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Display of required crossing speed improves pedestrian judgment of crossing possibility at clearance phase

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ABSTRACT

At crosswalks with countdown timers, pedestrians arriving at the clearance phase tend to start crossing when the remaining time is too short. It is unclear whether this phenomenon is due to errors in judging the possibility to finish crossing before signal lights turning red. This study evaluated and compared pedestrians' accuracy in judgment of crossing possibility based on two cues: the amount of remaining time, and the minimum required speed to finish crossing within clearance phase (*road width / remaining time*). The results showed that pedestrians overestimated crossing possibility when they made judgments based on remaining time, especially when the road was narrow. By contrast, the display of required speed resulted in higher overall accuracy and lower false alarm rate, due to higher sensitivity to different crossing possibilities and more conservative set of response criterion. This advantage is consistent across different road widths. These findings suggest that pedestrians' risky decisions based on the countdown timers are partly induced by overestimation of crossing possibilities. The advantages of required-speed display over traditional countdown timers indicate a strong possibility to improve pedestrian judgments by information design.

1. Introduction

1.1. Pedestrian choices at various remaining times

Pedestrian lights usually operate in the sequence of green phase, clearance phase, and red phase. During the clearance phase, a green man or "Don't Walk" message flashes, and a countdown timer displays the remaining time before the red-light onset. In clearance phase, pedestrians that are already on the crosswalk need to hurry up, and those haven't started should not enter the crosswalk. However, pedestrians who arrived in the clearance phase have been observed to make cross-or-wait decisions based on the remaining time, rather than wait at the roadside as required. Lee and Lam (2008) found that most pedestrians would cross the street immediately if they arrived within the first seven seconds of the flashing green phase. If pedestrians arrived within the final six seconds of the flashing green phase, less than 50% made the decision to cross (Lee and Lam, 2008). Similarly, in an observation in Singapore, Koh et al. (2014) found that if the remaining time before the red phase was longer than five seconds, all of the road users (pedestrians and cyclists) crossed. Within the last five seconds of the flashing green phase, 66% of them still chose to cross. More direct evidence shows that when the road width is constant, pedestrians are less likely to cross at shorter remaining time (Zhuang et al., 2018).

Crossing based on remaining time is relatively safe so long as pedestrians can finish crossing within the remaining duration. However, researchers have found that pedestrians tended to cross when the remaining time was too short, indicated by incomplete crossings after the clearance phase ended. Koh et al., (2014) found that all of the road users (including pedestrians and cyclists) failed to finish crossing before red-light onset if they began crossing in the last five seconds of flashing green phase. Even if they started crossing earlier at flashing green phase, 45% of them had incomplete crossings. Since pedestrians have lower speeds than cyclists, in a recent observation of pedestrians who started crossing on flashing green phase, the percentage of incomplete crossings increased to 79% (Zhuang et al., 2018). As a result, although more than half of the pedestrians ran to cross at the clearance phase, they still crossed 41% of the road width during red phase. A direct consequence of crossing the road during red phase is higher probability to encounter intersecting vehicles, thus increases risks to both pedestrians and drivers.

Why do pedestrians decide to cross when the remaining time is too short? While explaining the increased number of "late starters" after installation of countdown timers, Paschalidis et al. (2016) proposed a possible reason: countdown timers led to pedestrians' overestimation of

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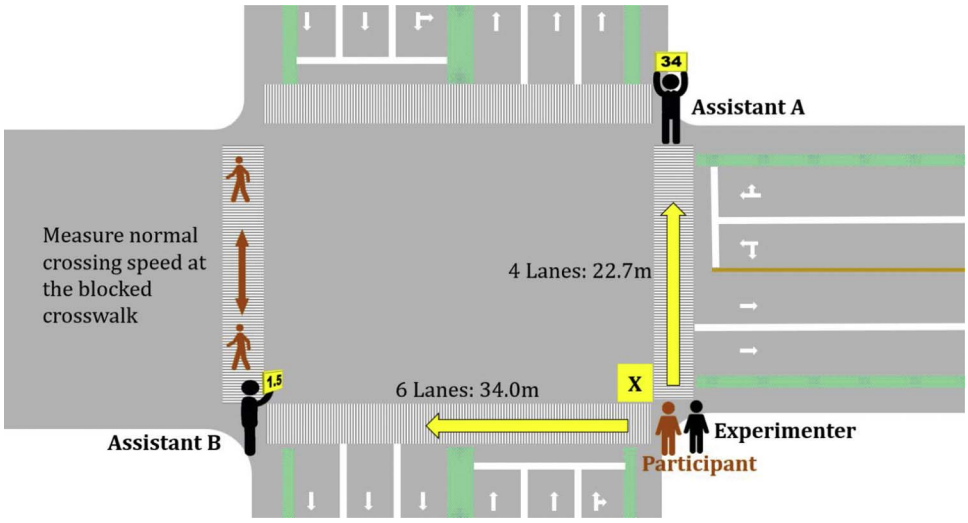

