participants' approach to each road interaction, a window of time considered enough to study the visual and motor reaction to different type of potential dangers while driving (Green, 2000; Summala, 2000), allowing to study the location, distribution and duration of gamers' visual attention while approaching each road interactions. The number, duration and spread of the fixations were analyzed using SPSS through General Linear Model 2 × 7 × 2 with repeated measures for the first two factors ((Type of Video: Real, Virtual Road) × (Type of Road Interaction: (Roundabout, Traffic Light, Give Way, Right of Way, Crossbuck, Right Turn, Stop) × (Driving Experience: Drivers, Non-drivers)) to compare the ocular movements inside the AOIs as functions of the gamer's driving experience, the nature of the road scenario and the type of road interaction.

3. Results

3.1. Driving experience: drivers vs. non-drivers

Three seconds before approaching all road interactions, experienced drivers looked in the AOIs on average six times for a duration of 2.62 s. Non-drivers approaching the same road interactions looked in the AOIs an average of two times for a duration of 0.76 s. The differences were found to be statically significant (Fig. 2) for both fixation count, $F(1,39) = 53.631$, $p < .000$, $\eta^2 = .585$, and duration of fixation, $F(1,39) = 51.556$, $p < .000$, $\eta^2 = .576$.

Differences between the two groups also emerge from a qualitative analysis of the gaze plot (Fig. 3). It is possible to identify a pattern in the experienced drivers (Fig. 3c) of organizing visual exploration with a defined monitoring pattern that selects some AOIs for each specific interaction (e.g. Fig. 3a), while non-drivers' visual exploration is more scattered around the center of the scene (Fig. 3d), without a specific focus on the AOIs (Fig. 3b). The radial distance from the mean fixation position to the mean of individual fixations of the two groups in all the scenarios was calculated, reporting an overall wider horizontal spread of fixation for gamers with driving experience (M = 40°, SD = 7.5°) then pre-driving gamers (M = 37°, SD = 8.5°) and a narrow vertical spread of the fixations (M = 34°, SD = 3.5°) then pre-driving gamers' (M = 36°, SD = 2.5°).

3.2. Scenario: reality vs. video game

The main effect is significant for both fixation count and fixation duration in the AOIs. For all participants, fixations were more frequent, $F(1,39) = 67.617$, $p < .000$, $\eta^2 = .640$, as well as longer, $F(1,39) = 82.581$, $p < .000$, $\eta^2 = .685$, in the road interactions taken from reality than in the same type of road interactions taken from the video game. The radial distance from the mean fixation position to the mean of individual fixations in the two scenarios was similar, with a horizontal spread of

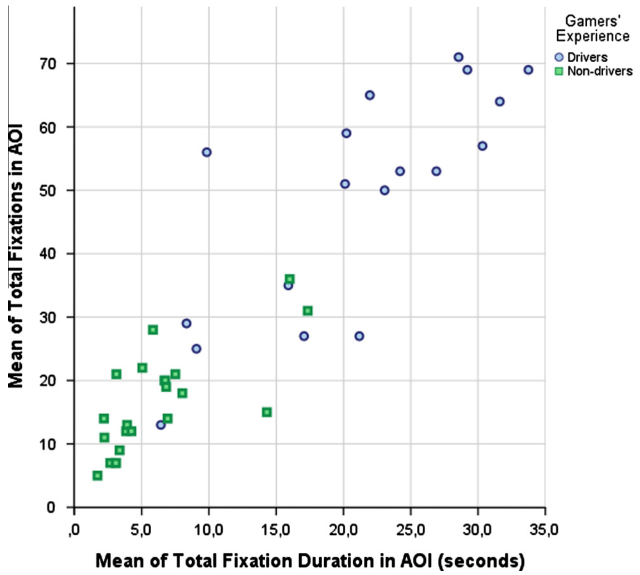

Fig. 2. Total number (frequency) and total length of the fixations (s) in all the Areas of Interest (AOI) for experienced drivers and non-drivers in all road interactions.

