☑ CE Article

The Effect of the Color of a Long Cane Used by Individuals Who Are Visually Impaired on the Yielding Behavior of Drivers

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Structured abstract: *Introduction:* A new market trend offers long canes for individuals with visual impairments in a variety of colors; however, the impact of these colors is unknown to orientation and mobility (O&M) specialists and individuals who are blind or who have low vision. The authors examined the impact of cane color on drivers' yielding behaviors; also, cane display effectiveness was assessed. *Methods:* At traffic signal–controlled intersections, drivers' yielding responses (yield–no yield and seconds to crosswalk) were recorded by two raters when a pedestrian presented one of two conditions (display and flagging) with four differently colored long canes (white, black, yellow, and green). *Results:* In trials where the pedestrian used a flagging cane technique, the white cane achieved 290% more yielding than the green cane, 100% more yielding than the yellow cane, and 40% more yielding than the black. Statistical differences were found between the white-with-red cane and the yellow and green canes. The measure of drivers' latency for moving forward was not statistically different between trials in which a pedestrian displayed a white cane at the crosswalk and trials in which no pedestrians were present. *Discussion:* Cane color appears to have a substantial effect on drivers' yielding responses. The results also indicate only a slight driver response to a highly visible cane display, confirming the results of previous studies that recommended more potent pedestrian movements to mitigate the threat from turning vehicles. *Implications for practitioners:* O&M specialists and cane travelers need to consider the options for cane color when using a cane to cross streets. A white cane, flagged at the onset of the walk signal, can achieve more desirable responses from drivers than can the long canes of other colors. More effective cane behaviors exhibited by pedestrians who are visually impaired should always be considered by O&M instructors in order to influence drivers.

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It was in 1930, according to the Lions International organization, when a local chapter president, George Bonham, noticed a blind man using a black-colored cane to cross the street. Thinking the cane was barely visible to motorists, he came up with the idea of a white cane. The idea quickly found popularity with others, and the white cane became ubiquitous throughout the United States (Lions International, 2014). Overseas, the white cane was claimed to be the 1921 invention of James Biggs in England (Strong, 2009). In both stories, the common-sense ideas of visibility and saliency were the basis for believing that a cane colored white to indicate vision loss would solicit a better response from drivers and others.

This premise has remained unchallenged, and the long white cane has become the most-used and best-known symbol of visual impairment along with dog guides. There are various professional opinions about the importance of the color of the long cane. For certain uses of the cane, such as gathering environmental information and detecting hazards, color has been considered irrelevant (Vision Aware, 2015). However, for purposes of recognition and safety, there are broad concerns about the effectiveness of canes in colors other than white, according to responses from the authors' enquiry of members in an online mailing list community of orientation and mobility (O&M) specialists and other vision rehabilitation stakeholders.

Currently, O&M specialists and cane manufacturers are exploring a new trend in canes that offer a variety of colors for the grip, shaft, and tips of the long cane. Ambutech, a major supplier of such canes, has found that the portion of sales of canes other than white has been increasing in recent years, accounting for 2.9% to 5.1%, most frequently with graphite models (personal communication, Gord Hudek, December 7, 2015). Considering the increasing popularity of canes incorporating colors other than white, the various professional opinions that surround the topic, and the lack of empirical study, the authors decided to examine the effect of cane color on the yielding and latency behaviors of drivers.

Yielding behavior by drivers is critical to pedestrian safety in situations at signalized street crossings where there are turning vehicles and the potential for vehicle-pedestrian conflict exists. In these situations, both the driver of the vehicle and the pedestrian are presented with signals (typically a green circular signal and a walk signal) indicating that they may enter the same space at the same time within a crosswalk. This common scenario may cause significant risk to pedestrians. In a 2006 study using National Highway Traffic Safety Administration data, researchers concluded that ". . . vehicle movement was a significant predictor of severe injuries . . . and fatalities [in pedestrians]" (Roudsari, Kaufman, & Koepsell, 2006, p. 283). A 2005 dissertation study reported that more than 26% of motorists turning right with a green signal did not yield when a pedestrian was present (Karkee, 2005).

