Published in final edited form as:

Transp Res Rec. 2011 January 1; 2264: 27–33. doi:10.3141/2264-04.

Do Advance Yield Markings Increase Safe Driver Behaviors at Unsignalized, Marked Midblock Crosswalks? Driving Simulator Study

Radhameris A. Gómez, Siby Samuel, Luis Roman Gerardino, Matthew R. E. Romoser, John Collura, Michael Knodler, and Donald L. Fisher

R. A. Gómez. Human Performance Laboratory, Department of Civil and Environmental Engineering; S. Samuel, L. R. Gerardino, and M. R. E. Romoser, Human Performance Laboratory, Department of Mechanical and Industrial Engineering; J. Collura and M. Knodler, Department of Civil and Environmental Engineering; and D. L. Fisher, Department of Mechanical and Industrial Engineering, University of Massachusetts, Amherst, Amherst, MA 01003

Abstract

In the United States, 78% of pedestrian crashes occur at noninter-section crossings. As a result, unsignalized, marked midblock crosswalks are prime targets for remediation. Many of these crashes occur under sight-limited conditions in which the view of critical information by the driver or pedestrian is obstructed by a vehicle stopped in an adjacent travel or parking lane on the near side of the crosswalk. Study of such a situation on the open road is much too risky, but study of the situation in a driving simulator is not. This paper describes the development of scenarios with sight limitations to compare potential vehicle–pedestrian conflicts on a driving simulator under conditions with two different types of pavement markings. Under the first condition, advance yield markings and symbol signs (prompts) that indicated “yield here to pedestrians” were used to warn drivers of pedestrians at marked, midblock crosswalks. Under the second condition, standard crosswalk treatments and prompts were used to warn drivers of these hazards. Actual crashes as well as the drivers' point of gaze were measured to determine if the drivers approaching a marked midblock crosswalk looked for pedestrians in the crosswalk more frequently and sooner in high-risk scenarios when advance yield markings and prompts were present than when standard markings and prompts were used. Fewer crashes were found to occur with advance yield markings. Drivers were also found to look for pedestrians much more frequently and much sooner with advance yield markings. The advantages and limitations of the use of driving simulation to study problems such as these are discussed.

Vulnerable road users are receiving increasing attention, as evidenced in part by the recent occurrence of the first international conference on vulnerable road users held in Jerusalem, Israel (May 2010). Pedestrians are among the most vulnerable of road users. What is perhaps most frustrating is that pedestrian crashes are often no less frequent at marked midblock crosswalks than at unmarked midblock crosswalks (1). The risk to pedestrians is especially high when a driver's view of pedestrians in a crosswalk is obstructed as the driver approaches the crosswalk (2). These situations are referred to throughout this article as “scenarios under sight-limited conditions.”

A number of alternatives to the standard yield markings (SYMs) at midblock crosswalks and the “Yield Here to Pedestrians” sign or prompt (Figure 1*b*) have been proposed as ways to decrease vehicle–pedestrian conflicts at marked midblock crosswalks (3). Among the most

effective and least costly of the alternatives are advance yield markings (AYMs) (4–6). AYM consists of a line of solid white triangles pointed toward approaching vehicles (Figure 1a). The line of triangles extends across the approach lane(s). Yield markings are placed upstream of the crosswalks to indicate the point at which the yield must be made. A prompt sign (“Yield Here to Pedestrians”) is placed next to the yield markings. The complete dimensions and placement of the AYM and prompt sign are given in the guidelines of the 2009 edition of the Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) (7).

Field comparisons of AYM and SYM indicate that when the sight distance is adequate, drivers exposed to AYM yield more often and do so farther upstream of the crosswalk (4, 5). Additionally, again, when the sight distance is adequate, drivers exposed to AYM glance toward the area where a pedestrian might emerge from behind an obstruction more often (8). However, when the sight distance is limited, as in Figure 1 (the pedestrian is on the right), those exposed to AYM show no increase in yielding behavior, although those drivers who do yield do so sooner. Drivers exposed to AYM still glance toward the potential hazard more often (8).