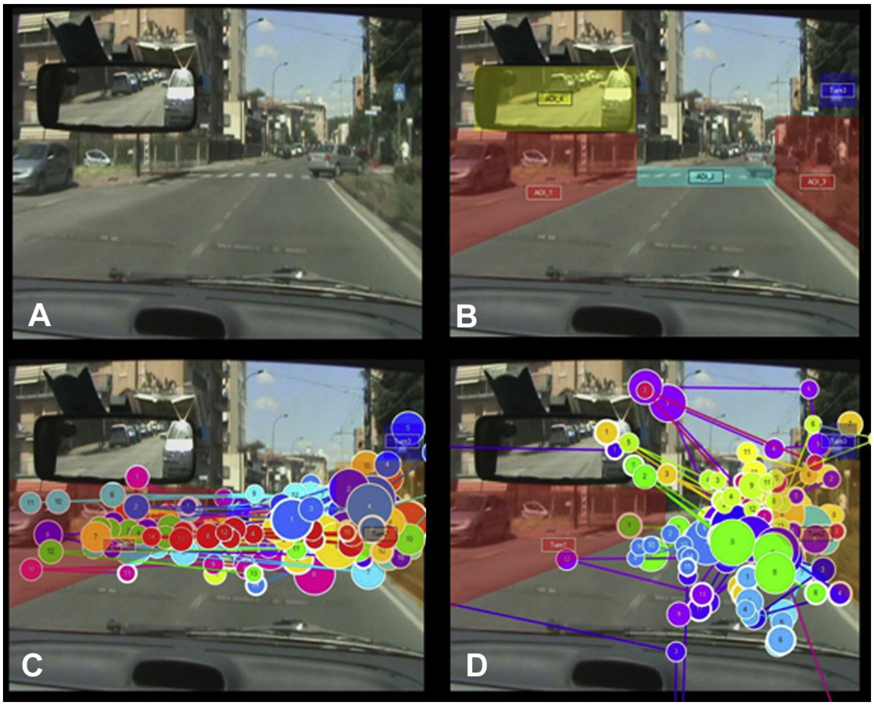

Fig. 3. (A) Real driving video. Leading car turning right, while another car approaches from the left, near a pedestrian crossing. (B) For this road interaction, four Areas of Interest were selected. (C) Gaze plot of expert drivers for this road interaction. (D) Gaze plot of expert gamers without drivers' license.

$M = 20°$, $SD = 11.5°$ in real scenario vs. $M = 20°$, $SD = 11$ in video game scenario, and vertical spread of $M = 17°$, $SD = 6.5°$ in real scenario vs. $M = 13°$, $SD = 4.5$ in video game scenario.

The interaction effect of video x driving experience was also significant, with more frequent, $F(1,39) = 25.364$, $p < .000$, $\eta^2 = .400$, and longer, $F(1,39) = 8719$, $p = .005$, $\eta^2 = .187$ fixations in the AOIs for experienced drivers in the real video (Table 1). Non-drivers also monitored the AOIs more frequently and for greater lengths of time in the real video, FC $F(1,39) = 18.230$, $p < .000$, $\eta^2 = .465$; FL $F(1,39) = 12.636$, $p = .002$, $\eta^2 = .376$, keeping the same ratio of the visual performance

Table 1
Frequency and mean of duration (in seconds) in the Areas of Interest for all road interactions by participants.

	Fixation count				Fixation duration (s)			
	Video game		Reality		Video game		Reality	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Drivers	16.05	7.26	27.33	10.39	6.31	3.18	12.45	4.89
Non-drivers	4.72	3.74	10.04	5.39	1.83	1.90	3.59	2.53

of the experienced drivers (Fig. 4), that, nonetheless, paid more attention to the AOIs in the video game than non-drivers did in the real video, FC $F(1,39) = 47.718$, $p < .000$, $\eta^2 = .737$; FL $F(1,39) = 67.465$, $p < .000$, $\eta^2 = .799$. The horizontal spread of fixation of gamers with driving experience was $M = 25°$, $SD = 13.5°$, in real road scenario and $M = 20°$, $SD = 6°$ in video game scenario, with pre-driving gamers that present similar horizontal spread in both scenarios: real $M = 17°$, $SD = 9°$ vs. video game $M = 18°$, $SD = 5.5°$.

3.3. Road interactions

Road interactions required different patterns of road exploration. The main effect of road interaction, for the number, $F(6,39) = 11.504$, $p < .000$, $\eta^2 = .232$, and duration, $F(6,39) = 15.463$, $p < .000$, $\eta^2 = .289$, of all fixations were significantly different for each road interaction. Analysis of deviation contrasts showed that the interactions that received less frequent and shorter fixations on the AOIs for both real and virtual video, were the crossbuck (FC: $M = 1.41$, FL: $M = 0.54$ s) and the traffic light (FC: $M = 1.63$, FL: $M = 0.63$ s), while the road interactions that required more frequent fixations on the AOIs for a longer duration during the entire crossing were the turn (FC: $M = 2.76$, FL: $M = 1.15$ s) and stop (FC: $M = 3.048$, FL: $M = 1.28$ s). The interaction effect with the type of scenario was significant, too. The mean on the numbers of fixations $F(6,39) = 5.225$, $p < .000$, $\eta^2 = .121$ and their mean duration $F(6,39) = 4.850$, $p < .000$, $\eta^2 = .113$ was different for every road interaction compared to the others, both taken from the real scenario and taken from the video game. However the less demanding interactions in the video game scenario were the same less demanding interactions in the real scenario, and for the give of way the number, $t(39) = -1.1940$, $p = .060$, and duration, $t(39) = -1.025$, $p = .312$, of fixation were identical in both scenarios (Fig. 5).

