ITS Animated LED Signals

Alert Drivers to Pedestrian Threats

by

Ron Van Houten and J.E. Louis Malenfant

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,[1] 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.[2] 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 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.

Two locations where such an ITS device could provide helpful to motorists are at exits to indoor parking garages and at midblock crosswalks that traverse multilane roads. 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.[3] At midblock crosswalks pedestrians are less conspicuous than at intersections, which increases the risk of multiple threat crashes.[4] 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 view of pedestrians approaching from the left was poor with pedestrians only becoming visible just before crossing the driveway. Because of the poor visibility of approaching pedestrians and the need for motorists 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 signage, 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 session at the parking garage and two sets of 20 pedestrians and at least as many drivers during each day of the experiment 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 the 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, drivers 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.

A photograph of both signals is shown in Figure 1. 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 cement 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.

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. When a pedestrian was detected 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 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.

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. The eyes looked back at forth with equal dwell times at a rate of 1 cps.

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 2. During baseline 25% of the drivers failed to look in the direction of approaching pedestrians. Introduction of the ITS 'eyes' signal reduced the percentage not looking for pedestrians to 11%. The return to baseline was associated with an increase in the percentage not looking to 20% and the reintroduction of the ITS ‘eyes’ signal lead to a further decline to 6%. 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).

The percent of drivers yielding to pedestrians during each session is presented in bottom frame of Figure 2. The mean percentage of drivers yielding during baseline averaged 58.4%. The introduction of the ITS sign was associated with an increase in yielding to 81.9%. During the return to baseline, the percentage yielding declined to 70.3%, increased to 82.2% after the ITS sign was reintroduced. 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).

The time to cross the two loops is presented in the top frame of Figure 3. The mean time to cross both loops increased by 0.5 seconds when the ITS sign was in operating. An 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 frame of Figure 3. Conflicts rarely occurred when the ITS sign was operating, However, a Kruskal-Wallis test did not reveal that these changes were significant.

Midblock Crosswalk

The percentage of drivers yielding to pedestrians is presented in Figure 4.

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 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 s.d. 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.

The percentage of drivers 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 to be an order of several times higher. 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.[2] 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 sign and yield locations with poor sight distance.

References

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

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

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

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

Acknowledgements

The authors thank: Angelo Rao, Director of Transportation and Parking for the city of St. Petersburg, and John Stevenson Signals Technician for the city of St. Petersburg, for there cooperation and support carrying out the research in St. Peterburg; Jack Brown, Traffic Operations Engineer, And David Anderson, Deputy Traffic Operations Engineer for the State of Florida for assisting in carrying out this research under FHWA permission to experiment; and the members of the ITS IDEA Panel for there helpful suggestions. The authors would also like to thank Richard Retting for his valuable editorial comments.

Figure 1. The upper frame shows the ITS sign used at the garage exit and the lower sign shows the ITS sign used at the midblock crosswalk.

