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Bicyclists overestimate their own night-time conspicuity and underestimate the benefits of retroreflective markers on the moveable joints

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ABSTRACT

Conspicuity limitations make bicycling at night dangerous. This experiment quantified bicyclists' estimates of the distance at which approaching drivers would first recognize them. Twenty five participants (including 13 bicyclists who rode at least once per week, and 12 who rode once per month or less) cycled in place on a closed-road circuit at night-time and indicated when they were confident that an approaching driver would first recognize that a bicyclist was present. Participants wore black clothing alone or together with a fluorescent bicycling vest, a fluorescent bicycling vest with additional retroreflective tape, or the fluorescent retroreflective vest plus ankle and knee reflectors in a modified 'biomotion' configuration. The bicycle had a light mounted on the handlebars which was either static, flashing or off. Participants judged that black clothing made them least visible, retroreflective strips on the legs in addition to a retroreflective vest made them most visible and that adding retroreflective materials to a fluorescent vest provides no conspicuity benefits. Flashing bicycle lights were associated with higher conspicuity than static lights. Additionally, occasional bicyclists judged themselves to be more visible than did frequent bicyclists. Overall, bicyclists overestimated their conspicuity compared to previously collected recognition distances and underestimated the conspicuity benefits of retroreflective markings on their ankles and knees. Participants mistakenly judged that a fluorescent vest that did not include retroreflective material would enhance their night-time conspicuity. These findings suggest that bicyclists have dangerous misconceptions concerning the magnitude of the night-time conspicuity problem and the potential value of conspicuity treatments.

1. Introduction

Bicyclists are among the most vulnerable of all road users, both in terms of their likelihood of being involved in a crash or near miss, and in the resulting severity of injuries resulting from crashes that involve bicyclists and vehicles (Kwan et al., 2002). Bicyclists have among the highest rates of self-reported near-miss crashes of any road users, significantly higher than that of motorists, and comparable to that of pedestrians, being as high as one incident every 5.59 miles (Joshi et al., 2001). In Australia, for example, bicyclists are over-represented in crash casualties, accounting for 14.6% of serious injuries in road based traffic crashes, yet bicyclist travel constitutes less than one percent of kilometers traveled by road (Henley and Harrison, 2009). The probability of a bicyclist being seriously injured following involvement in a crash was almost 27% in Australian data collected over a four year period (Watson and Cameron, 2006), and in a recent Australian survey 27% of regular bicyclists reported experiencing a bicycling injury over a one-year period (Heesch et al., 2011). Importantly, hospital records and police crash reports, on which most studies of bicycling injuries are based (Sikic et al., 2009), capture only a small, albeit more serious, fraction of total bicycling injuries and thus represent only the 'tip of the injury iceberg' (Heesch et al., 2011).

A number of studies have suggested that drivers do not detect bicyclists until it is too late to avoid a collision (Kwan and Mapstone, 2004; Räsänen and Summala, 1998). A significant proportion of crashes between vehicles and bicyclists have been identified as "looked-but-failed-to-see" crashes (Herslund and Jorgensen, 2003),

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where the driver of the vehicle fails to detect the bicyclist in time to prevent the crash, even though they report that they correctly looked in the direction of the bicyclist. Late detection of bicyclists suggests that their lack of conspicuity may be an important contributing factor to their crash involvement.

Research has shown that increasing the use of conspicuity aids may improve the ability of drivers to recognize bicyclists, as well as pedestrians, and that the ability of drivers to respond in time is greater when bicyclists or pedestrians make use of conspicuity aids (Kwan and Mapstone, 2004). Increased bicyclist conspicuity can also have important implications regarding the severity of injuries suffered in the event of a crash. After adjusting for potential confounds and level of exposure (i.e., kilometers ridden per year), the number of days off work following a bicycle crash injury was substantially lower among bicyclists who reported that they always wore high visibility clothing compared to those who reported that they never wore high visibility clothing (Thornley et al., 2008).

Increasing the visibility and conspicuity of bicyclists is especially important when considering low-light conditions. In his examination of fatal bicycle crashes in Victoria (Australia), Hoque (1990) noted that although a greater proportion of all fatal bicycle crashes were initiated by the bicyclists themselves, in 90% of night-time crashes the bicyclist was hit by an overtaking motorist, although this observation was based on a relatively small sample ($n = 28$). In addition, collisions between vehicles and bicyclists are more likely to result in a bicyclist fatality when they occur at night in locations without streetlights (Hoque, 1990). However, while bicyclists are generally well informed regarding the need to wear high visibility clothing and are aware of the benefits of visibility aids such as retroreflective vests and lights, they do not use such aids on a regular basis (Hagel et al., 2007).