The interaction effect road interactions × driving experience was also significant for both frequency, $F(6,39) = 5.727$, $p < .000$, $\eta^2 = .131$, and duration, $F(6,39) = 6.513$, $p < .000$, $\eta^2 = .146$, of the fixations. Drivers adapt visual exploration in response to the complexity of individual driving interactions by changing their fixations on the AOIs, while the frequency and duration of non-drivers' fixations are not as variable. The mean range among the road interactions for non-drivers is 0.43 s, varying from a minimum duration of 0.22 s in the AOIs for the roundabout and crossbuck, to a maximum of 0.65 s for the right of way. The mean range for drivers is almost triple, with a variation of attention of 1.19 s among the road interactions, lasting from a minimum of 0.87 s in the AOIs for the crossbuck and traffic light to a maximum of 2.06 s in the AOIs for the stop interaction.

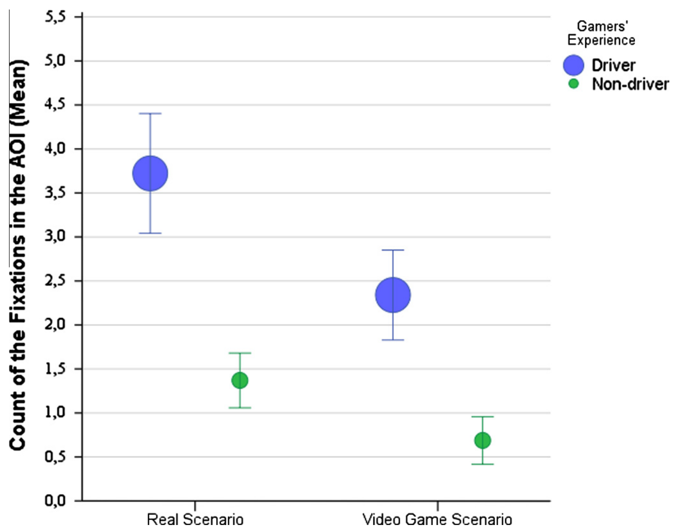

Fig. 4. Mean of the Fixation Count in the AOI for drivers and pre-drivers in the road intersections of the real and video game video. Target location in the video game require less elements to be considered in road interactions, yet the ratio of driving experience's effect is the same in virtual vs. real scenarios.

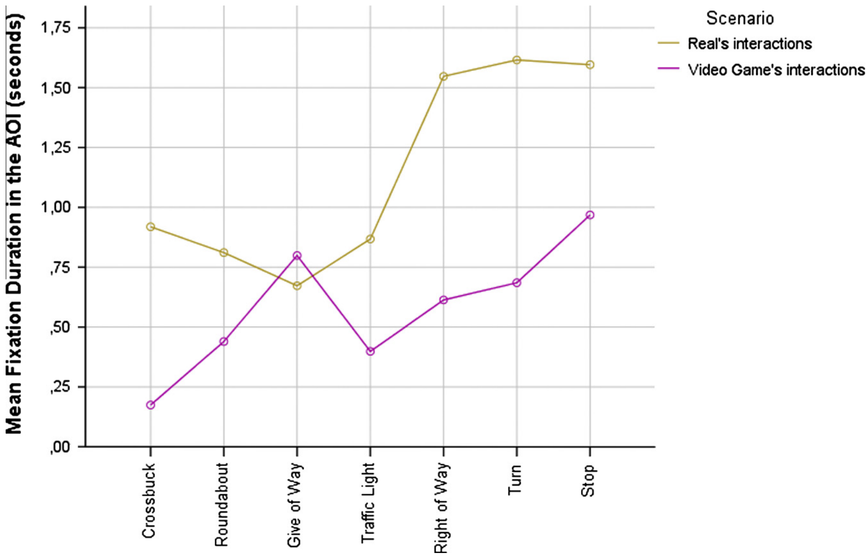

Fig. 5. Road intersections in real vs. virtual scenario: mean duration of gamers' fixations (s) in the Areas of Interest, approaching each type of road interaction.

4. Discussion

The aim of this research was to analyze patterns of visual exploration in order to understand how male players of racing video games without direct driving experience approach different road interactions. Three main considerations emerge from the results. First, as we hypothesized, gamers without real driving experience do not have a pattern of visual exploration of the road that is functional for real driving; thus, strategies for exploring road interactions learned while driving in virtual cities are not similar to the strategies of experienced drivers. The pattern of visual exploration of road interactions in virtual driving is not articulated and thus does not include some important elements for safe driving. Unlike experienced drivers, gamers' virtual driving attention is focused on only a few elements of the driving scene for only a short amount of time, and every scene is approached in the same way, without any evident differentiation in levels of attention. If pre-driver gamer thinks that video games make them better driver, then a potential risk of misplaced self-confidence may be present, pointing out a specific visual failure that could be used in injury prevention training (Hull, Draghici, & Sargent, 2012), that include not only risk-taking attitude (Fischer et al., 2009) but also specific visual abilities and strategies.

