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Applying an extended theory of planned behavior to predicting violations at automated railroad crossings

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ABSTRACT

Based on an extended Theory of Planned Behavior (TPB, Ajzen, 1985, 1991), we conducted surveys in order to explain and predict violations at a railroad crossing, among pedestrians ($n = 153$) and car drivers ($n = 151$). Measures were made with respect to three chronologically related railroad crossing situations that varied in risk level. The situations were described in scenarios and depicted on photographs. The participants were recruited in the suburbs of Paris, at two automated railroad crossings with four half-barriers. We found that the pedestrians had stronger crossing intentions than did car drivers, especially at the more congested crossing of the two under study. For both categories of road users, intentions and the amount of intention variance explained by the extended TPB factors decreased significantly with risk level. In the most dangerous situations, risk-taking was the most unlikely and the least predictable Self-reported past frequency of crossing against safety warning devices was the main predictor of the intention to commit this violation again, especially among males, followed by the attitude and the injunctive norm in favor the violation. Moreover, car drivers were influenced in their crossing intentions by the descriptive norm. The presence of another vehicle on the tracks when the safety warning devices were activated was perceived not as facilitating, but as an additional risk factor. The discussion addresses the importance of taking into account these determinants of violations in conceiving countermeasures. Our findings could be especially useful for conceiving risk-communication campaigns.

1. Introduction

Although the total number of railway accidents dropped substantially in the European Union between 2006 and 2012, the proportion of railroad-crossing accidents, related fatalities, and serious injuries increased during that period (ERA, 2014). There were similar concerns in other parts of the world, for example in Australia (Henley and Harrison, 2009) and in the US, where crashes between road vehicles and trains had diminished since the 1990s, but pedestrian safety at railroad crossings had shown no improvement (Metaxatos and Sriraj, 2013). Collisions involving different road users and trains can have very serious consequences, such as fatalities or extremely severe injuries (for a morbidity analysis in the American context, see Goldberg et al., 1998). Such collisions may take place at railroad crossings, or may result from trespassing (the latter applies especially to train-pedestrian collisions). According to New Zealand statistics cited by Lobb et al. (2003), the probability of surviving a collision with a train is about 30% for a pedestrian. As reported by the official website of Réseau Ferré de France[1] (RFF, 2012a), the risk of fatality in collisions between a train and a car is almost 50%, while it is 5% in other types of on-road collisions between cars.

In 2013, there were 148 collisions at railroad crossings in France, resulting in 29 fatalities and 19 serious injuries (RFF, 2012a). The French National Agency for Railway Safety (Etablissement public de sécurité ferroviaire, 2014) classified 42 of these collisions as "significant accidents", i.e., resulting in at least one fatality or serious injury, causing material damages worth 150,000€ or more, or interrupting rail traffic for at least six hours (Etablissement public de sécurité ferroviaire, 2014). The remaining collisions were probably minor incidents such as broken barriers that nonetheless incurred non-negligible repair costs and train delays. In France, the five-year rolling average of crashes at railroad crossings per million train kilometers in 2013 (0.082) was even higher than in preceding years

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[1] Owner and manager of the French railroad system.

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(0.08 in 2012, 0.078 in 2011 and 2010, and 0.079 in 2009), as was the rolling average of seriously injured railroad crossing users (0.031 in 2013 vs. 0.028 in 2012, 0.027 in 2011, 0.029 in 2010, and 0.027 in 2009).

Efforts have been made to improve safety devices aimed at reducing the risk of collision at railroad crossings (for examples, see Becker et al., 2008; Edquistet al., 2009; FRA, 2008; Lenné et al., 2011). In particular, a number of passive railroad crossings have been upgraded to active ones. Passive crossings are equipped with static controls such as crossbucks, stop signs, or yield right-of-way signs, while active crossings are equipped with automatic controls such as flashing red lights, sound signals, and barriers. These safety warning devices are activated automatically before the train passes by. The ultimate performance objective of a crossing is to ensure that road users can cross the tracks safely, and active crossings have proven better than passive ones (Evans, 2011; Meeker et al., 1997; Tey et al., 2011). This paper focuses on France, where passive crossings currently account for 24.1% and active crossings for 70.6% of all public railroad crossings.

In France, there are essentially two types of active crossings, defined in terms of the number of barriers: two half-barriers (2-HB), and four half-barriers (4-HB) (RFF, 2012a,b), the latter of which guarantees better safety performance (Ghazel and El-Koursi, 2014). Irrespective of the type of crossing, about 25 s before a train passes through, light and sound signals go off, and then shortly afterwards the half-barriers start to go down. At 2-HBs, there is one half-barrier on each side of the tracks, blocking the lane in which road users approach the crossing, but letting non-compliant road users (motorized vehicles in particular) go around the half-barrier via the adjacent lane. At 4-HBs, there are two additional half-barriers so that all lanes are blocked and there is no possibility of crossing after the half-barriers have gone down. At this type of crossing, however, the half-barriers blocking the lanes in the approach direction start to go down first (about 17 s before the train arrives), shortly before the other pair of half-barriers descends (which start to go down approximately 8 s before the train's arrival). Hence, there is a certain risk of being trapped on the tracks between the barriers if a non-compliant road user goes around a half-barrier, which is almost or completely down, through the adjacent lane where the half-barrier is still up (or has just begun to go down). The 4-HB crossings are less frequent and are located mainly in urban areas in the vicinity of train stations, where many trains stop. These crossings are frequently closed for prolonged periods of time, and long before a train passes through. One can also find these crossings in the vicinity of schools where they are intended to reduce children's non-compliant behavior and therefore increase their safety.

