IDEA

Innovations Deserving
Exploratory Analysis Programs

Intelligent Transportation Systems Program

ANIMATED LED "EYES" TRAFFIC SIGNALS

Final Report for ITS-IDEA Project 73

Ron Van Houten, Center for Education and Research in Safety,
Dartmouth, N.S., Canada

December 2001

TRANSPORTATION RESEARCH BOARD • NATIONAL RESEARCH COUNCIL

INNOVATIONS DESERVING EXPLORATORY ANALYSIS (IDEA) PROGRAMS MANAGED BY THE TRANSPORTATION RESEARCH BOARD (TRB)

This investigation by The Center for Education and Research in Safety, Dartmouth, N.S., Canada was completed as part of the Intelligent Transportation Systems (ITS) IDEA program which fosters innovations in development and deployment of intelligent transportation systems. The ITS-IDEA program is one of the five IDEA programs managed by the Transportation Research Board (TRB). The other four IDEA program areas are: Transit-IDEA, which focuses on transit practice in support of the Transit Cooperative Research Program (TCRP), NCHRP-IDEA which focuses on highway systems in support of National Cooperative Highway Research Program, High Speed Rail-IDEA (HSR), which focuses on high speed rail practice, in support of the Federal Railroad Administration, and Transportation Safety Technology (TST), which focuses on motor carrier safety practice, in support of the Federal Motor Carrier Safety Administration and Federal Railroad Administration. The five IDEA program areas are integrated to promote the development and testing of nontraditional and innovative concepts, methods, and technologies for surface transportation systems.

For information on the IDEA Program contact IDEA Program, (phone: 202/334-3310, fax: 202/334-3471, http://www4.nationalacademies.org/trb/dive-idea.nsf)

Table of Contents

Executive Summary

The use of animated searching 'eyes' LED signals to elicit looking has a biological and psychological basis which is unique to traffic control signals. This basis makes such devices easy to understand and conspicuous signals that could lead to a marked increase in compliance. In this research, completed under FHWA permission to experiment, we evaluated: The use of the animated 'eyes' display as part of the WALK indication on pedestrian signal heads to remind pedestrians to look for turning vehicles; as part of an ITS signal to warn drivers when pedestrians are about to cross the sidewalk in front of them at an indoor parking garage exit; as part of an ITS signal to warn drivers of the presence and direction of pedestrians crossing the street at a midblock crosswalk; and at a passive railroad crossing to remind motorists to stop and look for trains before crossing the railroad grade crossing. Each of the noted interventions produced large and statistically significant safety benefits.

Pedestrian Signal Studies

Previous work by Van Houten, Retting, Van Houten, Farmer and Malenfant (1999) has shown that an experimental animated light-emitting diode (LED) pedestrian signal head that included two eyes with eyeballs that scanned left and right significantly increased pedestrians' observing behavior and markedly reduced pedestrian-motor vehicle conflicts at two signalized intersections. Benefits were sustained over six months, suggesting they were not merely novelty effects. Both intersections examined in this research consisted of roads carrying two-way traffic. These finding are in agreement with earlier data reported by Zegeer, Cynecki and Opiela (1984) which showed that adding the words "WITH CARE" below the text message "WALK" signal reduced pedestrian/motor vehicles conflicts.

The research reported in this report examines the generality of the Van Houten et. al. finding by examining the efficacy of the animated eyes symbol with a variety of typical intersection geometries, and timing parameters.

Experiment 1: Multi Site Conflict Study

Method

Setting

This study was conducted at five signalized intersections in downtown St. Petersburg, Florida, two signalized intersections in Clearwater Florida, and one signalized intersection in Halifax, Nova Scotia, Canada. Two crosswalks were at intersection of one-way streets, four crosswalks were at the intersection of two-way streets, and two were at the intersection of a one-way street and a two-way street.

Data Collection

Three observers scored pedestrian/motor vehicle conflicts on weekdays between the hours of 9:00 a.m. and 4:30 p.m. Each session included the collection of data from 50 pedestrians starting to cross the street during the WALK interval at all eight intersections. A pedestrian/motor vehicle conflict was scored if the driver of a turning vehicle had to engage in abrupt braking, had to swerve to avoid striking the pedestrian being observed, or if the pedestrian had to take sudden evasive action to avoid being struck.

Inter-observer Agreement
Two observers independently scored pedestrian/motor vehicle conflicts during two sessions during the baseline condition and two sessions during the treatment condition at each of the eight sites. A measure of inter-observer agreement was computed by dividing the number of agreements on the occurrence conflicts by the number of agreements on the occurrence of conflicts plus disagreements. Inter-observer agreement was 100% for pedestrian-motor vehicle conflicts.

Apparatus
The equipment used in this research was an LED signal head. The 'eyes' display was populated with blue (460 nm) LEDs and consisted of two blue eyes with blue eyeballs that scanned left and right. The eyes were each 5 inches wide, 2.7 inches high and 2.25 inches apart. The WALK indication was an 11.2 inch-high outline of a walking person constructed from blue LEDs. The DON'T WALK indication was an 11.2 inch-high upraised hand constructed from orange (615 nm) LEDs. The DON'T START indication consisted of the flashing DON'T WALK, as specified in the Manual on Uniform Traffic Control Devices (U.S. Department of Transportation, 1988). A photograph of the device is shown below in Figure 1.

Figure 1, The experimental pedestrian signal.

Experimental Design
A before/after research design was employed in this research. Data were collected for 14 days at each site for a total of 700 pedestrian crossings during the baseline and treatment conditions.

Results

The number of conflicts per session observed at each of eight locations, before and after the treatment (baseline vs. animated 'eyes') is presented in Figure 2. It was hypothesized that there would be a decrease in conflicts as a result of the treatment. This was tested for each location, and for the total number of conflicts across all locations, using Wilcoxon-Mann-Whitney tests. This non parametric test was selected because the number of conflicts were non-normal but rather Poisson in nature. There is a significant (P=<05) decrease in median conflicts at 7 of the 8 locations, but the strongest and most interpretable result occurs across the total of all locations. In this case, the median number of conflicts drops from 8.5 (per 400 pedestrians) to just 1.0. As is seen, although actual numbers of conflicts are small in absolute terms, this decrease is not just statistically significant, but can surely be considered to have practical value. The median number of conflicts decreased in the range of 59% to 94% (95%confidence interval). The results of the Wilcoxon-Mann-Whitney procedure across all 8 sites was significant at the .001 confidence level.