Although one cannot stage the most dangerous of the marked, midblock scenarios in the field, that is, a scenario in which a pedestrian suddenly emerges in the crosswalk, one can do so in a driving simulator. Such a study was recently undertaken (9). Participants had to navigate two virtual drives of about 10 min each. Each drive involved scenarios with multiple marked, midblock crosswalks, for some of which sight was limited and for some of which it was not. In the experimental scenarios (sight-limited condition), an obstruction appeared in the right or left lane of two travel lanes on the immediate near side of AYM or SYM. The obstruction consisted of one or more vehicles (cars or trucks). A pedestrian was never present in the crosswalk in any of the experimental scenarios included in the first drive or the initial scenarios of the second drive, but a pedestrian was always present in the last experimental scenario of the second drive. For the last scenario, an invisible trigger was placed on the road at the same location for the AYM and SYM conditions. When the driver crossed the trigger, the pedestrian started walking toward and then into the crosswalk, emerging from behind the stopped vehicle but then turning back so that no collision would occur. Under the assumption that the drivers did not adjust their speed, the distance between the pedestrian and the driver when the driver traveled over the crosswalk was the same under the AYM and SYM conditions. Drivers exposed to the AYM yielded 61% of the time, whereas drivers exposed to the SYM never yielded. By design, the scenario included no crashes (the pedestrian never entered the driver's travel lane).

What the study described above does not indicate is whether the driver would actually have collided with the pedestrian if the pedestrian had continued into the driver's travel lane. Under both the AYM and the SYM conditions, drivers would perhaps have had enough time to maneuver around the pedestrian; the differences between the two conditions would hereby be reduced. The study described above also does not indicate whether a greater difference in the two conditions might have been observed if it had been more difficult for drivers to determine that a pedestrian was present in the crosswalk and if drivers had been performing a secondary task at the same time as they were driving. Thus, the number of potential collisions was potentially much smaller than it would have been under the AYM condition if the driver was not given a clue about the presence of a pedestrian or the driver was performing a secondary task.

Collisions can be staged only in a simulated environment, especially when the driver is performing a secondary task, and clues about the presence (or absence) of a pedestrian can be manipulated much more easily in a simulated environment. In short, to evaluate AYM

and prompt signs in situations in which actual collisions might occur and under conditions that increase the likelihood of a collision, one needs to turn to simulation. The study described here is an attempt to compare the behaviors of drivers exposed to AVMs and SYMs in scenarios under sight-limited conditions when the driver is performing a secondary task, when clues about the presence of a pedestrian in the crosswalk hidden by an obstruction are minimized, and when an actual collision might occur.

METHOD

Participants in the experiment were asked to navigate through a virtual world that contained a number of unsignalized, marked mid-block crosswalks while performing a secondary task. As the driver approached the crosswalk, pedestrians would sometimes be triggered to cross the street from the left or the right. When pedestrians were present, an obstruction was never in the travel lane adjacent to the driver, except in the final scenario. When no pedestrians were present, an obstruction was sometimes in the adjacent travel lane and sometimes not. The obstruction was always 3 work zone, which consisted of cones surrounding a bulldozer or other heavy equipment. Thus, up until the final scenario, the driver either navigates a scenario under sight-limited conditions at a marked, midblock crosswalk with no pedestrian or navigates a scenario without an obstruction but occasionally with a pedestrian. An attempt was made to link one stimulus (an obstruction) with the absence of a pedestrian and a second stimulus (no obstruction) with the presence of a pedestrian. This made the final scenario one in which it could be determined whether drivers maintain their vigilance under both the AYM and the SYM conditions.

