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Risk analysis of pedestrians' road-crossing decisions: Effects of age, time gap, time of day, and vehicle speed

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ABSTRACT

The current study investigated the effects of age, time gap, time of day, and speed of approaching vehicle on the decision of pedestrians to cross a road. Sixteen young and sixteen elderly participants were asked to watch pre-recorded videos in which a vehicle was approaching from the left and then decide the last moment at which they could safely cross. Data on pedestrians' walking speed, road-crossing decision performance, subjective confidence ratings and walking strategies, as well as responses given in post-experiment interviews were collected as dependent variables. A logistic regression model was constructed to analyse the risk of above mentioned variables yielding the odds that the road would be crossed safely. This study found that pedestrians' decisions on whether or not they would cross the road safely were made based on the distance between them and the oncoming vehicle; and thus the faster the vehicular approach, the higher the risk. Young pedestrians demonstrated a higher safe road-crossing ratio than their elderly counterparts. Elderly pedestrians might not have taken their decline in walking ability into consideration when they made the same road-crossing decisions as young pedestrians, resulting in a relatively higher risk of road crossing. In addition, the most significant determinant of risk was the time gap. The time gap, which is affected by the distance from the oncoming vehicle and its speed, could be easily misjudged.

1. Introduction

"The streets are like a tiger's mouth" is an old Chinese saying that aptly and vividly describes the dangers faced by pedestrians crossing the streets today. In total, 4092 pedestrians were killed and an estimated 59,000 people were injured in traffic accidents in the United States in 2009 alone. On average, a pedestrian was killed every 2 h and injured every 9 min in traffic accidents there (Traffic Safety Facts, 2009).

Understanding pedestrians' road-crossing decisions is an important traffic safety issue, especially for those countries, where populations are rapidly aging. Causes of pedestrians' traffic are many. In the United States, most fatal accidents occur at night (Traffic Safety Facts, 2009), with 24.8% of the fatalities occurring 6:00–9:00 pm and 22.4% from 9:00 pm to midnight. There accidents resulting in casualties are also concentrated at the time periods 6:00–9:00 pm (24.6%) and 3:00–6:00 pm (23.3%) (Traffic Safety Facts, 2009). In Taiwan, the highest number of accidents involving causalities, fatalities at the scene, or the fatalities within 24 h occur between 4:00 pm and 6:00 pm (14.28%) followed by 6:00–8:00 pm (12.44%) (Taiwan Ministry of the Interior, 2011).

Although the overall occurrence rate of traffic accidents involving elderly people aged above 65 is not the highest, probably because they have become less mobile and less active, the proportion of fatal accidents is still high. Elderly pedestrians of the United Sates over 65 years old made up 19% of all pedestrian fatalities and 8% of all pedestrian injuries in 2009. The fatality rate for older pedestrians aged above 65 was 1.96 out of 100,000 people, higher than the rates of all the other age groups (Traffic Safety Facts, 2009). Similar trends have been found in other countries (see International Road Traffic and Accident Database (IRTAD) Annual Report (2010) for details), showing that as society ages, the safety of zelderly pedestrians becomes increasing important and worthy of investigation.

Age has an obvious impact on walking speed, as many studies have reported that the walking speed of elderly people aged above 65 is significantly slower than that of young people (Oxley et al., 1997, 2005; Guerrier et al., 1998; Tarawneh, 2001). In addition to walking more slowly, elderly pedestrians take more time to decide whether or not they should cross the road (Lobjois and Cavallo, 2009; Holland and Hill, 2010). Oxley et al. (2005) found that elderly people above the age of 75 took the longest time to decide (1.45 s), followed by people aged 60–69 (0.88 s). The group with the shortest decision-making time on road crossing was the 30-

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to 45-year-old group (0.66 s). Moreover, with regard to subjective judgment, compared with young (aged 20–40) and middle-aged people (aged 41–60), the elderly (aged > 60) generally believed that crossing a road required a relatively longer perception time (Guerrier et al., 1998).

When a car approaches, the time span within which a pedestrian would decide to cross a road should ideally include the time gap, the distance between the approaching car and the pedestrian, the speed of the car, and the personal mobility of the pedestrian. However, empirical research has indicated that a pedestrian's judgment relies mainly on the distance between the approaching car and the pedestrian himself or herself (Oxley et al., 2005, 2006). Connelly et al. (1998), for example, reported that 63% of the pedestrians based their road-crossing decision on the distance between the approaching car and themselves.

On the contrary, only 10% of the pedestrians make their decisions based on speed of the approaching car. In particular, elderly people are more likely to make their road-crossing decision purely on the basis of distance (Lobjois and Cavallo, 2007). Under the same time gap, a fast-approaching vehicle is felt by elderly pedestrians to be at a greater distance than a slow-approaching vehicle. This incorrect perception is attributed to the fact that elderly pedestrians take only the distance gap into consideration when crossing the road. Subsequently, they make poorer decisions, based on the assumption that it is safer to cross the road when the distance gap is large regardless of whether the approaching vehicle is moving at a higher speed.

