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Attitudes of learner drivers toward safety at level crossings: Do they change after a 360° video-based educational intervention?

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ABSTRACT

In light of the growing number of level crossing accidents and the limited prevention programmes, this study examined relationships among attitudes toward traffic rules, impulsiveness, and behavioural intentions at level crossings. It explored the behavioural effects of an educational programme newly developed within the framework of the Croatian national safety project "Implementation of measures to improve the safety of the most vulnerable traffic participants at level crossings". The programme aimed to change risky attitudes and behavioural intentions of learner drivers at level crossings. It consists of a safety lecture accompanied by pictures, videos and the exposition to a 3D virtual reality film shot at a real level crossing, which allows the participant to experience, from the driver's perspective, safe and risky crossings. The programme was implemented in 11 driving schools. First, 285 participants (62.8% men) answered a questionnaire measuring safety attitudes toward traffic and impulsiveness, then they attended a lecture and participated in the virtual reality experience. Finally, they answered a questionnaire measuring planned future behaviour at level crossings. The results showed that attitudes toward level crossing risk significantly predicted intended driving behaviour at level crossings. Furthermore, the 360° video-based educational intervention altered the relationships connecting attitudes toward level crossings and risky driving behaviour at level crossings. The practical implications of these results are discussed.

1. Introduction

Level crossings are places of direct conflict between the railway and road traffic. Therefore, they are frequent sites of collisions, with the severest consequences in terms of fatalities and material damage (European Agency for Railways – ERA, 2018). For example, 21,763 accidents occurred at level crossings in the USA between 2007 and 2016, leading to 2,611 fatalities and accounting for 35% of all railway-related fatalities (Federal Railroad Administration, 2017). In Australia, an average of 78 accidents and 38 fatalities occur at 23,532 level crossings, and these accidents are the most frequent cause of rail-related fatalities in the country (Di Millia, Searle, & Dawson, 2012). In the European Union (EU), 7,067 accidents occurred at level crossings between 2006 and 2015, accounting for 29% of all railway-related accidents; the accidents at level crossings led to 3,377 fatalities, or 30% of all railway-related fatalities (European Commission – Eurostat, 2016). The relatively

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small EU member Croatia has 1,519 level crossings along 2,604 km of railway tracks; during 2007–2016, 438 accidents occurred at these crossings, accounting for 56% of all railway-related accidents and leading to 58 fatalities (Ministry of Interior, 2017).

One of the contributors to the high risk of accident and death at level crossings is inadequate safety infrastructure. In Australia, for example, only 33% of level crossings have active protection systems (Australian Transport Safety Bureau, 2017), defined as any type of safety indicator that changes its state (sound warnings, light signalling or mechanical gates) when a train is approaching. In the EU, only 49% have active systems, while more than half have passive protection systems, mainly limited to a St. Andrews cross, "Stop" sign and visibility triangle. In Croatia, the safety infrastructure is even less developed: only 37% of level crossings feature active protection systems, and in fact nearly half of all fatalities at level crossings during 2007–2016 occurred at actively protected crossings, suggesting alarming deficiencies in safety culture and intentional violation of the safety rules (Barić, Starčević, Anić, & Paić, 2017). Besides fatalities, one of the key safety indicators is the number of incidents where barriers are broken or damaged at actively protected level crossings when road vehicles run into them. This happens while they are being lowered down or are completely closed, meaning that every such incident could lead to a potential accident with serious consequences. Every year, the number of broken or damaged half-barriers is around 500 (Croatian Railways – Infrastructure, 2019). This suggests that in Croatia, as in many other countries, risky road user behaviour is a prime contributor to level crossing accidents.

The scientific literature shows that some users inadvertently engage in risky behaviour (Searle, Di Milia, & Dawson, 2012), which is typically referred to as human error (see Reason, 1990, for review), such as failing to see approaching trains and misjudging the risk of approaching trains at passive level crossings. These errors can be caused by cognitive factors, including inattention, distraction, fatigue, poor knowledge, misjudgement, poor lighting, and limited sight distance (Freeman, Rakotonirainy, Stefanova, & McMaster, 2013; Lobb, Harré, & Suddendorf, 2001; Ward & Wilde, 1995).

In addition, there are level crossing users who intentionally defy the rules; these events are known as violations. For example, an Australian study has shown that 24.5% of respondents intentionally violated the rules at pedestrian train crossings (Freeman & Rakotonirainy, 2015). Investigating the interactions, errors and escalating risks of users of fully protected level crossings in urban area of Melbourne, Larue, Naweed, and Rodwell (2018) show that despite all levels of protection at the crossing, both drivers and pedestrians violated road rules at the crossing repeatedly at frequently. Violations resulted in risky behaviours and lead to potential conflicts between the different road users: vehicle deliberately traversing the crossing when the flashing lights were activated, vehicles trapped on the crossing, pedestrian crossing the road at the crossing, and pedestrians going around and above the gate at the crossing (Larue et al., 2018).

Several factors have been identified as influencing a user's tendency to comply with rules at level crossings: individual factors such as age, gender, personality, and attitudes; social factors such as norms, enforcement, and behaviour of others nearby; and situational factors such as waiting time, haste, weather, distractions, mood, fatigue, familiarity, desire to maximise convenience, and influence of alcohol and drugs (e.g. Edquist, 2011; Freeman et al., 2013; check SAFER-LC D2.1, 2018, for review). For example, in a observational study of unsafe crossing at three black spot urban level crossings in Brisbane, Australia, (Stefanova et al., 2015) more transgressions were observed at the crossings located in more populated suburbs in close proximity to large shopping centres and school zones, whereas the smallest number of transgressions were observed at the least populated locations. The same study identified that younger adults were the most frequent transgressors and school children and elderly were most likely to transgress in groups (Stefanova et al., 2015).

In Croatia, more than 90% of accidents are caused by road users who failed to abide by the rules, consciously or unconsciously, and who work or live near the level crossing (Starčević, 2015). Therefore, Croatia provides a good testing ground for investigating road user behaviour at level crossings, especially the ones equipped with automatic safety measures.

In addition to technical solutions to increase safety at level crossings, education to raise the awareness of risks and to encourage safe behaviours is very important for accident prevention (Delhomme, De Dobbeleer, Forward, Simoes, Adamos, & Areal, 2009). The present paper focuses on improving traffic safety in Croatia by targeting a vulnerable category of road users and applying virtual reality (VR) technology in an effort to influence their future behaviour. The technology was integrated into a traffic education programme implemented in driving schools. The pre-driver education programme was developed within the framework of a national project, which contained both preventive measures (such as awareness campaign) and a part with the pilot programme status that is proposed to complement the traditional teaching methods used in driving schools. Nowadays young people widely use modern technology. Therefore, it should be useful to enrich traditional learning methods with modern ones, employing the same technological means which the young are familiar with. The authors' idea is to apply new learning techniques that are closer to new generations than traditional learning from the book. In particular, the present study examined whether a new accident prevention programme for level crossings, involving a lecture and virtual reality application with an immersive 360° video, can significantly influence the risky attitudes and the intended future behaviour of young learner drivers.