Fig. 1. Illustration of the intersection and experimental setting.

their ability to cross the road in time. That is, the remaining time may lead pedestrians to overestimate the crossing possibility. Yet, this assumption was not, and has not been tested. Thus, one aim of the study is to evaluate the pedestrians' accuracy in judging crossing possibility.

1.2. Information processing in judging crossing possibility

When pedestrians judge crossing possibility based on remaining time, they need to estimate their crossing time and compare it with the remaining time. However, estimating crossing time is itself a challenging task. In an interview (Wanty and Wilkie, 2010), pedestrian verbally reported the time needed to cross an intersection diagonally, and 80% of them underestimated the required time, despite having just crossed the intersection before the interviews were conducted. In another approach, pedestrians estimated crossing time by mentally simulating the process of crossing a road. While researchers reported inconsistent findings on how the accuracy changed with pedestrian age and mobility, they all reported inaccurate (mostly underestimate) estimations in some groups (Dommes et al., 2013; Holland and Hill, 2010; Naveteur et al., 2013; Zivotofsky et al., 2012, Zito et al., 2015). Theoretically, pedestrians can also calculate crossing time from the road width and their own speed. Yet, estimation of road width is not necessarily accurate (Gilinsky, 1951), and calculation is also not a strength of human beings. Therefore, the difficulty in estimating crossing time seem to forecast inaccurate judgments of crossing possibility.

Is it possible to judge crossing possibility without the estimation of crossing time? Yes, if we do not rely on the remaining time to make judgments. Basically, the remaining time is a cue of crossing difficulty indicating how hard it is to cross the street at the moment. Crossing difficulty can be framed as remaining time, or the required speed to cross (Road width/ remaining time). Although the two cues represent the same level of crossing difficulty, the mental processes in judging crossing possibility is different. For example, judgments based on required speed only require a simple comparison between the required speed and their own crossing speed. It relieves pedestrians from estimating crossing time, which may involve error-prone processes like estimating road width and calculating crossing time. Therefore, we expect the "required speed" to be more effective in assisting pedestrian judgment of crossing possibility than remaining time regardless of road widths. As "required speed" is a less intuitive and familiar concept than remaining time, its performance was tested in this study.

1.3. Objectives and hypotheses

The final goal of the study is to explain pedestrians' risky decision-making at the clearance phase and improve pedestrian judgment with intelligent signal design. In addition to the evaluation of pedestrians' accuracy in judging crossing possibility under traditional "remaining time" cue, it also proposed and tested the "required speed" as an alternative cue of crossing difficulty.

The hypotheses for this study were as follows: (1). Pedestrians overestimate crossing possibility when making judgements based on remaining time. (2). The "required speed" leads to more accurate judgments of crossing possibility than "remaining time". (3). The advantage of "required speed" over "remaining time" is independent of road widths.

2. Methods

2.1. Experimental design

The independent variables are cue of crossing difficulty (*remaining time vs. required speed*) and road width (*4 lanes vs. 6 lanes*). The combination of them produces four experimental conditions: display remaining time or required speed at a road that has four or six lanes. Each participant made equal number of judgements in the four conditions. The dependent variable is pedestrian judgement of crossing possibility measured by subjective rating.

2.2. Participants

A total of 44 pedestrians (18 male, 26 female) participated in the experiment. All participants received compensation. They were enrolled in colleges near the experimental site, and had an average age of 23.6 (3.2).

2.3. Experimental setting

The experiment was conducted in the field to simulate true-to-life road-crossing experiences. The site located at an intersection between Kehui South Rd. and Tianchen West Rd. in Beijing, China (see Fig. 1 for a graphic representation). It possessed several characteristics ideal for the experiment, including:

- The countdown timers installed on the pedestrian lights is not working. Therefore, we can present the remaining time or required speed to participants without conflicting with the numbers