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Pedestrians' estimates of their own nighttime conspicuity are unaffected by severe reductions in headlight illumination

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ABSTRACT

Introduction: At night pedestrians tend to overestimate their conspicuity to oncoming drivers, but little is known about factors affecting pedestrians' conspicuity estimates. This study examines how headlamp intensity and pedestrians' clothing influence judgments of their own conspicuity. *Method:* Forty-eight undergraduate students estimated their own conspicuity on an unilluminated closed road by walking in front of a stationary vehicle to the point at which they judged that they were just recognizable to the driver. Unknown to the participants, high beam intensity was manipulated between subjects by placing neutral density filters on the headlamps. *Results:* Estimated conspicuity distances did not significantly vary with changes in headlamp intensity even when only 3% of the illumination from the headlamps was present. *Practical applications:* These findings underscore the need to educate pedestrians about the visual challenges that drivers face at night and the need to minimize pedestrians' exposure to traffic flow at night.

1. Introduction

In the United States in the year 2010, more than 4,200 pedestrians were killed by traffic collisions and about 70% of these fatalities occurred at night (NHTSA, 2012). At a global level, Rumar (2001) estimated that 200,000 pedestrians are killed at night each year. Late detection of pedestrians at night is often stated as a key causal factor in such crashes (e.g., Rumar, 1990). Indeed, in their analysis of five major transportation safety issues facing the United States, Sivak et al. (2007) cited enhancing the safety of night driving – particularly reducing nighttime crashes involving pedestrians – as a “major opportunity” to advance road safety.

Researchers have repeatedly demonstrated that drivers' ability to see and respond to pedestrians at night decreases significantly when pedestrians wear clothing that does not contrast with the visual background and when they are illuminated by an approaching vehicle's low beams (Allen, Hazlett, Tacker, & Graham, 1970; Balk, Tyrrell, Brooks, & Carpenter, 2008; Shinar, 1984; Wood, Tyrrell, & Carberry, 2005). For example, drivers in one study responded to the presence of a pedestrian wearing black clothing at a mean distance of only 5.6 m when relying on low beam headlights. These same drivers responded to a pedestrian in the same location at a mean distance of 105 m when the driver used high beams and the pedestrian wore white clothing (Wood et al., 2005).

The use of high beam headlights has also been shown to increase the distance at which drivers are able to respond to pedestrians. Wood et al. (2005) reported that drivers responded to the presence of a pedestrian at an average distance of just under 60 m when low beams were used, yet, when high beam illumination was used in the same conditions the mean response distance increased to over 90 m. Despite the fact that high beams provide substantial benefits to drivers, drivers underutilize their high beam headlights. Both Mefford, Flannagan, and Bogard (2006) and Buonarosa, Sayer, and Flannagan (2008) collected data regarding the usage of low and high beam headlights from participants who drove instrumented vehicles. Participants in both studies used their low beam headlights far more often than their high beam headlights. Even when in conditions that were ideal for high beam usage (i.e., no opposing or leading vehicles present), large numbers of drivers failed to use their high beams.

While the reduced visibility levels that are associated with reduced ambient illumination are considered largely responsible for the fact that crashes resulting in pedestrian fatalities occur three to four times more often at night than during the day (Plainis & Murray, 2002), drivers' overconfidence in their visual abilities at night is also an important consideration (Leibowitz & Owens, 1977). While ambient visual functions facilitate drivers' ability to maintain steering performance even under conditions of dramatically reduced luminance, the focal visual functions that facilitate our ability to recognize and respond to infrequent, unexpected, and low-contrast hazards (including pedestrians) are severely degraded under these conditions (Brooks, Tyrrell,

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& Frank, 2005; Owens & Tyrrell, 1999). Leibowitz and Owens (1977) hypothesized that this pattern of "selective degradation" of visual functions at night results in drivers underestimating the impact that reduced illumination has on their ability to see objects on or near roadways at night. The fact that some objects that have been engineered to have a high level of contrast (e.g., retroreflective signage, retroreflective lane delineators, vehicle marker lights) are easily seen at night may provide further support for drivers' mistaken belief that their low beam headlamps adequately compensate for any visual challenges that result from reduced ambient illumination (Leibowitz, Owens, & Tyrrell, 1998).

Compounding drivers' overconfidence at night is the possibility that pedestrians fail to appreciate the difficulty that drivers have in seeing them. Indeed, results of several studies indicate that pedestrians typically overestimate their own conspicuity to drivers at night. Ferguson and Geddes (1941), and Ferguson (1944), the first to quantify pedestrians' estimates of their own visibility, asked pedestrians to estimate their own visibility by walking both towards and away from the headlights of a stationary vehicle to the point at which they believed they were just visible to the driver. Ferguson concluded that participants overestimated their visibility "to a dangerous degree" with over 80% of estimates being longer than actual visibility distance. Several later studies supported this conclusion (Allen et al., 1970; Shinar, 1984; Tyrrell, Wood, & Carberry, 2004). Allen et al. (1970) found that more than 95% of their participants overestimated their own visibility and that the participants' estimates were up to three times greater than their actual visibility distances. Shinar (1984) also reported that pedestrians significantly overestimated their own visibility, with estimated visibility distances averaging 20% longer than actual visibility distances. The fact that pedestrians do not appear to understand their own visibility at night may lead them to engage in dangerous behaviors (e.g., crossing the street outside of a crosswalk or jogging on the shoulder of a road) that put them at risk for collisions with vehicles.

