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Perception of Pedestrian Signals by Pedestrians with Varying Levels of Vision

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Abstract

This study evaluates the usability of pedestrian signals by persons with varying visual acuities under different conditions of symbol size, crossing length and type of background behind the pedestrian signal. While viewing photographs presented on a computer monitor under unimpaired viewing conditions (approx. 20/20 visual acuity) and under simulated visual impairment (approx. acuities of 20/100 and 20/300), participants attempted to determine the pedestrian phase (Walk or Don't Walk) and to report the number presented by the countdown timer display.

Performance on the phase discrimination task by those with simulated 20/300 acuity and with 9 and 12 in. high symbols often resulted in performance which was little better than chance despite a highly controlled environment (i.e., no moving vehicles or environmental distractions) and signals which were subjectively in excellent working condition and of high visibility (i.e., good luminance/contrast, no glare). Reading the countdown display was essentially impossible.

Participants with simulated 20/100 acuity were rather successful with regards to phase identification – averaging better than 87% correct under all stimulus conditions – but room for improvement exists as compared to performance in the 20/20 condition. Reading the countdown display was difficult for participants with simulated 20/100 acuity – averaging between 6.5% and 58.5% correct under the various stimulus conditions.

The effect of different backgrounds on the usability of the signals, as well as the implications of the findings with regards to signal size and crossing length on the current signals standards, are discussed.

INTRODUCTION

In an increasingly complex pedestrian environment, where the pedestrian phase may not be concurrent with vehicular green (e.g., some vehicular turn phasing strategies, exclusive pedestrian phases, and leading pedestrian intervals), recognition of pedestrian signal indications is necessary. Safe initiation of pedestrian crossing at signalized intersections depends on both knowledge of the onset of the walk interval, as indicated by the pedestrian signal, and on the ability to simultaneously monitor conflicting vehicular movement. Persons having reduced visual fields may have difficulty locating pedestrian signals set against visually cluttered backgrounds, and persons having low acuity often have difficulty discriminating the signal information.

The legal definition of blindness in the United States is visual acuity of 20/200 or worse (or a visual field less than 20 degrees in diameter), while vision impairment is defined as having acuity of 20/40 or worse; 20/40 serves as the cutoff for receiving an unrestricted driver's license in most states (1). Vision correctable to 20/20 with at least 180-degree field is considered 'normal vision'. A simplified explanation of visual acuity is that a person who is legally blind with 20/200 vision sees at approximately 20 ft what a person with 20/20 vision sees at 200 ft. The World Health Organization (WHO) defines low vision (categories 1 & 2 visual impairment) as acuity less than 20/70 with optimal correction, and blindness as visual acuity worse than 20/400 (2).

Older pedestrians typically have decreased contrast sensitivity and visual acuity, reduced peripheral vision, and reduced "useful field of view" (3), all of which may affect their ability to use pedestrian signal information while simultaneously monitoring vehicular movement. This assertion is supported by research which found that 25 percent of persons age 56 years or older surveyed in Orlando, FL reported that they had difficulty seeing pedestrian signals (4).

Estimates of the prevalence of visual impairment do vary depending upon methods and definitions. A national telephone survey commissioned by Lighthouse International investigating the prevalence of self-reported visual impairment found that one in six Americans (17%) age 45 years or older, representing 16.5 million middle-aged and older adults, report some form of vision impairment even when wearing glasses or contact lenses (5). Data from 1990 and 2001 regarding adult Americans over the age of 40 led to an estimate of 937,000 blind individuals (20/200; prevalence of 0.78%) and an additional 2.4 million individuals with low vision (20/40; prevalence of 1.98%) (6). The study projected that by 2020, the number of blind Americans will have increased to 1.6 million (increased prevalence to 1.1%), while the number of Americans with low vision will have increased to 3.9 million (increased prevalence to 2.5%), resulting in a combined 5.5 million visually impaired Americans over the age of 40 (6).