The researchers intended to study whether the increasing use of differently

colored canes can have an effect on the assumed reduction in risk for crosswalk conflicts from the use of these mobility devices.

Literature review

There is no corpus of work examining the color of the long cane, either within the field of O&M or in other disciplines. The authors are not aware of any significant writings or commentary on the topic of cane color. A small study was presented at an international conference, but the results were inconclusive (Penrod et al., 2013). Other than that, there has been no scholarly work on the topic. There is, however, a very large amount of research and interpretation concerning how human beings attend to and respond to visual stimuli. This research is selectively introduced in the following section.

The human vision cognition system

At any given time there is a limit to the quantity of information that can be processed by the human visual system. Psychologists have studied the psychophysiology of the human visual systems to learn about visual stimuli that alter "the direction of attention away from the prevailing focus" (Hughes, Vachon, & Jones, 2005, p. 736). They termed *attentional capture* as the result of a stimulus that alters the focus of attention away from the prevailing concentration ". . . without that person's volition" (Most, Scholl, Clifford, & Simons, 2005, p. 218). It is this phenomenon that can cause pedestrians about to enter a crosswalk to redirect attention, and therefore appropriate responses, from drivers. In particular, we were interested in the influence of cane color as it related to attentional capture.

Methods

Study procedures were approved by the Human Subjects Institutional Review Board of Western Michigan University. Since the only participants were the experimenters, a consent form was not required.

At a street corner in an urban location, a 6-foot-tall collaborating male pedestrian wore dark casual clothing, a cap, and dark sunglasses. He started each trial by standing on the curb ramp between the crosswalk lines before initiating one of several pedestrian behaviors. The pedestrian behaviors were selected either because they were determined to be the standard practice preferred by O&M practitioners in the field (Jacobson, 1993, 2013; LaGrow & Long, 2011; LaGrow & Weessies, 1994) or were known to elicit modest amounts of yielding (Bourquin, Wall Emerson, Sauerburger, & Barlow, 2014). These included: cane display—the pedestrian held a long cane at the curb, grip extended from the body and tip near the feet, held to the left such that it was visible to drivers in waiting vehicles (see Figure 1); and cane flagging—at the onset of the walk signal, the pedestrian moved a long cane laterally from the display position, touching the ground on his right then left side, lifting the cane up to approximately waist level at the middle of the swing. He then remained stationary for at least 10 seconds (see Figure 1).

Trials consisted of the pedestrian rotating through cycles, alternating the type of behavior and cane color. The following cane colors were examined:

- white cane, a cane with a white shaft and a red stripe above the tip;

Figure 1. Pedestrian flagging a cane from a display position to about waist level.

- yellow cane, a cane with a yellow shaft;
- black cane, a cane with a black shaft and a red stripe above the tip; and
- green cane, a cane with a green shaft.

Two raters, both highly experienced O&M specialists and researchers, recorded whether a yield had occurred (yield–no yield), and the type of yield. Yields were coded as no vehicle movement for three seconds or more, a full stop before the crosswalk, or a rolling yield where the driver continued to move forward slowly but was judged to be waiting for the pedestrian. Data were also collected on driver latency (seconds from the onset of the green vehicle signal and pedestrian walk signal until the vehicle crossed the middle of the crosswalk) when no pedestrian was present at the crosswalk, labeled "no-pedestrian" in the Results discussion.

