Department of Veterans Affairs

JRRD Volume 43, Number 6, Pages 771–776
September/October 2006
Journal of Rehabilitation Research & Development

Recognition distance of pedestrian traffic signals by individuals with low vision

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Abstract—Forty-one individuals with moderate-to-severe vision loss participated in a study to determine the minimum distance they required to correctly identify three different pedestrian traffic icon symbols, one of which was presented with an augmented light source. We found that subjects could identify the WALK icon without the augmented light source information, or animated eyes, from farther away than either the WALK icon with the augmented light source information or the DON'T WALK icon. These results differ from those of a previous study, which found that subjects could correctly identify the WALK icon with the augmented light source from a greater distance than the WALK or DON'T WALK icons without the augmented light source.

Key words: accessible pedestrian signals, animated eyes, blindness, crosswalk signals, low vision, low-vision pedestrians, pedestrians, recognition distance, traffic icons, vision rehabilitation.

INTRODUCTION

The focus of travel in the United States over the past 50 years has been on the automobile rather than the pedestrian. With the increased number of cars and drivers per family, traffic engineering has emphasized the unencumbered movement of automobile traffic. Some of these efforts have resulted in the right turn on red laws, roundabout intersections, and the actuated (dynamically adjusted by volume to traffic flow) traffic signals. Combined with these traffic control innovations, the production of quieter cars has made the task of safely crossing streets for the person with limited or no vision more complicated and dangerous. In an effort to facilitate safe street crossings for individuals with a visual impairment in the United States and many other countries, researchers and companies have developed a variety of accessible pedestrian signals (APS). Unfortunately, limited research has been conducted on comparing the effectiveness of these different APS or on developing signals that would also assist the partially sighted individual.

The number of individuals with vision loss and other disabilities is expected to grow in the coming decades [1–4], in tandem with the anticipated increase in the number of older persons in society. Desai et al. estimate that 14 percent of persons age 70 to 74 have serious difficulty seeing, even with their glasses, with an increase to 32 percent among persons 85 or older [5]. Likewise, the prevalence

Abbreviations: APS = accessible pedestrian signals, LED = light-emitting diode, logMAR = logarithm of minimum angle of resolution, SD = standard deviation, VA = Department of Veterans Affairs.

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DOI: 10.1682/JRRD.2005.02.0040

of blindness (in which no or very little remaining visual function exists) also increases with age. The Centers for Disease Control and Prevention and the National Centers for Health Statistics have recently estimated that the prevalence of blindness among persons age 70 to 74 is about 1 percent, but by age 85, nearly 2.5 percent of persons are blind [5]. By age 85, one in four older people cannot read a newspaper, even with best-corrected vision [6]. These predicted increases in visually impaired persons in society represent an important future reality of which traffic engineers and others must be aware.

Moreover, the population of veterans who experience vision impairment and blindness concomitant with other disabilities is expected to grow more rapidly than the general population [4]. Data-driven results that evaluate the efficacy of various assistive technologies for enhancing mobility for visually impaired travelers are essential.

Although efforts have been made to develop APS for the totally blind traveler, little attention has been given the problem of developing more effective visual signals for partially sighted individuals. The paucity of research in the area of APS that targets individuals with low vision is particularly problematic considering that more than 80 percent of the legally blind population has some remaining vision [7]. One recent study examined whether the inclusion of an augmented light source, or animated eyes, to a standard WALK icon resulted in improved safety of visually impaired or low-vision pedestrians by prompting them to look for turning vehicles and increasing overall icon recognition distance [8]. That study found that low-vision pedestrians could identify the shape of the WALK icon from 50 percent farther away when it included light augmentation with an animated eyes display. In this earlier study, the color of the signal icons was kept constant (the WALK and DON'T WALK icons were both illuminated with white light-emitting diodes [LEDs] or white incandescent bulbs), which allowed subjects to discriminate based on icon shape alone. Results from this previous study suggest that the addition of an animated eyes display to the WALK icon significantly improved recognition distance for the majority of the sample.