U.S. traffic engineering manuals such as the *Manual on Uniform Traffic Control Devices* (MUTCD) (7) and those published by the Institute of Transportation Engineers (ITE) provide minimal requirements and guidance on how to make pedestrian signal indications usable by pedestrians. These requirements include, but are not limited to, requirements related to the physical (e.g., size and shape) as well as photometric (e.g., luminance, chromaticity, and color uniformity) characteristics of the signals. Specific requirements include the use of solid symbols rather than outline style symbols for all new installations, and the MUTCD indicates that "For crosswalks where the pedestrian enters the crosswalk more than 100 feet from the pedestrian signal head indications, the symbols should be at least 9 inches high" (7; Part 4E.0 par 09). Minimum 6 in. high symbols are permitted for all shorter distances. However, despite the existence of such standards, no research has been

identified on the ability of pedestrians with either impaired or unimpaired vision to make crossing decisions based upon information provided by pedestrian signals varying in size or background clutter.

Three studies have examined perception-reaction time of pedestrians at signalized intersections; however, the nature of the signal indications, ambient light, and background complexity were not systematically varied, and pedestrians with reduced vision were not intentionally included in the samples (8, 9, 10).

Two recent projects have considered recognition distance of pedestrian signals of different shapes by pedestrians with low vision (11, 12). In both studies, research was conducted in daytime with relatively uncluttered backgrounds, and with signals always in the same location. Results of these studies were contradictory. Molino, Katz, Kennedy, and Hermosillo (13) investigated the legibility distances for reading countdown displays. They used an almost exclusively analytical approach in which they predicted the maximum distance from which countdown numerals of various heights would be legible to pedestrians with various levels of visual acuity. The authors based their predictions on current signals standards regarding luminance and contrast, and on an average legibility index (i.e., the number of feet of viewing distance per inch of letter height) based upon those used or recommended by the MUTCD, the United States Sign Council (USSC), and the American National Standards Institute (ANSI) (for details, see Molino et al. (13)). Molino et al. (13) predicted that for those at the upper end of the range of normal vision by U.S. standards (20/40), 6 in. high numerals would be legible up to 75 ft. For 20/70 acuity, the WHO boundary for category 0 visual impairment (mild or no visual impairment), Molino et al. (13) predicts that 6 in. high numerals would be legible up to only 43 ft. If such predictions are accurate, the present MUTCD standard of 6 in. minimum countdown numeral height for crossings up to 100 ft is insufficient to accommodate all pedestrians with normal vision.

Geruschat, Hassan, Turano, Quigley, and Congdon (14) used a portable eye tracker to measure where sighted and visually impaired pedestrians looked during actual street crossings. In the final four seconds before crossing, fully sighted pedestrians who chose to wait for the light tended to fixate more on the traffic controls than on the vehicles. Pedestrians with visual impairment fixated more on vehicles, and fixated quite infrequently on the traffic controls. One possible explanation for this difference between the visual behavior of sighted and visually impaired pedestrians is that those with visual impairment were unable to locate or confidently read the traffic signals. The participants had visual impairments that resulted from either age-related macular degeneration or glaucoma, and thus it is reasonable to speculate that at one time these participants would have performed similarly to the fully sighted participants. Perhaps as their vision deteriorated, they adapted their behavior as a result of finding that visual pedestrian signals were often too difficult to effectively use.

In the United Kingdom, near side pedestrian signals have been used since the early 1990's at Puffin (Pedestrian User Friendly Intelligent) crossings (15). The pedestrian signal at a Puffin crossing is normally mounted on a pole that is located where waiting pedestrians have a clear view of approaching traffic and the pedestrian signal simultaneously. Other pedestrian detection and timing changes are part of the standard installation. Installation guidance states that "the position of the near side signal should also help visually impaired people using crossings who may not be able to easily discern signals mounted across the road" (15, p. 40); however, no research seems to specifically included pedestrians who were visually impaired. Near side pedestrian signals have not been installed, to date, in the United States.

The research reported here is the first of a series of empirical research studies to determine the usability of pedestrian signals by persons with varying visual acuities under different conditions of signal design and environmental elements.

METHODS

Participants

Twenty-seven Elon University undergraduate students participated in the experiment in order to fulfill course requirements or for course extra credit. Data from two participants were excluded from the analysis due to the participants' failure to follow directions, and one participant was excluded due to experimenter error that resulted in lost data. The results discussed below are from the remaining 24 participants (11 males, 13 females). All participants, by self-report, had visual acuity of approximately 20/20, either with or without the use of contact lenses, and had otherwise healthy vision. Seven participants who wore contact lenses were asked to wear them for the study; no participants used spectacles for correction.