Second, video games do not seem to provide an organization of the visual attention towards salient elements for safe driving similar to real road, as even experienced drivers' performance is poorer in video games scenarios. Still the driving experience that result from real driving, shape the visual exploration of the road even in video game scenario, guiding experienced drivers gaze towards potential danger, in a way that is qualitative different from the visual exploration of pre-drivers. Experienced drivers consider the virtual road as the real road, as far as visual exploration, and pre-drivers do the opposite, pointing out two unexpected approaches to visually explore the road.

Third, road interactions differ in terms of salient elements that require attention. Both in real and virtual scenarios, as expected. Experienced drivers select visual strategies according to the complexity of the roadway, looking for specific interaction areas (Crundall & Underwood, 1998). The fact that the differences in visual attention required by each road interaction were the same, both in real and virtual interactions, and spread of fixations in real scenario were similar to spread in video games, suggest that even a commercial video game demands different distribution of visual attention, in order to face different road interactions. That could eventually train different type of visual exploration's pattern, empowering the shift from simple to more demanding road interactions. Yet facing different road interactions in video games alone is not enough for non-driving gamers to develop stabile strategies to meet the changing demands of real road interactions. This research did not address the fact that pre-drivers gamers' performance could still be different from pre-drivers non-gamers' performance in target localization and visual attention to road interactions and further research could investigate if the visual skills empowered in video games, or in other virtual driving simulators, may have effects that are actually transferred in the real driving performances. More research is needed in order to clarify the implications of these results to researchers that design video games experiences with different driving experiences, as well as to developmental researcher that study the effect of being a pre-driver gamer vs. being a pre-driver non-gamer, in developing risky attitudes and pattern of visual attention for real driving.

These main considerations were based on the analysis of the voluntary orientation of male gamers' gaze towards specifics areas of interest, but there are different limitations that may be relevant. Gaze toward the AOIs alone is not necessarily synonymous with attention to or awareness of the elements present in that region of space, nor was the participants' peripheral view included in this analysis (Crundall, Underwood, & Chapman, 2002). Other cohort variables could explain the difference in the two groups of gamers (Ivers et al., 2009). Only male participants were selected in this test, in order to control genre variability (Ozkan & Lajunen, 2006) and study the more vulnerable user of the road, so it would be interesting to study possible effect on female gamers, as the use of video games is becoming increasingly popular for female adolescent too; and on female tout cour as they are a less exposed category to road accident then their male peer (ACI-ISTAT, 2012). On the other hand, it remains to be explored why specifically virtual driving in video games does not aid in the development of an adequate exploration of road patterns. Is it the gaming structure? Is the task of the game? Is the targets' visual saliency different in a virtual scenario? Further research is required to understand if the same phenomenon will be confirmed with different video games or change after specific tests.

Nevertheless, the fact that voluntary fixations in the AOIs were found to be poor or absent for the non-driving gamers remains a strong risk indicator. Approaching the road while systematically ignoring certain elements is an interesting indicator of concrete risky behaviors that need to be tackled. A specific focus on visual strategies in training courses could be implemented, in order to understand if some changes can be facilitated earlier (McKenna, Horswill, & Alexander, 2006). Along with traditional trainings, a capitalization of the potential of specific racing video games to provide, in a safe and playful virtual environment, a differentiation of distribution of visual attention for different road interactions, could be used; empowering general visual attention and target localization into specific visual abilities, that are useful not only for the game experience, but also for future real driving experiences.

Acknowledgements

For their support and help in this project, we would like to thank all of the volunteer participants, Stefania Balzarotti, and all of the passionate workers at the Laboratory of Communication Psychology, Università Cattolica del Sacro Cuore-Milano.

