

*REDUCING CONFLICTS BETWEEN MOTOR
VEHICLES AND PEDESTRIANS: THE SEPARATE AND
COMBINED EFFECTS OF PAVEMENT MARKINGS AND
A SIGN PROMPT*

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The effects of a symbolic “yield here to pedestrians” sign and advance yield pavement markings on pedestrian/motor vehicle conflicts, motorists’ yielding behavior, and the distance motorists’ yield in advance of crosswalks were evaluated at multilane crosswalks at uncontrolled T intersections. In Experiment 1, the sign, when used alone, reduced pedestrian/motor vehicle conflicts and increased motorist yielding distance. The use of fluorescent yellow-green sheeting as the background of the sign did not increase the effectiveness of the sign. Further reductions in pedestrian/motor vehicle conflicts and further increases in yielding distance were associated with the addition of advance yield pavement markings. In Experiment 2, advance yield pavement markings, when used alone, were as effective in reducing pedestrian/motor vehicle conflicts and increasing yielding distance as the sign combined with pavement markings. These data suggest that the pavement markings were the essential component for reducing conflicts and increasing yielding distance.

DESCRIPTORS: conflict analysis, pavement marking prompts, pedestrian safety, sign prompts

Most pedestrian/motor vehicle crashes occur in urban areas. In the United States, pedestrian fatalities averaged 5,000 per year over the past 5-year period, with almost two thirds occurring on urban roadways (Shankar, 2003). In 2001, 4,882 pedestrians were killed and 78,000 were injured in traffic crashes in the United States, with 69% of the fatalities occurring in urban areas (U.S.

Department of Transportation, 2001). In Canada, pedestrian fatalities averaged 486 per year, and pedestrian injuries averaged 15,358 per year over a 10-year period (1988 to 1997), with 70% of all pedestrian fatalities and 94% of all pedestrian injuries occurring in urban areas (Transport Canada, 2001).

One approach to reducing pedestrian injuries and casualties is to develop safer pedestrian and motorist behaviors. A number of behavioral studies have demonstrated that pedestrian safety can be improved by prompting safe behaviors and providing feedback to drivers (Retting & Van Houten, 2000; Van Houten & Malenfant, 2000; Van

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Houten, McCusker, & Malenfant, 2001) and pedestrians (Retting, Van Houten, Malenfant, Van Houten, & Farmer, 1996; Van Houten, Malenfant, Van Houten, & Retting, 1998; Van Houten, Retting, Van Houten, Farmer, & Malenfant, 1999) and providing feedback to drivers (Malenfant & Van Houten, 1989; Van Houten, Malenfant, & Rolider, 1985). Prompting strategies are typically the most cost-effective approach.

Crosswalks on streets with multilane uncontrolled approaches (approaches not controlled by a full traffic signal) are associated with a type of motor vehicle/pedestrian collision termed a *multiple threat crash* (Snyder, 1972; Zegeer, Stewart, & Huang, 2001). A multiple threat crash involves a pedestrian being struck in a crosswalk by a vehicle traveling in the same direction as a vehicle that is yielding to a pedestrian in an adjacent lane. Vehicles yielding too close to the crosswalk obscure the view of motorists traveling in adjacent lanes (Snyder). One possible solution is to prompt motorists to stop farther back from the crosswalk, which increases pedestrian safety in three ways. First, it increases the sight distance between the pedestrian and the motorist approaching in the adjacent lane. Second, it increases the sight distance when a motorist attempts to pass a vehicle yielding for a pedestrian. Third, vehicles yielding farther back from the crosswalk are less likely to be driven into the pedestrian by reducing the chance of a *billiard ball crash*. This type of crash involves a vehicle striking the yielding vehicle from behind and pushing it into the pedestrian who is crossing in front of the yielding vehicle (Van Houten *et al.*, 2001).

Because crashes occur at a relatively low frequency and are therefore difficult to observe within the time frame of a typical study, traffic safety researchers typically examine pedestrian/motor vehicle conflicts. Such conflicts involve a motorist braking suddenly or swerving to avoid striking a pe-

destrian, or the pedestrian having to jump forward or back to avoid being struck by a vehicle, or both (Lord, 1996). Research has shown that yield-for-pedestrians signs placed in advance of the crosswalk and pavement markings resulted in reductions in pedestrian/motor vehicle conflicts at multilane crosswalks with an uncontrolled approach (Van Houten, 1988; Van Houten & Malenfant, 1992; Van Houten *et al.*, 2001). Van Houten and Malenfant found that the use of the sign alone and the sign combined with pavement markings reduced pedestrian/motor vehicle conflicts. However, the effect of the pavement markings alone was not evaluated.

