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Pedestrian gestures increase driver yielding at uncontrolled mid-block road crossings

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ABSTRACT

To protect pedestrians, many countries give them priority at uncontrolled mid-block crosswalks or pedestrian crossings. However, the actual driver yielding rate is not always satisfactory (only 3.5% in this study). To increase the yielding rate, this study proposed eleven pedestrian gestures to inform drivers of their intent to cross. The gestures were evaluated based on the process of human interaction with environment. Four gestures were selected as candidates to test in field experiments based on scores for visibility, clarity, familiarity and courtesy (see illustration in Fig. 2): (1) right elbow bent with hands erect and palm facing left (R-bent-erect), (2) left elbow bent with hands level and palm facing left (L-bent-level), (3) left arm extended straight to left side with palm erect facing left (L-straight-erect), and (4) a 'T' gesture for "Time-out". In the experiment, confederate pedestrians waiting at the roadside displayed the gestures (baseline: no gesture) to 420 vehicles at 5 sites in Beijing, China. When pedestrians used the L-bent-level gesture, the vehicle yielding rate more than tripled of that in the baseline condition. The L-bent-level gesture also resulted in a significant decrease in driving with unchanged speed (63.5–38.8%) and had no significant side effects in terms of drivers' horn use or lane changing. The effects of such gestures in other contexts such as when pedestrians are in the crosswalk and when they are interacting with turning vehicles are discussed, together with the applications in training vulnerable pedestrian groups (children or elderly) and facilitating pedestrian detection by drivers.

1. Introduction

1.1. Road rights at unsignalized crosswalks

Pedestrian safety worldwide is threatened: number of pedestrian deaths and their proportion among all road fatalities in low, middle and high income countries are 227,835 (45%), 161,501 (29%) and 22,500 (18%) (Naci et al., 2009). To protect pedestrians, engineering approaches (e.g. traffic lights), together with educational approaches have been stressed (Hebert Martinez and Porter, 2004). However, for efficiency or cost reasons, traffic lights are usually not installed in places that do not meet certain warrants on pedestrian or vehicle volume, etc. (General Administration of Quality Supervision, 2006). To compensate for the potential risk resulted from limited protection facilities, traffic laws in many countries require drivers to yield to pedestrians at these sites (e.g. Hakkert et al., 2002, China State Council, 2005). However, the marked crosswalks have still been found to be dangerous, even when compared with unmarked ones (Koepsell et al., 2002). In fact, Zegeer et al.'s (2002) comparison of 2000 marked and unmarked crosswalks in the USA showed that on multi-lane roads with vehicle volume higher than 12,000 per day, marked crosswalks could be riskier than their unmarked counterparts. Although this has been claimed to be the result of pedestrians' decreased carefulness in crossing (Leden et al., 2006), drivers' not obeying the yielding regulation contributes much to the problem. In Ibrahim et al.'s (2005) observation in Malaysia, most pedestrians had difficulty in crossing because the drivers did not yield to them. Várhelyi (1998) also observed that 95% drivers in Sweden did not give way when pedestrians were present. It is therefore important to explore which approaches may help to increase driver yielding rates.

1.2. Strategies to promote yielding

According to Lewin's equation (Sansone et al., 2004), human behaviors are determined both by the person and the environment:

$$\text{Behavior} = f(\text{person},\ \text{environment})$$

In the context of driver yielding behavior, the "person" element refers to top-down factors like drivers' attitude toward pedestrians, their understanding of the right of way, or their driving skills.

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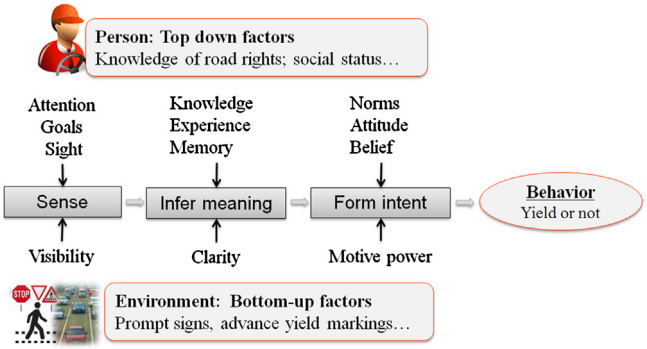

Fig. 1. Drivers' interaction with the environment (elaborating Lewin's equation in the driver yielding context based on the SIFT model).

Such personal factors have been found to influence drivers' yielding rate in natural observations. Piff et al.'s (2012) observations in San Francisco found that drivers with higher social status are less willing to yield to pedestrians. Ibrahim et al. (2005) also explained that drivers' observed failure to stop was because they either did not care about pedestrians or because of their misunderstanding of the rules of the road. Meanwhile, environmental factors are bottom-up determinants of behaviors. Researchers have identified several such factors influencing yielding behavior including speed limits (Turner et al., 2007), pedestrian's distance from the kerb (Himanen and Kulmala, 1988), pedestrian's clothes (Harrell, 1993) and the number of pedestrians waiting to cross (Sun et al., 2003).