Participants

Twenty-four subjects participated in the study. The participants ranged in age from 18 to 30 years. Twelve participants each were assigned to the control (SYM) and experimental (AYM) conditions. Fifty-four percent of the participants were females; the remaining 46% were males. The mean age of the participants under the SYM condition was 24.5 years, and that under the AYM condition was 24.9 years. The standard deviations in ages for the two conditions were 5.22 years for the SYM condition and 5.66 years for the AYM condition. Participants in both groups were aware of AYM and the associated prompt sign and had some level of familiarity with these in actual driving on the road. In particular, subjects in both groups indicated that they frequently drive in downtown Amherst, Massachusetts (an area where yield markings have been installed and have been in place for at least 3 years). Information was posted around the University of Massachusetts, Amherst, in regional online newspapers, and in local businesses to recruit subjects from the local area. The subjects received \$25 for their participation.

Stimuli

The SYM condition consisted of a stop bar located 10 ft before the crosswalk and a prompt sign asking drivers to yield for pedestrians. The AYM condition similarly consisted of AYM and prompt signs. Yield markings consisted of a line of solid white triangles (triangles are 24 in. wide at the base and 36 in. long) pointed toward approaching vehicles. The line of triangles extended across the approach lane; the space between each triangle was 12 in. Yield markings were placed 30 ft upstream of the crosswalks to indicate the point at which the yield was required to be made. Dimensions and placement of the yield markings followed the guidelines of the 2009 edition of the MUTCD (7). A prompt sign (MUTCD Sign R1-5) 24 in. wide by 30 in. high was placed next to the yield markings. The dimensions of the sign exceeded the guidelines provided in the 2009 MUTCD (i.e., they were 18 in. wide by 15 in. high) (7).

Driving Simulator

The fixed-base simulator included a full-size Saturn sedan in which all vehicle controls were fully operative (more information is available on the web at www.ecs.umass.edu/hpl). The visual world was displayed on three screens that allowed 150 degrees of vision in the horizontal direction and 30 degrees of vision in the vertical direction. Images were displayed with a refresh rate of 60 Hz and at a resolution of 1,400 by 1,050 pixels. The images themselves are updated 60 times per second by use of a network of four advanced simulator servers from Realtime Technologies, Inc., that process the images projected onto each of the three screens in parallel with high-end multimedia video processors. This is a high-fidelity simulator. Two side-view mirrors and one rearview mirror were projected onto the three screens. The simulator also used a surround-sound audio system. This system provides realistic wind, road, and other vehicle noises with appropriate direction, intensity, and Doppler shift.

Scenarios

Each participant was randomly presented with a single drive, either the SYM drive with the standard traditional markings and prompt sign or the AYM drive with the AYM and prompt sign. Each drive included nine scenarios (Table 1). The drive had four types of scenarios with two factors varied orthogonally: the presence or absence of an obstruction in the left lane and the presence or absence of a pedestrian at the side of the crosswalk. The four types of scenarios are no obstruction in the left lane with no pedestrian at the crosswalk (Scenarios 2, 7, and 8 in Table 1), no obstruction in the left lane with a pedestrian at the crosswalk (Scenarios 1, 4, and 6), an obstruction in the left lane with no pedestrian at the crosswalk (Scenarios 3 and 5), and an obstruction in the left lane with a pedestrian at the crosswalk (Scenario 9). Other pedestrians were included in the simulation (e.g., pedestrians who had completed street crossings at selected intersections) to show the driver that it was possible to encounter pedestrians elsewhere in the simulation. For both drives, a pedestrian was present in the crosswalk during the first, fourth, sixth, and final scenarios, the last of which included sight-limited conditions. For the final scenario in the drive, an invisible trigger was placed on the road at the same location for the SYM and AYM conditions; when the driver crossed the trigger, the pedestrian started walking toward and then into the crosswalk. The initial position, speed, and time of entry of the pedestrian were coordinated to remain the same for all participants under both the AYM and the SYM conditions.