References

Achtman, R. L., Green, C. S., & Bavelier, D. (2008). Video games as a tool to train visual skills. *Restorative Neurology and Neuroscience, 26*, 435–446.
ACI-ISTAT (2009). *Incidenti stradali: Sintesi dello studio 2009*.
ACI-ISTAT (2010). *Incidenti stradali: Sintesi dello studio 2010*.
ACI-ISTAT (2011). *Incidenti stradali: Sintesi dello studio 2011*. Sintesi dello Studio.
ACI-ISTAT (2012). *Incidenti stradali: Sintesi dello studio 2012*.
Adachi, P. J., & Willoughby, T. (2013). More than just fun and games: the longitudinal relationships between strategic video games, self-reported problem solving skills, and academic grades. *Journal of Youth and Adolescence*.
AESVI (2011). *Ottavo rapporto annuale sullo stato dell'industria videoludica in Italia*.
Anderson, C. A. (2002b). Violent video games and aggressive thoughts, feelings, and behaviors. In S. L. Calvert, A. B. Jordan, & R. R. Cocking (Eds.), *Children in the digital age* (pp. 101–119). Johns Westport, Connecticut: Praeger.
Anderson, C. A. (2013). Video games boost visual attention but reduce impulse control. *Society for Personality and Social Psychology* (August 4), 1–5.
Anderson, C. A., & Bushman, B. J. (2001). Effects of violent video games on aggressive behavior, aggressive cognition, aggressive affect, physiological arousal, and prosocial behavior: A meta-analytic review of the scientific literature. *Psychological Science, 12*(5), 353–359.
Anderson, C. A. (2003). Video games and aggressive behavior. In D. Ravitch & J. P. Viteritti (Eds.), *Kid stuff: Marketing sex and violence to America's children* (pp. 143–167). Baltimore, MD: Johns Hopkins University Press.
Bailey, K., West, R., & Anderson, C. A. (2010). A negative association between video game experience and proactive cognitive control. *Psychophysiology, 47*, 34–42.
Barg, F. K., Keddem, S., Ginsburg, K. R., & Winston, F. K. (2009). Teen perceptions of good drivers and safe drivers: Implications for reaching adolescents. *Injury Prevention, 15*(1), 24–29.
Barlett, C. P., Anderson, C. A., & Swing, E. L. (2009). Video game effects—Confirmed, suspected, and speculative. A review of the evidence. *Simulation and Gaming, 40*(3), 377–403.
Basak, C., Boot, W. R., Voss, M. V., & Kramer, A. F. (2008). Can training in a real-time strategy video game attenuate cognitive decline in older adults? *Psychology and Aging, 23*(4), 765–777.
Bavelier, D., & Davidson, R. J. (2013). Brain training: Games to do you good. *Nature, 494*, 425–426.
Beullens, K., Roe, K., & Van den Bulck, J. (2011). Excellent gamer, excellent driver? The impact of adolescents' video game playing on driving behavior: A two-wave panel study. *Accident Analysis and Prevention, 43*(1), 58–65.
Bjornskau, T., & Sagberg, F. (2005). What do novice drivers learn during the first months of driving? Improved handling skills or improved road-user interaction? In *3rd International conference on traffic and transport psychology*. Nottingham.
Breuer, J., & Bente, G. (2010). Why so serious? On the relation of serious games and learning. *Eludamos. Journal for Computer Game Culture, 4*(1), 7–24.
Carberry, S., & De Rosis, F. (2008). Introduction to special issue on affective modeling and adaptation. *User Modeling and User-Adapted Interaction, 18*(1), 1–9.
Cerri, S. A., Clancey, W. J., Papadourakis, G., & Panourgia, K. K. (Eds.). (2012). *Proceedings of Intelligent tutoring systems: 11th international conference*, ITS 2012, Chania, Crete, Greece, June 14–18, 2012. Berlin Heidelberg: Springer.
Chapman, P., Underwood, G., & Roberts, K. (2002). Visual search patterns in trained and untrained novice drivers. *Transportation Research Part F: Psychology and Behaviour, 5*, 157–167.
Chein, J., Albert, D., O'Brien, L., Uckert, K., & Steinberg, L. (2011). Peers increase adolescent risk taking by enhancing activity in the brain's reward circuitry. *Developmental Science, 14*(2), F1–F10.
Ciceri, M. R. (Ed.). (2004). *Comunicare il pensiero: Procedure immagini parole*. Torino: Omega Edizioni.
Ciceri, M. R. (Ed.). (2005). *MENTE inter-ATTIVA: Linguaggi, media e competenze*. Torino: Omega Edizioni.
Ciceri, M. R., & Confalonieri, F. (2012). Strategie di esplorazione visiva e percezione del rischio nei new drivers. *Ricerche di Psicologia, 1-2012*, 63–82.
Clarke, D. D., Ward, P. J., & Truman, W. A. (2005). Voluntary risk-taking and skill deficits in young driver accidents. *Accident Analysis and Prevention, 37*(3), 523–529.
Coleman, D. S. (2001). PC gaming and simulation supports training. *Proceedings of the United States Naval Institute, 127*, 73–75.
Crundall, D. E., & Underwood, G. (1998). Effects of experience and processing demands on visual information acquisition in drivers. *Ergonomics, 41*(4), 448–458.
Crundall, D., Underwood, G., & Chapman, P. (1999). Driving experience and the functional field of view. *Perception, 28*(9), 1075–1087.

Crundall, D., Underwood, G., & Chapman, P. (2002). Attending to the peripheral world while driving applied cognitive psychology. *Applied Cognitive Psychology, 16*(4), 459–476.

Deighton, C., & Luther, R. (2007). *Pre-driver education – A critical review of the literature on attitude change and development, good practice in pre-driver education and programme effectiveness*. Department for Transport, England. Wokingham, Berkshire RG40 3GA United Kingdom: Road Safety Research Report.

