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"Outta my way!" Individual and environmental correlates of interactions between pedestrians and vehicles during street crossings

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ABSTRACT

Because pedestrian crash rates remain lower than other collision types, surrogate measures such as traffic interactions are now used in road safety research to complement crash history. Using naturalistic data collection, we sought to assess 1) the likelihood of occurrence of interactions between pedestrians and vehicles based on individual and crossing characteristics; and 2) differences in interaction characteristics between children, adult and senior pedestrians. Observations of pedestrian crossing behaviours (n = 4687) were recorded at 278 crossings. For recorded interactions (n = 843), information was collected to characterize the behaviours of involved parties. A mixed-effect logit regression model was performed to assess the factors associated with interactions. Chi-square tests evaluated differences between age groups and characteristics of observed interactions. Older adults were those more likely to be involved in an interaction event. Bicycle paths, different crossing surface material and one-way streets were significantly associated with fewer interactions with vehicles, while parked vehicles nearby and crossings on arterial roads were significantly associated with more interactions. Children and the elderly (80 years of age or more) did have distinct patterns of interaction, with more careful drivers/cyclists behaviours being observed towards children and lesser regulation compliance towards the elderly. Given the growing emphasis and adoption of active transportation in many cities, the number of interactions between pedestrians and vehicles during street crossings is likely to increase. Educating drivers and pedestrians to respect each other's space requires an understanding of where, between whom, and under what circumstances interactions occur. Such an approach can also help identify which engineering and enforcement programs are needed to ensure safe pedestrian crossings since interactions can be good markers of uncomfortable crossing situations that may deter walking and lead to more collisions.

1. Pedestrians crash risk in cities: what to measure?

A growing number of North American cities have been actively promoting non-motorized transportation and developing road infrastructure to support the use of these travel modes. Despite this, crash statistics show that many unsafe conditions still exist for vulnerable road users such as pedestrians, partly because modern cities were (and are still) mostly built for cars (Dumbaugh and Rae, 2009; ITF, 2012; Kaparias et al., 2015).

On the other hand, local pedestrian crashes can be considered "rare events," at least from a statistical perspective (Miranda-Moreno et al., 2007; Theofilatos et al., 2016). Pedestrian crash counts are usually lower than those of any other type of road users at the city level, making it difficult for cities to effectively plan and justify preventive measures at specific site. In fact, past collisions alone are considered by many researchers to be inefficient at predicting future ones (Langbroek et al., 2012; Laureshyn et al., 2010; Zheng et al., 2014). As a result, surrogate measures such as traffic conflicts and interactions are increasingly used in road safety research as complementary to crash history (Hyden, 2016; Tarko et al., 2009) in order to have a better portrait of the situation and plan road design accordingly.

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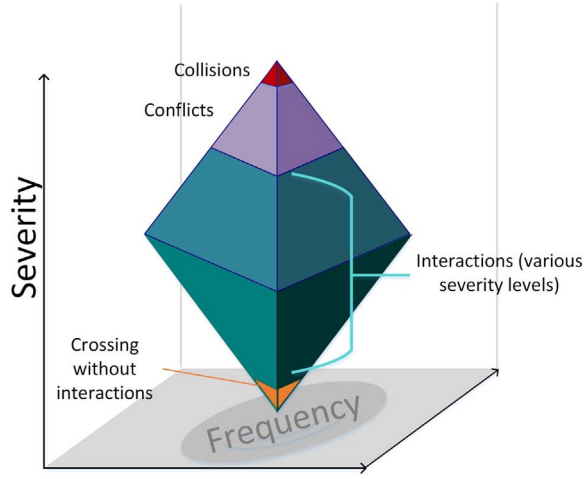

Fig. 1. Road safety continuum for vehicle–pedestrian interactions.

1.1. Surrogate measures of crash risk: Traffic conflict techniques and interactions

The concept of "traffic conflict techniques" was first proposed in the 1960s as a complementary approach to typical collision-based safety analysis. A traffic conflict was first described as an event where "two or more road users approach each other in space and time to such an extent that a collision is imminent if their movement remains unchanged" (Muhlrad, 1988). This definition has been extended throughout the years to include less critical conflicts—in other words, situations where road users adapt their behaviour ahead of the "conflicting zone", leaving time and space for fluid movement while both users are on the street. Those common pedestrian–vehicle conflicts, referred to as "interactions," can be seen as part of the road safety continuum shown in the diamond-shaped representation proposed by several authors (see Fig. 1) (Langbroek et al., 2012; Laureshyn et al., 2010; Davies et al., 2003). This broader definition of interactions, as event where both a vehicle and a pedestrians are on the roadway at the same time and adapt their behaviour consequently to avoid a collision, is the one used here.