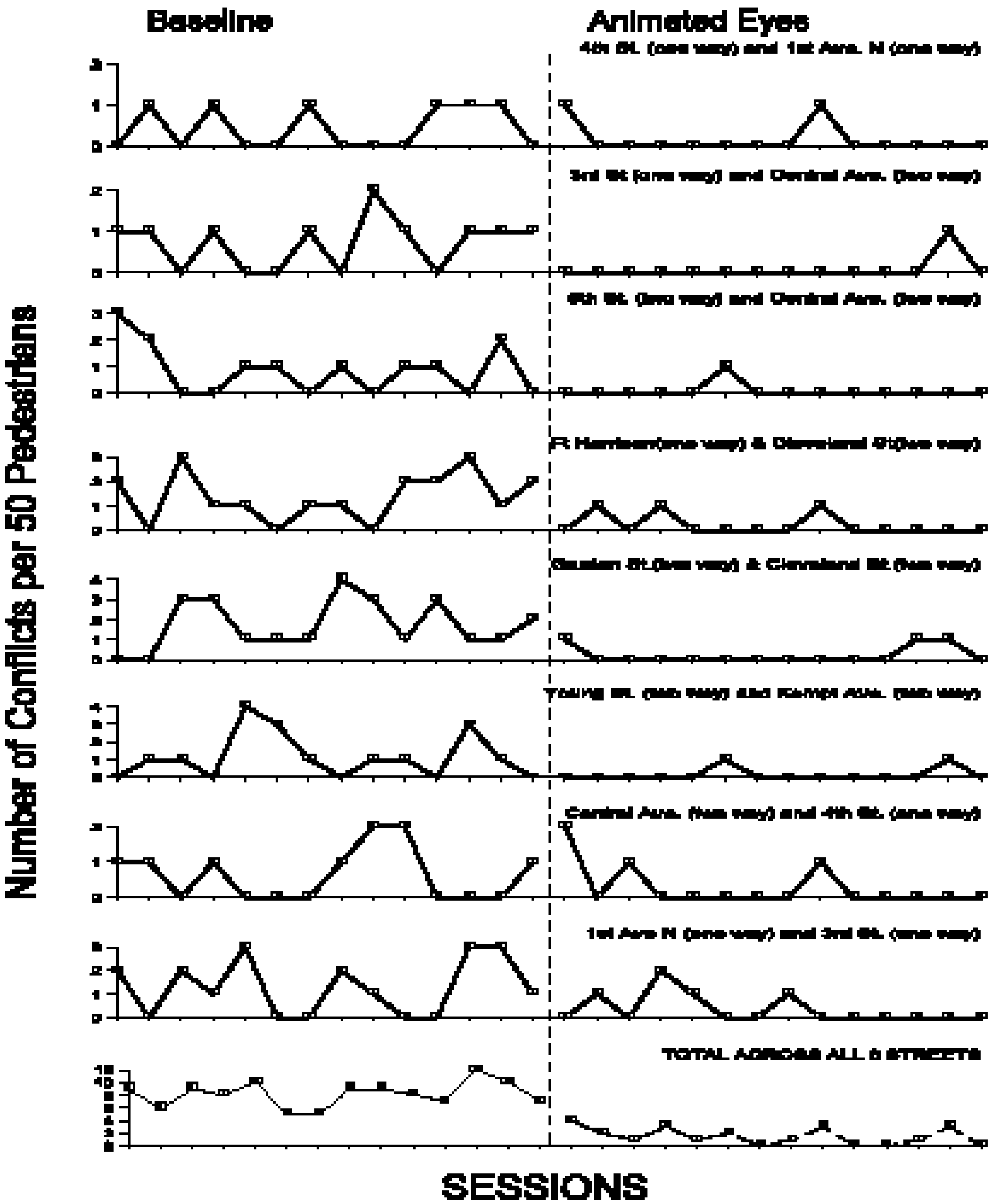

Figure 2, The number of conflicts per session at each site and the total across all sites before and after the animated 'eyes' were installed.

Table 1 shows the results of the Wilcoxon -Mann-Whitney procedure, adjusted for discrete distributions for each site. The null hypothesis is equality of the location parameter (i.e., medians), before and after the treatment, against the alternative that the location is shifted downward by the treatment.

Table 1, Wilcoxon-Mann-Whitney Results

Location	P-Value (2 decimals)	Location	P-Value (2 decimals)
4th St. & 1st Ave. N.	.05	3rd St. and Central Ave.	.01
5th St. & Central Ave.	.00	4th St. and Central Ave.	.07
1st Ave. N. and 3rd St.	.01	Ft. Harrison & Cleveland St.	.00
Garden St. and Cleveland St.	.00	Young Ave. & Kempt Rd.	.03

Discussion

These results confirm that the use of the animated 'eyes' can produce a significant reduction in motor vehicle/pedestrian conflicts that could be expected to translate into a meaningful reductions in crashes at signalized intersections. These data provide a systematic replication of the findings of Zegeer, Cynecki and Opiela (1984) who evaluated a "WALK WITH CARE" indication during the crossing interval at four test sites in three cities. They obtained significant reductions in total conflicts at all four sites. These data taken together with the results of the present studies demonstrate that modifying the WALK indication to remind pedestrians to be more cautious leads to significantly fewer conflicts between pedestrians and turning vehicles.

Experiment 2: Analysis of Directional Prompting and Repeated Prompting

One way to prompt a person to look in a particular direction is to repeatedly look in the direction you wish the other person to look. In many situations people will follow another persons gaze to see what they are looking at. One way to emulate directed looking with an animated 'eyes' display would be to increase the dwell time in the desired direction while decreasing the dwell time in the opposite direction. One purpose of the second study was to examine whether increasing the dwell time in the direction of traffic at crosswalks on one-way streets would be more effective than having the eyes look both ways with equal dwell times.

In previous research Van Houten, Retting, Van Houten, Farmer and Malenfant (1999) compared having the eyes on only during the first 2.5 seconds of the WALK interval with repeating the 2.5 second presentation of the eyes every 7 seconds during the entire WALK interval. They found that repeating the eyes were more effective than just presenting it once at the start of the WALK interval. Another purpose of this experiment was to determine if repeating the animated eyes more often would be still more effective.

Method

Setting

This study was conducted at three signalized intersections in downtown St. Petersburg, Florida, 1st Ave North and 4th Street, Central Avenue and 3rd Street, and Central Avenue and 5th Street. First Avenue North and Fourth Street are one-way, four lane streets with 1st Ave North carrying west bound traffic and 4th Street carrying south bound traffic. Data were collected at the crosswalks on the west side of 1st Avenue North and the north side of 4th Street because these crosswalks had conflict points with right and left turning traffic respectively. Central Avenue has one lane in each direction at the intersection with 3 rd Street and one lane in each direction with right turning lanes at the intersection of 5th Street. Third Street is a one-way with four lanes carrying southbound traffic. Data were collected at the south crosswalk on Third Street because it had both right and left turning conflicts with vehicles turning from Central Avenue. Fifth Street is a four lane road with two lanes in each direction. Data were collected at each crosswalks on this street. All crosswalks were 10 feet wide and marked with two parallel white lines. The duration of the WALK indications were: 12 seconds for crosswalks on 1st Avenue North and 20 seconds for crosswalks on 4th Street; 6 seconds for the crosswalk at Central Ave and 4th Street; and 15 seconds all crosswalks at Central Avenue and 5th Street.

Data Collection

Three observers scored pedestrian's observing behavior and pedestrian/motor vehicle conflicts on weekdays between the hours of 9:00 a.m. and 4:30 p.m. Each session included the collection of data from 50 pedestrians crossing at the start of the WALK interval and as many pedestrians that could be scored crossing during the remainder of the WALK interval. To be scored as crossing during the start of the WALK interval the pedestrian had to begin to cross within 4 seconds of the start of the WALK indication. Pedestrians that started to cross during the remainder of the WALK indication were scored as crossing during the WALK interval. Because the WALK indication was only 4 seconds long at 3rd Street and Central Avenue, no pedestrians could be scored as beginning to cross during the WALK interval at this site.

