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The effects of age and traffic density on street-crossing behavior

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ABSTRACT

Past research has shown that road users accept shorter time gaps when the waiting time/number of vehicles they let pass before attempting to merge into the traffic increases. While elderly pedestrians are known to be an extremely vulnerable group of road users, very few studies dealt with the effect of environmental constraints and crossing complexity on this population's safety. The present study aimed at determining whether or not street-crossing decisions and behavior of younger and older pedestrians were differently affected by a traffic flow. In an interactive street-crossing task, we assessed whether mean time gap and crossing decisions depended on the position of the gap pedestrians selected into the traffic stream. Results revealed that irrespective of their age pedestrians accepted a smaller time gap when they chose the second interval of the traffic compared to the first one. Contrasting with previous hypotheses, this traffic-related behavior was not accompanied by an increase in the decisions risk. The findings also showed that the transition threshold from rejecting to accepting time gaps was shorter when the second interval was selected compared to the first one. This increment in task constraints might help younger and older pedestrians alike to perceive action possibilities more accurately and to be better attuned to traffic conditions by comparing gaps between each other. This opens an interesting perspective in the understanding and the training of the ability of elderly road users to remain accurate in their judgements.

1. Introduction

International accident statistics indicate that elderly pedestrians are an extremely vulnerable road-user group (NHTSA, 2001; OECD, 2001). In France, more than half of all pedestrians killed on the road (51%) in 2004 were over 65 years old, whereas this age group represents less than 15% of the population (ONISR, 2005).

Studies which have looked into age-related changes in elderly pedestrians showed that sensorimotor deficits (e.g., Lobjois and Cavallo, 2009; Oxley et al., 2001), cognitive deficits (e.g., Oxley et al., 2001) or changes in the crossing strategies (e.g., Lobjois and Cavallo, 2009; Oxley et al., 1997) have the potential to explain why this age group is over-represented in accidents. Past studies have also dealt with the effects on older pedestrians' crossing behavior of exogenous factors such as oncoming vehicles speed (e.g., Lobjois and Cavallo, 2007, 2009; Oxley et al., 2005) or crossing complexity (e.g., one way versus two-way roads; Oxley et al., 1997). Little is known about the causes of accidents in elderly pedestrians and more importantly about the environmental factors that affect or improve the behavior of elderly people in street crossing. Research addressing the impact of a traffic stream on crossing behavior of elderly people is still scarce, as most of the research has been conducted with only one or two approaching vehicles (Dommes and Cavallo, 2012; Dommes et al., 2012; Lobjois and Cavallo, 2007, 2009; Oxley et al., 2005; te Velde et al., 2005). Thus the goal of this study was to assess the effect of a traffic stream on gap acceptance and crossing decisions of younger and older pedestrians.

The effect of a traffic stream on decision making has been addressed in natural conditions with studies on gap acceptance for turning maneuvers of motorists when stopped at an intersection. Ashworth and Bottom (1977) showed that the accepted time gap depended on the velocity of the oncoming traffic and on the front-of-queue delay before right-turn movement execution. Time gaps decreased when both the approach speed of the opponent vehicle and waiting time increased. Similar results were also obtained by Adebisi and Sama (1989), who showed in addition that the drop in the gap size was due to an increase in the traffic flow on the major road the drivers planed to cross or merge into. It is reasonable to think that an increase in traffic flow would lead to decreased gap

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sizes between approaching vehicles and thus would affect waiting time and accepted time gap. To further explore the origin of the relationship between gap size and waiting time, Kittelson and Vandehey (1991) compared accepted time gap and waiting time between one group of drivers whose accepted gap was longer than all previously rejected gaps and one group of drivers whose accepted gap was shorter than one or more previously rejected gaps. The first group of drivers actually corresponded to one group who took the first affordable gap (all rejected gaps were lower than the one accepted) while the second group first missed crossable gaps before drivers merged into the traffic. Interestingly, results revealed that drivers who took the first affordable gap waited for 9 s in average and accepted a mean time gap of 5.5–7 s while the other group accepted a time gap of 3–4 s after having waited for 19.5 s.

Alexander et al. (2002) carried out a study using a driving simulator and showed contradictory results. Younger and older participants drove repeatedly around a circuit which included turning-right maneuvers at an unsignalised junction. At this junction, gaps between vehicles in the traffic stream randomly varied between 1 and 14 s. Results revealed that drivers accepted a smaller gap at higher approach velocities but that the mean accepted time gap increased with the number of gaps participants let pass before they executed their turning maneuver (8.3 s for the first gap accepted, 9 s for the fourth or 10 s for the seventh).

In a virtual environment, Plumert et al. (2007a,b, 2011) examined gap choices in traffic-filled intersections while participants cycled an interactive simulator. Participants first encountered a set of four intersections, in which randomly ordered gaps ranged from 1.5 to 5 s (in 0.5-s increment). Participants then had to cross a new set of intersections, in which uncrossable gaps (1.5 and 2 s) were followed by alternating sets of two same-size crossable gaps (3–4 s in 0.5-s increment) and four uncrossable gaps. Results showed that participants were willing to accept much smaller gaps when they had to wait for a long time before they could merge into the traffic (mean time gap of 4.8 and 3 s for the first and second set of intersections, respectively).