These earlier findings suggest that the WALK icon combined with the augmented light source, or animated eyes, could increase correct icon identification distance and potentially reduce the frequency of pedestrians with low vision inadvertently crossing against the traffic signal. Although these findings are promising, they need to be replicated with a larger number of low-vision participants under field conditions. Likewise, conducting any replication of the earlier study with color (the WALK icon displayed in white and the DON'T WALK icon displayed in orange) added to the signal device icon panel for maintaining real-world visual appearance is important. In this study, we performed a field replication of the earlier study to determine whether a measurable difference exists in the relative conspicuousness of APS among a sample of low-vision subjects in an ecologically valid environment [8].

METHODS

Participants

Individuals with moderate-to-severe vision loss were the target population recruited for this study. We screened potential subjects to determine eligibility based on two specific criteria: (1) visual acuity between 20/70 and 20/300 and (2) demonstrated ability to ambulate unassisted. We measured binocular distance visual acuities of subjects using a Bailey-Lovie 3-meter logarithm of minimum angle of resolution (logMAR) acuity assessment chart [9]. We calculated the logMAR acuity scores using the per-letter method, which has demonstrated enhanced reliability over the per-line method in previous research [9–11]. The scores were then converted into a Snellen-equivalent acuity score. Subject binocular acuities ranged from 20/70 to 20/332. An examination of the duration of visual impairment reported by participants found that a majority (n = 23, 56%) reported experiencing "serious" vision problems for 7 years or more.

Out of a total recruitment pool of 76 screened individuals, 41 participants successfully completed the protocol, which represents a participation rate of 54 percent of all potential subjects. Persons who did not participate in this study were determined to have visual acuities outside the specific vision criteria established by the research team. Recruitment efforts for this study drew from both the veteran and civilian visually impaired population and primarily targeted persons who resided in a large southeastern metropolitan area.

Individuals who were eligible for this study were provided detailed information regarding the study protocol, and informed consent procedures from institutional review board approved human subjects guidelines were followed. Subjects who participated in this study

received a $50.00 incentive payment at the completion of the protocol. Participants had a mean age of 65.9 years (standard deviation [SD] = 13.5) and ranged in age from 38 to 86. The sex of participants in this sample was 73 percent male (*n* = 30) and 27 percent female (*n* = 11). The racial/ethnic profile of participants was 63 percent white (*n* = 26), 34 percent African American (*n* = 14), and 2.4 percent Hispanic (*n* = 1). More than half the participants (*n* = 25, 61%) reported prior participation in either a Department of Veterans Affairs (VA) or non-VA blind or low-vision rehabilitation program.

Subjects were asked to identify any previously diagnosed eye conditions or disorders from a list read to them by a research team member. The most commonly reported eye diseases reported were age-related macular degeneration (*n* = 19, 46%), followed by cataracts (*n* = 17, 42%), diabetic retinopathy (*n* = 12, 29%), and glaucoma (*n* = 12, 29%). Other less commonly reported eye diseases included retinitis pigmentosa (*n* = 2, 4.9%), non-age-related maculopathy (*n* = 1, 2.4%), optic atrophy (*n* = 1, 2.4%), Stargardt's disease (*n* = 1, 2.4%), nystagmus (*n* = 3, 7.3%), and retinopathy of prematurity (*n* = 1, 2.4%). Twenty-five subjects (61%) reported multiple eye conditions, including glaucoma and cataracts (*n* = 4, 9.7%); age-related macular degeneration and cataracts (*n* = 3, 7.3%); diabetic retinopathy and cataracts (*n* = 3, 7.3%); and age-related macular degeneration, cataracts, and glaucoma (*n* = 3, 7.3%).