Pedestrian observing behavior was scored whenever a pedestrian looked in the direction of a potential conflict before crossing the conflict path. Because turning vehicles can turn into more than one lane at the junction of two one-way streets the pedestrian had to check for turning vehicles before crossing several lanes. At 5th Street and Central Avenue the pedestrian had to look for vehicles turning right on red, left on green and right on green before entering the turning vehicle's lane of travel. To be scored as checking for a particular threat, a pedestrian had to orient his or her head in the direction from which the vehicle would be coming prior to and within three seconds of entering that vehicle path. From each group of waiting pedestrians, a lead pedestrian was selected. Pedestrians/motor vehicle conflicts were scored as described in the preceding study.

Inter-observer Agreement

Two observers independently scored pedestrian behavior and pedestrian/motor vehicle conflicts during two sessions for each research condition. A measure of inter-observer agreement was computed by dividing the number of agreements on the occurrence of each behavior by the number of agreements on occurrence plus disagreements. Inter-observer agreement averaged 85% for not looking for any threats, 90% for looking twice, 85% for looking for all threats, and 100% for pedestrian/motor vehicle conflicts.

Apparatus

The LED signal head with the 'eyes' display described above was employed during the treatment condition at each site. The signal head used in previous research (Van Houten, Retting, Van Houten, Farmer, & Malenfant, 1999) was redesigned so that scanning rate, dwell times, and presentation duration could each be programmed on site.

Experimental Design

A reversal design was employed at each site in this research. At 3rd St. and Central the eyes looking back and forth with equal dwell times was compared with the eyes looking one way (unequal dwell times). At 5th St. and Central alternating presenting the eyes on for 3.5s and off for 3.5s during the WALK interval was compared with alternating presenting the eyes on for 3.5s and off for 7s. Both interventions were examined at 4th St. and 1st Ave. North.

Following the baseline condition at the At 4th St. and 1st Avenue North site the 'eyes' looking both ways (equal dwell times of 0.5 seconds in each direction) was first introduced. Next the eyes were programmed to look one way with a dwell time of 0.7 seconds in one direction and 0.3 seconds in the other direction (a value that equated cycle duration). This value was selected because the data from a human factors study showed that 30 out of 30 subjects stated that they perceived this display as looking in the direction of the longer dwell time. Next the device was programmed to look both ways again followed by a condition where the eyes looked only one way. Next the interval that the eyes were off was varied from 3.5 to 7 seconds.

At 3 rd Street and Central Avenue the 'eyes' looking both ways (equal dwell times of 0.5 seconds in each direction) was introduced following the baseline assessment. Next the 'eyes' were programmed to look one way (in the direction of the one way traffic) with a dwell time of 0.7 seconds in one direction and 0.3 seconds in the other direction. Next the device was programmed to look both ways again. After 9 sessions in this condition the 'eyes' display was programmed to look in the direction of the threat with a dwell time of 1 second and in the other direction with a dwell time of 0.25 seconds (the value which gave the best perception of directed looking in human factors testing). This condition was followed with a return to the 'eyes' looking both ways for 14 sessions and a return to the 'eyes' looking one direction with the 1 second and 0.25 second dwell times for the final condition. At 5th Street North and Central Avenue the 'eyes' looking both ways was introduced following the baseline condition with the 'eyes' on for the first 3.5 seconds of the WALK interval and repeated after being off for 3.5 seconds. Next the 'eyes' were alternately on for 3.5 seconds and off for 7 seconds. During the final condition the 'eyes' were alternately on for 3.5 seconds and off for 3.5 seconds.

Results

Data Analysis

An arcsin transformation was applied to stabilize the variances in each of the three statistical analysis. In addition, suspected outliers were detected and removed. This correction had no effect on the significance of any of the analyses. After the arcsin transformation there was no evidence of heteroscedasticity or non-normality ($P > .05$ in all cases). The data collected at 4th Street and 1st Avenue North were analysed with a one way anova with treatment groups broken down into baseline, eyes looking one way, eyes looking both ways, eyes repeated every 3.5 seconds and eyes repeated every 7 seconds. A significant difference among treatments was found in each case ($P= <.0001$). A Tukey's analysis revealed that overall there were highly significant differences in the percentage looking for no threats and the percentage looking twice at the start of the WALK and during the remainder of the WALK between the baseline vs the animated 'eyes' condition ($p= <.05$) and that in each case repeating the eyes after 3.5 seconds was superior to repeating them every 7 seconds ($p= < .05$).

The data collected at 5th Street and Central Avenue were analysed with a one way anova with treatment groups broken down into baseline, eyes repeated every 3.5 seconds and eyes repeated every 7.5 seconds. Overall there were highly significant differences between the treatment groups ($p= <.0001$). The Tukey's analysis revealed that this resulted from the baseline vs. animated 'eyes' contrast rather than the 3.5 second repeat interval vs. 7 second repeat interval contrast. The data collected at 3rd Street and Central Avenue were analysed with a one way anova with treatment groups broken down into baseline, eyes looking one way and eyes looking both ways. Overall there were highly significant differences between the treatment groups for the percentage not looking ($F=54.14$, $P<.0001$) and the percentage looking twice ($F=8.63$, $P<.0001$). The Turkey's contrast analysis indicated that the percentage not looking during treatment differed from baseline ($p<.05$). However, the percentage not looking did not differ between the two way and one way prompting conditions.

Discussion

The results of this research demonstrated that the use of the animated ‘eyes’ display was effective in increasing pedestrian observing behavior at all major urban intersection geometries. The results also showed that prompting pedestrians to look in the direction of the threat was no more effective than prompting them to look both ways.

There are several possible reasons why prompting pedestrians to only check for threats in one direction did not produce a marked improvement in the percentage of pedestrians looking for threats with turning vehicles: First, pedestrians who look both ways are as likely to see threats as people who only look in the correct direction. Second, most pedestrians who cross in downtown St. Petersburg are regular users, who are familiar with the streets and therefor already know which way to look for turning vehicles.

Although the use of directional prompts does not seem to present a major advantage at crosswalk applications it may be more useful in ITS applications where the threat can be detected as coming from a particular direction. For example, at garage exits pedestrians are usually not present, but when they are they could come from either direction and it is important that drivers know which direction to look first because they are only visible for a relatively short time before crossing the vehicle path. In this type of application directionality may offer significant advantages. Furthermore, it is possible to increase the directional effect by having a pictograph of the threat on each side of the ‘eyes’ display. The detection of a threat in one direction could then be associated with both eyes repeatedly looking in the direction of an illuminating the target symbol oriented in the direction that the pedestrian is crossing.

Although repeating the ‘eyes’ display was more effective in prompting pedestrians at 4th St. and 1st Ave N. it did not produce a significant improvement at 5th St. and Central Ave. One possible reason for the small effect at 5th St. and Central Avenue are differences in the site characteristics. At 4th St. and 1st Ave N. the approach to the intersection was less clearly visible because physical features such as outdoor eating establishments, awnings etc. could block the view of the signal head, while at the 5th St. and Central Ave. site the intersection was relatively open and the signals could be seen by pedestrians approaching the intersection from a block away. Thus it is more likely that pedestrians would see the animated ‘eyes’ display as they approached this intersection. Another possible reason why little difference was detected at the 5th and Central Ave. site was that high levels of looking behavior at this site may have imposed a ceiling effect on further improvement.

Experiment 3: Presenting the ‘Eyes’ During the Entire WALK Interval

Because no sign of cognitive capture was noted in the previous studies the purpose of this study was to evaluate the effect of presenting the ‘eyes’ display throughout the entire WALK interval.