1.1. Risky attitudes, impulsiveness and behavioural intentions

From a psychological viewpoint, three broad classes of explanation for driver behaviour can be distinguished (Goldenbeld, Levelt, & Heidstra, 2000): planned or reasoned behaviour, impulsive or emotional behaviour and habitual behaviour. Habitual behaviour is less relevant for future drivers who are currently in the pre-driving education phase, therefore in this paper we refer only to the first two classes of behaviour which apply to young learner drivers.

Many projects and safety campaigns have aimed at studying and improving drivers' attitudes toward unsafe driving, such as the CAST and SARTRE projects (Delhomme et al. 2009; Cestac & Delhomme, 2013). The underlying assumption is that changing drivers' attitudes can lead them to alter their behaviour. The theory of planned behaviour (Ajzen, 1985, 1991) postulates that a person's behaviour is a direct consequence of one's intention to perform that behaviour. In other words planned behaviour is under volitional control of the individual and is driven by intention to commit the behaviour, which, in turn, is determined by attitudes, perceived behavioural control and subjective norms. In this theory, attitudes refer to general beliefs about the intended behaviour and its outcomes (i.e. the potential positive or negative consequences of the behaviour, weighted by the perceived probability of those consequences). This theory is widely applied in several fields, and it has proven effective at explaining the variance in behavioural intentions of road users (e.g. Barton, Kologi, & Siron, 2016; Elliott et al., 2003, 2007; Stradling & Parker, 1997) and is frequently cited in driver behaviour literature, also in relation to predriver education campaigns (e.g. Floreskul, Žardeckaitė-Matulaitienė, Endriulaitienė, & Šeibokaitė, 2017; Markl, 2016). Nevertheless, it has rarely been used in studies of safety at level crossings. For example, Palat, Paran, and Delhomme (2017) used an extended theory of planned behaviour to predict violations by pedestrians and car drivers at a level crossing. They found that the combination of individual attitudes, past risky behaviour as well as injunctive and descriptive norms were predictors of intended risky behaviour. The more the participants' attitudes and perceived subjective norms were in favour of this behaviour, the greater their perceived control over the behaviour, their familiarity with the crossing, and their reported frequency of crossing against safety warning devices, the stronger their intentions to do so again in the near future. In this level crossing study attitude was found to be a strong predictor of the driver's intention to cross in two out of three risky-crossing situations involving actively protected crossings (Palat et al., 2017).

Significant relations between drivers' attitude and their risk-taking behaviour (especially speeding) were found in early traffic psychology studies using the theory of planned behaviour (e.g., Elliott et al., 2003, 2007; Parker et al., 1992, 1998; Stradling & Parker, 1997). In fact, other studies have identified attitudes as one of the most powerful predictors of risky intended or actual behaviour. Attitudes rely on beliefs about the potential positive or negative consequences of the elicited behaviour, weighted by the perceived probability of those consequences. Ulleberg and Rundmo (2003) found that attitudes towards traffic safety were the only variables directly associated with risky driving behaviour. Yilmaz and Celik (2004) showed that risky drivers' attitudes are related to obedience, speed limits, risk-taking tendency in traffic and positive attitudes towards traffic. (Iversen, 2004) showed that attitudes towards rule violations, speeding, careless driving of others, and drink-driving accounted for 52% of the total variance in risky driving behaviour.

Interventions to alter drivers' attitudes and therefore behaviour may be more effective when delivered during the predriving phase. Attitudes are more susceptible to change before a habit forms (Rowe, Maughan, Gregory, & Eley, 2013), and attitudes towards driving and associated behaviours can already be stable in adolescence (Waylen & McKenna, 2002; according to OECD, 2006).

Further to planned behaviour, emotional or impulsive behaviour may explain risky driving (Goldenbeld et al., 2000). Impulsiveness is a multifaceted psychological construct that deals with one's control over one's thoughts and behaviours. It includes at least three dimensions: poor focus on the current task (attention), acting on the drive of the moment (motor activity), and no planning or thinking (planning) (Patton, Stanford, & Barratt, 1995). Previous studies have linked impulsiveness with different types of risky behaviours, including alcohol use, illicit drug use, and suicidal behaviours (Lynam, Miller, Miller, Bornovalova, & Lejuez, 2011; Murphy & MacKillop, 2012). High impulsiveness has also been associated with greater tendency to engage in risky driving behaviours such as drink-driving, reduced seatbelt use, or ignoring of traffic signs (Dahlen, Martin, Ragan, & Kuhlman, 2005; Constantinou, Panayiotou, Konstantinou, Loutsiou-Ladd, & Kapardis, 2011; Lazuras, Rowe, Poulter, Powell, & Ypsilanti, 2019; Pearson, Murphy, & Doane, 2013; Smorti & Guarnieri, 2016; Stanford, Greve, Boudreaux, Mathias, & Brumbelow, 1996). A review of the literature about trait impulsivity and different aberrant driving outcomes also found positive relation between impulsiveness and aberrant driving behaviours (Bıçaksız & Özkan, 2016). Thus, impulsiveness is likely to be another predictor of risky behaviour at level crossings in young learner drivers. To our knowledge, no previous study has assessed potential relationships between risky behaviour at level crossings and the three dimensions of impulsiveness presented above.

Numerous studies suggest that men hold less strict views on traffic violations than women and that they receive traffic violations more often (González-Iglesias, Gómez-Fraguela, & Luengo-Martín, 2012; Lonczak, Neighbors, & Donovan, 2007; Waylen & McKenna, 2002). Women view law as something relevant, clear and reasonable, which leads to a feeling that laws should be obeyed. Thus, women tend to obey traffic laws even in non-risk situations (Lucas, Mendes-Da-Silva, & Lyons, 2017; Yagil, 1998). Furthermore, women are more afraid of punishment (tickets or fines), while men weigh risk and benefits differently, such that they may conclude, for example, that speeding brings more benefits than risks. Sarkar, de Faria & Andreas (2002) measured attitudes towards aggressive driving before and after a seminar on aggressive driving. Attitudes among men were less positive after the seminar, but still higher than women's scores. Men also tend to overestimate their driving capabilities more than women (Tasca, 2000).