In the only pedestrian behavior study, by Simpson et al. (2003), participants had to choose the most appropriate gap and cross a virtual road while facing a traffic stream of 10 vehicles. Gap sizes between vehicles randomly varied between 4 and 10 s, in 2-s increment. Results showed that the greater the number of gaps prior to crossing, the shorter the gap chosen to cross in. This confirmed that pedestrians accept smaller gaps after waiting to cross (7.1, 6.1 and 5.8 s for 0, 1 and 2 or more gaps rejected before crossing, respectively).

In sum, previous research indicates that pedestrians (Simpson et al., 2003), cyclists (Plumert et al., 2007a) and motorists (Adebisi and Sama, 1989; Ashworth and Bottom, 1977; but see also Alexander et al., 2002, for opposite patterns) accept shorter time gaps when they let pass time/vehicles before attempting to cross the road. Different hypotheses have been put forward. Assailly (1993) proposed that time wasting might contribute to impatience and increased risk taking. For Hamed (2001), when waiting time increases, pedestrians are more likely to accept higher risk by forcing approaching vehicles to brake. According to Kittelson and Vandehey (1991), the size of the accepted gap decreases particularly when a crossable gap is previously missed. Another explanation could be that the waiting time gives a possibility of viewing several gaps before crossing and is used to improve the attunement of the crossing behavior to choose shorter gaps. This attunement would correspond to a better calibration of the crossing action in reference to the available time.

Thus the purpose of our study was to examine the effect of a traffic stream on gap acceptance, road-crossing decisions and behavior of younger and older pedestrians. While the density of the traffic stream clearly impacts the behavior of road users, it is important to investigate this effect on elderly people, especially given that the elderly have been shown to be particularly affected in their perception and decision-making when the environmental constraints increase. For instance, Oxley et al. (1997) showed that older pedestrians adopted less safe road crossing strategies on two-way undivided roads than on one-way roads. In similar vein, older pedestrians were more impaired than younger ones when the speed of approaching vehicles was systematically varied, as they consistently accepted shorter and shorter gaps as speed increased (Lobjois and Cavallo, 2007, 2009; Oxley et al., 2005). This turned into unsafe crossing decisions at high speeds and missed crossing opportunities when car speeds were low.

The present investigation carried out in a simulated interactive road-crossing situation was aimed at determining whether older pedestrians were more or less influenced than younger ones by a traffic stream in the choice of the gap to cross a road. Our second goal was to determine whether the expected drop in the second gap size was the result of a risky behavior or a better attunement-calibration of the crossing behavior.

2. Methods

2.1. Participants

Sixty seven participants took part in the study and were divided into three age groups: 20–30 years old (11 women, M_{Age} = 27.1 years, SD = 3.2 years, and 11 men, M_{Age} = 28.1 years, SD = 3.3 years), 60–70 years old (11 women, M_{Age} = 67 years, SD = 2.5 years, and 11 men, M_{Age} = 67.1 years, SD = 2.4), 70–80 years old (13 women, M_{Age} = 75.4 years, SD = 3.3 years, and 10 men, M_{Age} = 75.8 years, SD = 3.3 years). The elderly participants were retired individuals living on their own. They were recruited with the assistance of the Health Department of the surrounding cities and through advertisements. All participants underwent a medical examination whose purpose was to check certain criteria (i.e., walking perimeter greater than half an hour without a cane or crutch, ability to easily read 90° to the left through the combined rotation of the head and trunk, horizontal gaze direction when standing at rest, corrected visual acuity of at least 6/10, and absence of major cardiac, neurological, or visual disorders and diseases). Because of the interactive situation and the need for crossing a distance of several meters corresponding to the virtual road, the participants with mobility and other health problems were screened out. This resulted in a healthy sample of older participants in comparison to the actual older population at risk. All signed an informed consent form before participating in the experiment; the study was approved by the local ethics committee.

2.2. Experimental setup

Until recently, much of the research examining gap acceptance was based on estimation tasks, either in children (e.g., Connelly et al., 1996, 1998; Pitcairn and Edlmann, 2000) or elderly pedestrians (e.g., Lobjois and Cavallo, 2007; Oxley et al., 2005). Estimation tasks require participants to give a verbal response or to press a button to indicate whether they would cross the road in front of oncoming traffic. Although estimation tasks provide the advantage of having no physical risk and no need to simulate a portion of the road, their ecological validity has been criticized (e.g., Simpson et al., 2003). It has been showed that the interactive modality of the road-crossing situation improves the perception of crossing possibilities in comparison with button-press or verbal responses (e.g., Lobjois and Cavallo, 2009; te Velde et al., 2005). Such interactive design provides a better possibility to couple perception and action