Method

Subjects and Setting

This study was conducted at 1st Ave North and 4th Street in St. Petersburg, Florida between December/98 and January/99.

Data Collection
Observers scored pedestrian's observing behavior and pedestrian-motor vehicle conflicts on weekdays between the hours of 9:00 a.m. and 4:30 p.m. Each session included the collection of data from 50 pedestrians crossing at the start of the WALK interval. To be scored as crossing during the start of the WALK interval the pedestrian had to begin to cross within 4 seconds of the start of the WALK indication. Pedestrians that started to cross during the remainder of the WALK indication were scored as crossing during the WALK interval. Pedestrian observing behavior and motorist/pedestrian conflicts were recorded in same way as described in the previous studies.

Apparatus
The equipment used in this research was the LED signal head described in the first field study.

Experimental Design
An ABA reversal design was employed in this research. The 'eyes' were programmed to look both ways (equal dwell times of 0.5 seconds in each direction) throughout the experiment. During the intermittent presentation condition the 'eyes' display onset was simultaneous with the onset of the WALK indication and terminated after 3.5 seconds. The 'eyes' display was then repeated after being switched off for 3.5 seconds. During the continuous presentation condition the 'eyes' were programmed to remain on during the entire WALK interval.

Results
The results of this study showed that fewer pedestrians starting to cross later during the WALK interval looked for no threats when the 'eyes' were presented continuously and that more pedestrians looked twice for threats when the 'eyes' were presented continuously. However, none of these differences were significant. Only one conflict was detected during this study.

Discussion
The results of this study show that presenting the animated 'eyes' throughout the entire WALK indication is not less safe than presenting the animated 'eyes' intermittently. Because it is technically easier to present the animated 'eyes' throughout the entire WALK interval it is recommended that crosswalk signals should be designed to perform in this manner.

Low Vision Pedestrian Study
In recent years the traffic safety community has begun to study the problems of blind pedestrians. The majority of the work that has been done has focused on the totally blind traveler and the use of auditory and/or haptic information with little attention to the visual signals for the partially sighted individual. This lack of research is particularly problematic when considering that approximately 80-85% of the legally blind population has some remaining vision. The purpose of this study was to compare incandescent and LED pedestrian signals with and without the animated eyes feature.

Method
Participants
Eighteen adults, 6 males and 12 females classified as legally blind served as participants in this experiment based on acuity and useful visual field. Participants ranged in age form 20 to 72.

Apparatus
The following seven stimuli were tested in this study: an incandescent white pedestrian symbol, a LED white pedestrian symbol; a LED blue pedestrian symbol; a LED blue pedestrian symbol with animated

eyes; a LED white pedestrian symbol with animated eyes; an incandescent white hand symbol; a LED white hand symbol; a LED blue hand symbol. The 'WALK' indication was an 11.2-inch-high outline of a walking person (standard pedestrian symbol) in all cases. The EYES display was the same type as described in the previous study. Brightness was equated to an average luminous intensity of 110 Candela by adjusting the pulse width modulation of the internal power supply. Light measurements (in Lux) were made with a N.I.S.T. certified illuminance meter (Yokogowa 510-02) and converted to luminous intensity.

Procedure
Because LED signals and animated eyes were not in general use in the city of Halifax at the start of the study, each participant was first shown each of the stimuli at a distance of 10 feet and 40 feet indoors in order to ensure that they would be familiar with the stimuli used in the study. They were also asked what each of the stimuli resembled at the further distance in order to require them to attend to the critical features of each stimulus. Most participants mentioned: The dark area in the center of the palm and the thumb extending off at 45 degree angle on the hand for the LED hand symbol; the legs forming an inverted 'V' for the LED and incandescent pedestrian symbol; and that the display looked like a fussy digit '7' (or inverted 'L') for the LED pedestrian symbol with the animated eyes (the pedestrian symbol being the vertical portion of the seven and the eyes forming the top of the seven). All data were collected outdoors between the hours of 1:00 pm and 4:00 pm. Stimuli were presented in 4 blocks, with each block containing one trial with each of the stimuli associated with the WALK indication and an equal number of DON'T WALK stimuli presented in a random order. Trials were initiated by having the participant stand 130 feet from the pedestrian signal. The participant was then asked if they could identify the color or the shape. If they could not they were instructed to approach the signal until they could and then tell the experiment their response. The experimenter recorded the distance along with their selection. They proceeded until they identified both the color and shape. Participants were not given feedback on the correctness of their selection. Once they had identified the shape of the object they were asked to continue walking and report if they wished to change their mind. If any subject changed their mind the second distance was also recorded. This procedure ensured that a distance for correct recognition was obtained for each participant on each trial.

Results

Participants were able to identify signals with the animated eyes at a distance 57 percent further away. A two-way ANOVA using a weighted least squares showed significant effects. The subject, and treatment sources of variability, as well as the overall model, were all significant with a P value < .0001 (Model F = 21.47; Subject F = 17.88; Treatment F = 38.07). Tukey's method showed a significant contrast between the signals with the animated eyes display and signals without this display (F = 149.88, P - value < .0001). There were no significant differences between the incandescent and LED signals without the animated eyes or between the blue and white LED signals.

Although recognition distances varied considerably from Individual to individual, the overall group trends are closely reflected in the individual data. For example, 15 out of 18 participants were able to recognize the WALK symbol further away when the eyes were present. Of the remaining 3 participants 1 could recognize WALK plus eyes stimuli at the maximum distance and the remaining 2 participants showed little difference in recognition distance. It should be noted that neither of these participants reported being able to see a large figure, such as a '7' or upside down 'L' when identifying the WALK plus 'eyes' display.

Discussion

It should be noted that the LED pedestrian signals were equated for brightness with the incandescent signals. Normally LED pedestrian signals are significantly brighter than incandescent signals which should lead to improved recognition distance. However, when brightness was controlled there was little difference in the discriminability of the LED and incandescent signals. However, the addition of the EYES display to the WALK indication lead to a significant increase in the distance that pedestrians could identify the WALK indication with confidence. Although many low vision pedestrians could discrimination the 'WALK' and 'DON'T WALK' signal based on color cues there always exists a certain degree of uncertainty because they could not always tell whether the white or orange light was actually part of the pedestrian signal. This is a particular acute problem in an urban environment where there are many white and orange lights present.

General Discussion on Pedestrian Results

The results of all this research and of previously reported studies (Van Houten, Retting, Van Houten, Farmer and Malenfant, 1999; Van Houten, Van Houten, Malenfant, & Andrus, 2000) document that the animated 'eyes' display can improve safety in a number of sites where it is important for drivers and pedestrians to look for potential threats. These results support these findings and show that the animated eyes display is effective at all common intersection geometries.

Because the animated eyes display prompt pedestrians to look for threats from turning vehicles they should be on during the entire WALK interval if it is an unprotected pedestrian phase. The eyes could be omitted when the pedestrian phase is exclusive. The results of the study with blind pedestrians with low vision also showed that the presence of animated eyes can assist these pedestrians to determine when it is safe to cross.