Further evidence of the effectiveness of a sign and pavement markings has been demonstrated in a more recent study by Van Houten, McCusker, Huybers, Malenfant, and Rice-Smith (2003). This study examined the effectiveness of a sign and advance yield markings along with either the traditional white sign with a black pedestrian symbol used to designate Canadian crosswalks or the same sign with a fluorescent yellow-green background. The results of this study showed that the fluorescent yellow-green signs, although rated as more conspicuous in human factors studies, did not reduce pedestrian/motor vehicle conflicts or increase the percentage of motorists who yielded farther back from the crosswalk compared with baseline.

Although it has been demonstrated that prompting signs used along with pavement marking prompts can be effective in increasing the percentage of drivers who yield well in advance of the crosswalk (Van Houten *et al.*, 2003), it is unclear how much each of these components contribute to the success of the treatment package. Further, the combined effects of these components and fluorescent sheeting is uncertain (Dutt, Hummer, Clark, & Blakely, 1996). Because each element of the package has an associated cost, it is critical to determine the relative

contribution of each component to minimize the cost of a large-scale implementation of this treatment. Therefore, the purpose of the present series of studies was to determine the separate and combined effects of a sign with fluorescent yellow-green sheeting, with and without pavement markings. The second experiment examined the effects of pavement markings without the sign.

EXPERIMENT 1

METHOD

Participants and Setting

The participants in this experiment were motorists and pedestrians observed at four multilane crosswalks each at uncontrolled locations in Halifax, Nova Scotia. Each of the sites was equipped with pedestrian-activated flashing yellow beacons placed next to an illuminated sign with a white pedestrian symbol and black background (Canadian RA 5 sign). All four sites were equipped with right- and left-handed crosswalk signs that were mounted on both sides of each signpost. The crosswalk signs were Canadian RA 4 signs containing a black pedestrian symbol on a white background. The first crosswalk (C1) on Duke Street crossed two lanes of traffic in each direction and formed a T intersection with Argyle Street, a one-way street. The second crosswalk (C3) on Young Street crossed two lanes in each direction and formed a T intersection with a minor road controlled by a stop sign. The third and fourth crosswalks on Robie Street (C2) and Wyse Road (C4) each crossed three lanes of traffic in either direction divided by a median, and both formed T intersections with minor roads controlled by stop signs. Halifax has a population of approximately 300,000 people, and three of the four crosswalks were located on busy arterial roads. Weekday traffic counts averaged 5,654 vehicles on Duke Street, 17,678 on Robie

Street, 17,678 on Young Street, and 17,128 on Wyse Road. Therefore, it is likely that most of the drivers scored each day were different people.

Apparatus

White signs. "Yield here to pedestrian" signs were used to prompt motorists to yield to pedestrians at or behind the advance yield markings. These signs measured 60 cm wide by 75 cm high and showed a 30-cm red yield symbol, the text "HERE TO" written in 7.7-cm black letters, a black pedestrian symbol, and a black arrow (see Figure 1). When signs were also placed on the median, a mirror-image arrow was used. These signs had white reflective backing.

Yellow-green signs. Signs used during this condition were identical to those described in the white-sign condition except that instead of white, the background was fluorescent yellow-green.

Yield markings. The advance yield pavement markings were 40 cm wide at the base of each triangle and 60 cm long. Triangles were made of reflective marking material and were separated by 8 cm (Figure 1). Signs and advance yield markings were placed 10 m to 25 m in advance of the crosswalk, depending on traffic engineering considerations such as the location of the cross streets or exits from major parking lots. A typical application of the markings and sign is shown in Figure 2.

Experimental Design

A multiple baseline across crosswalks design was used with an ABCD sequence of conditions. Following a baseline condition in which standard crosswalk markings were employed without any prompts to increase yielding farther in advance of the crosswalk, each crosswalk first received the white sign, then the yellow-green sign, then the white sign plus pavement markings in a staggered fashion across crosswalks.