Materials

Digital photographs were taken of 12 pedestrian signalized crossings in the metro-Boston, MA area. All photographs were taken on mostly sunny, relatively cloudless days, between the hours of 10:00am and 2:00pm in order to control for lighting and shadows. The photos were displayed on a 19 in. flat-panel computer monitor, situated approximately 18 in. from participants' viewing position. This distance resulted in the visual angles produced by the various elements within the photographs being approximately equal to those in the natural environment.

Three stimulus variables were manipulated either through the use of natural intersection differences or digital photo manipulation. Crossings were chosen with two of the stimulus variables in mind; pedestrian crossing length and background for the visual pedestrian signal. Pedestrian crossing length was measured along the center of the crosswalk from the near-end curb-line to a position directly below the pedestrian signal head. Six of the intersections were classified as long pedestrian crossings – six to eight lanes of traffic with pedestrians entering the crosswalk 99 to 129 ft (30.2 to 39.3 m) from the pedestrian signal head indications, with an average distance of 110 ft (33.5 m). The other six intersections were classified as short – five to six lanes of traffic with pedestrians entering the crosswalk 70 to 85 ft (21.3 to 25.9 meters) from the pedestrian signal head indications, with an average of 77 ft (23.5 m). The use of the term “short” is relative to the longer crossings; however, while not particularly short in an absolute sense, these crossing distances are common in the U.S.

The second stimulus variable of interest was the type of background behind the visual pedestrian signal – foliage, buildings, or sky. There was some variability in the natural environment, but digital photo manipulation was used in some cases in order to alter the background. Figure 1 shows example crossings, although in the reduced size presented here, the pedestrian signals are quite difficult to see (signals have been circled for the purposes of this article).

For the third and final stimulus variable of interest, pedestrian signal size, digital manipulation was first used on all photographs in order to remove the original pedestrian signal and often the pole on which it was mounted. A photo of an LED pedestrian signal subjectively judged to be in excellent working condition and highly visible was then digitally inserted into each photograph. This was done in order to control for variations in signal visibility (e.g., luminance level of the display, glare and other lighting features). The

symbols used had heights of either 9 or 12 in. (22.9 and 30.5 cm). Nine inch high symbols were chosen based on guidance provided in the MUTCD (minimum 9 in. high symbols for crosswalk entry to pedestrian signal distances of 100 ft or more (7, Part 4E.0 par 09)) and by the ITE (minimum 9 in. high symbols for crossings of 60 ft or more (16, Part 3.1)). Twelve inch symbols represent a class 4 signal as defined by the ITE (16), one of three acceptable classes of pedestrian signal indication for crossings of 60 ft or more. Given the number of variables to be considered, and the need to cross all levels of all variables, we chose to limit the included signal sizes to these two conditions. The decision to not test 6 in. high symbols was made based on evidence provided by others that suggested that even 9 in. symbols would pose considerable challenges to pedestrians with the simulated acuities used here and for the included crossing distances (13).

Digital resizing of the pedestrian signal head was conducted so that for all crossings the photographs contained signals with characters that produced the same visual angles when viewed on the monitor as they would when viewed in the natural environment at either 77 or 110 ft (i.e., the average crossing distances present in the photographs). For example, a 9 in. high character viewed at 110 ft produces a visual angle of 0.391 degrees, and thus characters 1/8-in. high were displayed in the experiment resulting in a visual angle of 0.398 degrees. The average difference between the real-world visual angle and the visual angle present in the experiment for the four combinations of crossing length and signal size was 0.01 degrees.

All signals used the white walking man symbol for the Walk interval, used the orange upraised-hand symbol for the Don't Walk intervals, and included orange countdown displays in the Don't Walk conditions to the right of the upraised-hand symbol (countdown numbers were not presented for signals displaying the Walk interval). The countdown display indicates the amount of time remaining on the current pedestrian phase – in this research, a number from 1 to 12.