Two examples of the driver's view of the various scenarios are given below. They include the AYM condition with no obstruction and a pedestrian getting ready to cross from the right side (Scenarios 4 and 6 in Table 1 and Figure 2) and the SYM condition with an obstruction present in the left lane but no pedestrian in view (Scenarios 3 and 5 in Table 1 and Figure 3). The driver's view of the roadway ahead with no obstruction and no pedestrian (Scenarios 2, 7, and 8) is similar to the driver's view when a pedestrian is present (with the exception that no pedestrian is present in Scenarios 2, 7, and 8). The driver's view of the roadway ahead with no obstruction and a pedestrian crossing from the left side (Scenario 1) is identical to the driver's view of the roadway ahead with no obstruction and a pedestrian crossing from the driver's right side, with the exception that the pedestrian is located on the left side. Finally, the driver's view of the roadway ahead with an obstruction in the left lane and a pedestrian in the middle of the crosswalk (Scenario 9) is identical to the driver's view when the driver approaches this intersection with the obstruction located in the left lane and no pedestrian (Scenarios 3 and 5). It is only as the driver passes the obstruction that the pedestrian in the crosswalk that is hidden by the obstruction becomes visible.

Procedure

The participants were first asked to sign an informed consent form and were then provided with a pretest questionnaire that consisted of questions about the participant's driving history and demographics. A simulator sickness questionnaire with a pretest component and a posttest symptoms section was administered. This was followed by a practice drive of about 5 min.

The practice scenarios included situations in which the driver approached uncontrolled, marked midblock crosswalks with an obstruction in the left lane (i.e., a work zone on the left lane with barrels at the periphery and safety vehicles within the work zone). The virtual world simulated was an urban environment, and the posted speed limit was 30 mph. The driver traveled a two-way, four-lane road with controlled traffic in the opposite direction, with traffic approaching from the right or left side at stop-controlled intersections, and with traffic entering or leaving parking lots. The simulation also included construction zones and other physical obstructions in the travel lane as well as pedestrians. One drive contained nine scenarios with SYMs; the other drive contained nine scenarios with AYM (the order of the scenarios was the same for each drive and is given in Table 1). Each participant navigated only one of these drives. In either case, participants followed directional display signs placed just before intersections to guide them along the virtual environment to an unknown destination.

The participants were given a secondary task to increase the cognitive load (10). A set of 50 sentences was scripted into the drive. These 50 sentences were played on an audio player, and the participants were asked both to identify the subject and object of the sentence and to indicate if the sentence made sense. An example would be, "Jimmy sat on the cloud." For this sentence, the expected response from the participant would be, "Jimmy, cloud, and no." The participants were given a practice run of the cognitive load task during the practice drive. A 4-s pause between sentences was used to provide the participants with sufficient time to cognitively process the information.

Dependent Variables and Data Collection

The dependent variables included (a) whether the driver did or did not fixate on predefined areas of visual interest in the driving environment, (b) whether drivers yielded, and (c) whether drivers crashed or were in a near crash.

For the first dependent variable, two sets of reference points were used to define the areas of visual interest: one set defined the area of the roadway in which the driver must be operating when the fixation was scored (the launch zone), and the other defined the area of the roadway or environment at which the driver must be looking (the target zone). If the driver was in the launch zone when he or she fixated in the target zone, then the driver was considered to have looked at the risky situation or area of interest along the road. These experiments included two such launch zones and two such target zones (a total of four visual zones) under each condition.

Target Zone 1 for glances to the right was defined to be the area to the right of the crosswalk when a work zone obstruction is present and the driver is expected to glance right for an oncoming pedestrian (Figure 4). Target Zone 1 for glances to the left was defined to be the area ahead of the work zone at the middle portion of the crosswalk (the work zone is at the AYM under the AYM condition and at the stop bar under the SYM condition). The work zone served as a visual obstruction blocking the view of a potential pedestrian entering the crosswalk from the left. Launch Zone 1 for glances to the right or left was defined as the area extending from the 30 to 150 ft in advance of the crosswalk (Launch Zone 1 ends at the AYM for the AYM condition). It was assumed that drivers predicted the risk if they fixated

on the area from which a pedestrian may emerge or was actually located. If the driver fixated on this area, a hit or a correct response (value = 1) was recorded; otherwise, a miss (value = 0) was recorded.