Ulleberg and Rundmo (2003) in their study based on a self-report survey carried out among 1,932 adolescents in Norway attempt to integrate two of research traditions, the personality trait approach and the social cognition approach, in order to understand the mechanisms underlying young drivers' risk-taking behaviour in traffic. The questionnaire included measures of risk perception, attitudes towards traffic safety and self-reported risk-taking in traffic. Attitude towards traffic safety was the only variable with a direct effect on risky driving behaviour in the path model. The attitude measure seemed to function as a mediating variable in the relation between personality traits and behaviour. However, the personality variables accounted for 47% of the total variance in the attitude measure, suggesting that the attitude measure also had an independent effect on risk-taking behaviour. In other words, risk-taking attitudes can be said to predict additional variance in behaviour. The results of a structural equation model suggested that the relation between the personality traits and risky driving behaviour was mediated through attitudes. On this basis it was concluded that personality primarily influences risky driving behaviour indirectly through affecting the attitudinal determinants of the behaviour. Among the items used by Ulleberg and Rundmo (2003) to measure general attitude in road traffic, we were mainly interested in those items relevant for a level crossing approach, namely obedience speed rules and violations of basic traffic rules. Therefore, these two sets of items were selected as attitude scales in our study. In addition, the items on self-reported risk-taking in traffic were adapted in the driving behaviour scale. Another relevant research by Wallace (2008) investigated the present context of motorist behaviour at LCs in relation to key variables of attitudes, norms, self-efficacy, perceived risk, environmental constraints and driver skills. A variety of data collection methods were used for three studies in this research. One research question in this study concerned the relationship between attitudes and unsafe driving intention. According to research results, no relationship between attitudes and unsafe driving intention was found. The research used a bipolar scale (from −3 to +3) to measure attitudes towards driving at level crossings. Participants were asked to complete statements by rating pairs of adjectives while driving at level crossings (e.g. good/bad). The bipolar scale was then recoded using unipolar 1–7 scale. Another study from this research used a set of 19 items to measure specific risky motorist behaviour at passive and active level crossings (e.g. Trying to beat the train at a level crossing; Overtaking cars that are stopped at the crossing; Not looking at passive crossings; Going through flashing lights; etc.).

In their study, Iversen and Rundmo (2012) explored changes in driver behaviour in traffic and attitudes in Norway over the nine-year period from 2000 to 2008. They used self-report surveys carried out with two independent and representative samples of Norwegian drivers, with data collected in 2000 (n = 2614) and 2008 (n = 1731). The results show that although both attitudes and self-reported behaviour changed significantly, the changes were small to moderate, and all except one were in the direction of greater safety.

1.2. Changing risky attitudes and behavioural intentions through educational interventions and new technologies

Awareness campaigns and preventive programmes conducted at the national or international levels about safety at level crossings aim to increase awareness of risks for users of crossings and people living nearby. Various media, including posters, commercial media (TV, radio, newspaper), web sites, social networks and different events (workshops, safety trainings) have been deployed to raise the public's awareness about the dangers of being on the tracks, as well as about the consequences of an accident.

Specific examples of international awareness programmes on level crossing safety include the International Level Crossing Awareness Day (ILCAD – http://www.ilcad.org) and Operation Lifesaver. Other well-known nationwide programmes are TrackSAFE New Zealand, which was strengthened in 2013 with the amalgamation of the rail safety charity the Chris Cairns Foundation (http://www.tracksafe.co.nz/) and TrackSAFE Australia (http://tracksafefoundation.com.au). In Europe, several countries have active educational programmes on level crossing safety, including the UK, Poland, Latvia, Belgium, and Croatia. In the 2000s, Croatian Railways launched a safety and prevention educational campaign, :The Train is Always Faster", which was initially intended to warn children on how to behave near the tracks and about the risk of playing at level crossings. The action has expanded its focus to include drivers.

Traffic safety campaigns have been conducted for more than 50 years, but whether they are efficient is unclear (Tay & Watson, 2002). Some studies show limited or no effect (Glendon & Walker, 2013; Markl, 2016). A meta-analysis of road safety campaigns showed a 9% decrease in traffic accidents, but this effect proved short-term: it was evident only during the campaign (Phillips, Ulleberg, & Vaa, 2011). Fear-based campaigns can have limited results (Phillips et al., 2011) or even lead to contradictory effects (Taubman-Ben-Ari, Florian, & Mikulincer, 2000). Further, there is limited evidence of the application of the theory of planned behaviour, or another attitudinal model, to the study of pre-driver education. The assessment of an anti-speeding campaign (Stead, Mackintosh, Tagg, & Eadie, 2002) is good example of an evaluation of an attitude change initiative. The evaluation was based on a three-year longitudinal survey of drivers aged 17–54, and found that the campaign resulted in a significant decrease of speeding attitudes.

Despite the growing popularity of programmes to raise awareness and educate users about level crossing safety, very few studies have evaluated the effects of railway-related safety interventions and most of these studies refer to railway trespass prevention among the youth. Since illegal track crossing (i.e. trespass) is an intentional violation which resembles the road user violations at actively protected level crossings, there may be transferrable lessons learned from these studies. For example, Lobb, Harre and Suddendorf (2001) reported a significant effect of fencing combined with warning signs, posters and school-based education: the rate of trespass dropped from 59% to 40%, and the decrease persisted even three months later (from 40% to 36%). In a second study (Lobb, Harre, & Terry, 2003), education significantly raised awareness that trespassing was illegal and it significantly improved the ratio of safe to unsafe crossings, independently of user age. Silla and Kallberg (2016) showed at least a moderate effect on increasing the safety knowledge and intended behaviour of schoolchildren 8–11 years old in Finland. The lessons on safe behaviour included a set of drawings adapted for this age group and were held in four schools near railway lines.

In general, the road safety literature identifies several behaviour change techniques may be used to improve unsafe driver behaviour such as informing, persuading, rewarding, or punishing, etc. (Delhomme et al., 2009; Goldenbeld et al., 2000). Yet, according to Goldenbeld et al. (2000), the simplest and most straightforward way to implement a persuasive road safety campaign and road safety education is by transmitting objective knowledge which aims to change the reasoned driver behaviour and its underlying precursors such as attitudes.