To prevent use of the crosswalks as a definite indication of the signal location, since signals are not consistently located within the crosswalk in the U.S., the location of the signal was also systematically varied. The signal was in one of four basic locations, either outside the lines of the crosswalk to the left, outside to the right, or within the crosswalk but off-set slightly to the left or to the right.

The approximate visual acuity of participants was also manipulated in a within-subjects manner. This was achieved by using a special set of goggles with interchangeable lenses, and by affixing Bangerter occlusion foils to some sets of lenses. One set of lenses remained unoccluded, while foils were affixed to other sets in order to simulate visual acuities of 20/100 and 20/300. Bangerter occlusion foils are thin flexible vinyl foils of varying opacities typically used in the treatment of amblyopia (17) and diplopia (18), but they have also been used in research to simulate cataracts (19, 20).

Degrading acuity by means of simulation was used instead of participants having reduced acuities, as reduced acuity has numerous etiologies, and persons with reduced acuity often have multiple pathologies that affect more than visual acuity. Participants having similar visual acuities may have quite different functional vision. Acknowledging that reducing the acuity of a fully sighted participant is not the same as the acuity loss from an eye with pathology, degrading acuity of persons having 20/20 vision by means of simulators enabled us to greatly reduce the variability that occurs when using participants with visual pathology, thereby reducing the necessary sample size to investigate the variables of interest.

Procedure

Participants were tested individually in approximately 20-minute sessions. After reading and signing an informed consent document, participants sat at a table with a computer keyboard in front of them, and the monitor approximately 18 in. away. Each trial began with a 750 millisecond display of a white screen with a black fixation cross (“+”) randomly positioned at one of 12 locations equidistant from the center of the screen. Participants were asked to direct their vision and attention to the cross each time it appeared. The fixation screen was then replaced by one of the photographs, displayed for five seconds. Participants were asked to judge whether the pedestrian signal indicated it was a Walk or a Don’t Walk interval by pressing one of two specific keys on the keyboard. They were instructed to make their judgment as quickly and accurately as possible. If a participant did not respond within five seconds, the screen went to black, and after another five seconds, a prompt screen appeared instructing them to respond. Following the pedestrian interval response, a prompt screen appeared which allowed participants to type in the number of seconds indicated by the countdown display, if present. In the absence of a countdown display, as was true for all pictures showing the Walk interval, participants were instructed not to enter a number and to simply press space to skip the response screen. The numbers entered by participants appeared on the screen in very large type so that they could be read even while wearing the occlusion foils, a procedure that allowed participants to verify that they had typed the number they intended and correct it if necessary. Following this response, a new fixation screen appeared, followed by a new photograph. There was one exception to this procedure. In the simulated 20/300 condition, pilot testing revealed that discrimination of the time on the countdown display was essentially impossible for participants. Thus in the 20/300 condition, participants completed the interval discrimination task and did not complete the countdown task.

Participants responded to 20 practice photos under normal viewing conditions. They then completed 4 blocks of 12 trials in each of the 3 vision conditions, for a total of 48 trials in each vision condition and 144 trials in total. The order of the three vision conditions was counterbalanced. Within each block, 12 photographs were presented in random order, each depicting a unique combinations of the three stimulus variables. Although photos of the same crossings were used in each block, identifying a specific crossing as having been previously seen would not help a participant in making the requested judgments. Photos were digitally manipulated such that in each presentation of a given crossing the location of the pedestrian signal, as well as the interval and countdown information being displayed, was variable. Stimuli were created and selected such that the prevalence of Walk and Don’t Walk intervals was equal and the prevalence of the various countdown values (1–12) was nearly equal.

RESULTS

Each photo represented a combination of the three stimulus variables – crossing length (short vs. long), symbol height (9 vs. 12 in.), and background (foliage, buildings, or sky) – resulting in 12 unique combinations. Each specific combination of variables was displayed four times in each of the three vision conditions; thus for any specific condition (e.g., 20/100, 9 in. symbols, long crossing, foliage background), a participant could score zero to four correct interval identifications (WALK or DON’T WALK) and zero to two correct countdown responses (countdown only present on DW trials – half of all trials). Due to the complexity of an analysis including all four independent variables, the results from the three vision conditions were analyzed separately.