DeWall, C. N., Anderson, C. A., & Bushman, B. J. (2011). The general aggression model: Theoretical extensions to violence. *Psychology of Violence, 1*, 245–258.

Dill, K. E., & Dill, J. C. (1998). Video game violence: A review of the empirical literature. *Aggression and Violent Behavior: A Review Journal, 3*, 407–428.

Dumas, T. M., Ellis, W. E., & Wolfe, D. A. (2012). Identity development as a buffer of adolescent risk behaviors in the context of peer group pressure and control. *Journal of Adolescence, 35*(4), 917–927.

Durkin, K. (1995). *Developmental social psychology: From infancy to old age*. Oxford: Blackwell.

Durkin, K. (Ed.). (2006). Game playing and adolescents' development. In P. Vorderer, J. Bryant, P. Vorderer, & J. Bryant (Eds.). *Playing video games: Motives, responses, and consequences* (Vol. Playing video games: Motives, responses, and consequences, pp. 325–345). Mahwah, NJ: Lawrence Erlbaum Associates.

Durkin, K., & Barber, B. (2002). Not so doomed: Computer game play and positive adolescent development. *Journal of Applied Developmental Psychology, 23*, 373–392.

Dye, M. W., Green, C. S., & Bavelier, D. (2009). Increasing speed of processing with action video games. *Current Directions in Psychological Science, 18*, 321–326.

Elliot, M. A., & Baughan, C. J. (2003). *Adolescent road user behaviour: A surevy of 11–16 year olds*. Crowthorne: TRL.

Endsley, M. (1995). Measurement of situation awareness in dynamic systems. *Human Factors, 37*, 65–84.

ESA (2013). *Essential facts about the computer and video game industry*.

Feldman, R. S. (2011). *Understanding psychology* (10th ed.). New York: McGraw-Hill.

Fischer, P., Greitemeyer, T., Morton, T., Kastenmüller, A., Postmes, T., Frey, D., et al (2009). The racing-game effect: Why do video racing games increase risk-taking inclinations. *Personality & Social Psychology Bulletin, 35*(10), 1395–1409.

Fleming, M. J., & Rick Wood, D. J. (2001). Effects of violent versus nonviolent video games on children's arousal, aggressive mood, and positive mood. *Journal of Applied Social Psychology, 31*(10), 2047–2071.

Galeazzi, A., D'Incerti, L., & Franceschina, E. (2003). Sensation seeking scale VI: Italian standardization for young people from 14 to 20 years old. *Testing-Psicometria-Metodologia, 10*(4), 131–140.

Gatersleben, B., & Haddad, H. (2010). Who is the typical bicyclist? *Transportation Research Part F, 13*, 41–48.

Gentile, D., Trad. Media violence and children. (2003). Westport, CT: Praeger.

Gentile, D. A., Choo, H., Liau, A. K., Sim, T., Li, D., Fung, D., et al (2011). Pathological video game use among youths: A two-year longitudinal study. *Pediatrics, 127*, e319–e329.

Gorini, A., Gaggioli, A., & Riva, G. (2007). Virtual worlds, real healing. *Science, 318*(5856), 1549.

Green, M. (2000). 'How long does it take to stop?' methodological analysis of driver perception-brake times. *Transportation Human Factors, 2*, 195–216.

Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature, 423*, 534–538.

Green, C. S., & Bavelier, D. (2007). Action video game experience alters the spatial resolution of attention. *Psychological Science, 18*(1), 88–94.

Green, P. (2002). Where do drivers look while driving (and for how long)? In R. E. Dewar & P. Olson (Eds.), *Human factors in traffic safety* (pp. 77–110). Tucson, AZ: Lawyers and Judges Publishing.

Groeger, J. (2001). *Understanding driving: Applying cognitive psychology to a complex everyday task*. Hove: Psychology Press.

Hull, J. G., Draghici, A. M., & Sargent, J. D. (2012). A longitudinal study of risk-glorifying video games and reckless driving. *Psychology of Popular Media Culture, 1*(4), 244–253.

Husband, P. (2010). *Young and emerging drivers: A review of the evidence on education, training and publicity for young and emerging drivers (16–25 years old): Implications for practice*. Devon County Council and University of Plymouth.

Imamizu, H., Higuchi, S., Toda, A., & Kawato, M. (2007). Reorganization of Brain activity for multiple internal models after short but intensive training. *Cortex, 43*(3), 338–349.

ISFE (2012). *Videogames in Europe: Consumer study*. Ipsos Media CT.

Ivers, R., Senserrick, T., Boufous, S., Stevenson, M., Chen, H., Woodward, M., et al (2009). Novice drivers' risky driving behavior, risk perception, and crash risk: Findings from the DRIVE study. *American Journal of Public Health, 9*(99), 1638–1644.

