Transportation Research Part F 58 (2018) 228–241

Contents lists available at ScienceDirect

Transportation Research Part F

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

Impact of smartphone distraction on pedestrians' crossing behaviour: An application of head-mounted immersive virtual reality

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ARTICLE INFO

Article history:
Received 7 February 2018
Received in revised form 28 May 2018
Accepted 17 June 2018

Keywords:
Head-mounted immersive virtual reality
Pedestrian
Distracted street crossing
Multi-tasking
Smartphone use
Surrogate analysis
Smart LED lights safety treatment

ABSTRACT

A novel head-mounted virtual immersive/interactive reality environment (VIRE) is utilized to evaluate the behaviour of participants in three pedestrian road crossing conditions while 1) not distracted, 2) distracted with a smartphone, and 3) distracted with a smartphone with a virtually implemented safety measure on the road. Forty-two volunteers participated in our research who completed thirty successful (complete crossing) trials in blocks of ten trials for each crossing condition. For the two distracted conditions, pedestrians are engaged in a maze-solving game on a virtual smartphone, while at the same time checking the traffic for a safe crossing gap. For the proposed safety measure, smart flashing and color changing LED lights are simulated on the crosswalk to warn the distracted pedestrian who initiates crossing. Surrogate safety measures as well as speed information and distraction attributes such as direction and orientation of participant's head were collected and evaluated by employing a Multinomial Logit (MNL) model. Results from the model indicate that females have more dangerous crossing behaviour especially in distracted conditions; however, the smart LED treatment reduces this negative impact. Moreover, the number of times and the percentage of duration the head was facing the smartphone during a trial and a waiting time respectively increase the possibility of unsafe crossings; though, the proposed treatment reduces the safety crossing rate. Hence, our study shows that the smart LED light safety treatment indeed improves the safety of distracted pedestrians and enhances the successful crossing rate.

1. Introduction

Although walking is perceived as an automatic thought process, it in fact entails attention to surrounding environmental information and details to act upon. Past studies show that adult's performance and efficiency decrease when multi-tasking especially for seniors (see (Kramer & Madden, 2008)). Moreover, studies on different adult age categories in this context indicated that dual-task decreases the memory encoding and walking speed in general for everyone but more considerably for seniors and mid-aged adults (Neider et al., 2011). That said, in the past decade many studies have focused on the effects of using cell phones on road users' reactions in the transportation planning field. Findings show that drivers are significantly

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https://doi.org/10.1016/j.trf.2018.06.020
1369-8478/

impaired when using their cell phone. Also, the probability of a pedestrian crossing the intersection successfully decreases, which in some cases leads to unsafe crossing attempts. These studies make use of either real observed or simulated environment data for their analysis.

In the field of transportation studies, pedestrian safety has been a topic of interest for many years, however, despite the vast number of studies and implemented safety measures, pedestrian road injuries and fatalities are still among the top causes of death. The most recent World Health Organization study on road traffic crashes reported that globally, vulnerable road users suffered roughly 625,000 fatalities and 25 million injuries (World Health Organization, 2016). Canadian statistics from 2005 reported 11.8% of all road fatalities and 10.4% of all road injuries to be pedestrians (Ifedi, 2005). Comparing these values to the following decade, we see that in 2015, pedestrian fatality increased to 15.2% of all road casualties, and pedestrian serious injury had an increase to 14.3% of total road injuries (Transport Canada, 2015). One of the controversial reasons for this increase is the rise in distracted pedestrians, who are on their phones talking, texting, surfing the web, looking for directions, or playing games (Nasar & Troyer, 2013; Nasar, Hecht, & Wener, 2008; Tapiro, Oron-Gilad, & Parmet, 2016). Before the widespread use of smartphones and other portable technologies, pedestrian violations were among the top injury and fatality contributors (Transport Canada, 2010). In recent years, violations such as J-walking, crossing during the red-light phase and failure to yield to vehicles is combined with distractions related to smartphone use which creates a high-risk situation resulting in an increase in pedestrian road injury and fatality. Hence, some studies have focused on different types of pedestrian crossing facilities to address the unsafe crossing concerns (e.g. see (Anciaes & Jones, 2018; Gitelman, Carmel, Pesahov, & Hakkert, 2017)). However, this increase in fatality and injury rate is alarming given the numerous studies, policies, educational and safety measures, improvements and implementations aiming to reduce these risks.