It may be possible to increase the efficacy of awareness-building and educational programmes in level crossing safety by integrating information and persuasion strategies through novel virtual reality technology (Cipresso, Gigliolo, Raya, & Riva, 2018), which can be easily experienced by combining one's smartphone and virtual reality head gear. Already used in the treatment of phobias, anxieties and other disorders, virtual reality shows promise as a persuasive technology in traffic safety educational programmes. Virtual reality offers multimodal sensory simulation and immersion that cannot be achieved with 2D pictures or videos. Through this simulation and immersion, participants can experience future possible events and consequences of the present behaviours, through multi-sensory modalities, including visual, auditory, and kinaesthetic, that assure the realistic representation of the environment and the sense of being "present" in the virtual environment (Slater & Usoh, 1993). This exposure to future possible risks may impact risk perceptions and attitudes, in the present. On the contrary, if an individual has not the experience of future negative outcomes or consequences of a risky behaviour, he may not perceive the real danger involved by that behaviour (Brewer et al., 2007; Weber, 2006). This suggests that a 3D immersive experience may effectively influence attitudes and behavioural intentions. Applied to traffic psychology, we can anticipate that through virtual reality participants are able to experience future risky driving behaviours without being in a real danger. Further, this experience impact risk perception and, consequently, risky behaviour and attitudes toward risky driving. This assumption was previous tested in different fields of research, like education, healthcare, entertainment, etc., showing that VR experience determine positive outcomes in terms of attitudes and behaviours (Tussyadiah, Wang, Jung, & tom Dieck, 2018). Indeed, Chittaro, Sioni, Crescentini and Fabbro (2017) showed that a head-mounted virtual reality display significantly affected users' attitudes towards risk and arousal. Schwebel, McClure, and Porter (2017) used a virtual pedestrian environment to elicit change in self-reported intent to text and cross the road and also in perceived vulnerability, although it failed to elicit community-based change. These initial efforts suggest the potential of virtual reality to influence attitude and behaviour in traffic safety, prompting us to explore its use for improving safety at level crossings.

The present study aimed to examine relationships among attitudes toward traffic rules, impulsiveness, and behavioural intentions at level crossings in young learner drivers who received or did not receive virtual reality-based education. Based on previous literature, we anticipated that stronger attitudes toward risky driving would be positively related to behavioural intention to break rules at level crossings (hypothesis 1); high levels of impulsiveness would be positively related to behavioural intention to break rules at level crossings (hypothesis 2); and the relationships among attitudes toward risky driving, impulsiveness, and behavioural intention to break rules at level crossings would be moderated by a 360° video-based educational programme (hypothesis 3).

2. Method

2.1. Participants and procedure

A sample of 274 participants between 18 and 34 years old voluntarily participated in the study. From the total sample, 62.4% were men. The participants were recruited from 11 driving schools in the Croatian capital of Zagreb and in Osijek. Another part of the sample was comprised by university students (first and second year). No participant had a driving license.

This research was conducted under the supervision of master students at the Faculty of Transport and Traffic Sciences of the University of Zagreb in April 2018. The participants' data was collected in the University. The survey took place in groups of 20 students, on a regular school day, and lasted for about 30 min. The participants were randomly allocated to one of the two study conditions, the intervention group or the control group, by an experimenter blind to the purpose of the study. Thus, a subset of the sample (N = 127, 63.0% male, range age = 18–34) used the 360° video-based application for five minutes, during which time they watched the "Safe" and "Risky" scenarios. Initially, the participants provided information about their age and gender and filled in the questionnaires measuring safety attitudes toward traffic and impulsiveness. Once the application was launched, the car began to move and as it approached the level crossing, the video paused and a question appeared on the main menu (Fig. 1): "What is your choice?" The learner driver had to choose "Safe" driving (Fig. 2) or "Risky" driving across the level crossing (Fig. 3). In the second run, the driver had to choose the other option. At the end, the participants completed the scale measuring driving behaviour at rail level crossing and the follow-up survey. The order of virtual reality presentation (safe driving vs. risky driving with a crash as consequence) was not suggested to the participants, the choice was left to them.

The remaining 147 students (N = 147, 61.9% men, range age = 18–34) did not participate in the 360° video-based experience and were not present in the room when the other students used the technology. Specifically, they answered questions about gender and age, then they filled in the scales measuring safety attitudes toward traffic, impulsivity, and future behaviour on LC. The students were between 18 and 34 years old from Zagreb. The two groups of students did not discuss the virtual reality experience with each other.

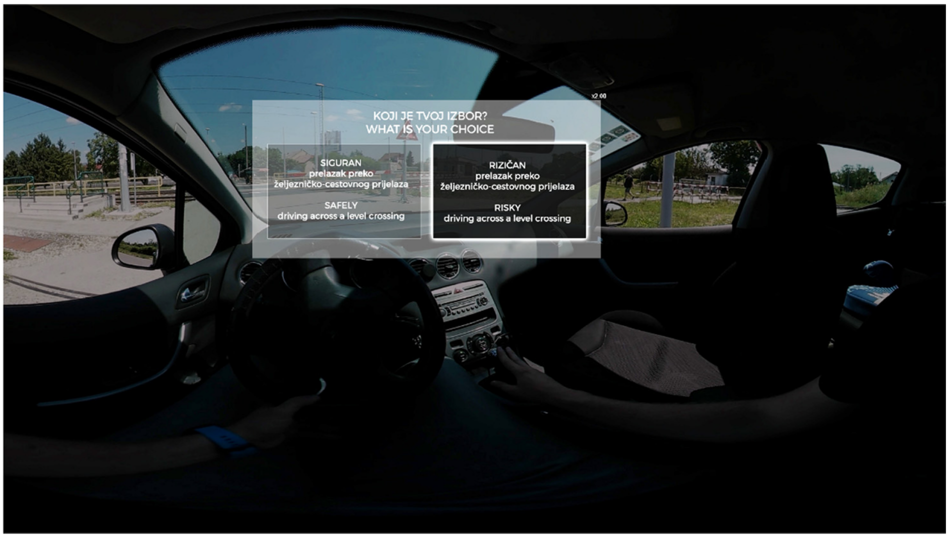

Fig. 1. Screenshot of the 360° video-based application, showing the *Main menu* with the question "What is your choice?" and the two options, "Safe" or "Risky" driving.

Fig. 2. Screenshot of the "Safe" driving across the level crossing in the virtual reality view through 360° glasses.

Fig. 3. Screenshot of the "Risky" driving across the level crossing in the virtual reality view through 360° glasses.

2.2. Assessment instruments

In order to inform the assessment scales used in our study, we analysed previous studies using questionnaires in relation to the driver behaviour at level crossing (see Section 1.1) and selected useful sets of items relevant for our variables (e.g. Iversen & Rundmo, 2012; Ulleberg & Rundmo, 2003; Wallace, 2008) from which we used or adapted some questions for our own study. The main changes concerned: (1) changing the type of scale on which participants provide their answer and reducing all answers to 5-point Likert scales; (2) removing items which were irrelevant for our study scope, for example those items referring to passive level crossings; (3) reformulating some of the remaining items in a more specific manner for clarity purposes, for example replacing "Driving around the boom gates" with "Drive around the half barriers (zig-zag)".