Similarly, Target Zone 2 was to the extreme right of the crosswalk to score glances to the right (Figure 5) and to the extreme left of the crosswalk to score glances to the left. Launch Zone 2 was defined to be the area within 30 ft in advance of the crosswalk (ahead of the AYM's under the AYM condition). Launch Zone 2 is closer to the crosswalk than Launch Zone 1.

For the second dependent variable described above, drivers were scored to have yielded if they initiated braking in advance of the crosswalk and gradually slowed before stopping. Drivers were scored to have not yielded if they passed in front of the pedestrian and did not stop when the pedestrian arrived at the crosswalk.

For the third dependent variable described above, drivers were scored for collisions and near collisions. They were scored to have collided if the participants failed to apply the brakes in time to avert contact with the pedestrian on the crosswalk. Near collisions were defined as collisions that were effectively avoided because of the use of emergency vehicle maneuvers by the participant, for example, hard braking and swerving, in the near launch zones defined by the experimenter (of the two launch zones, the one nearer the crosswalk). In this case, the participant just about manages to avoid colliding with the pedestrians.

Hypotheses

The authors anticipated that drivers approaching a crosswalk would be more likely to look for pedestrians when the crosswalks have AYM's and pedestrian crosswalk prompt signs than when they have the standard traditional markings and prompt signs. It was also expected that drivers would stop or yield more often for a pedestrian when AYM's were used. Finally, it was anticipated that under the SYM condition the drivers would experience more collisions because of the shorter response time available.

RESULTS

This section provides a discussion of the crash results, followed by a discussion of the glance results.

Crashes

The total number of crashes and near crashes is almost twice as high under the SYM condition ($n = 20$) as under the AYM condition ($n = 11$) (Table 2). The number of crashes is more than eight times as high under the SYM condition ($n = 16$) as it is under the AYM condition ($n = 2$). When just the two scenarios in which crashes occurred (Scenarios 4 and 9) are used, the hypothesis that the proportion of crashes under the AYM and the SYM conditions is identical can be rejected [χ^2 (1 degree of freedom) = 17.4, $p < .001$]. However, the number of near crashes is more than twice as high under the AYM condition ($n = 9$) as it is under the SYM condition ($n = 4$). By use of just the three scenarios in which near crashes occurred (Scenarios 4, 6, and 9) to test the hypothesis that the proportion of near crashes is identical in these three scenarios, it was found that this null hypothesis cannot be rejected.

The number of crashes and near crashes in Scenario 3 is almost five times as high under the SYM condition ($n = 9$, of which six are crashes and three are near crashes) as it is under the AYM condition ($n = 2$, both of which are crashes). No obstruction to vision was present under this condition. A pedestrian enters the crosswalk on the right side and continues walking into the path of the driver. The driver has plenty of time to yield, yet this did not

happen in many cases for the drivers under the SYM condition. In a later repetition of this scenario, Scenario 6, drivers become more cautious. Only one near crash occurs under both the AYM and the SYM conditions, which indicates that drivers were indeed trying to avoid crashes [$\chi^2(1 \text{ degree of freedom}) = 13.0, p < .001$].

The numbers of crashes and near crashes increase dramatically in Scenario 9 ($n = 18$) compared with Scenario 6 ($n = 2$) indicating that the pedestrian truly was unexpected in the last scenario [$\chi^2(1 \text{ degree of freedom}) = 17.7, p < .001$].