ITS 'Eyes' Application Experiments

Introduction

A good deal of evidence suggests that driver inattention is a major cause of motor vehicle crashes. When drivers do not attend to critical features of the driving environment they cannot respond in a timely manner to threats. One way to alert drivers to the presence of potential threats is the use of flashing yellow warning beacons. However, this type of signal does not provide specific information about the nature or direction of the threat nor does it request specific action on the part of the driver. One study that examined the effect of yellow flashing beacons at midblock crosswalks reported only small increases in motorist yielding behavior (Gallagher,1999). Previous research has demonstrated that adding animated eyes that scan from side to side at the start of the WALK signal can increase pedestrians' observing behavior and decrease conflicts between pedestrians and turning vehicles (Van Houten, Retting, Van Houten, Farmer, & Malenfant,1999), Benefits were sustained over six months, suggesting they were not merely novelty effects. It is also possible to employ the animated eyes display to signal a motorist to look for a particular threat, and the animated eyes display can be supplemented with a symbol representing the threat the driver should attend to, e.g. pedestrian, vehicle, bicycle, trolley, etc. Such a signal could be further enhanced by providing information on the direction of the threat by only illuminating a symbol of the threat on the appropriate side of the 'eyes' display. Such an ITS sign displays the nature of the threat, the direction of the threat, and instructs the motorist to look in the direction of the threat.

Indoor parking garage exits and midblock crosswalks that traverse multilane roads are two locations where such an ITS device could provide helpful information to motorists. At parking garage exits drivers often have poor visibility of pedestrians approaching on the sidewalk in front of them, and many pedestrians are struck at these locations (Hunter, Stutts, Pein, & Cox, 1996), Pedestrians at midblock crosswalks are less conspicuous than at intersections, which increases the risk of multiple threat crashes (Snyder,1972). In a multiple threat crash a pedestrian is struck after another vehicle(s) has yielded to the pedestrian blocking the vision of motorists approaching in the next lane of traffic.

The purpose of this study was to examine the efficacy of an ITS signal that included animated 'eyes' and pedestrian symbols at a garage exit with limited visibility, and to compare the ITS signal with an animated eyes display with an ITS flashing beacon at a midblock crosswalk location.

Method

This study was conducted at the exit to the indoor parking garage at the municipal services building, and at a midblock crosswalk on Central Avenue in the city of St. Petersburg, Florida. Vehicles exited the indoor parking garage onto a one-way street and had to turn left upon exiting. Drivers therefore had to look right to determine an appropriate gap in traffic. The drivers view of pedestrians approaching from the left was poor with pedestrians only becoming visible just before crossing the driveway. Because drivers visibility of pedestrians approaching from the left was poor and motorists needed to look to the right to determine whether they had an appropriate gap, management had installed a convex mirror to enable motorists to see pedestrians approaching from the left and posted a number of warning signs at the exit.

The midblock crosswalk linked two major bus stops on each side of Central Avenue. Central Avenue is a four lane road carrying two way traffic with a speed limit of 30 mph and an ADT of 10,000. The crosswalk was well marked with advance signing, and included advance yield markings and signs prompting motorists to yield at the yield markings to reduce the risk of yielding vehicles blocking the view of the pedestrian.

Data were collected on each of 25 drivers per daily session at the parking garage exit and two sets of 20 pedestrians and at least as many drivers during each daily session of the experiment at the midblock crosswalk. It typically took approximately 6 hours of observation to collect data on 25 drivers exiting while pedestrians were present at the parking garage exit, and approximately 2 hours of observation to collect data on 20 pedestrians at the midblock crosswalk. Data were not collected on driver behavior when pedestrians were not present during any condition of the experiment. Data were collected by observers on weekdays between 8:30 a.m. and 5:30 p.m. Observers measured driver yielding to pedestrians, and motor vehicle-pedestrian conflicts at the parking garage and midblock locations. Observers also scored whether drivers looked in the direction of the pedestrian at the parking garage location, and the percentage of pedestrians stranded in the middle of the road at the midblock crosswalk location. Two inductive loops measured the time it took for vehicles to traverse the last 11 feet before crossing the sidewalk at the garage exit. The loops only recorded transit time when a pedestrian was present on the sidewalk. Transit times were not collected during the final two sessions of the study because of equipment failure.

Parking Garage Exit

Observers were positioned at a location behind and to the side of exiting vehicles that afforded a good view of the driver and the vehicle and scored driver behavior only when a pedestrian was approaching or present. The observer could see a set of lights that indicated the presence and direction of approaching pedestrians (these lights were not visible to drivers). Looking in the direction of the pedestrian was defined as the driver turning his or her head in the direction of the approaching pedestrian before crossing the sidewalk. A motor vehicle/pedestrian conflict was scored if the driver of an exiting vehicle had to engage in abrupt braking, or if the pedestrian had to take sudden evasive action to avoid being struck. The driver was scored as yielding to a pedestrian whenever the driver stopped and waited for the pedestrian to cross the exit. The pedestrian was scored as yielding whenever the pedestrian stopped and waited for the driver to exit before proceeding to cross the exit. The event was scored as not applicable if the pedestrian was already most of the way across the exit when the driver was in a position to leave or the driver left before the detected pedestrian appeared at the start of the exit.

Midblock Measures
An observer measured the percentage of motorists yielding to pedestrians. Pedestrians had to indicate their intention to cross the street by standing at the curb between the crosswalk lines facing the roadway or oncoming traffic. Only drivers who were more than 185 feet beyond the crosswalk (specific reference points were used) when the pedestrian indicated an intention to cross the street, were scored as yielding or not yielding to pedestrians. Drivers inside this reference point when the pedestrian appears at the crosswalk were not scored. When the pedestrian first started to cross, only drivers in the first two lanes were scored for yielding. Once the pedestrian approached the painted median, the yielding behavior of motorists in the remaining two lanes were scored.

A conflict between a motorist and a pedestrian was scored whenever a motorist had to suddenly stop or swerve to avoid striking a pedestrian or a pedestrian had to jump, run or suddenly step or lunge backward to avoid being struck by a vehicle. A pedestrian was scored as stranded in the center whenever he or she had to wait at the painted median because cars in the final two lanes of travel did not yield to them.

Inter-observer Agreement
Two observers independently scored pedestrian behavior and motor/vehicle pedestrian conflicts during two sessions for each research condition at each site. A measure of inter-observer agreement was computed by dividing the number of agreements on the occurrence of each behavior by the number of agreements on occurrence plus disagreements. At the garage exit Inter-observer agreement averaged 94% for not looking in the direction of the pedestrian, 88% for yielding to pedestrians, and 100% for conflicts between motorists and pedestrians. At the midblock crosswalk location inter-observer agreement averaged 88% for yielding behavior, 100% for conflicts, and 96% for pedestrians stranded at the centerline.

Apparatus

ITS Animated Eyes Signals
The device used in this research consisted of a pair of animated 'eyes' positioned between two pedestrian symbols. On the right side of the eyes was an LED pedestrian symbol with the pedestrian approaching from the right and on the left side was a mirror image pedestrian symbol approaching from the left. When a pedestrian was detected at the garage location approaching from only one side, the icon on that side was illuminated and the eyes looked back and forth with a longer dwell time on the approaching side at a rate of 1 cps. When pedestrians were detected approaching from both sides, both pedestrian icons were illuminated and the eyes looked back at forth with equal dwell times at a rate of 1 cps. At the midblock crosswalk the eyes looked back at forth with equal dwell times at a rate

of 1 cps whether the left, right or both pedestrians symbols were illuminated because the pedestrian(s) could be located anywhere in the crosswalk.