The **Safety Attitude Scale towards Traffic (SASTT)** questionnaire (Ulleberg & Rundmo, 2003) was used to assess attitudes toward traffic flow in terms of rule obedience (9 items; e.g., Sometimes rules need to be circumvented to allow traffic to flow) or in the case of speeding (5 items; e.g., I think it's okay to drive fast if the traffic conditions allow it). Items were rated on a 5-point Likert scale, from 1 - strongly disagree to 5 - strongly agree. Average scores were computed, and higher scores indicated stronger risk attitudes. In order to verify the factorial validity of the scale, we performed a confirmatory factor analysis with maximum-likelihood estimation and reported the following fit indices: goodness of fit index (GFI), adjusted goodness of fit index (AGFI), normed fit index (NFI), comparative fit index (CFI), and root mean square error of approximation (RMSEA) (Hu & Bentler, 1999). The indices revealed a good fit of the model with two factors: χ^2 (63) = 73.41, p = .174; GFI = 0.96; AGFI = 0.94; NFI = 0.94; CFI = 0.99; RMSEA = 0.02 [0.00, 0.04]. Cronbach's α values were 0.80 for the rule obedience subscale and 0.77 for the speeding subscale.

The **Attitudes Toward Rail Level Crossings scale** was adapted from Wallace (2008). The scale consists of three items (e.g., I think it is okay to cross the level crossing despite the flashing lights and sound signal, if there is no train in sight) rated on a 5-point Likert scale, from 1 - strongly disagree to 5 - strongly agree. Cronbach's α in our sample was 0.73. An average score was computed, and higher scores indicated stronger risk attitudes.

The **Barratt Impulsiveness Scale (BIS)** (Patton et al., 1995) assesses personality constructs of impulsiveness. Items are rated on a 5-point Likert scale, from 1 - never to 5 - always. Three factors were computed, measuring attentional impulsiveness (5 items; e.g. I'm not paying attention to some things), motor impulsiveness (8 items; e.g., I act on the spur of the moment), and non-planning impulsiveness (6 items; e.g. I plan tasks carefully). The indices revealed a good fit of the model with three factors: χ^2 (1 4 1) = 143.93, p = .416; GFI = 0.95; AGFI = 0.92; NFI = 0.91; CFI = 0.99; RMSEA = 0.009 [0.00, 0.03]. Cronbach's α ranged from 0.68 to 0.71.

The **Driving Behaviour at Rail Level Crossings Scale** consists of 14 items (e.g., I plan to drive through the level-crossing without stopping if no train is visible) adapted from the SASTT questionnaire (Ulleberg & Rundmo, 2003) and the Attitudes Toward Rail Level Crossings Scale (Wallace, 2008), and it measures how one intends to behave in the future when using level crossings. Items were rated on a 5-point Likert scale, from 1 – low probability to 5 – high probability. Average scores were computed, and higher scores indicated a strong tendency to engage in risky driving behaviours. Cronbach's α in our sample was 0.88.

A follow-up survey was designed specifically for the purposes of this study. It consists of 5 items that measure the following issues: the perceived level of realism of the VR application (one item – i.e., How real was the application to you? – was evaluated on a 5-point Likert scale, from 1 – not at all real to 5 – completely real); the perceived level of immersivity of the VR application (one item evaluated on a 5-point Likert scale, from 1 – not immersive at all 5 – completely immersive); the anxiety felt during the 360° video-based application (one item evaluated on a 5-point Likert scale from 1 – not at all to 5 – very much, indicating the degree they felt anxiety); the perceived impact of VR as an education tool on future behaviour of traffic participants (one item evaluated on a 5-point Likert scale, from 1 – no influence to 5 – great influence); and the probability of changing behaviour after experiencing this 360° video-based application (How likely is it that traffic participants will change their behaviour after experiencing this application? – evaluated on a 5-point Likert scale, from 1 to very unlikely to 5 – very likely).

2.3. 360° video-based intervention

The educational intervention evaluated in this study is part of the Croatian national project "Implementation of measures to improve the safety of the most vulnerable traffic participants at level crossings", developed within the framework of the *National Programme of Road Traffic Safety of the Republic of Croatia 2011 – 2020* (Barić, Starčević, Pilko, Hozjan, Gotić, Anić, Paić, & Kulušić, 2018; https://www.fpz.unizg.hr/projekt-sigurnost-na-zcp/). The programme moves beyond simply learning about road risks, to providing young and learner drivers with strategies to avoid risky situations. It comprises the following activities and educational materials: a 15-minute lecture about safety at railway crossings, a 15-minute lecture on the causes and consequences of accidents at railway crossings, a presentation of videos and photographs about risky behaviour at railway crossings, and an immersive 3D experience based on virtual reality 360° glasses in which the driver experiences the possible consequences of safe and risky driving through a level crossing from a driver's perspective (see Fig. 4). This involves learner drivers as active participants in the learning process. The video used in the virtual reality application was filmed at the "Trnava" level crossing, located at the intersection of the Zagreb Main Railway Station – Dugo Selo (M102) railway line at km 430 + 112 and non-classified roads in Zagreb. The M102 railway line is a major international railway line, along which approximately 199 trains pass daily; their maximum average speed when passing through the Trnava section is 140 km/h.

Fig. 4. Participants using the virtual reality application with 360° glasses at Croatian driving schools.

The Trnava level crossing features active protection comprising flashing lights, sound warnings and half-barriers. This level crossing is highly risky: from 2007 to 2018, six accidents involving seven deaths and two injuries occurred (HŽ Infrastruktura, 2018).

The video was filmed in 360° format from the driver's perspective and included two scenarios. In the "Safe" crossing, the vehicle waits for the train to pass, the half-barrier lifts and the light-sound alerts cease. In the "Risky" scenario, the vehicle crosses the level crossing while the half-barrier is still down, and it attempts to zig-zag between the half-barriers. As the vehicle attempts this manoeuvre, a train suddenly appears from the left side, and the sounds of braking followed by a loud crash are heard. The approaching train was added to the "Risky" video as a post-processing simulation.

3. Results

3.1. Overview

First, we conducted preliminary analysis in order to evaluate how the 360° video-based intervention was perceived by the participants. Independent samples *t* tests were also conducted to examine whether there were gender differences and difference between the experimental and the control groups in risky driving attitudes and risky driving behaviour at level crossings in our sample. Second, the associations among main variables were computed. Third, we tested the relations between attitudes towards traffic rules, impulsiveness and behavioural intentions at level crossings, as well as the moderating role of the 360° video-based intervention. To test our hypotheses, we used the PROCESS custom dialogue for IBM SPSS (Hayes, 2013). This solution permits building bootstrap-based confidence intervals in order to test the statistical significance of moderation (Preacher & Hayes, 2004). In the present study we used 5,000 resamples in order to estimate 95% confidence intervals. Further, the graphical display of the significant moderation was facilitated through the ModGraph web-based application (Jose, 2013), designed to visualize the interaction effects between a continuous variable and a two-level categorical variable, based on the unstandardized regression coefficients (B), the mean, and the standard deviation of the independent variables, as well as the B for the interaction term and the constant. This method also allows to compute the values of the simple slope and whether these slopes differ significantly from zero.