Identifying the pedestrian interval

For participants with self-reported normal or corrected-to-normal vision (approximate acuities of 20/20), rates of success in correctly identifying the pedestrian interval were nearly perfect for all 12 combinations of the three stimulus variables (see Table 1). Performance by participants with simulated visual acuities of 20/100 was marginally worse, while the performance of participants with 20/300 acuity was rather poor.

The 3-way ANOVA measuring success rates in identifying the correct signal interval on the crossing by participants with 20/100 vision revealed no significant interactions and significant main effects for crosswalk length [$F(1, 23) = 16.376, p < .001$] and signal size [$F(1, 23) = 4.264, p = .05$]. Participants averaged 3.8 correct identifications (95%) with short crossings (average distance to pedestrian signal head of 77 ft) and 3.7 (92.5%) with long crossings (average distance of 110 ft). They averaged 3.8 (95%) correct interval identifications with 12 in. symbols and 3.7 (92.5%) with the 9 in. symbols. Although these main effects are statistically significant, it is debatable whether they reflect any practical significance given the high level of accurate identification on all trials and small absolute difference in rates of accurate phase identifications.

The 3-way ANOVA of success rates in identifying the pedestrian interval by those with simulated acuities of 20/300 also results in a significant main effect of crosswalk length [$F(1, 23) = 6.564, p < .05$]. Participants averaged 2.6 (65%) correct interval identifications when the crosswalk was short and 2.3 (57.5%) when it was long. Contrary to what was found in the other vision conditions, the type of background also significantly affected the participants' pedestrian interval judgments [$F(2, 46) = 14.598, p < .001$]. Participants averaged 2.8 (70%) correct identifications when the signal was set in front of foliage, 2.4 (60%) when it was set against buildings, and 2.1 (53%) when it was set against the sky. Given the dichotomous nature of the response, and scores out of 4, it can be estimated from the obtained data that average correct identifications would need to exceed 2.53 (63%) in order to represent performance which is statistically significantly better than chance. There was also a significant crossing length by background interaction [$F(2, 46) = 3.190, p = .05$]; however, it is of little practical importance given that for both crossing lengths participant performance was best in the foliage and worst in the sky condition.

Reading the time on the countdown display, when one was present

Preliminary testing showed that countdown displays were completely unreadable by participants with simulated 20/300 vision; thus participants were not asked to complete this task in this vision condition.

Although a 3-way ANOVA on accuracy of reading the countdown display for those with 20/20 vision reveals a significant 3-way interaction [$F(2, 46) = 7.882, p < .001$], each of the 12 condition means is between 1.8 and 2.0 (90% to 100% correct), suggesting that any statistically significant differences may not be of practical significance (see Table 1). Therefore, no further analyses were conducted for the 20/20 condition.

Participants had considerable difficulty accurately reading the countdown displays in the 20/100 condition, with condition means as low as 0.13 correct identifications out of the possible 2.0 (6.5% correct). A 3-way ANOVA on countdown display reading accuracy for participants with simulated 20/100 acuity reveals a significant three-way interaction [$F(2, 46) = 4.463, p < .05$], a significant crossing length by background interaction, and significant main effects for each of the three manipulated variables. In order to understand the nature of the three-way interaction, post-hoc analyses were conducted in order to

consider the 2-way interactions between signal size and crossing length at each type of background.

Sky Background—When looking only at those pedestrian signals situated in front of a sky background, the length of the crossing is a significant factor [$F(1, 23) = 7.667, p < .05$], with participants performing better on shorter crossings ($M = 0.6$; 30%) than longer ones ($M = 0.4$; 20%; see Figure 2). The main effect of symbol size was also significant [$F(1, 23) = 7.881, p < .05$], with participants performing better with 12 in. symbols ($M = 0.6$; 30%) than 9 in. symbols ($M = 0.3$; 15%). The interaction between the two was not significant.

Building Background—For pedestrian signals set in front of buildings, there was a significant main effect of both signal size [$F(1, 23) = 16.264, p < .001$] and crossing length [$F(1, 23) = 32.833, p < .001$], and no interaction between the two. Overall, people performed better with 12 in. symbols ($M = 0.8$; 40%), than with 9 in. symbols ($M = 0.6$; 30%; see Figure 2). They also performed better on short crossings ($M = 1.1$; 55%) than long ones ($M = 0.3$; 15%). This is the same general pattern of results as occurred in the sky condition described above.