A photograph of both signals is shown in Figure 3. The garage signal measured 36 cm. high by 90 cm. wide, the eyes were each 12.7 cm. wide, 7 cm. high and 5.7 cm. apart, and the pedestrian symbols were each 32 cm.-high. The 'eyes' and pedestrian symbol displays were populated with yellow (590 nm) LEDs. The garage signal was mounted in the lower portion of the concrete header wall just above the sidewalk. The midblock crosswalk sign measured .67 meters high by 1.3 meters wide, the eyes were each 19 cm. wide, 10 cm. high and 8.8 cm apart, and the pedestrian symbols were each a 45 cm.-high outline of a walking person. The 'eyes' were populated with white LEDs and pedestrian symbol displays were populated with yellow (590 nm) LEDs. The midblock signs were mounted over the lane line in each direction on two span wires with a downward angle of 5 degrees. The yellow flashing beacons were installed next to the animated 'eyes' sign. A switch in the control cabinet allowed the researchers to select either the beacons or the animated 'eyes' operational mode.

Figure 3, Garage and crosswalk signals

Pedestrian detection
Pedestrians were detected at the garage exit using two microwave detectors, mounted on the outside wall of the garage and aimed down and along the sidewalk toward the path of approaching pedestrians. The sensors were directional and turned on the eyes and illuminated the appropriate pedestrian symbol depending on the direction that pedestrian was approaching. The signal was activated for the duration of detection plus 5 seconds.

Pedestrians were detected at the midblock location using two departure microwave sensors. The sensors were directional and activated the appropriate display based on the pedestrian travel path. The signal was activated for the duration of detection plus 15 seconds.

Experimental Design

Garage Exit
A reversal design was employed at this location. Following a baseline period during which the sensors were functioning but the sign was not present, the sign was installed and connected to the microwave sensors. The treatment was kept in effect for 7 sessions, covered for 3 sessions, and uncovered for the final 5 session of the experiment. This design allowed the site to serve as its own control because the return to baseline levels when the signal was removed and the replication of the treatment effect when

the signal was reintroduced showed the signal rather than other variables was responsible for the treatment effect.

Midblock Crossing
An alternating treatments design was employed at this site. Following a baseline period during which two data points were collected per day, the beacon and the ITS animated 'eyes' sign were introduced in succession for one data point each day. The order in which the signals were introduced was determined by a flip of a coin. If the coin flip was heads the ITS beacon was switched on first and if the coin flip was tails the ITS animated 'eyes' sign was switched on first. The signal that was not in effect was held in the dark phase. Once data were collected for 20 pedestrians the other signal was switched on and data were collected for another 20 pedestrians. This design allowed us to collect data on each of the two interventions each day at a single site thereby allowing a powerful comparison of the effects of two interventions that was not contaminated by differing site characteristics or variation caused by variables correlated with particular time periods, such as, increased police enforcement, changes in driver or pedestrian characteristics, or weather.

Results

Garage Exit
The percentage of motorists not looking in the direction of approaching pedestrians is shown in the top frame of Figure 4. During baseline 25% of the drivers failed to look in the direction of approaching pedestrians. Introduction of the ITS 'eyes' signal reduced the mean percentage not looking for pedestrians to 11%. The return to baseline was associated with an increase in the mean percentage not looking to 20% and the reintroduction of the ITS 'eyes' signal lead to a further decline to a mean of 6%. An arcsin transformation of Y was done before the statistical analysis. The residual analysis then showed no significant violation of normality (P=.97 with Wilks-Shapiro test). A one way ANOVA revealed that there were significant differences between conditions (F=12.91, P-value = .0001). Tukey's method showed no significant difference between the two baseline levels, nor between the two ITS sign conditions. However an F contrast between baseline vs. the ITS 'eyes' sign is significant at the .0001 level (F=27.27). Table 1 shows the SAS output for these analysis.

The percent of drivers yielding to pedestrians during each session is presented in bottom frame of Figure 4. The mean percentage of drivers yielding during baseline averaged 58%. The introduction of the ITS sign was associated with an increase in yielding to 82%. During the return to baseline, the percentage yielding declined to 70%, increased to 82% after the ITS sign was reintroduced. A normalizing arcsin transformation of Y was performed before the statistical analysis. The residual analysis then showed no significant violation of normality (P=.29 with Wilks-Shapiro test). A one way ANOVA revealed significant differences between conditions (F=3.95, P-value = .05). Tukey's method showed no significant difference between the two baseline levels, nor between the two ITS sign conditions. However an F contrast between baseline vs. the ITS sign was significant with F=7.46 (P=.0133).

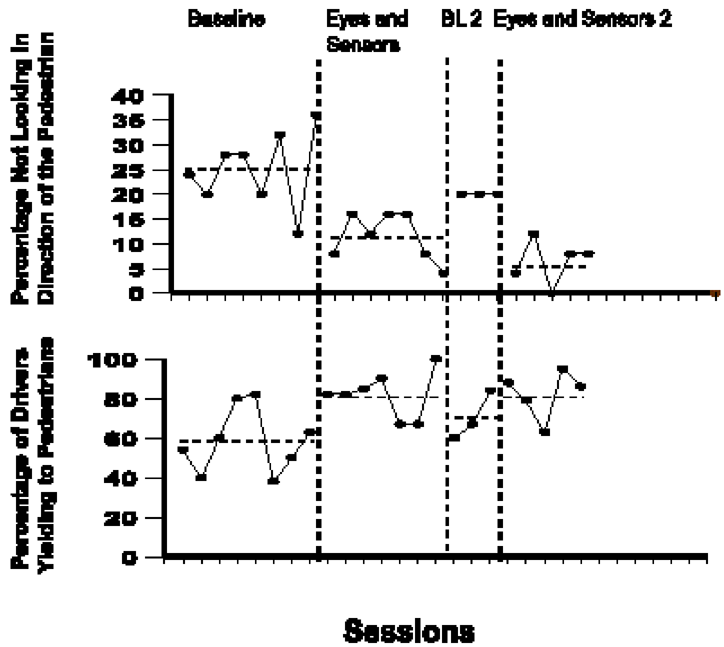

Figure 4, Motorists looking and yielding data for garage exit experiments.

The time to cross the two loops is presented in the top frame of Figure 5. The mean time to cross both loops increased by 0.5 seconds when the ITS sign was operating. A t-test of the raw data was significant at the .05 level, T=2.543 P-value = .0113.

The percentage of conflicts per session is presented in bottom the frame of Figure 5. Conflicts rarely occurred when the ITS sign was operating, However, a Kruskal-Wallis test did not reveal that these changes were significant.