Tyrrell, Wood, and Carberry (2004) were the first to manipulate and measure the effect of clothing reflectance on pedestrians' estimates of their own conspicuity. Participants dressed in a variety of clothing conditions and walked in place on the side of a closed road. The participants watched a single vehicle approach and pressed a button when they were confident that the approaching driver could recognize that a pedestrian was present. Overall, the pedestrians overestimated the conspicuity distances by a factor of 1.8×, estimating that they would be recognized at a mean distance of 135 m whereas drivers responded to the pedestrian at a mean distance of only 77 m. Participants' overestimates were greatest for those conditions in which actual conspicuity was minimal (e.g., black clothing with no retroreflective treatments, low beam illumination), and they failed to appreciate the benefits of conspicuity treatments that are known (by researchers) to be effective.

Because pedestrians who overestimate their own conspicuity to approaching drivers are likely to behave in ways that increase their danger, the present study is a first attempt to determine what information pedestrians rely upon when judging their own conspicuity to approaching drivers at night. Specifically, this study was designed to determine whether pedestrians make use of illumination information when judging their own conspicuity at night. If we are walking towards an approaching vehicle at night one reasonable approach to evaluating our own conspicuity is to be mindful of the magnitude of illumination that reaches us. We could potentially combine this illumination information with information about the reflective characteristics of our own clothing thus yielding a rough estimate of our own luminance (as viewed from the perspective of the driver). Alternatively, a simpler heuristic would be to monitor the increasing headlamp illumination as the vehicle approaches and to judge that we become conspicuous to the driver at the moment that the illumination reaches a critical level. Of course yet another possibility is that pedestrians do not attend to illumination at all when judging their own conspicuity. To determine whether the amount of illumination from a facing vehicle's headlamps influences pedestrians' judgments, our participants walked in front of a stationary car at night to the point that they judged that they would be just recognizable to the driver of the vehicle. High beam intensity was manipulated by mounting neutral density filters on the headlamps. In order to make this manipulation less salient to the participants this variable was manipulated between subjects. Clothing configurations were manipulated within subjects.

2. Method

2.1. Participants

A total of 48 (24 females) people participated in this study, ranging from 18 to 33 years of age ($M = 19.85$, $SD = 2.27$). Participants were college students who received course credit in exchange for participation. All participants achieved a binocular acuity of 20/40 or better. None of the participants reported having any visual pathology other than corrected refractive errors. Participants reported a mean of 4.3 years of driving experience ($SD = 2.6$) and that, on average, 35% ($SD = 14$) of their driving time was completed at night.

2.2. Experimental design

This study utilized a 4 (headlight intensity) × 4 (clothing) × 2 (direction walked) mixed design. The four headlight intensities were: an unfiltered high beam and three filtered high beam intensities. Headlight intensity was manipulated between-subjects such that each participant was randomly assigned to one of four groups of twelve participants. High beam intensity was manipulated between-subjects in order to eliminate any demand characteristics or biases that might have arisen had the participants been aware that headlight intensity was being manipulated. The dependent variable was the recognition distance that was estimated by the participants.

2.3. Materials

Large neutral-density filters (GAM Products, Los Angeles, CA) reduced headlight intensity. These filters reduced the illumination by 0.6 (High), 0.9 (Medium), or 1.5 (Low) log units, or by 75%, 87%, and 97%, respectively. The filter material was attached to the outer glass surface of the headlamps of the test vehicle such that no light escaped the filter. The magnitude of the illumination from the headlights that reached the pedestrian's eyes appears in Fig. 1.

The four levels of the clothing condition (Street clothing, Black clothing, White clothing, and a retroreflective Vest) were manipulated within-subjects. In the Street condition participants wore the clothing that they were wearing when they arrived at the lab. In the Black

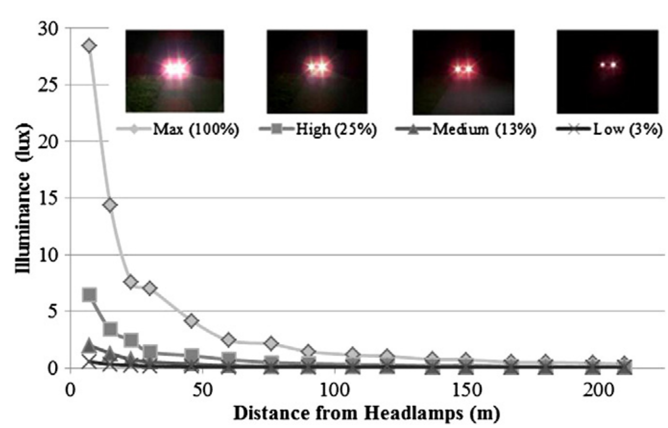

Fig. 1. Illumination from the high beam headlights of the test vehicle as a function of distance for each level of headlight intensity; percentage of high beam illumination transmitted is displayed in parentheses. Illumination was recorded at the eye heights of two experimenters (1.6 m and 1.9 m tall) and then averaged.