3.2. Evaluation of the 360° video-based intervention

Table 1 shows the mean and standard deviation for participants' evaluations of how real and immersive the VR experience was. From the total sample, 56% rated the VR application as "somehow real", and 37.8% as "completely real". Moreover, the large part of the sample rated the application as "somehow immersive" (39.4%) and "immersive" (28.3). The anxiety thought to be invoked by the application was graded relatively low (M = 1.91, *SD* = 0.93). As for the influence of the VR

Table 1
Descriptive statistics of the main study variables.

Variable	N	Mean	SD	Minimum	Maximum
1. Attitudes toward traffic flow	272	2.65	0.75	1.00	4.89
2. Attitudes toward speeding	272	2.81	0.91	1.00	5.00
3. Attitudes toward rail LC	272	1.53	0.79	1.00	5.00
4. Attentional impulsiveness	272	3.02	0.71	1.00	5.00
5. Motor impulsiveness	272	2.41	0.67	1.00	5.00
6. Non-planning impulsiveness	272	2.88	0.64	1.09	5.36
7. Driving behaviour at rail LC	272	1.50	0.61	1.00	3.86
8. VR exercise realism	127	4.39	0.53	3.00	5.00
9. VR exercise immersive	127	4.16	0.61	3.00	5.00

Note. LC – level crossing.

on behaviour, most of the sample (70.2%) considered that the application would have influence on future driving behaviour, 21.7% of the sample had a neutral position about the potential of VR application to change traffic behaviour (M = 3.40, SD = 1.02). There were no significant gender differences concerning the evaluations of how real, $t(1\ 2\ 5) = 0.34$, $p = .733$, and immersive, $t(1\ 2\ 5) = 0.47$, $p = .634$, the 360° video-based intervention was.

3.3. Preliminary analysis

Descriptive statistics for the main variables are presented in Table 1. There were significant gender differences in risky driving behaviour at level crossings [$t(2\ 7\ 2) = 4.66$, $p < .001$], as well as in attitudes toward level crossings [$t(2\ 7\ 2) = 4.51$, $p < .001$], traffic flow vs. rule obedience [$t(2\ 7\ 2) = 4.08$, $p < .001$] and speeding [$t(2\ 7\ 2) = 4.76$, $p < .001$]. Men reported higher scores than women on all the parameters examined: risky driving behaviour at level crossings, M = 1.62, SD = 0.66 vs. M = 1.31, SD = 0.45; attitudes toward rail level crossings, M = 1.67, SD = 0.88 vs. M = 1.29, SD = 0.52; attitudes toward traffic flow vs. rule obedience, M = 2.79, SD = 0.77 vs. M = 2.41, SD = 0.65; and attitudes toward speeding: M = 3.01, SD = 0.88 vs. M = 2.49, SD = 0.86. Therefore, gender was controlled in all subsequent analyses.

Further, the results revealed that there is no significant difference between the experimental and the control groups on the following characteristics: attitudes toward level crossing [$t(2\ 7\ 2) = -1.67$, $p = .096$], attitudes toward speeding [$t(2\ 7\ 2) = -0.81$, $p = .417$], attitudes toward traffic rules [$t(2\ 7\ 2) = 1.83$, $p = .068$], attention impulsiveness [$t(2\ 7\ 2) = 1.00$, $p = .315$], and motor impulsiveness [$t(2\ 7\ 2) = -1.07$, $p = .282$]. However, participants from 360° video-based intervention reported higher scores for non-planning impulsiveness (M = 3.25, SD = 0.53), compared with the participants from the control condition (M = 2.55, SD = 0.55), $t(2\ 7\ 2) = -10.51$, $p < .001$.

In the experimental group, 76.4% of the sample have chosen "Safe" driving first, while 23.6% have chosen "Risky" driving across the level crossing as their first choice. The results revealed non-significant differences between these two groups of participants included in virtual reality condition in risky driving behaviour at level crossing [$t(1\ 2\ 5) = -0.96$, $p = .339$]. We also computed a cross-tabulation analysis and we found a non-significant relation between gender and choice of the order in which the participants were exposed to the videos ($\lambda^2 = 2.06$, $p = .150$).

3.4. Associations among study variables

Correlational analyses indicated that risky driving behaviour at level crossings was significantly and positively associated with attitudes toward traffic flow vs. rules of obedience, speeding, and rail LC for the participants from the 360° video-based intervention, as well as for the participants from the control condition. Risky driving behaviour was also significantly and positively associated with attentional and motor impulsiveness for the participants in the 360° video-based condition, as well as for those in the control condition. Moreover, risky driving behaviour positively correlated with non-planning impulsiveness only for the participants in the control condition. These results are presented in Table 2.

3.5. Regression analysis to test the relations between variables and the moderating role of the 360° video-based intervention

We tested the relations between traffic attitudes, impulsiveness, and risky driving behaviour at level crossings, as well as the moderating role of the 360° video-based intervention. Gender was introduced in the model as a controlled variable.

Table 2
Associations among the main study variables for the participants from the 360° video-based condition and control condition.

	1	2	3	4	5	6	7	8
360° video-based intervention (n = 127)								
1. Attitudes toward traffic flow								
2. Attitudes toward speeding	0.63***							
3. Attitudes toward rail LC	0.44***	0.34***						
4. Attentional impulsiveness	0.21*	0.17*	0.16					
5. Motor impulsiveness	0.31***	0.20*	0.23**	0.55***				
6. Non-planning impulsiveness	−0.02	−0.001	−0.21*	0.25**	0.10			
7. Driving behaviour at rail LC	0.35***	0.22*	0.45***	0.19*	0.38***	−0.04		
8. VR realism	0.007	0.01	−0.04	−0.11	−0.04	0.06	−0.16	
9. VR immersive	−0.02	0.06	0.02	−0.01	−0.07	0.09	−0.03	0.50***
Control condition (n = 147)								
1. Attitudes toward traffic flow								
2. Attitudes toward speeding	0.80***							
3. Attitudes toward rail LC	0.42***	0.34***						
4. Attentional impulsiveness	0.33***	0.34***	0.08					
5. Motor impulsiveness	0.32***	0.35***	0.07	0.44***				
6. Non-planning impulsiveness	0.25**	0.21*	0.26**	0.15	0.22**			
7. Driving behaviour at rail LC	0.45***	0.47***	0.58***	0.24**	0.24**	0.17*		

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

Concerning hypothesis 1, the results showed that attitudes toward level crossing risk and attitudes toward speeding significantly predicted risky driving behaviour at crossings. However, driving behaviour at level crossings was not predicted by attitudes toward traffic flow vs. rule obedience. These results are presented in Table 3.