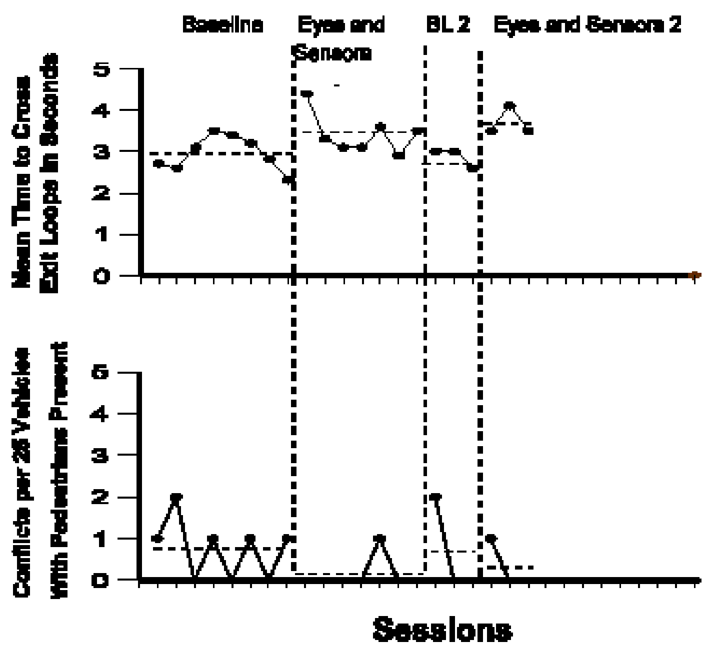

Figure 5, Vehicle speed and pedestrian conflicts for garage exit experiments.

Midblock Crosswalk

The percentage of drivers yielding to pedestrians is presented in Figure 6. Only 15% of motorists yielded to pedestrians during the baseline phase. The graph shows two data paths because data were collected twice during each day that the baseline conditions were in effect. The introduction of the beacon and the ITS 'eyes' sign without a sun shade led to an increase to 36% for the beacon and 50% for the ITS 'eyes' sign. The addition of a sun shade to the ITS 'eyes' sign lead to a further increase in the mean percentage yielding to 62%. A one way ANOVA revealed highly significant differences between conditions (F = 189.05, P-value = .0001). Tukey's method showed significant differences between all pairs of treatment levels, at the .01 level of significance. An F-test for the contrast between the beacons vs. the ITS 'eyes' signs is highly significant (F= 44.54, P = .0001). No outliers were detected and a normalizing arcsine transformation of Y was done before the above analysis. The residual analysis then shows no significant violation of normality (P = .24 with Wilks-Shapiro test). Because the standard deviation among the levels were obviously different the analysis was performed using weighted least squares. The weights chosen were the usual reciprocals of the variance. A runs test indicated no significant violation of randomness.

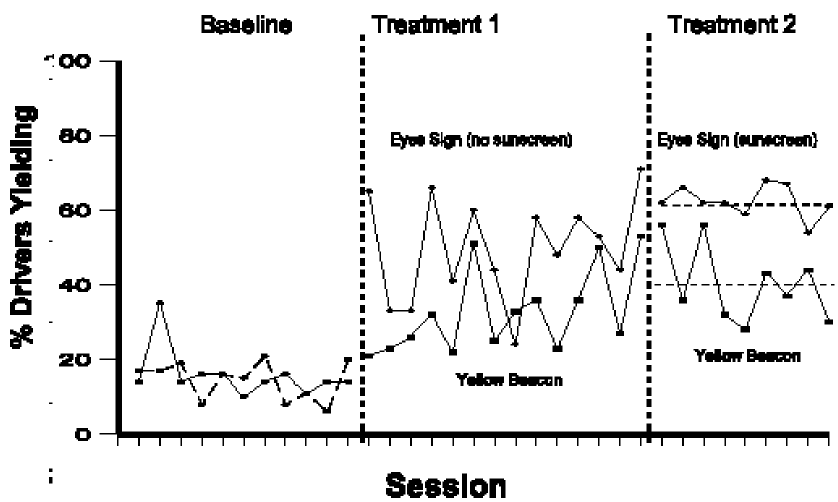

Figure 6, Drivers yielding to pedestrians in midblock experiments.

The mean percentage of pedestrians stranded at the center line declined from 17% during baseline condition to 6% during beacon operation and to 3% for the ITS 'eyes' sign operation. A one way ANOVA revealed highly significant differences among the treatment levels (F = 14.34, P-value = .0001). Tukey's method, however, shows significant differences only between baseline and all other treatments, with no other differences seen at the .05 confidence level.

The Kruskal-Wallis test, a non-parametric version of one-way ANOVA, was used to examine the number of conflicts during each condition. The test statistic H = 25.95 (adjusted for ties) is highly significant (P<.0005). However, it is clear from the data that this is entirely due to the contrast baseline vs. others. Further testing could find no significant differences amount the other treatment levels.

Discussion

The results of this study demonstrated that the introduction of the ITS signs were associated with an increase in the percentage of motorists yielding to pedestrians at both the garage exit and midblock crosswalk locations and the eyes produced a significantly larger increase than the flashing beacon at the midblock crossing. At the garage exit there was also a reduction in the percentage of motorists not looking for pedestrians, an increase in the percentage of exiting motorists yielding to pedestrians, and an increase in the time to cross the two loop detectors when pedestrians were present. The increase in time required for vehicles to cross the two loop detectors, though significant, was not particular large. However, it should be noted that vehicles already yielded during the baseline condition could not contribute to the results nor could motorists that left when the pedestrian had just about finished crossing (scored as NA). Hence the overall effect on those motorists that responded to the treatment was eroded by those who could not be expected to change during the intervention. The actual increase in crossing time for those drivers that participated in increased yielding was therefor likely greater than measured. Although conflicts were lower when the ITS signal was in place the number of conflicts occurring during the baseline condition were not significantly high enough to detect an effect.

At the midblock site both the ITS signal and the yellow beacon were associated with a reduction in the percentage of pedestrians stranded in the center of the road, and the number of conflicts. The results of this experiment showed that the ITS 'eyes' display produced a significantly larger increase in the percentage of drivers yielding to pedestrians than the flashing beacon even though both devices only operated when a pedestrian was crossing the street. The poor effect of the flashing beacon was consistent with the results of an earlier study (Gallagher, 1999). One reason why the ITS 'eyes' display may have been more effective was because it provided more information than the flashing beacon. Specifically, the pedestrian icon showed the direction of the pedestrian who was crossing the street, and the searching 'eyes' display provided a specific request of the drivers to look for the pedestrian.

These results show that the ITS 'eyes' display is inherently understood by drivers and produced a significant increase in yielding behavior and a reduction in conflicts. The ITS 'eyes' display could be employed in a large number of other applications. For example: the 'eyes' display with emergency vehicle symbols could be used at emergency vehicle exits; the 'eyes' display with trolley symbols could be used at intersections where trolley traffic can approach from the right; the eyes could be used with pedestrian and vehicle symbols at locations where multi use trails cross roads; and the eyes could be use with vehicle symbols at stop and yield sign locations with poor sight distance.

Field Research on a Passive Railroad Crossing Signal Unit

Introduction

Crashes at railway grade crossings kill over 500 people per year and injure 1,754. In the State of Florida 22 people were killed and 50 injured in 1995. Because 45 percent of injury crashes and 42 percent of fatal crashes occur at rail grade crossing protected only with cross bucks, it was decided to evaluate the animated 'eyes' technology at such sites (USDOT, 1996). The low power requirements of LED signals and piezo sensors make it practical to power these signals with a solar array in any part of the nation.

Method

Subjects and Setting
Subjects were east bound drivers at a passive railroad crossing on Ralph Road in Polk County, Florida. Ralph Road is a 18 foot wide paved street with one lane in each direction. The east bound direction was selected because of the poor sight distance due to heavy tree growth on the right side of the road. Cross bucks were erected 15 feet back from the center of the railroad tracks, and the STOP sign was located 10 feet behind the cross bucks. A stop bar was located next to the cross bucks. A W10-1 warning sign was placed 300 feet before the crossing. Because of previous crashes, Polk County had installed stop signs at all passive railroad crossings. The speed limit on Ralph Road was 30 mph and the ADT in the eastbound direction was 133 vehicles per day. Two school busses used the crossing and rail traffic was 4 switch trains per day.

