Accident Analysis and Prevention 80 (2015) 67–75

Contents lists available at ScienceDirect

Accident Analysis and Prevention

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

Red light violations by adult pedestrians and other safety-related behaviors at signalized crosswalks

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ARTICLE INFO

Article history:
Received 5 December 2014
Received in revised form 3 March 2015
Accepted 3 April 2015
Available online 14 April 2015

Keywords:
Pedestrians
Signalized crosswalk
Observation
Violation
Safety

ABSTRACT

To study human factors linked to red light violations, and more generally to safety-related behaviors at signalized crosswalks, the present study combines the collection of observational data with questionnaires answered by 422 French adult pedestrians. Thirteen behavioral indicators were extracted (12 before and while crossing, and red light violation), and the roles of several demographical, contextual and mobility-associated variables were examined. The results of the stepwise logistic regression analyses carried out on each of the 12 behavioral indicators observed before and while crossing revealed that gender had no major impact, but age did, with more cautious behaviors as pedestrians were older. The three contextual variables (group size, parked vehicles, and traffic density), as four mobility-associated variables (driving and walking experiences, self-reported crossing difficulties and falls in the street) were also found to be important factors in safety-related crossing behaviors. A wider logistic regression analysis, made specifically on red light violations with all behavioral indicators observed before and while crossings and the several demographical, contextual and mobility-associated variables put together, showed that red light violations were mostly affected by current situational factors (group size, parked vehicles) and particularly associated with some behavioral patterns (looking toward the traffic, the ground, the light, running and crossing diagonally). The overall results encourage the development of safer pedestrian infrastructures and engineering countermeasures.

1. Introduction

Among road users, pedestrians are the most vulnerable to traffic injury. It has become highly challenging for pedestrians, especially older ones, to cope with the complex, sometimes hostile, traffic conditions that characterize today's cities and towns (ITF, 2012). The Organization for Economic Co-operation and Development (OECD) reported in 2011 that over 20,000 pedestrian fatalities occur annually in its member countries, ranging from 8 to 37% of all road fatalities. Worldwide, the number of pedestrians killed every year on the road exceeds 400,000.

In France, national statistics show that almost 30% of pedestrian crashes occur at signalized crosswalks (Observatoire National Interministériel de Sécurité Routiere (ONISR), 2012). Signalized intersections with crosswalks appear to help channel pedestrian traffic but prove unable to persuade pedestrians to comply with the signal indications (Sisiopiku and Akin, 2003). Studies on adult pedestrian behavior at signalized crosswalks actually show a high level of irregular crossings, especially when pedestrians deliberately choose dangerously short gaps to cross against the light (Koh and Wong, 2014) and when they cross in the last seconds of the pedestrian red light (King et al., 2009). To understand such illegal crossings and red light violations, many authors have investigated the effects of both external environment and internal human factors, but with more emphasis on external factors.

Red light violations are frequently associated with road and traffic characteristics, such as vehicular traffic conditions (Guo et al., 2011; Sisiopiku and Akin, 2003; Wang et al., 2011; Yagil, 2000; Yang et al., 2006), waiting time (Brosseau et al., 2013; Guo et al., 2012; Li and Fernie, 2010; Tiwari et al., 2007; Van Houten et al., 2007), or length of the crossing (Cambon de Lavalette et al., 2009; Cinnamon et al., 2011).

Individual characteristics such as gender and age have also been shown to be important contributing factors to pedestrian violations, gender having been more studied than age. Male pedestrians are observed and reported to violate traffic rules more

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http://dx.doi.org/10.1016/j.aap.2015.04.002
0001-4575/

frequently than females and are more likely to cross in riskier situations (Guo et al., 2011; Hamed, 2001; Moyano Diaz, 2002; Rosenbloom, 2009; Rosenbloom et al., 2004; Tiwari et al., 2007; Tom and Granié, 2011). In a recent study, Ren et al. (2011) show a contradictory finding: they observe male pedestrians to be more likely to comply with traffic rules on signalized crosswalks whereas female pedestrians (especially those who are middle-aged) tend to cross streets in a hurry, once they find a gap to cross, regardless of other unforeseen events.

Age has been much less studied as a factor influencing violation behaviors. The overrepresentation of older pedestrians in crash statistics is often explained by altered decision-making and gap-acceptance processes in situations where no helping signals or markings are provided (see e.g., Dommes et al., 2014, 2013; Dommes and Cavallo, 2011; Holland and Hill, 2010; Oxley et al., 1997, 2005). Whereas many studies show that older drivers are able to compensate for their reduced abilities to still drive safely (by driving less, more slowly, for example), such adaptive behaviors have rarely been examined in older pedestrians. Indeed, they might also adapt their crossing strategies to adjust for sensory, cognitive and motor changes they are experiencing by using signalized crosswalks and having a greater respect for traffic rules. The rare studies on this topic show that older pedestrians (>60 years) wait for a longer time than younger ones at crossing signals (Guo et al., 2011) and they also appear to be more inclined to comply with traffic laws (Granié et al., 2013; Ren et al., 2011; Rosenbloom et al., 2004). But in several other studies, age fails to yield significant differences in offending crossing behaviors (see e.g., Rosenbloom, 2009).