Participants were asked to indicate whether or not they had been diagnosed with any condition within seven major areas of illness, including cardiac problems, cognitive problems, diabetes, neurological problems, neuropathy, pulmonary problems, or renal disease requiring hemodialysis. The most commonly reported health condition among participants was diabetes requiring either oral or injected medications (*n* = 19, 46%), followed by cardiac involvement (*n* = 15, 37%), neuropathy (*n* = 6, 15%), and pulmonary involvement (*n* = 5, 12%). In addition, 15 percent of participants (*n* = 6) had experienced a severe loss of hearing, with 10 of the 41 subjects reporting that they currently required the use of hearing aids.

Relume Pedestrian Signal Device

The device used in this study, the Relume Signal Eyes device (Relume Corp, Troy, Michigan), is a variant of the standard pedestrian signal icon display typically installed in many pedestrian crossing locations nationwide (**Figure**). The WALK and DON'T WALK Class 4 hand/man pictograph symbols are illuminated by 11.2 in.-high outlines of a hand icon (Portland orange 605 nm LED) and a walking person icon (white 460 nm LED). This pedestrian signal device is also equipped with a white LED animated eyes display that comprises two white eyes (each LED eye measures 5 in. wide × 2.7 in. high) that scan left to right at a rate of one cycle per second. The Signal Eyes device is touted by the manufacturer as "inducing looking behavior by pedestrians for greater awareness to threats from turning traffic." This signal device projects a relatively narrow (15°) field of view. This narrow field of view is a desirable feature of this pedestrian signal device because it generally limits the optimal observation area to the pedestrian walkway [8].

Figure.
Relume pedestrian signal device (Relume Corp, Troy, Michigan).

Procedures

All testing for this study was conducted between 8:00 am and 4:30 pm Eastern Daylight Time in a variety of ambient lighting conditions from near dark to bright sun. We attempted to approximate the dynamic lighting conditions encountered in the real world by allowing variations in lighting levels between subjects. Two research team members accompanied each subject to the test site located at the main entrance to the campus of the VA Medical Center in Atlanta, Georgia. A research team member familiarized the subject with the pedestrian signal device, demonstrated the various icon shapes that would be displayed, and assured the subject that a team member would be within arms reach at all times as the

subject attempted to identify the different pedestrian signal icons. Subjects were then turned away from the pedestrian signal and led by a team member 200 ft from the signal location. Subjects were instructed to turn around and walk forward toward the signal until they could correctly identify the icon being presented. Additional instructions were given to each subject: they were asked to imagine a scenario in which they were accompanying a young child and determine whether or not the presented icon indicated a safe condition to cross the street. At the point of correct identification, a team member recorded the distance to the signal using a laser distance measurement device. In the event of an incorrect identification, subjects were asked to continue forward until they could correctly recognize the presented icon. Order of trials and presentation of signal icons were randomized and counterbalanced across participants. All subjects were presented with 30 randomized pedestrian signal icon trials in this manner. Total time to setup and identify these signals averaged ~1 h.

RESULTS

Subjects were, on average, able to identify the WALK icon without animated eyes from farther away than either the WALK icon with animated eyes or the DON'T WALK icon. The mean ± SD distance for correct identification of the WALK icon without animated eyes was 108.4 ± 42.4 ft, the mean ± SD distance for correct identification of the WALK icon with animated eyes was 89.3 ± 39.8 ft, and the mean ± SD distance for correct identification of the DON'T WALK icon was 92.2 ± 42.3 ft. A within-subject repeated measures analysis (matched randomized block design) examining differences in means between the three signal icons found statistically significant effects between all conditions ($F_{(1.16,\ 46.5)} = 21.6$, $p < 0.001$, with Huyn-Feldt correction). A post hoc within-subject repeated measures contrast examining differences between each of the three icon conditions (Bonferroni corrected for multiple comparisons) was statistically significant between the WALK icon with animated eyes and the WALK icon without animated eyes ($t = -5.39$, $p < 0.001$). However, a statistically significant result was not detected between the WALK icon with animated eyes and the DON'T WALK icon ($t = -2.37$, $p = 0.07$). Post hoc within-subject repeated measures contrast between the WALK icon without animated eyes and the DON'T WALK icon was statistically significant ($t = 4.14$, $p < 0.001$). Based on these findings, we conclude that the WALK icon without animated eyes proved most recognizable at a greater distance than either of the other two icons.

