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The effects of speed and orientation on recognition judgments of retro-reflectively clothed pedestrians at night

Jasmine Mian [a], Jeff K. Caird [b,*]

[a] Department of Psychology, University of Calgary, Calgary, Alberta, Canada
[b] Departments of Psychology and Community Health Sciences, University of Calgary, Calgary, Alberta, Canada

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ABSTRACT

Background: Insufficient conspicuity of pedestrians at night is a fundamental contributor to injuries and fatalities. Retro-reflective clothing that enhances biological motion perception increases detection and identification of pedestrians at night.
Objective: To determine how speed of motion and body orientation affect observers' judgments about the recognisability of pedestrians with bio-motion retro-reflectors.
Method: The stimuli used in this study were videos of a retro-reflectively outfitted pedestrian on a treadmill filmed in a nighttime road environment. Forty undergraduate students observed videos of pedestrians who were standing, walking or running with the side or back of their body oriented towards the observer. Participants decided which of the two pedestrians was most recognizable as a person. Judgments were made in high beams and low beams at 80 m, 160 m and 240 m.
Results: For both orientations, observers judged that walking and running pedestrians were more recognizable than standing pedestrians. Observers also judged that running pedestrians were more recognizable than walkers. The effect of pedestrian orientation was dependent on speed. When standing, pedestrians in the back orientation were selected more often, but when running, side-oriented pedestrians were selected as the most recognizable.
Conclusions: Speed of motion and body orientation affect observers' judgments of the recognisability of pedestrians wearing retro-reflectors at night. Observers choose moving pedestrians (i.e., those who are walking or running) in biomo retro-reflectors as more recognizable as people than pedestrians who stand. The results fill several gaps in the literature and have practical and future research implications, which are discussed.

1. Background

Pedestrians are considered vulnerable road users and account for about one-fifth of the people killed on the roads each year (WHO, 2013). In Canada (Transport Canada, 2013), pedestrians accounted for 15.6% of road user fatalities. Sixty percent of the pedestrian fatalities that occurred in Canada between 2004 and 2008 occurred at night or in reduced lighting (Transport Canada, 2011). Pedestrians are most at risk during the first hour of darkness and twilight. This is likely the result of pedestrian volumes remaining high around sunset despite a sharp reduction in visibility (Griswold, Fishbain, Washington,

* Corresponding author at: Department of Psychology, University of Calgary, 2500 University Dr. N.W., Calgary, Alberta T2N 1N4, Canada.
E-mail addresses: jmian@ucalgary.ca (J. Mian), jkcaird@ucalgary.ca (J.K. Caird).

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& Ragland, 2011). To understand the contribution of ambient light in pedestrian fatalities, researchers have examined fatality rates before and after daylight saving. Sullivan and Flannagan (2002) examined pedestrian fatalities in the weeks before and after the transition over an 11-year period. They found that the number of fatal pedestrian crashes was between 3 and 7 times greater in dark conditions than at the same time of day in light conditions. The effect was present for pedestrian fatalities occurring at intersections and was most pronounced for rural roads with no fixed overhead lighting. Dark conditions reduce pedestrian conspicuity, making it harder for pedestrians to 'stand out' from their environment and more difficult for drivers to see.

1.1. Retro-reflective clothing and biological motion perception

The use of retro-reflective clothing is an effective way for pedestrians to make themselves more conspicuous to drivers. Relative to other kinds of interventions, retro-reflective material on clothing is a simple and cost-effective way to alert drivers to pedestrian presence and behaviour. The material is often found on active wear (e.g., running shoes, jackets, backpacks) and safety apparel (e.g., safety vests, coveralls, hard hats). Unlike other light reflecting surfaces, retro-reflective material is uniquely manufactured to return light back to the source, which helps pedestrians 'stand out' in reduced lighting (Olson, Dewar, & Farber, 2010). As a result, the use and configuration of retro-reflectors has been a major variable of interest in the pedestrian conspicuity literature.

Identifying the ideal retro-reflector configuration is important because different configurations have different consequences for pedestrian identification. Given that there are many retro-reflective objects on the road (e.g., signage, lane markings, delineators), the mere presence of retro-reflectors on a pedestrian does not signal to the driver that a person is near. This has been most clearly shown in work examining the identification of pedestrians in traditional retro-reflective safety vests. Balk, Tyrrell, Brooks, and Carpenter (2008) found that identification distances for pedestrian in vests were no better than when pedestrians wore no retro-reflective markings at all. Furthermore, Wood, Tyrrell, and Carberry (2005) found that drivers' ability to identify pedestrians while wearing all white was actually better than it was for pedestrians in retro-reflective vests. These results suggest that both contrast and highlighting the human figure are important aspects of being identified at night. For retro-reflectors to aid pedestrian identification, they need to be configured in a way that allows pedestrian identification to occur simultaneously with first detection (Owens, Antonoff, & Francis, 1994). If drivers detect something in their visual field and immediately identify it, they have more time to respond appropriately than if identification takes longer. Retro-reflective vests do little for identification of pedestrians because material is confined to the torso. As a result, vests are poor at conveying important cues such as human motion and shape. Moving some of the retro-reflective material from the torso to the extremities has shown to have a positive impact on the distance at which drivers identify pedestrians (Wood et al., 2005).

Researchers have incorporated aspects of 'Biological Motion' or 'biomo' into their studies of retro-reflective pedestrian clothing. Biological motion is a perceptual phenomenon that was first identified by Gunnar Johansson. By attaching small light bulbs to the movable joints of a person wearing all black, Johansson (1973) developed a method for studying human motion that was not affected by other distracting variables such as hair, clothing, size, skin colour, etc. When he presented these moving displays to participants, they recognized the stimuli as humans even with exposure times as short as 100–200 ms (Johansson, 1975). Biomo retro-reflectors are an application or translation of Johansson's basic research. The movable joints of a pedestrian's body (e.g., shoulders, elbows, wrists, hips, knees and ankles) are highlighted with retro-reflective material (e.g., see Fig. 1 below). Unlike safety vests, biomo retro-reflectors highlight both human motion and body shape, which allows pedestrian identification and detection to occur almost simultaneously (Owens et al., 1994).

Field studies have investigated different biomo retro-reflector configurations and found that they significantly improved pedestrian identification compared to configurations that confine retro-reflective material to the torso (Balk, Graving, Chanko, & Tyrrell, 2007; Balk et al., 2008; Blomberg, Hale, & Preusser, 1986; Luoma & Penttinen, 1998; Luoma, Schumann, & Traube, 1996; Owens, Wood, & Owens, 2007; Sayer & Mefford, 2004; Tyrrell et al., 2009; Wood, Marszalek, Lacherez, & Tyrrell, 2014; Wood et al., 2005, 2012). This pattern of results is known as the 'biomo advantage'. Compared

Fig. 1. Biological motion configuration of pedestrian model depicted in the back orientation (left) and side orientation (right).