Glances

Participants exposed to the AYM and prompt sign glanced toward the side more often (53.85%) than drivers exposed to the SYMs and prompt sign (39.93%). The difference was the most marked for glances in Zone 1 when an obstruction was present: under the AYM condition they glanced toward the pedestrian 66.67% of the time, whereas under the SYM condition they glanced toward the pedestrian 40.3% of the time [$\chi^2(1 \text{ degree of freedom}) = 10.1, p < .002$]. The difference was smaller in Zone 1 when no obstruction was present, but it was still statistically significant: 53.5% of the participants glanced toward the pedestrian under the AYM condition, whereas only 36.1% glanced toward the pedestrian under the SYM condition [$\chi^2(1 \text{ degree of freedom}) = 8.78, p < .003$]. The differences between the AYM and the SYM conditions in Zone 2 with and without an obstruction were not significant.

DISCUSSION OF RESULTS

Crashes

The fact that in the last scenario drivers had 10 crashes under the SYM condition and drivers had no crashes (but eight near crashes) under the AYM condition when they were cognitively loaded and when the clues about the presence of a pedestrian were minimal points vividly both to the effectiveness of the AYM and to the utility of driving simulators. The most dangerous of the scenarios in which a particular treatment is likely to have the greatest effect is often difficult, if not impossible, to study in the field. This is not true on the driving simulator, in which safety considerations are minimal (and of a different type).

Under both the SYM and the AYM conditions, drivers saw the same scenarios and drove in similar environments. More to the point, Scenarios 4 and 6 were the same under both the SYM and the AYM conditions. This could explain why fewer crashes were seen in Scenario 6 than in Scenario 4. In particular, the natural expectation would be for the existence of crashes in Scenario 4 to hypersensitize drivers to crashes in later scenarios (and, in particular, in the identical scenario, Scenario 6). This in turn could have been reflected in the reduced number of crashes by drivers in Scenario 9. This was not the case, however. In fact, the number of crashes in Scenario 9 was greater than the number of crashes in Scenario 4 (under the SYM conditions). The authors hypothesize that this is because the pedestrian walks out from behind the obstruction in Scenario 9. However, the authors acknowledge that fatigue could be a possible reason for the increased number of crashes in the last scenario (although recall that the drives lasted only 6 min).

Glances

The finding that drivers were much more likely to glance toward the pedestrian in Zone 1 when an obstruction was present under the AYM condition than the SYM condition points to the reason why the drivers had many fewer crashes under the AYM condition than under the SYM condition. In particular, if one takes glance behavior as an indication of an awareness of a potential pedestrian on the part of drivers, then under the AYM condition the

driver is looking for pedestrians more frequently as he or she approaches the obstruction (Zone 1) and then as he or she passes the obstruction (Zone 2), although the latter difference is not statistically significant. Furthermore, the finding that drivers were more likely to glance toward the pedestrian in Zone 1 when no obstruction was present under the AYM condition than the SYM condition points to the reason why the drivers are more likely to yield under the AYM condition, as reported in several field studies (8).

A seeming anomaly needs to be addressed: Figure 6 shows that drivers are more likely to glance toward the pedestrian when an obstruction is present than when it is not present. The authors speculate that drivers may believe that they can detect pedestrians out of the periphery of their vision—which may or may not be the case—when no obstruction is present. However, when an obstruction is present, the drivers will not believe that they can detect pedestrians and so will glance toward the side more frequently.

Limitations of Driving Simulation

One of the major concerns with the use of driving simulators is that the participants may not take their driving as seriously as they do in the real world. Increasingly, evidence indicates that this is not the case, at least for patterns of visual search (11) and the division of attention (12). Nevertheless, real concern that what a person learns on a driving simulator may not generalize to the real world still exists for any one of a number of different reasons.

In this case, some evidence is consistent with the conclusion that the drivers in this experiment were taking their driving seriously, at least in the final scenario. The specific and perhaps somewhat unrealistic evidence is that drivers in Scenario 3 either crash or have a near crash when a pedestrian enters the crosswalk from the right. The pedestrian is always visible as the driver approaches the crosswalk and clearly appears to be heading toward the crosswalk. However, in a later repetition of that scenario (Scenario 6), it was found that none of the participants had a crash or near crash. Moreover, in the most difficult of the scenarios, the final scenario, none of the drivers exposed to the AYM actually crashed. It is known from their glance patterns that they were looking for a potential pedestrian. Thus, one can have some confidence that the participants in the experiment were taking seriously their instructions to drive safely.