DISCUSSION

The results of this study indicate that the subjects were, on average, able to identify the walking man icon without animated eyes from farther away than either of the other two icons. Speculating why the addition of the animated eyes was significantly different than the WALK icon alone is interesting. One might assume that the movement of the animated eyes offers a perceptual advantage. However, given the magnitude of the movement in the eyes, individuals may have to be at a certain distance before they are able to discriminate that movement. When the subject is exposed to the icon, the animated eyes may actually introduce "visual clutter," and the subject may not be able to clearly discriminate the icon. Therefore, the subject must be closer to identify the icon with animated eyes than the icon without animated eyes.

These findings are not consistent with results reported by Van Houten et al. [8], who found that the WALK icon with animated eyes "significantly increased the distance that pedestrians could identify the WALK indication with confidence." Several distinctions between this study and the earlier study may explain the inconsistent results. First, little overlap existed in the eye conditions and visual acuity between the two groups. Second, this study was conducted under field conditions, unlike the previous study in which trials were conducted in a controlled test setting. Likewise, and in contrast to this study, the previous study relied on pretest training and verbal prompts to respondents for aiding in signal recognition. The discrepancy between the findings in this study and the earlier work by Van Houten et al. is likely a result of the differences in the procedures. In the present study, 46 percent of participants were diagnosed with age-related macular degeneration, 42 percent with cataracts, 29 percent with diabetic retinopathy, and 29 percent with glaucoma. The eye disease profile reported in the earlier study differed remarkably from this current study: nearly half of the participants in the earlier study were diagnosed with congenital vision disorders, including retinopathy of prematurity, congenital coloboma, congenital cataracts, and aniridia. Likewise, more than 75 percent of subjects in the current study had visual acuities that were better than 20/200 (not meeting the criteria for legal blindness)

compared with the previous study in which 75 percent of the sample was reported to have visual acuity of 20/200 or worse. Also noteworthy is that the mean age of subjects differed remarkably between the two studies, with younger subjects participating in the earlier study (mean age = 39) compared with older subjects in the current study (mean age = 66).

Another distinction between the current study and the previous study involves the training and prompting protocols Van Houten et al. used in their earlier study. Subjects were provided indoor pretest training on the identification of the signal device to "ensure that they would be familiar with the stimuli used in the study" [1]. Additionally, investigators in the previous study prompted participants to use visual mnemonic strategies "to force them to attend to critical elements" [1], including visualizing various shapes and images (inverted 7 or L, dark spots on the icon lens) to enhance recognition. We chose not to provide pretest training or to prompt subjects to enhance their recognition skills and instead relied on real-world recognition skills unassisted by visual mnemonic strategies. Whether or not the pretest training and, perhaps more importantly, the prompts and mnemonic strategies Van Houten et al. used influenced outcomes in the earlier study is debatable.

Interestingly, we conducted field trials under nighttime conditions with four subjects who had previously participated in daytime. In all four cases, subjects were able to identify all icons at the maximum testing distance (>180 ft). While these results were gathered on a very small subsample of subjects and thus lacked adequate statistical power to draw conclusions, the higher contrast conditions offered at night clearly enhanced subject performance in recognition of all device icons presented.

CONCLUSIONS

This study suggests that changes to the pedestrian display need to be evaluated for the various types of eye conditions that cause low vision. Additional research examining the relative conspicuousness of the Relume Signal Eyes device among individuals with low vision who have a range of acuity levels and eye diseases as well as elderly visually impaired individuals is warranted.

ACKNOWLEDGMENTS

This material was based on work supported by the VA Rehabilitation Research and Development Service, grant C2489R. Relume Corp, Troy, Michigan, had no involvement in the study design; data collection, analysis, or interpretation; or writing or submission of this article.

The authors have declared that no competing interests exist.

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Submitted for publication February 8, 2005. Accepted in revised form November 18, 2005.