Foliage Background—Participant performance when signals were set in front of foliage was somewhat different than when set in front of other types of backgrounds, a difference that can thus explain the presence of the significant three-way interaction. The two-way interaction between crossing length and signal size is significant [$F(1, 23) = 7.667, p < .05$] (see Figure 2). As was the case in the other background conditions, participants performed best on short crossings with 12 in. symbols ($M = 1.0$; 50%) and somewhat less well on short crossings with 9 in. symbols ($M = 0.6$; 30%) [$F(1, 23) = 4.600, p < .05$]. However, contrary to the simple main effect seen in other background conditions, participants performed better on long crossings when symbols were 9 in. high ($M = 0.7$; 35%) than when they were 12 in. high ($M = 0.5$; 25%), although this simple main effect was not significant [$F(1, 23) = 1.643, p > .05$].

There is no obvious way to explain this relatively good performance of participants on long crossing/small signal trials. It may simply be the result of a chance occurrence. In fact, analysis of unpublished data collected by these authors, using these same methods, did not replicate this particular finding. In that analysis, the pattern of results with foliage background was most similar to that of the buildings background (see Figure 2). Additional testing and/or replication will be necessary to determine if this finding does in fact reflect a unique interaction between the foliage background and the other factors.

Main Effects—The main effect of signal size on countdown recognitions for signals in the Don't Walk interval [$F(1, 23) = 12.286, p < .01$] was such that participants performed better on average with 12 in. symbols ($M = 0.7$; 35%) than 9 in. symbols ($M = 0.5$; 25%). Participants' average performance was also better on short crossings ($M = 0.8$; 40%) than long ones ($M = 0.4$; 20%) [$F(1, 23) = 38.809, p < .001$]. The main effect of background [$F(1, 23) = 3.790, p < .05$] indicates that participants were most accurate when the signal was set against a building or foliage ($M = 0.7$ in both cases; 35%), and somewhat less accurate when the signal was set against the sky ($M = 0.5$; 25%).

9 inch Symbols on Short Crossings vs. 12 inch Symbols on Long Crossings—

An analysis was conducted to compare participant performance with 12 in. symbols on longer crossings and 9 in. symbols on shorter crossings. These two conditions have symbols which produce nearly equal visual angles, and thus one might hypothesize that participant performance ought to be highly similar. However, there is a significant difference between

the two, with participants, on average, performing better on short crossings with 9 in. symbols ($M = 0.7$; 35%) than long crossings with 12 in. symbols ($M = 0.5$; 25%) [$F(1, 23) = 4.285$, $p < .05$]. The interaction between these signal size and crosswalk combinations and background type is marginally significant [$F(2, 46) = 3.150$, $p = .052$]. This is the result of highly similar performance regardless of background with 12 in. symbols on longer crossings (all means between 25% and 27%) but performance dependent upon background with 9 in. symbols on short crossings (sky, $M = 0.5$, 25%; foliage, $M = 0.6$, 30%; buildings, $M = 1.0$, 50%; [$F(2, 46) = 5.863$, $p < .05$]).

GENERAL DISCUSSION AND FUTURE DIRECTIONS

There are a large number of potentially contributing factors to pedestrian success at acquiring visual pedestrian signal information. What is clear is that the U.S. regulations which currently allow 6 in. symbols for crossings up to 100 ft create a pedestrian-signaled environment which is largely unusable by those with 20/300 acuity. Performance on the phase discrimination task by those with simulated 20/300 acuity and with 9 and 12 in. symbols often resulted in performance which was little better than chance despite a highly controlled environment (i.e., no moving vehicles or environmental distractions) and signals which were subjectively in excellent working condition and of high visibility (i.e., good contrast/luminance, no glare). The inability to perform the countdown task is in agreement with the predicted numeral legibility distances provided by Molino et al. (13), which estimated that for those with 20/300 acuity, 12 in. numerals would be legible up to about 20 ft, as compared to the 77 and 110 ft used in this study. Reasonable increases to signal size, or related changes to maximum installation distances, may thus improve interval discrimination by those with this level of visual impairment, but are relatively unlikely to allow for the use of countdown displays (e.g., Molino et al. (13) would estimate a numeral legibility distance for people with 20/300 acuity of only 30 ft for 18 in. numerals).