Unsignalized road crossing, although thought of as a simple task, demands an individual's undivided attention and concentration. To successfully select a gap that allows for safe crossing, individuals must accurately judge the spatial and temporal size of the gap in relation to their own ability to cross the gap in time. This process is further complicated when there is more than one lane of traffic (Plumert & Kearney, 2014). When traffic flow increases in both directions, safe crossing gaps become smaller and less frequent (Wang, Cardone, Corradi, Torresani, & Campbell, 2012). Since crossing violations are in part due to added pressure from temporal restraints, the act of crossing is usually rushed, resulting in more careless crossings. When the cognitive demand required for crossing is divided by distractions, the pedestrian's awareness is reduced resulting in unsafe and risky crossing behaviours (Banducci et al., 2016; Lin & Huang, 2017; Nasar et al., 2008). As a result of the increase of distracted pedestrian, different counter measures have been proposed such as the development of smartphone applications that display warning signs on the phone of the distracted pedestrian when initiating a road crossing.

To study the behavioural and safety aspects of distracted and undistracted street crossings, several methods have been used. The use of visual attributes in transportation safety studies have caused controversy in literatures (see (Farooq, Cherchi, & Sobhani, 2018; Olshannikova, Ometov, Koucheryavy, & Olsson, 2015)). To study perception, past visualization tools relied on pictures, photomontages, maps or simulation videos (e.g. see (Song, Lehsing, Fuest, & Bengler, 2018)). An emerging interactive technology in the field of transportation studies are Virtual Reality (VR) tools which have opened a new window for practical applications and scientific investigations of human perception and behaviour. VR allows the user to immerse in a controlled environment for in-depth evaluation of user perception and behaviour. Its ability to overlay the physical environment with virtual elements such as information or images, and to allow participants to interact with the physical environment in real time, provides new possibilities for content delivery. VR allows the sensation of immersion in the activities on the screen and the virtual elements (Animesh, Pinsonneault, Yang, & Oh, 2011; Faiola, Newlon, Pfaff, & Smyslova, 2012; Farooq, Cherchi, & Sobhani, 2018; Jennett et al., 2008; Nah, Eschenbrenner, & DeWester, 2011). Moreover, recent advances in computer graphics and technology have provided new opportunities for generating more realistic virtual scenarios that are suitable for behavioural studies (Patterson, Darbani, Rezaei, Zacharias, & Yazdizadeh, 2017). VR environment experiments have successfully been conducted in various fields of cognitive studies (Blissing, Bruzelius, & Eriksson, 2017; Farooq et al., 2018). For example, Lehsing and Feldstein analysed social interaction in transient where a car driver in a driving simulator encounters a pedestrian in a second simulator in varying situations by adapting VR as their survey tool (Lehsing & Feldstein, 2018). Also, studies have shown that people can develop realistic spatial knowledge in the VR environment that is similar to the actual physical environment (O'Neill, 1992; Perroud, Régnier, Kemeny, & Mérienne, 2017; Ruddle, Payne, & Jones, 1997; Rusch et al., 2013; Tlauka & Wilson, 1996). The main advantage of adapting the VR in research studies is the freedom and versatility in setting up experiments which enables scientists to measure not only perception, but physical reactions of participants by adopting electrocardiography, skin conductance, electroencephalogy, and eye-tracking (Patterson et al., 2017; Wiener, Hölscher, Büchner, & Konieczny, 2012). A Head-Mounted VR display device uses an optical system to directly present virtual scenes received by the display and works with the human brain to produce a strong sense of immersion (Wang, Liu, et al., 2016). Feldstein et al. used a combination of a driving simulator along with a visual based motion capture system with a head-mounted virtual reality device to link a driving simulator to a pedestrian simulator so that both participants meet in the same virtual environment to analyse their interactive behaviour simultaneously (Feldstein, Lehsing, Dietrich, & Bengler, 2016). Immersive virtual environments which allow a locomotive interface may preserve the perception-action coupling that is critical in examining many visual timing skills (Wu, Ashmead, & Bodenheimer, 2009). Researchers also applied virtual environments to study pedestrian route choice and reaction to information in evacuation scenarios. However, most of these studies lack the extensive two-way interactivity and dynamics necessarily to create realistic experiments. Specifically, there is a strong need for the incorporation of user's actions within the environment and