The study has another obvious limitation. In particular, the test sample was small and not fully representative of the driver population. Nevertheless, the sample size was not small for simulator studies such as the one described here.

CONCLUSIONS

This article has discussed the detailed development of scenarios that may be used to evaluate on a driving simulator the effectiveness of two different types of pavement markings: AYM and SYMs (together with prompt signs). Scenarios that could not safely be evaluated in the real world and that were designed to accentuate the differential effectiveness of the two different types of pavement markings were specifically developed. The implications for traffic engineering are straightforward. Both in the field and on the driving simulator, AYM lead drivers both to behave more safely (e.g., look more often for pedestrians) and, as the behaviors would suggest, to crash less frequently on a driving simulator.

The results are sufficiently consistent and dramatic over time (4, 5, 8, 9) that it appears that the next study should be an epidemiological one in the field in which behaviors at a number of existing midblock crosswalks with SYMs are compared with behaviors at existing midblock crosswalks with AYM, but with the assumption that appropriate safety

precautions could be taken. Given the results across a number of studies, the goal should be for AYMs to become a standard instead of simply guidance in the MUTCD (7).

Acknowledgments

This research has been supported in part by a grant from the New England University Transportation Center to John Collura and Donald L. Fisher and by a grant to Donald L. Fisher from the National Institutes of Health.

REFERENCES

1. Zegeer, CV.; Stewart, JR.; Huang, H.; Lagerwey, P. Transportation Research Record: Journal of the Transportation Research Board, No. 1773. TRB, National Research Council; Washington, D.C.: 2001. Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations: Analysis of Pedestrian Crashes in 30 Cities; p. 56-68.
2. Snyder, MB. Highway Research Record 406. HRB, National Research Council; Washington, D.C.: 1972. Traffic Engineering for Pedestrian Safety: Some New Data and Solutions; p. 21-27.
3. NCHRP Report 500: Guidance for implementation of the AASTHO Strategic Highway Safety Plan, Vol. 10: A Guide for Reducing Collisions Involving Pedestrians. Transportation Research Board of the National Academies; Washington, D.C.: 2004.
4. Van Houten, R.; Malenfant, JEL.; McCusker, D. Transportation Research Record: Journal of the Transportation Research Board, No. 1773. TRB, National Research Council; Washington, D.C.: 2001. Advance Yield Markings: Reducing Motor Vehicle-Pedestrian Conflicts at Multilane Crosswalks with Uncontrolled Approach; p. 69-74.
5. Van Houten, R.; McCusker, D.; Huybers, S.; Malenfant, JEL.; Rice-Smith, D. Transportation Research Record: Journal of the Transportation Research Board, No. 1S1S. Transportation Research Board of the National Academies; Washington, D.C.: 2002. Advance Yield Markings and Fluorescent Yellow-Green RA 4 Signs at Crosswalks with Uncontrolled Approaches; p. 119-124.
6. Huybers S, Van Houten R, Malenfant JEL. Reducing Conflicts Between Motor Vehicles and Pedestrians: The Separate and Combined Effects. Journal of Applied Behavior Analysis. 2004; 37(4):445-456. [PubMed: 15669404]
7. FHWA. , editor. Manual on Uniform Traffic Control Devices for Streets and Highways. U.S. Department of Transportation; 2009. 2009
8. Garay-Vega, L.; Fisher, DL.; Knodler, M. Evaluation of Drivers' Performance in Response to Sight-Limited Crash Scenarios at Midblock Crosswalks: Benefits of Advance Yield Markings and Symbolic Sign-age. Proc., Annual Meeting of the Human Factors and Ergonomics Society; New York: Santa Monica, Calif.: Human Factors and Ergonomics Society; 2008.
9. Garay, L. Drivers' Performance in Response to Sight-Limited and MultiThreat Crash Scenarios at Mid-Block Crosswalks: An Evaluation of Advance Yield Markings and Sign Prompts. Civil and Environmental Engineering, University of Massachusetts; Amherst: 2008.
10. MutEart, JW.; Fisher, DL.; Knodler, MA., Jr.; Pollatsek, A. Transportation Research Record: Journal of the Transportation Research Board, No. 2078. Transportation Research Board of the National Academies; Washington, D.C.: 2007. Driving Without a Clue: Evaluation of Driving Simulator Performance During Hands-Free Cell Phone Operation in a Work Zone; p. 9-14.
11. Pradhan AK, Pollatsek A, Knodler M, Fisher DL. Can Younger Drivers Be Trained to Scan for Information That Will Reduce Their Risk in Roadway Traffic Scenarios That Are Hard to Identify as Hazardous? Ergonomics. 2009; 52(6):657-673. [PubMed: 19296315]
12. Pradhan, AK.; Divekar, G.; Masserang, K.; Romoser, M.; Zafian, T.; Blomberg, RD.; Thomas, FD.; Reagan, I.; Knodler, M.; Pollatsek, A.; Fisher, DL. The Effects of Focused Attention Training (FOCAL) on the Duration of Novice Drivers' Glances Inside and Outside the Vehicle. Technical report. Human Performance Laboratory, Department of Mechanical and Industrial Engineering, University of Massachusetts; Amherst: 2010.