The U.S. regulation is further called into question by the demonstrated difficulty using countdown indications on signals with 9 and 12 in. symbols by those with 20/100 acuity. This condition is of particular interest given the increasing prevalence of visual impairment with age (4, 5, 6). Furthermore, Brabyn, Haegerström-Portnoy, Schneck, and Lott (21), in a study of the functional vision of 900 people over the age of 55, including 450 in the 75–100 age group, found that although visual acuity as measured by standard clinical testing is preserved relatively well in old age, there were dramatic losses in visual function indicated by the performance of common visual tasks. Three quarters of participants over 85 years of age functioned at 20/200 or worse on a task involving viewing a low contrast target with glare.

The empirical data collected in our simulated 20/100 condition also exhibits good agreement with the predictions of numeral legibility distance computed by Molino and his colleagues (13). Using their methodology, the predicted numeral legibility distance for a 12 in. numeral by an individual with 20/100 acuity would be 60 ft. Thus one could predict that for a 77 ft crossing, participants with simulated 20/100 acuity would have some success but not perform perfectly. In fact, participants in our study made correct numeral identifications on about 47% trials with short crossing and 12 in. symbols (well above chance performance which at best would be 8%).

Evidence provided above demonstrates that the visual angle created by a symbol is not alone sufficient information to predict successful perception of signal information. It may be that with the increased distance, the greater number of foreground objects between the viewer and the signal interferes with task performance. Another possibility is that when signals are at greater distances from the observer, the flanking and background elements will

individually create smaller visual angles, and the result may be that psychologically the background appears more cluttered and/or distracting. In any case, it seems that on longer crossings, symbols which produce larger visual angles may be necessary in order to achieve equivalent performance with that on shorter crossings.

In those conditions where the background influenced participant performance (20/300 interval judgments and 20/100 countdown recognitions), it was often the case that participants performed best when the signal was in front of some type of foliage, and occasionally performed best when signals were in front of buildings. Perhaps the use of backplates would improve overall performance, especially where signals are set in front of open sky, and is something which could be considered in future investigations.

This investigation provides some answers, but also serves to better focus subsequent experiments as we consider additional factors. We did learn that for those with approximately 20/20 acuity, none of the tasks posed much difficulty, and thus this condition may not be highly relevant in future testing. However, the scenarios tested all represented relatively ideal viewing conditions—daytime, without strong shadows or glare. Also, the experimental tasks did not require making actual crossing decisions in the presence of moving traffic.

Future testing could consider additional simulated acuities not tested here, perhaps 20/70 (World Health Organization boundary between categories 0 and 1 visual impairment) and 20/200 (the U.S. legal definition of blindness). It was also found that for those with simulated acuities of 20/300, identifying the numbers on countdown displays under the experimental conditions was essentially impossible, and performance in identifying the pedestrian interval was in 8 of 12 conditions no better than chance. The most consistent finding within the 20/300 condition was that of the 12 combinations of stimulus variables, the four that included foliage as background resulted in four of the five most accurate average interval judgments.

Future research will need to consider what sorts of displays and display characteristics allow such pedestrians to make use of the visual signals and succeed on pedestrian judgment tasks. Perhaps 12 in. symbols at distances of less than 50 ft would allow successful identification of the pedestrian interval, suggesting the importance of pedestrian signal installations on medians for longer crossings. Or perhaps Puffin (Pedestrian User Friendly Intelligent) facilities (i.e., nearside pedestrian signals) would be an effective treatment with regards to low vision pedestrians; a possibility which has been suggested by others (15), but not formally evaluated.