Theoretically, both types of factor help to understand driver yielding behavior. When it comes to actively manipulate factors to get a higher yielding rate, however, personal factors like social status are impossible or much more difficult to control than environmental factors. Therefore, previous studies aiming to increase driver compliance have resorted to changing the latter, on the basis that environmental information can make a difference when processed in the human mind properly. The SIFT model (Straker, 2008) states that an individual's inner process of interacting with the outer world has four phases: sensing, inferring meaning, formulating intent and translating into actions. Based on this model, the "person" element in Lewin's equation (Sansone et al., 2004) in the context of driver yielding can be elaborated as in Fig. 1. First, drivers sense the surrounding environment, mostly via vision. For instance, drivers may see a line of white triangular markings on the road ahead of a crossing. Second, drivers interpret what the scene means. In the above example, they may remember that the marking is a reminder of crosswalks ahead, and they need to yield to pedestrians. Third, considering that not yielding is against traffic regulations, they form a yielding intention. Finally, the driver translates the intention into action: braking. This process also stands when applied to explain drivers' responses to other treatments such as prompt signs that remind with text "yield to pedestrians" (Van Houten and Malenfant, 1992; Huybers et al., 2004; Benekohal et al., 2007), pedestrian activated flashing beacons (Schroeder, 2008) and responsive warning lights that flash when pedestrians are detected (Hakkert et al., 2002).

Emphasizing mental activities, the SIFT model focuses on the personal element (Straker, 2008). In Figure 1, rrequirements for "environment" elements corresponding to the first three phases have also been added. "Visibility" refers to how easy a treatment can be identified from surroundings. "Clarity" means that the intended meaning of a treatment should not be misinterpreted, and "Motive power" requires that a treatment has to connect with a motivator that can push the driver toward a desired action. In other words, a treatment should have high visibility to facilitate the sensing phase, as well as high clarity to avoid misinterpretation, and a strong connection with motivators to encourage intent formation. In fact, in traffic sign design and evaluation, understandability (i.e. clarity) and conspicuity (i.e. visibility) have been considered by experts to be the most important two principles (Dewar, 1988).

Considering the three criteria, previous mainstream treatments can be assessed as in Table 1 (for the moment, please ignore the grayed columns). All the treatments have medium to high visibility, and can convey the meaning clearly after training. Among them, prompt signs can stimulate different motivations, depending on the text on the sign. Most of them can remind drivers of the law (Van Houten and Malenfant, 1992; Huybers et al., 2004; Benekohal et al., 2007), while others may encourage yielding via social approval (Nasar, 2003). Advance yield markings ahead of crosswalks can also increase yielding by informing drivers of approaching crossings nearby (Huybers et al., 2004). In addition to these static approaches, flashing beacons and responsive lights can dynamically show the position of the crosswalk, thus increased visibility and law awareness.

Although the above treatments have been successful in terms of effectiveness, hidden dimensions may undermine them (see the last 3 columns of Table 1). First, all the facilities need to be built by a third party (e.g. the transport ministry) beyond the drivers and pedestrians who are main parties involved in the context. Another important attribute of the treatments is whether they are responsive – i.e., can be activated by the user. This is important because responsive treatments like pedestrian activated flashing beacons (Schroeder, 2008) and responsive lights only operate when needed, thus they are less disturbing to drivers when no pedestrians are around. Compared with devices that operate regardless of pedestrians' existence, the responsiveness attribute of a signal also enforces the connection between the yielding behavior and the signal, thus facilitating drivers' future responses to such warnings. Unfortunately, responsive facilities are currently very expensive to install.

This study therefore aims to explore an alternative approach to traditional driver warnings. Besides the three basic requirements (visibility, clarity, motive power), the method must be able to work without any need to install equipment by a third party and should also be responsive and cheap to apply. A promising candidate that satisfies all the requirements is to allow pedestrians, in a sense, to "step out, *tell* drivers their crossing intention, and *ask* drivers to yield". Of course, the road context is often very noisy and complex, thus potentially effective ways to "tell" and "ask" in this context must be non-verbal. Some possible strategies can be gleaned from the way drivers communicate with each other using blinkers, headlamps, horn-use, car movements and gestures (Renge, 2000).

Table 1
Comparison of approaches aiming to increase driver yielding rate.

Treatments	Visibility	Clarity	Motive power	Initiator	Cost	Responsive
Prompt signs	Medium/high	High	Law; social approval	Govt.	Medium	No
Yield markings	High	High	Law	Govt.	Medium	No
Flashing beacons	High	High	Law	Govt.	High	No/yes
Responsive lights	High	High	Law	Govt.	High	Yes
Pedestrian gestures	High	Varying	Social influence	Pedestrians	Low	Yes