Results

Inter-rater agreement

Two raters judged all trials for whether a yield occurred, what type of yield occurred, and the time from the onset of the circular green signal to when the right-turning vehicle crossed the midpoint of the crosswalk. In all, 176 trials were assessed. On identifying whether or not a yield occurred, the two raters agreed on 160 of the 176 trials (90.9%). In all trials where the two raters disagreed, it was because one rater coded a rolling yield (where a vehicle did not fully stop) while the other rater did not consider the slowness of the vehicle to have constituted a rolling yield. Further analysis was completed on each color condition in this order: black ($n = 21$), green ($n = 21$), white ($n = 20$), and yellow ($n = 19$). With all trials considered, inter-rater agreement for yield–no yield respectively for each color was: 95%, 95%, 89%, and 84%. When only the flagging cane data were examined, inter-rater agreement for yield–no yield respectively for each color was: 95%, 95%, 91%, and 86%.

Because inter-rater agreement was below 95% for the white and yellow cane trials, and the specific disagreements involved only the qualitative measure of the vehicle movement (rolling), we wanted to confirm agreement with a more robust assessment. Therefore we calculated Cohen's kappa coefficients for each color item for the flagging cane trials; we also wanted to account for the possibility of agreement and disagreement occurring by

chance. All the coefficients fell into the substantial to almost-perfect range for agreement (Viera & Garrett, 2005). For the black cane there was almost-perfect agreement ($\kappa = .909$, $p < .0001$); for the green cane there was almost-perfect agreement ($\kappa = .879$, $p < .0001$); for the white cane there was substantial agreement between the raters' judgments ($\kappa = .79$, $p < .0001$); and for the yellow cane there was substantial agreement ($\kappa = .713$, $p = .001$).

On the crosswalk time, the values recorded by Rater 1 ranged from 2.54 to 23.04, with a mean of 7.59 ($SD = 3.12$), while those of Rater 2 ranged from 3.47 to 23.74, with a mean of 7.67 ($SD = 3.15$). The two raters significantly correlated on this measure at $r = .906$, $p < .0001$.

Statistical power

Statistical power for the χ^2 tests ranged from .76 to .90, and was .85 for Z tests when a large effect size ($f = .4$) was assumed (Cohen, 1988). All statistical analyses were conducted with SPSS version 20, except for power analyses, which were conducted with G*Power Version 3.1.9.2 (Erdfelder, Faul, & Buchner, 1996). This power analysis indicates that the sample size used in this study was sufficient to find any statistically significant moderate-to-large differences between conditions that we compared.

Differences between the experimental conditions

Because an initial examination of the results indicated that the use of a cane display alone did not substantially affect drivers' yielding behavior, we focused on the trials in which the pedestrian flagged his cane.

Drivers' yielding to cane color with a cane flagging

After eliminating trials where the raters disagreed (for flagging trials, this included three yellow cane trials, two white cane trials, and one trial each with the black and green canes), yielding results for each color item can be found in Figure 2.

An χ^2 test indicated that there was a significant difference in yielding across the four color conditions—χ^2 (3) = 9.44, $p = .02$. Further testing showed that the white cane did not have significantly more yielding than the black cane—χ^2 (1) = 2.11, $p = .15$—but did have significantly more yielding than the yellow—χ^2 (1) = 4.31, $p = .04$—or green—χ^2(1) = 8.79, $p = .003$—canes. There was not a significant difference in yielding rates across the black, yellow, and green canes—χ^2 (2) = 2.59, $p = .27$.

Drivers' yielding to cane display and flagging

We looked at drivers' yielding for each pedestrian behavior. Given the high correlation between the two raters, data from the primary rater is reported for these analyses. Yielding when the pedestrian only displayed a cane was generally low. Driver yielding when the pedestrian flagged the cane was approximately twice as great (see Table 1). This was a significant difference—χ^2(1) = 13.99, $p < .0001$.