If pedestrian demographic characteristics contribute to red light violations, the particular contextual characteristics in which pedestrians are crossing may do so even more. For example, Rosenbloom (2009) shows that the level of pedestrian density, i.e., the number of pedestrians waiting to cross together (group size), is an important factor in red light violations: the higher the number of pedestrians present at the curb, the lower the rate of people crossing on the red light (Rosenbloom, 2009; Brosseau et al., 2013). But Ren et al. (2011) show contradictory findings: pedestrians who cross in a group tend not to obey the traffic signal. The presence of parked vehicles near the crosswalk is another contextual characteristic that may also be related to pedestrian safety. While the scientific literature points to the presence of parked vehicles as a causal factor in pedestrian accidents, especially among children (Brenac et al., 2003; Roberts et al., 1995; Stutts et al., 1996), only a few studies have explored the effect of parked vehicles on adult pedestrian crossing behavior. Tom and Granié (2010) show that adult pedestrians display more cautious crossing behavior when there are no parked vehicles in the area (crossing diagonally less often, starting and finishing on the pedestrian crossing) and are more focused on traffic in the presence of parked vehicles. However, a very recent study found contradictory results: the presence of illegally parked vehicles makes the adult pedestrians more careful (measured by larger gap acceptation) and discourages them from crossing the street (Yannis et al., 2013). Better knowledge is thus needed about the effects of parked vehicles on pedestrian behaviors before and during crossings, including red light violations.

One last possible factor behind age and gender differences or behind traffic-related characteristics in pedestrian accident statistics and safety-related behaviors is mobility patterns. Driver experience has been shown to influence a number of skills involved in pedestrian crossing, such as visual search (Underwood et al., 2002), judging vehicle arrival times (Carthy et al., 1995), and making safe crossing choices (Holland and Hill, 2010). Likewise, walking experience may play a role in the way pedestrians behave on roads, despite the lack of studies on this specific topic. Negative experiences on the road, such as falls and accidents experienced as pedestrians, could influence behaviors as well, particularly the visual attention given to approaching vehicles when crossing (Avineri et al., 2012; Job et al., 1998; Scheffer et al., 2008; Woollacott and Tang, 1997).

Beyond simulator studies about pedestrian crossing behavior (see e.g., Dommes et al., 2014; Meir et al., 2013; Oxley et al., 2005; Schwebel et al., 2012; Tapiro et al., 2014), most of the field studies that are led in real environments employ methodology such as video analyses (Brosseau et al., 2013; Hamed, 2001; Tiwari et al., 2007; Zhuang and Wu, 2011, 2012), observation grids (Cinnamon et al., 2011; Rosenbloom, 2009) or questionnaires alone (Moyano Diaz, 2002; Yagil, 2000). Sisiopiku and Akin (2003) did use video analyses as well as questionnaires, but to study the reasons behind a pedestrian's choice to cross at a specific location. Guo et al. (2011) also used both observations and questionnaires, but only some of the observed pedestrians were questioned. Finally, Ren et al. (2011) analyzed videos combined with questionnaires, but with different participants.

The present study aims to fill gaps in research on adult pedestrian behaviors at signalized intersection crossings, including red light violations, by studying human factors under three aspects: (i) the individuals' demographic characteristics (age and gender); (ii) the context in which individuals cross the street (group size, presence of parked vehicles, traffic density); (iii), and general mobility patterns of these individuals. To meet these objectives, the present study combines observational data (collected during the pedestrian's crossing) and subjective data from the same pedestrian (collected from his or her answers to an on-site questionnaire, mostly related to mobility patterns). This unique database may allow the analysis of several related human factors to better understand the reasons why pedestrians cross against the signal and sometimes behave dangerously on signalized crosswalks.

2. Methods

2.1. Location of observations

Fifteen urban crosswalks located at six different signalized intersections in the city of Lille, in the north of France, were chosen as experimental sites. All were on two-way streets, with no pedestrian refuge islands. They all had zebra crossings, pedestrian and traffic lights, and a speed limit of 50 km/h on each road segment. Traffic density was available for each observed crosswalk in three categories, measured by the metropolitan community as the average annual daily traffic (AADT): from 1500 to 6000 vehicles per day (4 crosswalks), from 6001 to 13,000 vehicles per day (4 crosswalks) and from 13,001 to 30,000 vehicles per day (7 crosswalks).

2.2. Observation grid and questionnaire

A grid was used to observe pedestrian behaviors during all the crossing task phases (Tom and Granié, 2011). This grid was designed to follow each participant from the curb approach to the very end of the crossing. Such a division into three areas stems from Geruschat et al. (2003), who found that crossing a street is done in three phases: walking to the curb (from 5 to 0.5 m before the marked crosswalk), standing at the curb (preparation to the crossing), and the crossing itself (from the start of the pavement to the opposite curb).

The observation grid was based on previous works and adapted to observe pedestrian behaviors on French crossroads (Granié, 2007; Latrémouille et al., 2004; Rivara et al., 1991; Routledge et al., 1974; Van der Molen, 1983; Zeedyk and Kelly, 2003). Pedestrian red light violation, waiting position (on the curb versus on the road), walking pace (running behavior) and crossing path (straight or