There are limitations to the present study. As noted earlier, degrading acuity by means of simulation does not result in a sample that is perfectly reflective of those with low vision. Often, individuals with low vision will have deficits that extend beyond reduced acuity, and individuals with similar visual acuities may have quite different functional vision. Furthermore, participants in the study were not practiced in identification of pedestrian signals with reduced acuity. It is possible that a sample of individuals with actual visual impairment, who are more practiced at such judgments and who may have developed task-specific techniques for discerning pedestrian interval information, would be more successful. However, the task at hand was to a large extent a psychophysical one. That is, the size of the signal and the type of background were manipulated, and participants were asked to provide two judgments that reflected their perceptual experience. Many techniques that pedestrians with low vision may have developed for interpreting the pedestrian interval in a natural environment would be unlikely to assist on this task. Moreover, in the natural environment the flashing of the Don't Walk indication and the countdown timer provides an

additional cue which would make the pedestrian signal more recognizable than when presented in a static photograph. For these reasons, one could argue that pedestrians with low vision might perform better in a natural setting than what is suggested by the results reported here. It could also be argued, however, that the task would be more difficult in the natural environment; additional visual distractions would exist (e.g., vehicle and pedestrian movements), audible distractions would exist (e.g., ambient noise and traffic noise), and pedestrian signals may be of reduced visibility due to poor luminance, contrast, and/or glare. Despite the limitations, simulations are commonly used in the context of vehicle and pedestrian behavior and decision making (e.g., 22, 23). Thus, we feel that simulations are informative, although eventual validation of findings at real intersections with participants who have low vision would be highly beneficial.

In future studies, we plan to use the methodology described herein to look at whether the concurrent presentation of the upraised hand and countdown display rather than the countdown display alone has an impact on participant judgments of the pedestrian interval information by those with visual impairments. There has been some advocating for the replacement of Don't Walk symbols with just the countdown display, with the belief that the color of the numeric symbols and the "flashing" produced by the changing numbers would be sufficient to indicate a Don't Walk interval. Singer and Lerner (24) have studied the effect of such experimental countdown pedestrian signals; however, while their sample did include middle-age (30–55) and older (60+) adults, no specific focus was placed on vision status. What we discovered in the research reported herein is that participants with simulated 20/100 acuity performed very well at pedestrian interval discriminations, but had greater difficulty judging the amount of time remaining as indicated by the countdown displays. Whether or not the countdown display alone would be sufficient information for such pedestrians to accurately judge the pedestrian interval remains to be investigated. Given the success on interval identification by those with simulated 20/100 acuity, and difficulty with the countdown time identification, the removal of the Don't Walk symbol certainly has the potential to negatively impact interval identification, and may also have subjective consequences (e.g., making pedestrians less confident or more stressed).

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FIGURE 1.

Examples of photos and signal types used in the study. A) 6-lane, 79 foot (24.1 m) crossing with foliage behind the signal (12 in. high symbol). B) 7-lane, 108 foot (32.9 m) crossing with buildings behind the signal (9 in. high symbol). C) Diagrammatic representations of the type of pedestrian signal indication used in this study (indications which meet MUTCD standards for new installations).

FIGURE 2.

Average percent correct countdown identifications on Don't Walk signals for different pedestrian signal symbol heights, crosswalk lengths, and backgrounds by those with simulated 20/100 acuity.

TABLE 1

Average Scores for the 12 Combinations of Stimulus Variables by Level of Visual Acuity

Signal Size	12 in. high symbols						9 in. high symbols					
	Short (~77')			Long (~110')			Short (~77')			Long (~110')		
	F	B	S	F	B	S	F	B	S	F	B	S
Crossing Length												
Background*												
Identifying Pedestrian Interval (Walk or Don't Walk) Maximum Possible Score = 4.0 Chance Performance = 2.0												
20/20	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	4.0	3.9
20/100	3.8	3.9	3.9	3.8	3.8	3.7	3.7	3.9	3.8	3.7	3.6	3.5
20/300	3.2	2.6	2.1	2.6	2.3	2.3	3.1	2.4	2.1	2.5	2.2	1.8
Identifying Time on the Countdown Display Maximum Possible Score = 2.0 Chance Performance = 0.17												
20/20	2.0	1.9	2.0	2.0	2.0	1.9	2.0	2.0	1.8	2.0	2.0	2.0
20/100	1.0	1.2	0.7	0.5	0.5	0.5	0.6	1.0	0.5	0.7	0.1	0.2

* F=foliage, B=Buildings, S=Sky