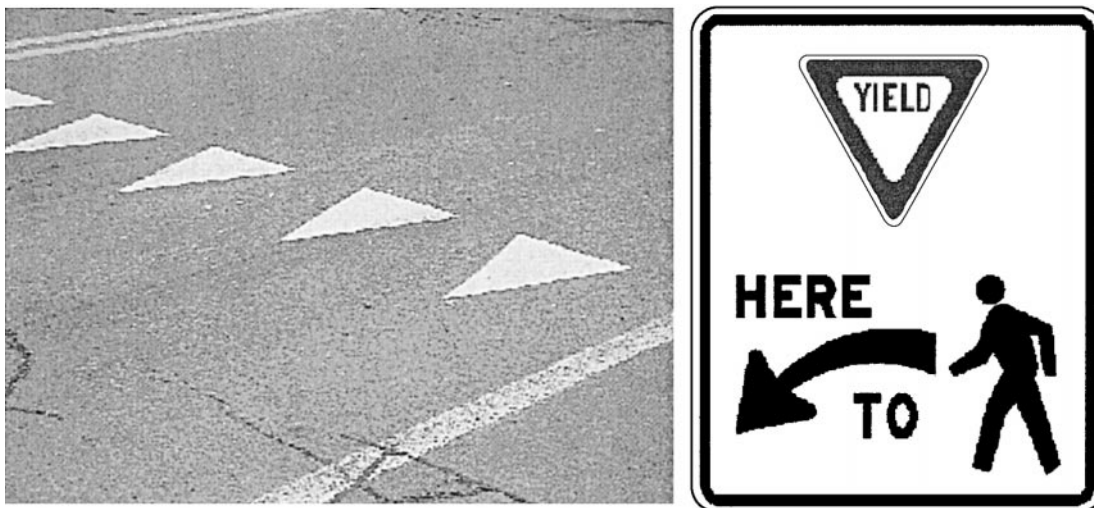


Figure 1. The left frame shows the advance yield markings, and the right frame shows the “yield here to pedestrians” sign.

Signs and markings were placed 10 m in advance of the crosswalk on the side of the road without the T intersection and 15 m in advance of the crosswalk on the side of

the street that intersected with the street that forms the T (25 m on Young Street because the street that forms the T is wider than the other three intersecting streets). This was



Figure 2. A picture showing a typical application of the advance yield markings and sign.

done because the sign or markings could not be placed in the middle of an intersection. Previous research had shown that placing the advance markings at 10 or 15 m in advance of a crosswalk yielded similar results (Van Houten et al., 2001).

Procedure

Each weekday, two observers scored motorist and pedestrian behaviors during sessions scheduled between 7:30 a.m. and 5:00 p.m. beginning in July and ending in late November. Data were not collected on rainy days because fewer pedestrians walked when it was raining. If a session was missed because of rain at one of the sites on a particular day, these data were made up before continuing to collect data at all four sites. Each session included yielding and conflict data from 20 pedestrians who crossed while vehicles were present. Observational sessions typically lasted from 45 min to 1 hr. Data were collected between 7:00 a.m. and 9:00 a.m. at C1, 10:30 a.m. and 12:00 p.m. at C2, 12:00 p.m. and 2:00 p.m. at C3, and 3:00 p.m. and 5:00 p.m. at C4, because these times represented the best times for pedestrian activity at each of these sites.

At C3 and C4, the observer recorded data from her car, which was parked in a parking lot perpendicular to the crosswalk. At C1 and C2, the observer stood or sat perpendicular to the end of the crosswalk, 2 to 4 m from the crosswalk. Observers were instructed to remain inconspicuous while recording data and used university folder-style binders to hold data rather than the typical clipboards used in traffic studies. It is unlikely that drivers were aware that their behaviors were being scored because of the distance the observers were located from the crosswalk and the large number of pedestrians present.

Measures

Evasion conflicts. A pedestrian/motor vehicle evasion conflict was defined as either

(a) the motorist engaging in abrupt braking or swerving to avoid a pedestrian, or (b) the pedestrian running, jumping, or lunging forward or backward to avoid being struck by a vehicle. Abrupt braking was defined as braking hard enough to cause the rear end of the vehicle to suddenly rise. The percentage of evasion conflicts were computed by dividing the number of conflicts by the number of pedestrians who crossed when vehicles were present.

Motorist yielding distance. Marks were placed at 3-m intervals in advance of the crosswalk. Observers recorded the distance of the farthest mark the motorists stopped or slowed behind. A motorist was scored as not yielding if he or she passed in front of the pedestrian and did not stop when the pedestrian arrived at the crosswalk. The distance that a driver could safely come to a complete stop was calculated using the signal-timing formula and was measured and marked to facilitate objective scoring. Drivers were scored for not yielding only if they were behind this line and could safely stop for the pedestrian. Motorists were scored as yielding to pedestrians if they stopped or slowed to allow the pedestrian to pass ahead of them. The observers scored only those vehicles that were in the same half of the roadway that a pedestrian was crossing because most jurisdictions in North America require that the motorist give right of way to the pedestrian when the pedestrian is crossing his or her half of the roadway. Motorist distance was scored only at the moment the pedestrian crossed in front of the target vehicle because this is the critical point for visual screening.