Measures

Vehicle speeds were measured by the Polk County Traffic Engineering Division using two counter hoses, one on each side of the stop bar.

Apparatus

The animated 'eyes' signal used in this research is shown below in Figure 7. This device measured 6.5 inches high by 20.25 inches wide and consisted of a pair of white animated 'eyes'. The 'eyes' were each inches 7.5 inches wide, 4 inches high and 3.25 inches apart. The eyes were mounted on a post four feet to the right of the stop sign at a height of 10 feet above the roadway. The 'eyes' were activated by a microwave sensor that detected approaching vehicles at a distance of 150 to 180 feet. The sensor was mounted at a height of 12 feet above the roadway on the same post as the eyes. The devices were activated by breaking a normally closed circuit so that a broken circuit would turn the signal on all of the time. The signal was activated for 10 seconds as soon as an approaching vehicle was detected and stayed on until either 10 seconds elapsed or the vehicle passed out of view whichever duration was longer. The eyes looked back at forth with equal dwell times at a rate of 1 cps.

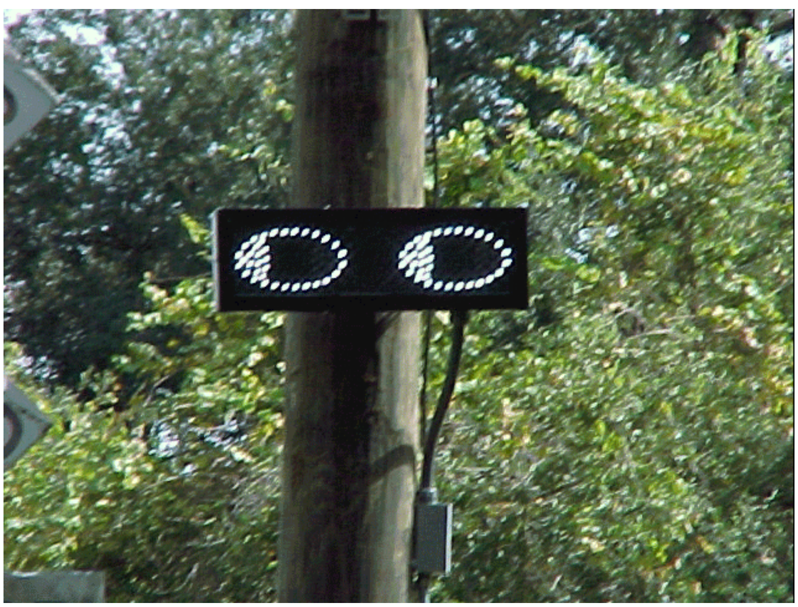

Figure 7, Animated 'eyes' signal used in this rail crossing experiments.

Experimental Design
A pre/post experimental design was employed in this research. Following an eight day baseline period during which the speed of all vehicles was measured as they crossed the stop line, the animated 'eyes' display was introduced and data were collected for an additional eight days.

Results

The introduction of the animated 'eyes' sign at the passive rail crossing was associated with a 49 percent reduction (from 5.5% to 2.8%) in the number of vehicles crossing the loops with speeds over 15 mph while the percentage of vehicles travelling in the direction not treated by the sign showed an increase in the number of drivers crossing the loops travelling over 15 mph. A two sample z-test for the difference between the two proportions was performed. This test was appropriate because of the large sample sizes. The value of z was 3.9 (P=.0001). A two sample z-test was also used to test whether the increase in the percentage of vehicles travelling over 15 mph in the direction opposite the sign was statistically significant. The results showed that this change was also highly significant ($z = -5.7$, $P = .0001$). It is interesting to note that 2.1% of the drivers were travelling over 30 mph as they crossed the loops during the baseline condition while only 0.6% were travelling that fast after the sign was installed.

Discussion

The results of this experiment showed that the animated 'eyes' sign reduced the percentage of motorists not stopping or significantly slowing at the site by about half. These data are consistent with other data showing that the efficacy of the 'eyes' display at crosswalks, garage exits and midblock crossing sites. They also replicate another study showing that the use of animated 'eyes' can increase the percentage of motorists coming to a complete stop at stop sign locations with a high crash history (Van Houten & Retting, 1999). Follow-up data collected after the sign has been up for 6 months should help determine whether the effects of the sign persist over time.

General Discussion on Results

The results of all this research and of previously reported studies (Van Houten, Retting, Van Houten, Farmer and Malenfant, 1999; Van Houten & Retting, 1999; Van Houten, Van Houten, Malenfant, & Andrus, in press) document that the animated 'eyes' display can improve safety in a number of sites where it is important for drivers and pedestrians to look for potential threats. These results also show that an ITS version of the sign that includes symbols of the relevant threat activated by sensors can significantly improve safety. It is interesting to note that this type of ITS display could be used at a number of other potentially hazardous sites. For example: the 'eyes' display with emergency vehicle symbols could be used at emergency vehicle exits; the 'eyes' display with trolley symbols could be used at intersections where trolley traffic can approach from the right; the eyes could be used with pedestrian and vehicle symbols at locations where multi use trails cross roads; and the eyes could be use with vehicle symbols at stop sign and yield locations with poor sight distances.

References

Gallagher, B. (1999) “Microwave sensors show some success in detecting pedestrians at crosswalks in L.A.” *The Urban Transportation Monitor*, (July 1999):2.

Hunter, W.W., Stutts, J.C., Pein, W.E., and Cox, C.L. (1996). “Pedestrian and bicycle crash types of the early 1990's.” FHWA-RD-95-163. Washington, DC: U.S. Department of Transportation,

Snyder, M.B. (1972). Traffic engineering for pedestrian safety: Some new data and solutions. *Highway Research Record, 406*, 21-27.

U.S. Department of Transportation. (1988) *Manual on Uniform Traffic Control Devices* (Federal Highway Administration SA-89-006). Washington, DC:U.S. Department of Transportation.

U.S. Department of Transportation. (1988) *Manual on Uniform Traffic Control Devices* (Federal Highway Administration SA-89-006). Washington, DC:U.S. Department of Transportation.

USDOT- FRA (1996). Highway-rail crossing accident/incident and inventory bulletin, No. 18, Calendar Year 1995.

Van Houten, R., Van Houten, J., Malenfant, J.E., & Andrus, D. (2000). Use of animated EYES to prompt motorists leaving indoor parking garage to look for pedestrians. *Transportation Research Record*. No. 1674, 57-60.

Van Houten, R., Retting, R.A., Van Houten, J., Farmer, C.M., & Malenfant, J.E.L. (1999). Use of Animation in LED Pedestrian Signals to Improve Pedestrian Safety, *ITE Journal*. 69, pgs. 30-38.

Van Houten, R., Van Houten, J., Malenfant, J.E., & Andrus, D. (In press). Use of animated EYES to prompt motorists leaving indoor parking garage to look for pedestrians. *Transportation Research Record*.

Zegeer, C.V., Cynecki, M.J., % Opiela, K.S. (1984). Evaluation of Innovative Pedestrian Signalization Alternatives. Transportation Research Record 959, pgs. 109-121,