Explaining the causes of railroad-crossing crashes is a complex and challenging task, as illustrated by studies applying a system-based approach (Mulvihill et al., 2016; Read et al., 2016; Salmon et al., 2013, 2016; Stefanova et al., 2015). Although crossing against safety warnings can be unintentional, e.g., caused by faulty expectancies while approaching a railroad crossing (Salmon et al., 2013), it is generally agreed that a significant proportion of these behaviors are due to intentional non-compliance (Freeman and Rakotonirainy, 2015; Illinios Commerce Commission, 2005; Pickett and Grayson, 1996; RFF, 2012a). To tackle this deliberate risk-taking, then, and to further reduce the number of collisions at railroad crossings that result from it, we need more knowledge of people's motivations for committing violations at railroad crossings.

A considerable amount of research has been carried out to identify the circumstances and road user characteristics associated with risky railroad-crossing behaviors by pedestrians and car drivers. As regards pedestrians, males (Clancy, 2007; Edquistet al., 2011; Metaxatos and Sriraj, 2013), especially young ones, and children (Khattak and Luo, 2011) were found to be particularly likely to cross the tracks against safety signals and protection devices. In particular, such risky behaviors were more likely to be observed when pedestrians were in groups (Khattak and Luo, 2011; Metaxatos and Sriraj, 2013). This facilitating group effect seems contrary to what was observed on signaled pedestrian street-crossings, where the presence of other pedestrians had an impeding influence on non-compliant crossing (Rosenbloom, 2009). Moreover, in the study conducted by Beanland et al. (2015), heavy traffic conditions had an impeding effect on the decision to cross non-compliantly, but road users who arrived first at the crossing after the safety warnings were activated were more likely to cross than those who arrived later. In survey-based studies (Clancy, 2007; Metaxatos and Sriraj, 2013), pedestrians mentioned several common concurrent activities that could interfere with situation awareness while crossing, such as talking on the phone, pushing a stroller, or listening to music. This awareness also seemed to decrease with age: elderly pedestrians were generally less likely to take risks than were young ones between the ages of 18 and 25. Moreover, the perception of active and passive warning devices was moderated by age: older users were more likely to pay attention to passive signs, while younger ones paid more attention to active ones. Several studies based on cognitive work analysis (Mulvihill et al., 2016; Salmon et al., 2016) or focused on situational awareness at railroad crossings (Beanland et al., 2015) found that different categories of road users directed their attention to different types of warning devices when making their stop/go decisions: the motorized road users (car drivers and motorcyclists) paid more attention to visual signals, whereas non-motorized ones (pedestrians and cyclists) paid more attention to auditory warning signals. When intending to cross against safety warnings, the non-motorized road users were also likely to check for how close an approaching train was from the crossing. Contradictory conclusions have been drawn as to whether familiarity with crossing situations is a factor influencing railroad-crossing behavior, insofar as some researchers have found that regular railroad-crossing users were more risk-aware and safety-oriented (Metaxatos and Sriraj, 2013), while others noted that familiarity with crossings was linked to accidents (Beanland et al., 2015; Clancy, 2006). In the Beanland et al. (2015), Clancy (2007), Metaxatos and Sriraj (2013), and Read et al. (2016) studies, road users reported adopting risky crossing behaviors, and/or were seen doing so when under time pressure. They also explained that they crossed against safety warning devices if they suspected them to be defective (Beanland et al., 2015; Clancy, 2007).

The latter reason may explain why car drivers were especially likely to cross the tracks against safety signals beyond a certain threshold of waiting time (Abraham et al., 1998; Richards and Heathington, 1990). Risky behaviors at railroad crossings by this category of motorized road users may also be facilitated by sensation-seeking, in that sensation-seekers find it exciting to "beat the train" or want to avoid the boring experience of waiting (Witte and Donohue, 2000). This finding seems quite consistent with research on the impact of sensation-seeking on several risky behaviors behind the wheel (Hatfield et al., 2014; Jonah, 1997) such as speeding (Delhomme et al., 2012) and yellow-light running (Rosenbloom and Wolf, 2002a,b). Finally, motorized and non-motorized road users reported taking their own capabilities into account (acceleration/braking for drivers, running across for pedestrians) when deciding whether to cross against or abide by safety warnings (Beanland et al., 2015).

In contrast to the research reviewed herein, we argue that applying a more holistic approach to the analysis of motivation to cross against safety warnings could provide additional insights, not only into the stable motivational factors involved in such risky decision-making but also into some possible countermeasures for tackling this safety problem. One of the most popular and powerful theoretical frameworks used to study motivations, and to make