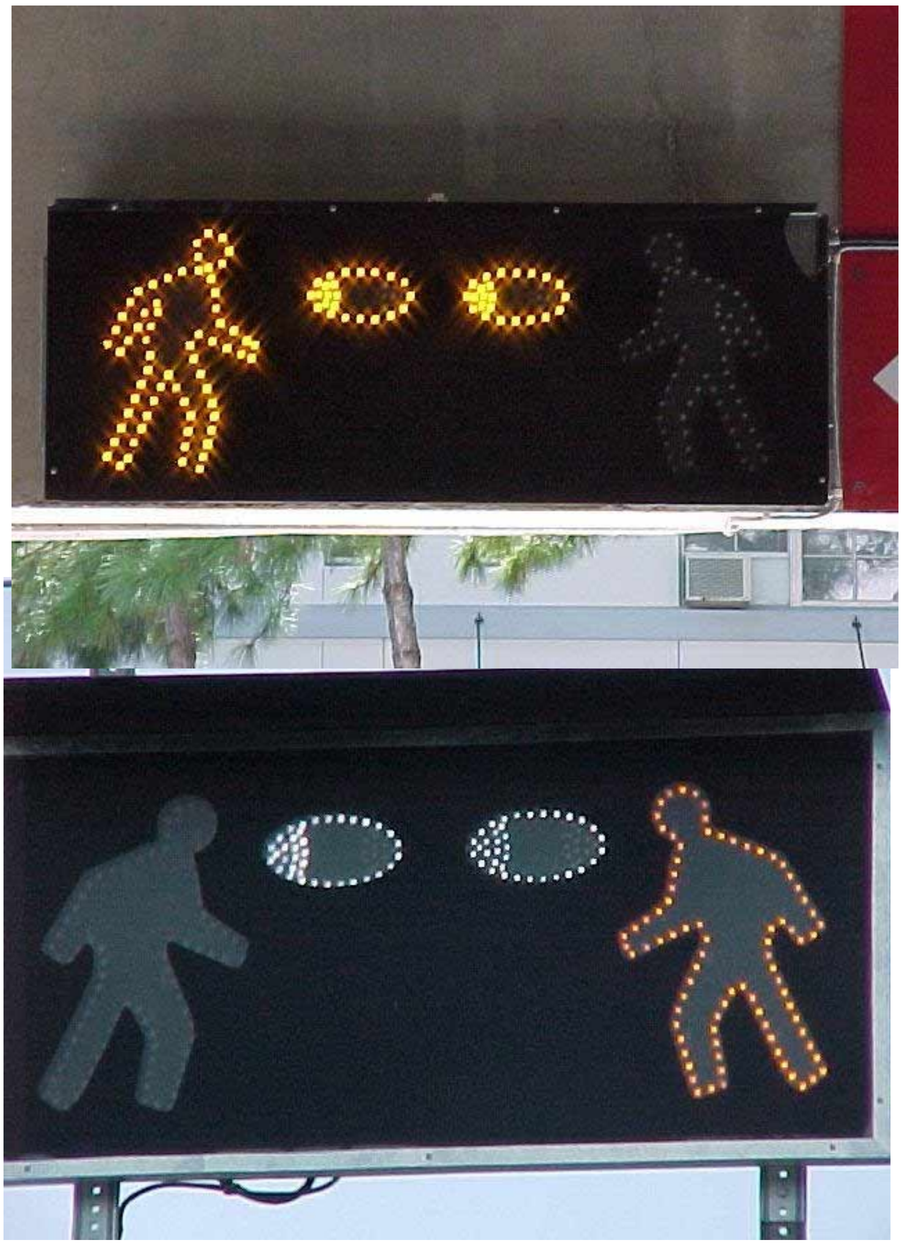

Figure 2. The upper frame shows the percentage of motorists not looking for the approaching pedestrian and the bottom frame shows the percentage of motorists yielding to pedestrians during each condition of the experiment.