Using the time (seconds) data for how long it took a vehicle to reach the crosswalk after the light turned green, as one would expect, the distribution of crosswalk times with no pedestrian present

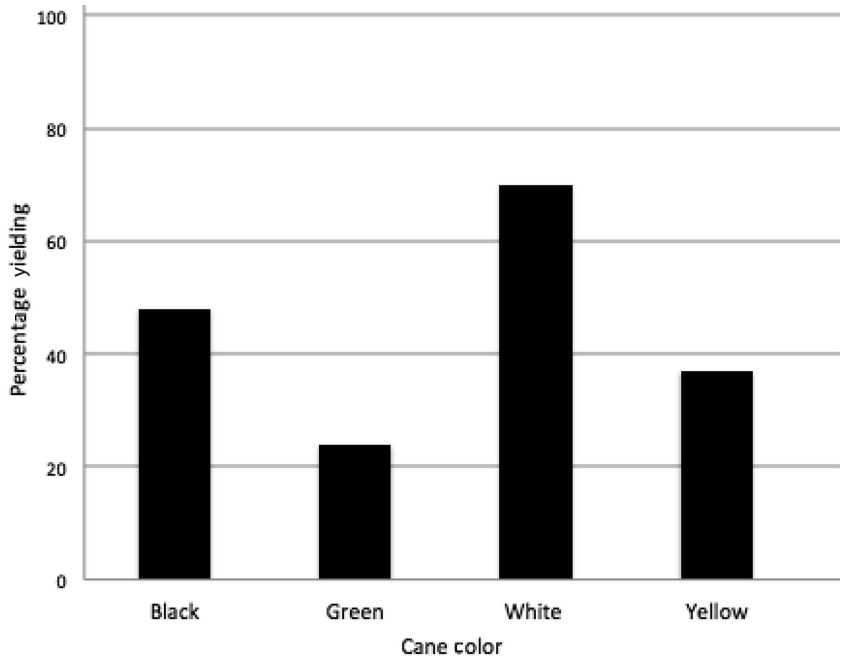

Figure 2. Percentage of yields in cane flagging condition: black 48; green 24; white 70; yellow 37.

was significantly different from the distribution of crosswalk times for trials rated as yields ($M = 10.35$, $Z = 4.91$, $p < .0001$). This finding means that for trials in which a yield was coded, it generally took a vehicle longer to eventually reach the crosswalk. Similarly, the distribution of crosswalk times with no pedestrian was not significantly different from the distribution of crosswalk times for trials rated as not having a yield. Given the low overall yielding rate for the display trials, we wanted to check how this yielding rate compared to situations in which no pedestrian was present at the intersection. When we limited trials to only the white cane for the purpose of better simulating current trends in long cane use, there was no significant difference in yielding (using time to reach the crosswalk as a proxy) between the no-pedestrian data and the display condition ($Z = -.33$, $p = .74$).

Table 1
Average yielding rates by pedestrian behavior.

	Yield	No yield	Yields %
Cane display	18.5	69.5	21.2
Cane flagging	39.5	48.5	44.89

Discussion and conclusions

Cane color and vision cognition

The primary finding demonstrates the effect of the color of the shaft of a long cane on the turning behavior of drivers. Visual cognition psychologists, who study how vision in humans is redirected and how we respond to environmental stimuli, have conducted voluminous research in vision cognition and, in particular, the involuntary redirection of a person's scrutiny. Their findings have to do with what and how drivers notice people and objects within the scope of vision.

According to Most and Astur (2007), "Within the traffic safety literature, much effort has been devoted to understanding the cognitive factors contributing to accidents" (p. 130).

The natural environment provides a great number of stimuli that a driver has to observe and identify visually. Simply stated, redirection of vision toward an object can be compelled by both the nature of the stimuli (object-driven, in this case the cane), or subject-driven (internal cognition, the stored data and experiences of a driver) (Turatto & Galfano, 2001). Therefore, it is the interplay between an object and an observer that determines if something is the target of visual attentional capture (Goodhew, Kendall, Ferber, & Pratt, 2014). Objects that are visually salient, that have sudden movement, are recognizable, and that have explicit meaning to the observer are likely to elicit responses that overcome the existing attentional goals of drivers. In a situation in which a pedestrian is standing at a crosswalk, having the driver attend to and understand the pedestrian's intention to cross is crucial to pedestrian-driver interaction and safety.