In a survey of 1460 participants (622 drivers and 838 bicyclists), Wood et al. (2009) explored the beliefs and attitudes of bicyclists and drivers regarding bicyclist visibility and safety, and bicyclists' use of different clothing configurations. The data demonstrated that there was a mismatch between the bicyclists and drivers in terms of their perceptions of visibility, where the bicyclists estimated that they were visible at more than twice the distance estimated by a driver under the same circumstances. This provides preliminary evidence that, like pedestrians (Tyrrell et al., 2004b), bicyclists may overestimate their own conspicuity in low-light conditions. This tendency to overestimate conspicuity may form a potential barrier to the use of visibility aids and may result in less cautious bicyclist behavior. The survey also revealed that although bicyclists endorsed the use of high visibility clothing and aids, particularly in low-light conditions, relatively few bicyclists reported wearing high visibility clothing on a regular basis. Bicyclists as a group may thus underestimate the importance of attracting other road users' attention at night.

In our survey (Wood et al., 2009), we also found that cyclists overestimate the usefulness of some visibility aids – for example, fluorescent clothing – at night. Given that fluorescent materials act by converting ultraviolet light (present in sunlight) to longer visible wavelengths, leading to an overall increase in reflected visible light under daytime conditions (Joint Technical Committee SF/4, 1999), they are not particularly valuable as conspicuity aids at night-time. The majority of the cyclists and drivers in our survey considered fluorescent bicycle clothing to be more visible at night than white clothing. Therefore, road users may also be inadequately informed regarding the limitations of certain visibility aids. The failure of road users to understand such issues could be critical.

Bicyclists also rated wearing a retroreflective vest as being the most effective means of improving their visibility, over and above the use of retroreflective strips worn on the moveable joints. This is relevant because empirical research on the night-time conspicuity of pedestrians (Balk et al., 2008; Tyrrell et al., 2009; Wood et al., 2005) and more recently for bicyclists, (Wood et al., 2012), has repeatedly revealed the opposite: that retroreflective strips on the major moveable joints are highly effective in improving conspicuity, presumably due to humans' high perceptual sensitivity to distinctively human patterns of joint movement ("biological motion" or "biomotion") (Johansson, 1973). It is thought that retroreflective vests are less useful because they limit the placement of the retroreflective material to the torso, which presents less motion information to approaching drivers. Although the patterns of movement involved in bicycling are inherently different to those associated with being a pedestrian, highlighting a bicyclist's movements (by placing retroreflective markings on the bicyclist's ankles and knees) has recently been shown to be an effective and low-cost approach to enhancing bicyclist conspicuity (Wood et al., 2012). Our data suggest that interventions would be best targeted in the first instance to addressing bicyclists' use of visibility aids, which is less than optimal in this population, as well as re-educating both groups regarding conspicuity issues.

In the current study we evaluated the ability of bicyclists to judge their own visibility and to judge the benefits of a range of visibility aids at night. To determine the extent to which increased exposure to bicycling, and thus increased experience of the interactions of bicyclists with other vehicles, might impact on bicyclists' ability to judge their own conspicuity, we included both frequent and infrequent bicyclists in our sample. We compared the on-road data of estimated visibility distances collected here with data collected previously for a separate group of participants, where the actual distances at which drivers responded to bicyclists was determined (Wood et al., 2012).

2. Methods

Participants included 25 visually normal adults who were divided into two groups: one group consisted of 13 people who were frequent bicyclists in an Australian context (who cycled at least once a week – mean age 37.7 years, range 18–59), the other group consisted of 12 people who cycled only occasionally (once a month or less – mean age 34.5, range 17–56). The frequent bicyclists reported through questionnaire response that a mean of 23.3% of their bicycling occurred at night (range = 0–60%) while the infrequent bicyclists reported that only 2.9% of their bicycling (range = 0–20%) occurred at night. The volunteers were recruited via presentations by the research team, recruitment notices placed on university notice-boards and participation in previous studies. All participants were licensed drivers and passed the minimum Australian drivers' licensing criteria for binocular visual acuity of 6/12 (20/40) or better and wore the optical correction they normally wore while cycling or driving, if any.

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Queensland University of Technology Human Research Ethics Committee. All participants were given a full explanation of the experimental procedures, and written informed consent was obtained with the option to withdraw from the study at any time.

Both visual acuity and contrast sensitivity were measured binocularly under photopic conditions. Distance visual acuity was assessed using a high contrast logMAR letter chart, at a viewing distance of one meter using an appropriate working distance correction. Visual acuity was scored on a letter by letter basis, where each letter correctly identified represented a score of 0.02 log units.

Letter contrast sensitivity was measured using a Pelli-Robson chart under the recommended viewing conditions (Pelli et al., 1988), where each letter reported correctly was scored as 0.05 log units.