While there are more published accounts of conflicts between motorists, traffic conflict literature that focuses on pedestrians (Kaparias et al., 2015; Ismail et al., 2009) is less frequent. So far, there is no reason to think that this surrogate measure of crash risk is not applicable to pedestrian/vehicle conflicts, even if the predictability of the pedestrian behaviour is more complex than that of motorists. However, the reflection on how suitable the usual conflict and interaction indicators are when pedestrians are at stake still needs to be undertaken, as stated in a recent report (Laurenshyn et al., 2016). Moreover, even when interactions do not lead to injuries, they may be symptomatic of environments that are not adapted to pedestrians. In this context, studying interactions can provide insight into the initial circumstances that may lead to crashes (or not). It is even more important to have a better understanding of interactions involving the most vulnerable pedestrians, namely children and seniors. In a context where these sub-populations are already targeted in active living and transportation policies and programs (Child Friendly Cities, 2014; World Health Organization, 2016), these interactions might contribute to their risk perception while on the street and consequently have an effect on the decisions they make to move around as pedestrians.

1.2. Objectives

This paper seeks to provide a better understanding of the individual and environmental determinants associated with the occurrence of interactions between pedestrians and other road users (cars and bikes, other) during pedestrian crossings at intersections. As a secondary objective, it seeks to explore differences in interaction characteristics when comparing observed children, adult and senior pedestrians. By providing findings related to these objectives, we seek to strengthen the research background on pedestrian interactions through an important observational study.

2. Individual and environmental determinants of pedestrian–vehicle collisions and interactions

Individual and environmental determinants of pedestrian crashes are well known and have unfortunately changed very little in the past 25 years, especially in the Western hemisphere (World Health Organization, 2015). Similarly, research using surrogate measures highlights the same causal patterns in both near misses (conflicts) and crashes (Tarko et al., 2009; Gharieh et al., 2014; Guo et al., 2010), at least for car-to-car events. Since pedestrians are rarely targeted by this research, our analytical framework below is based on both collision, conflict and interaction literature and explores relationships to sociodemographic, behavioural and physical crossing environment characteristics.

When evaluating associations between individual characteristics and pedestrian–vehicle collisions, age and gender are two variables often taken into account. Compared to the general population, ageing pedestrians are overrepresented in crashes compared to their relative proportion of the population (Dommes and Cavallo, 2011; Fontaine and Gourlet, 1997); up to 50% of all injured pedestrians in OECD countries are seniors (ITF, 2012). They are also more severely injured in road crashes and experience longer hospital stays (3–5 times more than injured pedestrians between 15 and 64 years old) (Abou-Raya and ElMeguid, 2009; Loo and Tsui, 2009), due to their prior physical condition. Children generally experience fewer injuries (LaScala et al., 2000), but within the 0- to 18-year-old group, 5- to 9-year-olds are most at risk due to cognitive (less mature), physical (shorter, less visible through traffic) and exposure (beginning of independent mobility) reasons (Burigusa, 2011; Zeedyk et al., 2001). As for gender, middle-aged men are the most at-risk pedestrians (LaScala et al., 2000; Lee and Abdel-Aty, 2005), along with younger boys (5–9), who might be more involved in collisions because of their greater exposure to traffic (more independent mobility than girls) (Burigusa, 2011). Lastly, behaviour such as walking speed has been the focus of much attention lately, namely for elderly pedestrians. In fact, some have hypothesized an association between their slower walking speed, due to the process of ageing and change in their capabilities, and their injury risk, referring to this as the "slow walking speed hypothesis" (Dunbar, 2012), which was positively tested in a recent paper on elderly pedestrians who complete their crossing on a red light (Lachapelle and Cloutier, 2017). If we consider the time spend on the street as a measure of exposure to risk at the crosswalk level (Julien and Carré, 2002), this walking speed variable should be analyzed accordingly.

Beyond these individual characteristics, streets and intersections have also been studied for their associations with pedestrian crashes, but also with pedestrian behaviours. Characteristics such as presence of arterial roads are known to increase collision rates (Dumbaugh and Li, 2011; Miranda-Moreno et al., 2011; Morency et al., 2015). On the contrary, signalized intersections (traffic lights) are known to decrease the probability of collisions for children (Burigusa, 2011; Rothman et al., 2014) and the probability of fatal collisions for adults (Rifaat et al., 2011). However, Svensson and Hydén (2006) found that signalized intersections seem to produce more high-severity interactions than non-signalized ones. One-way streets are related to more collisions in children (Rothman et al., 2014; Wazana et al., 2000), but Dai et al. (2010) found the opposite on university campuses. As for marked crosswalks, the higher collision rates found for adults (Morency et al., 2015; Leden et al., 2006), seniors (Koepsell et al., 2002) and