The second hypothesis was not confirmed by our results. Motor impulsiveness, attentional impulsiveness, and non-planning impulsiveness are non-significant predictors for driving behaviour at level crossings (all $p > 0.05$) (see Table 3).

Furthermore, we tested whether the 360° video-based intervention altered the strength of relationships among attitudes toward traffic, impulsiveness, and risky driving behaviour at level crossings (hypothesis 3). Specifically, we tested whether the relations between attitudes toward traffic, impulsiveness, and risky driving behaviour at level crossings are conditioned in strength and direction by the 360° video-based intervention. The results showed that the 360° video-based intervention interacted with attitudes toward level crossing risk and attitudes toward speeding in predicting driving behaviour at crossings. When the participants reported stronger risky driving attitudes toward rail level crossing, they reported higher tendency to adopt risky driving behaviour in the control condition, compared to the participants from the 360° video-based intervention condition (see Fig. 5). The simple slope for intervention group (value of slope = 0.22, $p = .027$) and control group (value of slope = 0.41, $p < .001$) are significantly different from zero. Further, when the participants reported stronger risky driving attitudes toward speeding, they reported higher tendency to adopt risky driving behaviour in the control condition (see Fig. 6) (value of slope = 0.12, $p = .046$). The simple slope for the intervention group (value of slope = −0.02, $p = .824$) is not significant.

4. Discussion

The current study explored the relationships among traffic safety attitudes, impulsiveness, and risky driving behaviour at level crossings in a sample of learner drivers. It also examined whether these relationships are moderated by a virtual reality-based educational intervention. To the best of our knowledge, this is the first study to measure the effectiveness of virtual reality technology in an educational programme about safety at level crossings.

Table 3
Results for the Regression Models Used for Testing the Moderation.

	Coefficient	SE	*t*	*p*	Confidence interval 95%	
					Lower limit	Upper limit
Attitudes toward traffic flow	0.12	0.07	1.74	0.081	−0.0160	0.2704
Attitudes toward speeding	0.12	0.06	2.02	0.044	0.0031	0.2393
Attitudes toward rail LC	0.41	0.06	6.85	< 0.001	0.2989	0.5399
Attentional impulsiveness	0.05	0.05	0.84	0.401	−0.0674	0.1680
Motor impulsiveness	0.11	0.06	1.77	0.077	−0.0127	0.2446
Non-planning impulsiveness	−0.04	0.07	−0.64	0.521	−0.2030	0.1030
Attitudes toward traffic flow × VR	−0.09	0.08	−1.11	0.266	−0.2590	0.0718
Attitudes toward speeding × VR	−0.14	0.06	−2.17	0.030	−0.2816	−0.0141
Attitudes toward rail LC × VR	−0.19	0.07	−2.49	0.013	−0.3536	−0.0418
Attentional impulsiveness × VR	−0.05	0.08	−0.60	0.547	−0.2240	0.1191
Motor impulsiveness × VR	0.08	0.09	0.94	0.346	−0.0950	0.2698
Non-planning impulsiveness × VR	0.11	0.11	0.95	0.341	−0.1195	0.3439

Note. VR – 360° video-based intervention with VR environment.

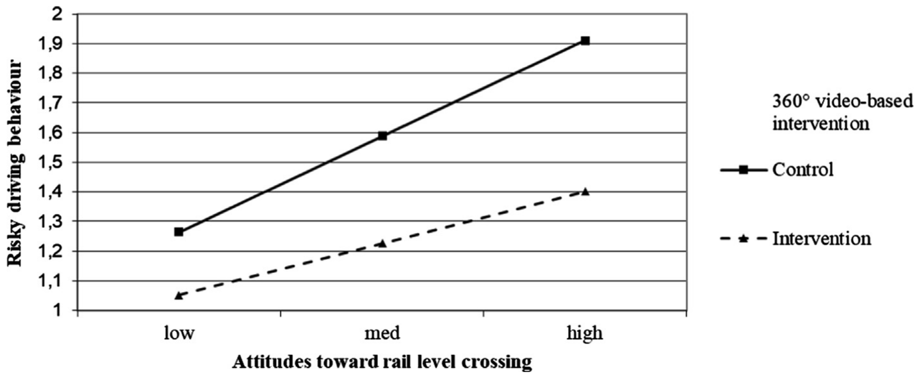

Fig. 5. Risky driving behaviour at level crossing as a function of VR exercise and attitudes toward rail level crossing.

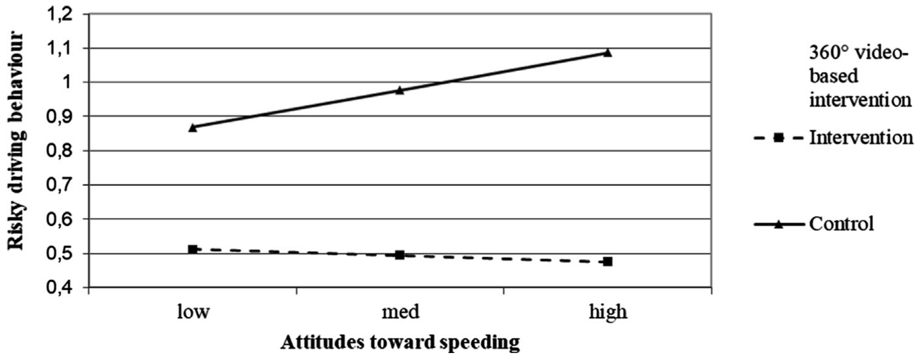

Fig. 6. Risky driving behaviour at level crossing as a function of VR exercise and attitudes toward speeding.

We found gender differences in risky attitudes toward level crossings and, more generally, toward traffic safety. This is in accordance with previous research (González-Iglesias et al., 2012; Laapotti, Kaskinen, & Rajalin, 2003; Lucas et al., 2017; Yagil, 1998). Such differences in attitudes may reflect different social norms and different upbringing of boys and girls. They highlight the potential need to tailor intervention programmes to each gender. Further, as we hypothesised, when participants reported riskier traffic attitudes, they also reported a greater tendency to adopt risky driving behaviour at level crossings in the future. Our observation that future behaviour at level crossings was best predicted by driving attitudes is in accordance with the theory of planned behaviour (Ajzen, 1985, 1991), in which attitude influences the intention to behave. Other studies have also demonstrated a positive relationship between attitudes toward risky driving and risky driving behaviour (e.g. Iversen & Rundmo, 2012; Phillips et al., 2011), especially speeding (e.g. Elliott et al., 2003, 2007; Stradling & Parker, 1997). Attitude is a significant predictor of pedestrians' crossing intentions and drivers' risk-taking behaviour at level crossings (Palat et al., 2017). The present study extends this literature by performing path analysis involving attitudes toward traffic rule, speeding, and risky behaviour at level crossings, while controlling for gender. We found that attitudes toward level crossing risk significantly predicted driving behaviour at the crossings, while attitudes toward traffic flow vs. rules obedience or speeding did not. This finding supports the theory of domain-specific attitudes (Goldstein & Weber, 1997), which states that a risk-taking attitude is closely linked to the specific content and choice alternatives in one specific domain. Our results suggest that level crossing risk is likely to be judged independently from other road risk domains such as speeding or more general rule violations. These results also suggest that interventions designed to change a specific road behaviour should take into account participants' specific attitudes toward that behaviour. Thus, perception of the necessity of compliance with traffic rules at level crossings is a better predictor of intention to engage in risky behaviours at crossings than are participants' attitudes toward traffic norms.