Jackson, L., Chapman, P., & Crundall, D. (2009). What happens next? Predicting other road users' behaviour as a function of driving experience and processing time. *Ergonomics, 52*(2), 154–164.

Jenkins, H. (2002). Game theory. *Technology Review, 29*, 1–3.

Juul, J. (2011). *Half-real: Video games between real rules and fictional worlds*. Cambridge: The MIT Press.

Kass, S. J., Cole, K. S., & Stanny, C. J. (2007). Effects of distraction and experience on situation awareness and simulated driving. *Transportation Research Part F, 10*(4), 321–329.

Klasen, M., Weber, R., Kircher, T. T., Mathiak, K. A., & Mathiak, K. (2012). Neural contributions to flow experience during video game playing. *Social Cognitive and Affective Neuroscience, 7*(4), 485–495.

Klauer, S. G., Dingus, T. A., Neale, V., Sudweeks, J., & Ramsey, D. (2006). *The impact of driver inattention on near-crash/crash risk: An analysis using the 100-car naturalistic driving study data*. National Highway Traffic Safety Administrationo. Document Number, Washington, DC.

Knoblich, G., & Flach, R. (2003). Action identity: Evidence from self-recognition, prediction, and coordination. *Consciousness and Cognition, 12*, 620–632.

Konstantopoulos, P., Chapman, P., & Crundall, D. (2010). Driver's visual attention as a function of driving experience and visibility. Using a driving simulator to explore drivers' eye movements in day, night and rain driving. *Accident Analysis and Prevention, 42*(3), 827–834.

Konstantopoulos, P., Chapman, P., & Crundall, D. (2012). Exploring the ability to identify visual search differences when observing drivers' eye movements. *Transportation Research Part F, 15*, 378–386.

Lakoff, G., & Nunez, R. E. (2000). *Where mathematics comes from: How the embodied mind brings mathematics into being*. New York: Basic Books.

Lee, J. D. (2008). Driving attention: Cognitive engineering in designing attractions and distractions. *The Bridge, 38*(4), 93–102.

Mann, H. N., & Lansdown, T. (2009). Pre-driving adolescent attitudes: Can they change? *Transportation Research Part F: Traffic Psychology and Behaviour, 12*(5), 395–403.

Martens, M. H. (2004). Stimuli fixation and manual response as a function of expectancies. *Human Factors, 46*(3), 410–423.

Martens, H., & Fox, M. R. (2007a). Does road familiarity change eye fixations? A comparison between watching a video and real driving. *Transportation Research Part F, 10*, 33–47.

Martens, M. H., & Fox, M. R. (2007b). Do familiarity and expectations change perception? Drivers' glances and response to changes. *Transportation Research Part F, 10*, 476–492.

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*, 683–691.

McKenna, F. P., Horswill, M. S., & Alexander, J. L. (2006). Does anticipation training affect drivers' risk taking? *Journal of Experimental Psychology-Applied, 12*(1), 1–10.

Metzger, M. J., & Flanagin, A. J. (2008). Digital media and youth: Unparalleled opportunity and unprecedented responsibility. In M. J. Metzger & A. J. Flanagin (Eds.), *Digital media, youth, and credibility. The John D. and Catherin T. MacArthur foundation series on digital media and learning* (pp. 5–27). Cambridge: The MIT Press.

Mitgutsch, K., Rosenstingl, H., & Wimmer, J. (Eds.). (2012). *Applied playfulness: Proceedings of the vienna games conference 2011: Future and reality of gaming*. Vienna: New Academic Press.