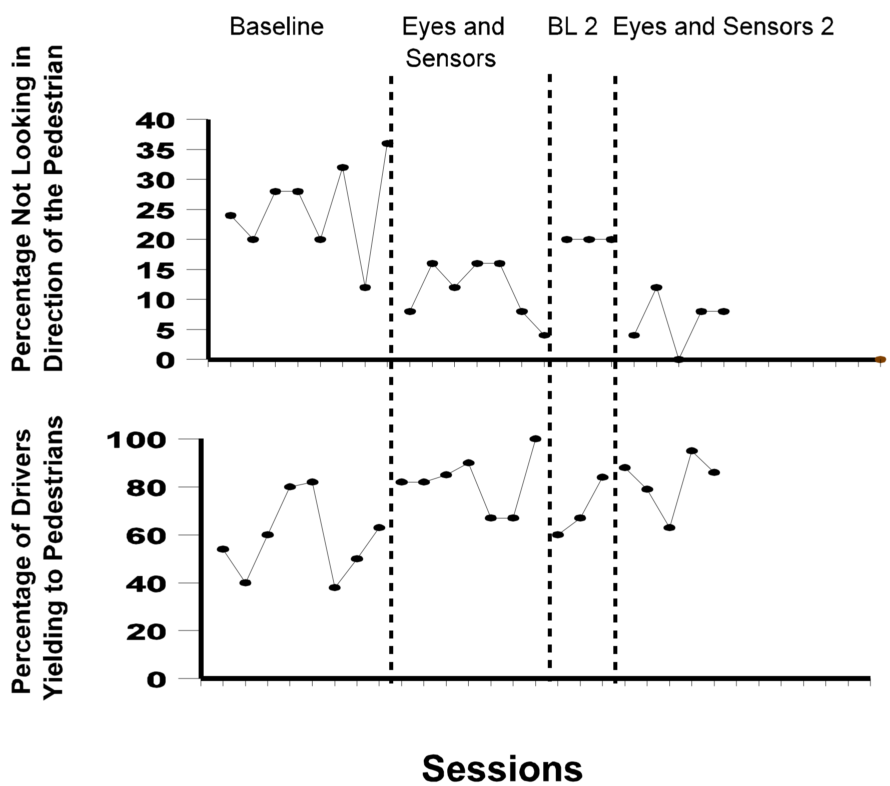

Figure 3. The upper frame of this figure shows the mean time to cross the exit loops and the lower frame shows the number of conflicts per 25 vehicles when pedestrians were present during each condition of the experiment.

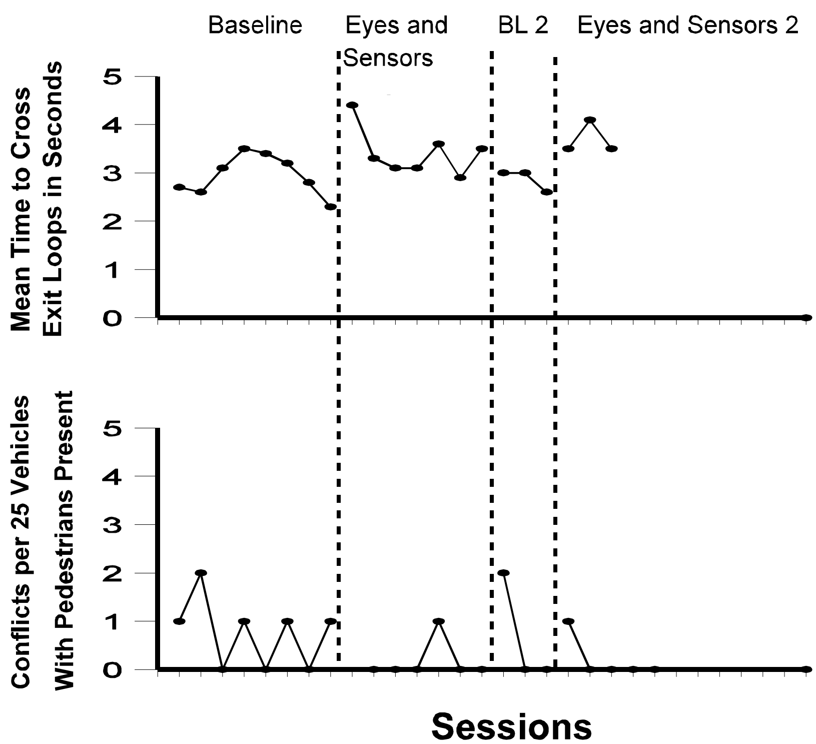

Figure 4. The percentage of drivers yielding to pedestrians during baseline and when the ITS Eyes Sign and Yellow Beacon were in use. During Treatment 1 the Eyes sign did not have a sun shade and during Treatment 2 a sun shade was installed.