In accordance with previous literature (Dahlen et al., 2005; Pearson et al., 2013; Smorti & Guarnieri, 2016), the present study revealed significant positive relations between the three types of impulsiveness measured by our survey instruments and risky driving behaviour. Previous studies addressed the relation between impulsiveness and different risky driving behaviours, like drunk-driving, reduced seatbelt use (Dahlen et al., 2005; Pearson et al., 2013; Smorti & Guarnieri, 2016), but as far as we know no previous study assed the relation between impulsiveness and risky behaviour at level crossings. Thus, we confirmed and also extended previous literature about the relation between impulsiveness and risky behaviour. The effect sizes for the relation between the dimensions of impulsiveness and risky driving at level crossings are comparable with those reported in other studies that linked impulsiveness with different driving behaviours like aggressive driving or violation of traffic rules (e.g., Dahlen et al., 2005; Lazuras et al., 2019; Smorti & Guarnieri, 2016). However, in the regression analysis, the dimensions of impulsiveness did not predict risky driving. A previous recent study reported the same pattern of results, where attention impulsiveness and non-planning impulsiveness were significantly related to driving violations but did not prove to be significant predictors in the regression analysis (Lazuras et al., 2019). These results may suggest that the relation between impulsiveness and risky driving is more complex and may be mediated or moderated by other factors. For example, Lazuras et al. (2019) found that the relations between motor impulsivity and driving errors, lapses, and violations are mediated by attitudes toward driving safety. The 360° video-based intervention did not prove to be a significant moderator in our study. Impulsiveness may be defined as a stable disposition and it may require long term interventions in order to reduce its effect.

The 360° video-based intervention moderate the relationships among traffic safety attitudes and driving behaviour at rail level crossings. Participating in the 360° video-based exercise weakened the ability of attitudes toward level crossings to predict driving behaviour at crossings, and it weakened the association between attitudes toward speeding and risky driving behaviour at crossings. These results suggest that educational intervention based on virtual reality exercises can increase the likelihood of safe behaviour at level crossings even for participants with favourable attitudes toward risky driving. The results confirmed our expectations, offering preliminary support for the effectiveness of interventions based on VR in a less explored area of risky driving such as level crossings. Although VR interventions proved their success in other domains, like education or healthcare, being associated with positive outcomes (Tussyadiah, Wang, Jung, & tom Dieck, 2018), less is known about their potential to promote traffic safety. To increase their external validity, the results of this study should be verified and extended with larger samples, including learner drivers and high school students. These two populations may require different types of accident prevention programme. Future studies should also assess the effects of virtual reality experiences on actual behaviour.

Participants graded the VR application as real and immersive, which is not surprising since the video was filmed on the actual LC with a real car and driver, but the feeling of accompanying anxiety was low. This suggests that some participants had difficulty perceiving themselves as physically present in a non-physical world. This may in part reflect the relatively short video: risky scenario lasted 25 sec, safe scenario lasted 45 sec. Prolonging the car's approach to the level crossing could allow participants to adapt better to the virtual reality equipment and to the psychological stimuli of the virtual reality environment (Ronen & Yair, 2013). The immersive experience may be further improved by having participants control the driving, even if only following a predesigned route.

Participants were also asked how much influence this VR application would have on future behaviour and how probable is their behaviour change after the VR experience. Although many participants evaluated the VR application as having the potential to change the driving behaviour, a part of the sample dismissed this program as effective. One possible reason for this is that the participants lacked driving experience and did not realise the tasks entailed by driving. Another possible reason is that they may dismiss warnings about risks, thinking that they will behave properly in that situation. It is also possible that because most of our subjects probably had little experience with virtual reality, they focused more on the experience itself than on the content of the exercise. This, along with the rare occurrence of LC accidents, could be the reason why they judged that it is not that probable that they will be fined for an illegal LC crossing. In order to better understand the impact of the VR application on future behaviour and on changing traffic behaviours, longitudinal studies should be implemented, with measures in different time moments, several weeks or months after experiencing VR application. Further studies should address these questions.

There are some limitations of this research. It is possible that learner drivers were giving socially desirable answers, so future research should consider implementing this programme with a larger sample, perhaps including new drivers. The cross-sectional nature of this study meant that we did not measure whether the virtual reality exercise was associated with long-term changes in attitudes or behavioural intentions. Future research should consider long-term monitoring, and it should attempt to familiarise participants more with the virtual reality headgear. We should also mention that our VR application used only visual and sonorous experience without actual interactivity by the participants. However, the participants were exposed to an immersive video rather than to a virtual (simulated) world, which is an advantage in terms of scenario realism. The 3D video resulting in an immersive environment was created through the integration of computers, head-mounted displays, 3D graphics (only for train simulation in risky scenario) and headphones (Rizzo & Shilling, 2017). Finally, the main character in the VR application was a man, while the study participants were both men and women. Although participants could not actually see the face of the person from the video, the male character might have had a differential effect (i.e. less realism) on our female participants. However, men and women from our sample manifested similar levels of perceived realism and immersion of virtual environment, therefore we have good reasons to believe that in this study the application facilitated a similar absorption in virtual environment for women and men.

4.1. Conclusion

This study examined relationships among attitudes toward traffic rules, impulsiveness, and behavioural intentions at level crossings and explored whether these relationships can be moderated by a virtual reality-based education experience. We found that attitudes toward level crossing risk significantly predicted driving behaviour at level crossings, and that men had riskier attitudes than women. Moreover, the three dimensions of impulsiveness were associated with risky driving, but they did not represent significant predictors. Participating in the 360° video-based exercise weakened the ability of attitudes toward level crossings and toward speeding to predict driving behaviour at rail level crossings. This highlights the potential of immersive virtual reality technology to contribute to traffic safety and prevention programmes.

CRediT authorship contribution statement

Danijela Barić: Conceptualization, Methodology, Investigation, Resources, Writing - original draft, Supervision. **Grigore M. Havârneanu:** Methodology, Validation, Formal analysis, Resources, Writing - review & editing, Supervision. **Cornelia Măirean:** Methodology, Validation, Formal analysis, Resources, Writing - review & editing, Supervision.

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