Some studies have applied the "safety margin" concept to judging whether a pedestrian can cross a road safely. The smaller the safety margin, the greater the risk. The safety margin of blind and inebriated people is smaller than it is for ordinary people (Guth et al., 2005; Oxley et al., 1997). In general, the safety margin becomes smaller with increasing road-crossing time, which includes both decision-making time and walking time. The reduction of safety margin for the elderly is more obvious than that for the young (Oxley et al. 2005, 2006). In particular, when the speed of an oncoming car is high, it was more likely for the elderly to make unsafe decisions than when the oncoming car was slow (Lobjois and Cavallo, 2007, 2009; Oxley et al., 2005).

In this study, we conducted simulated pedestrian road-crossing experiments to explore whether pedestrian road-crossing behaviors and decision-making varied across different age groups (elderly vs. young) and at different times (midday vs. dusk) when oncoming cars approached at different speeds creating different car-pedestrian time gaps. Using logistic regression, a pedestrian road-crossing risk evaluation model was constructed to analyse these factors.

2. Methods

2.1. Participants

The participants included 16 young people (9 men and 7 women) aged 24–29 years (mean age = 26.06; s.d. = 1.34) with normal or corrected vision of over 0.8 (Snellen fraction = 16/20) and 16 elderly people (6 men and 10 women) aged 61–79 years (mean age = 71.19; s.d. = 4.71) with normal or corrected vision of over 0.52 (Snellen fraction = 10.4/20). The visual acuities of the participants were examined using a CHART PROJECTOR CP-500 (see http://shin-nippon.jp/ for details). None of the participants had muscle or bone injuries and all passed the Ishihara Color Blindness Test. All were found to hear well based on their ability to easily engage in normal conversation with the experimenter in the laboratory. All subjects participated in the experiment voluntarily, and were given a stipend of US$30 upon completion of the trial.

2.2. Apparatus

(1) About 32-in. LCD TV (Philips 32PF1700T/96 with aspect ratio of 16:9; resolution of 1366 × 768; brightness of 500 cd/m^2; contrast of 1200:1; response time of 8 ms): The experimental road scenes were displayed on three identical 32-in. LCD TV screens placed to the left, in front of, and to the right of the participant, creating an intersection scene where road crossing scenario would be simulated.
(2) SONY HDD DCR SR85 digital camera: Three digital cameras, which were used to film real road scenes, were placed at the side of the intersection and adjusted stand at the average height of the bridge of the nose of a Taiwanese (anthropometric data obtained by Wang et al. (2002)). The context of the scenario was an intersection of a road with two-way traffic. The road had two 3.5-m-wide lanes, one for each direction. The intersection did not have traffic signals, but it was surrounded by a few buildings, street signs, lamps, and trees (see Fig. 1).
(3) Ulead VideoStudioV.10 and the Flash: Ulead software was used to post-produce and edit the film and Flash software was used to program a time gap timer starting each time a car appeared on the scene.
(4) ASUS PK1100 lap-top computer: The lap-top computer was used to collect the data and control the experimental videos. The participants were instructed to make their road-crossing decision by pressing the space bar on the keyboard.

2.3. Experimental designs

Being aware of the possible limitations of studying the small number of 16 participants, the within-subjects experiments were designed for the three different variables (i.e., time of day, time gap, and approaching vehicle speed) to secure this study's internal validity. This experiment was a 2 (age: elderly vs. young, between-subjects) × 2 (time of day: midday vs. dusk, within-subjects) × 3 (time gap: 3 s vs. 5 s vs. 7 s, within-subjects) × 3 (approaching vehicle speed: 40 km/h vs. 60 km/h vs. 80 km/h, within-subjects) mixed factorial design. In addition, each of the 18 conditions (2 × 3 × 3) was repeated four times; and therefore, a total of 72 trials were performed by each participant. The amount of data we collected made possible further robust statistical analyses. To avoid the effect of repeated order, the trials were randomly sequenced.

The pre-recorded road scenes at midday and at dusk were filmed in February. The midday scenes were recorded between 11:30 am and 12:30 pm. Because available light changed quickly at dusk in February, the dusk scenes were filmed between 5:50 pm and 6:10 pm, assuming the least light change during this time period.

3. Data collection

3.1. Objective data

(1) Walking time (s). Following Oxley et al. (2005), the walking time for each age group was calculated by averaging the participants' normal and fast walking time for a distance of 10 m.
(2) Decision time (s). The decision time was began when the road scene appeared on the TV to when the participants pressed the keyboard space bar to indicate the last moment they believed they could cross the road safely.
(3) Remaining time (s). Remaining time was the time difference between the time gap and the decision time.