FIGURE 1.

Scenario under sight-limited conditions: [a] AYM and prompt and [b] SYMs and prompt [D = driver; O = obstruction].

FIGURE 2.
Scenario with AYMs with no obstruction and pedestrian on right side [Scenarios 3 and 5].

FIGURE 3.
Scenario with SYMs with obstruction in left lane and no pedestrian.

FIGURE 4.

Launch Zone 1 [LZ 1] and right side Target Zone 1 [TZ 1] with obstruction [0] on left: [a] AYM and [b] SYM.

FIGURE 5.

Launch Zone 2 [LZ 2] and Right Side Target Zone 2 [TZ 2] with obstruction [0] on left: [a] scenario with AYMs and [b] scenario with SYMs.

FIGURE 6.

Probability of a glance toward pedestrian as a function of how close the driver is to crosswalk and type of pavement markings [Zone 1 is far; Zone 2 is close].

TABLE 1

Descriptions of Nine Scenarios with AYMs and SYMs Used on Driving Simulator

Scenario	Scenario Description for Midblock Crosswalk
1	No obstruction and pedestrian entering from left side
2	No obstruction and no pedestrian
3	Obstruction in left lane and no pedestrian
4	No obstruction and pedestrian entering from right side
5	Obstruction in left lane and no pedestrian
6	No obstruction and pedestrian entering from right side
7	No obstruction and no pedestrian
8	No obstruction and no pedestrian
9	Obstruction in left lane and pedestrian at the middle of the crosswalk and attempting to traverse toward the right side

TABLE 2
Number of Crashes and Near Crashes Under Conditions with AYM's and SYM's

Scenario	Scenario Description for Midblock Crosswalk	AYM		SYM	
		No. of Crashes	No. of Near Crashes	No. of Crashes	No. of Near Crashes
1	No obstruction and pedestrian entering from left side	0	0	0	0
2	No obstruction and no pedestrian	0	0	0	0
3	Obstruction in left lane and no pedestrian	0	0	0	0
4	No obstruction and pedestrian entering from right side	2	0	6	3
5	Obstruction in left lane and no pedestrian	0	0	0	0
6	No obstruction and pedestrian entering from right side	0	1	0	1
7	No obstruction and no pedestrian	0	0	0	0
8	No obstruction and no pedestrian	0	0	0	0
9	Obstruction in left lane and pedestrian at the middle of the crosswalk and attempting to traverse toward the right side	0	8	10	0
Total		2	9	16	4
Average		0.17	0.75	1.33	0.33