Along with the salience (that is, the ability of an object to stand out visually) of any particular color, it is likely that the effect of a standard long cane was even greater because it was recognizable and had meaning. Once a target (a cane, for example) has a driver's attention, further cognitive processes determine if it is familiar and if it has meaning to the observer. If it does, it may elicit a quick, strong, and appropriate response (Most & Astur, 2007). "Although salience appears to increase the likelihood of detection, it does not seem to match the power of attentional set [the memory of relevant items] in influencing detection" (Most et al., 2005, p. 232). A standard white-colored cane appears to be recognizable and relevant to many drivers.

In terms of cane colors among the studied options, yielding to the white cane was 22% to 46% greater than for other color canes. The white cane garnered 2.9 times the yields of the green cane. The authors infer that the significant and practical differences reported mean that cane color influences how often drivers may yield to a pedestrian waiting or initiating a crossing.

Cane technique: display and flagging

A secondary finding of the study involves pedestrian manipulation of the long cane. The authors found that the latency for drivers arriving at the crosswalk (the time between the vehicle at standstill and the vehicle passing the midpoint of the crosswalk) when the pedestrian simply displayed the cane while waiting to cross the street (at the onset of the vehicle green signal and the walk signal) was the same as it was when there was no pedestrian there. The results of this study confirmed previous findings and went further toward assessing the effectiveness or ineffectiveness of simply displaying a static cane at the corner. A consistent but modest influence on drivers has been noted across numerous studies (Ashmead, Guth, Wall, Long, & Ponchillia, 2005; Bourquin, Wall Emerson, Sauerburger, & Barlow, in press; Geruschat & Hassan, 2005; Harrell, 1992), and Bourquin et al. (2014) found that, "regarding driver responses when the vehicle crossed the crosswalk: a cane display was not significantly different

from no cane display . . .” (p. 173). Orientation and mobility specialists may want to examine the assumptions of the positive effect of passively displaying a cane as it relates to increasing driver awareness and substantially reducing risk from drivers who do not yield. Flagging and other techniques that have prompted higher rates of yielding have been reported (Bourquin et al., 2014, in press).

Practical application: alerting drivers to presence and intention

It appears that regardless of the color of a long cane, a cane display alone did not achieve the goals of informing the drivers of the visually impaired pedestrian’s presence or an intention to enter the crosswalk. Flagging the cane affected the drivers’ yielding behavior, probably because it provided movement and sudden onset, as predicted by vision cognition science. When flagging, the cane’s color made a difference. The white cane increased yielding over the other colors: approximately 46% more yields than a green cane, 37% more yields than a yellow cane, and 22% more yields than a black cane. This finding is explained by the white cane’s status as a ubiquitous symbol well-recognized by the public.

Pedestrians with vision often communicate in subtle ways with drivers as they negotiate street crossing in spaces that are potentially shared; eye contact or its absence and body language are presumed to be ways in which these interactions can happen (Vanderbilt, 2008). For similar reasons, blind pedestrians may choose to empower themselves with techniques by which drivers are most likely to notice, understand their intentions, and yield as they prepare or begin to cross a street. Our results indicate that the behavior and cane color that are most likely to have this effect are flagging a traditionally white cane. Flagging canes of other colors is less effective than flagging a white cane, and simply displaying a cane had no effect on the drivers’ behavior, regardless of its color.

Strengths and limitations

The study represents a first look at the contemporary issue of differently colored long canes. It was conducted at a single location during daylight hours and used a relatively limited number of trials; however, the statistical power of the analyses were robust. Interrater agreement could have been improved with additional pretrial practice or with the use of equipment for speed detection technologies. Only four differently colored canes were used, and other colors may provide different results. Cane luminance was not considered. The researchers do not know the effects of cane color after the pedestrians have fully entered the crosswalk or in low-light conditions. Additionally, only a male collaborator was used as the pedestrian; gender-related yielding research is necessary to complement and inform the current study.

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