OECD (2006). Young drivers. *The road to safety*. Joint Transport Research Centre, ECMT and OECD, Paris.
Ozkan, T., & Lajunen, T. (2006). What causes the differences in driving between young men and women? The effects of gender roles and sex on young drivers' driving behaviour and self-assessment of skills. *Transportation Research Part F, 9*, 269–277.
Pascha, M., Bianchi-Berthouze, N., Van Dijkc, B., & Nijholt, A. (2009). Movement-based sports video games: Investigating motivation and gaming experience. *Entertainment Computing, 1*(2), 49–61.
Pillay, H. (2003). An investigation of cognitive process engaged in by recreational computer game players: Implications for skills of the future. *Journal of Research on Technology in Education, 34*, 336–349.
Poulter, D., & McKenna, F. P. (2010). Evaluating the effectiveness of a road safety education intervention for pre-drivers: An application of the theory of planned behavior. *British Journal of Educational, 80*(2), 163–181.
Reyes, M. L., & Lee, J. D. (2008). Effects of cognitive load presence and duration on driver eye movements and event detection performance. *Transportation Research Part F, 11*, 391–402.
Ritterfeld, U., Cody, M. J., & Vorderer, P. (2009). *Serious games: Mechanisms and effects*. New York: Routledge.
Rivoltella, C. P. (2006). *Screen generation. Gli adolescenti e le prospettive dell'educazione nell'età dei media digitali*. Milano: Vita e Pensiero.
Ruscio, D. (2012). Simulating real danger? Validation of driving simulator test and psychological factors in brake response time to danger. In *Proceeding ICMI '12 proceedings of the 14th ACM international conference on multimodal interaction* (pp. 345–348). New York: ACM.
Seung, A., & Jin, A. (2009). Avatars mirroring the actual self versus projecting the ideal self: The effects of self-priming on interactivity and immersion in an exergame, wii fit. *CyberPsychology and Behavior, 12*(6), 761–765.
Shahar, A., Alberti, C. F., Clarke, D., & Crundall, D. (2010). Hazard perception as a function of target location and the field of view. *Accident Analysis and Prevention, 42*(6), 1577–1584.
Summala, H. (1996). Accident risk and driver behavior. *Safety Science, 22*, 103–117.
Summala, H. (2000). Brake reaction times and driver behavior analysis. *Transportation Human Factors, 2*(3), 217–226.
Thin, A. G. (2011). Flow experience and mood states while playing body movement-controlled video games. *Games and Culture, 6*(5), 414–428.
Twisk, D., Vlakveld, W., Mesken, J., Shope, J. T., & Kok, G. (2013). Inexperience and risky decisions of young adolescents, as pedestrians and cyclists, in interactions with lorries, and the effects of competency versus awareness education. *Accident Analysis and Prevention, 55*, 219–225.
Underwood, G. (Ed.). (2005). *Traffic and transport psychology. Theory and application: Proceedings of the ICTTP 2004*. Oxford: Elsevier.
Underwood, G. (2007). Visual attention and the transition from novice to advanced driver. *Ergonomics, 50*(8), 1235–1249.
Underwood, G., Chapman, P., Bowden, K., & Crundall, D. (2002). Visual search while driving: Skill and awareness during inspection of the scene. *Transportation Research Part F: Traffic Psychology and Behaviour, 5*(2), 87–97.
Underwood, G., Chapman, P., Brocklehurst, N., Underwood, J., & Crundall, D. (2003). Visual attention while driving: Sequences of eye fixations made by experienced and novice drivers. *Ergonomics, 46*(6), 629–646.
Underwood, G., Crundal, D., & Chapman, P. (2002). Selective searching while driving: The role of experience in hazard detection and general surveillance. *Ergonomics, 45*(1), 1–12.
Underwood, G., Crundall, D., & Chapman, P. (2011). Driving simulator validation with hazard perception. *Transportation Research Part F: Traffic Psychology and Behaviour, 14*(6), 435–446.
Villani, S. (2001). Impact of media on children and adolescents: A 10-year review of the research. *Journal of the American Academy of Child and Adolescent Psychiatry, 40*(4), 392–401.
Vingilis, E., Seeley, J., Wiesenthal, D. L., Wickens, C. M., Fischer, P., & Mann, R. E. (2013). Street racing video games and risk-taking driving: An internet survey of automobile enthusiasts. *Accident Analysis and Prevention, 50*, 1–7.
Vorderer, P., & Klimmt, C. (2006). *Rennspiele am computer: Implikationen fuer die Verkehrssicherheitsarbeit. Zum Einfluss von Computerspielen mit Fahrzeugbezug auf das Fahrverhalten junger Fahrer* (Vol. 1). Verlag fuer Neue Wissenschaft: Bremerhaven.
Vorderer, P., & Bryant, J. (Eds.). (2006). *Playing video games – Motives, responses, and consequences*. Mahwah, NJ: Lawrence Erlbaum Associates.
Walke, L., Butland, D., & Connell, R. W. (2000). Boys on the road: Masculinities, car culture, and road safety education. *The Journal of Men's Studies, 8*(2).
Waylen, A., & McKenna, F. P. (2002). Attitudes to driving in pre-17-year-olds. *Behavioural research in road safety: Twelfth seminar* (pp. 188–194). Dublin.
Waylen, A. E., & McKenna, F. P. (2008). Risky attitudes towards road use in pre-drivers. *Accident Analysis and Prevention, 40*(3), 905–911.
Whiteley, L., Spence, C., & Haggard, P. (2008). Visual processing and the bodily self. *Acta Psychologica, 127*(1), 129–136.
Williams, A. F. (2003). Teenage drivers: Patterns of risk. *Journal of Safety Research, 34*(1), 5–15.
Zakrajsek, J. S., Shope, J. T., Greenspan, A. I., Wang, J., Raymond Bingham, C., & Simons-Morton, B. G. (2013). Effectiveness of a brief parent-directed teen driver safety intervention (checkpoints) delivered by driver education instructors. *Journal of Adolescent Health, 58*(1).
Zlatev, J., Racine, T., Sinha, C., & Itkonen, E. (Eds.). (2008). *The shared mind: Perspectives on intersubjectivity*. Amsterdam: John Benjamins.