Interobserver agreement. Interobserver agreement was obtained by having two observers independently record conflicts and yielding distance on at least two recording sessions at each site during each experimental condition. During sessions when agreement data were collected, the two observers

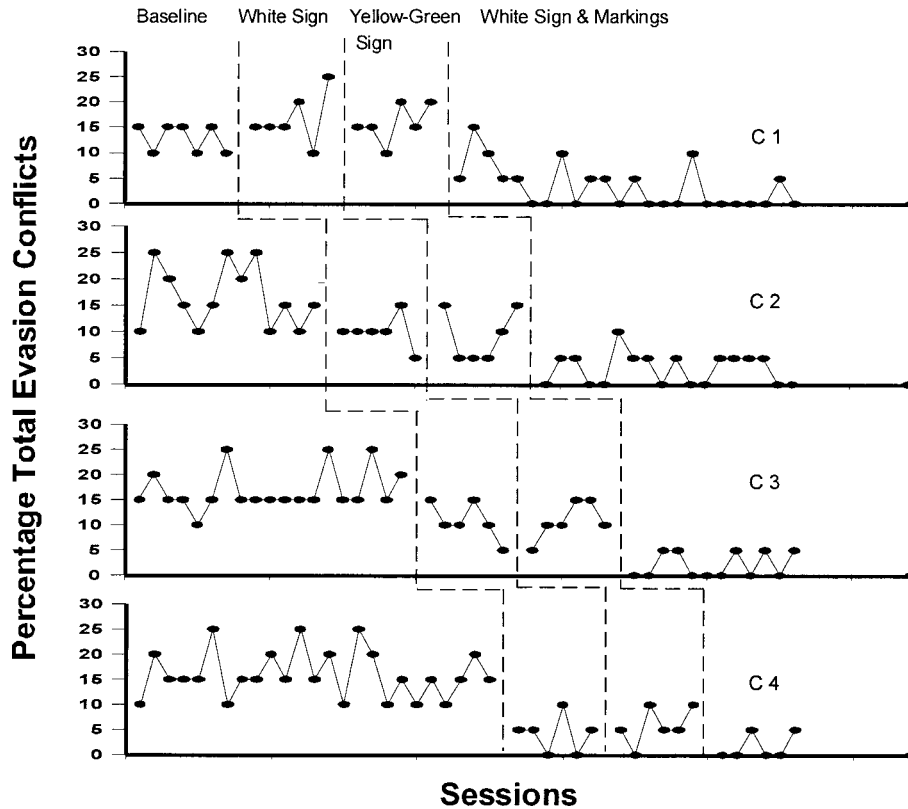


Figure 3. Percentage of total evasion conflicts during each session of Experiment 1.

either sat together in the car (C3 and C4) or stood 1 m apart (C1 and C2). When more than one pedestrian was crossing at a particular crosswalk at the same site, the primary observer identified which pedestrian was the target for observation and recording. This was necessary because occasionally pedestrians crossed from both ends of the crosswalk. Interobserver agreement was computed by dividing the number of agreements on the occurrence of each target behavior by the number of agreements plus disagreements and multiplying by 100%. An agreement on stopping distance was scored when both observers scored the driver as stopping at the same distance in advance of the crosswalk, and an agreement on the occurrence of conflicts was scored when both observers scored an event as a conflict. Interobserver agreement was 100% for conflicts. Agree-

ment on yielding distance averaged 90%, with a range of 75% to 100%.

RESULTS AND DISCUSSION

The percentage of conflicts observed at the four crosswalks is presented in Figure 3. During baseline, conflicts averaged 12.8% at C1, 16.5% at C2, 16.8% at C3, and 16.6% at C4. The introduction of the white sign alone or the yellow-green sign alone was not associated with a reduction in conflicts at C1 but was associated with conflict reductions at the three remaining crosswalks, with conflicts averaging 10% and 9.2% for the white and yellow-green signs, respectively, at C2, 10.8% for both signs at C3, and 5.8% for the white and yellow-green signs, respectively, at C4. The introduction of the white sign plus markings was associated with reductions in conflicts at all four sites, with

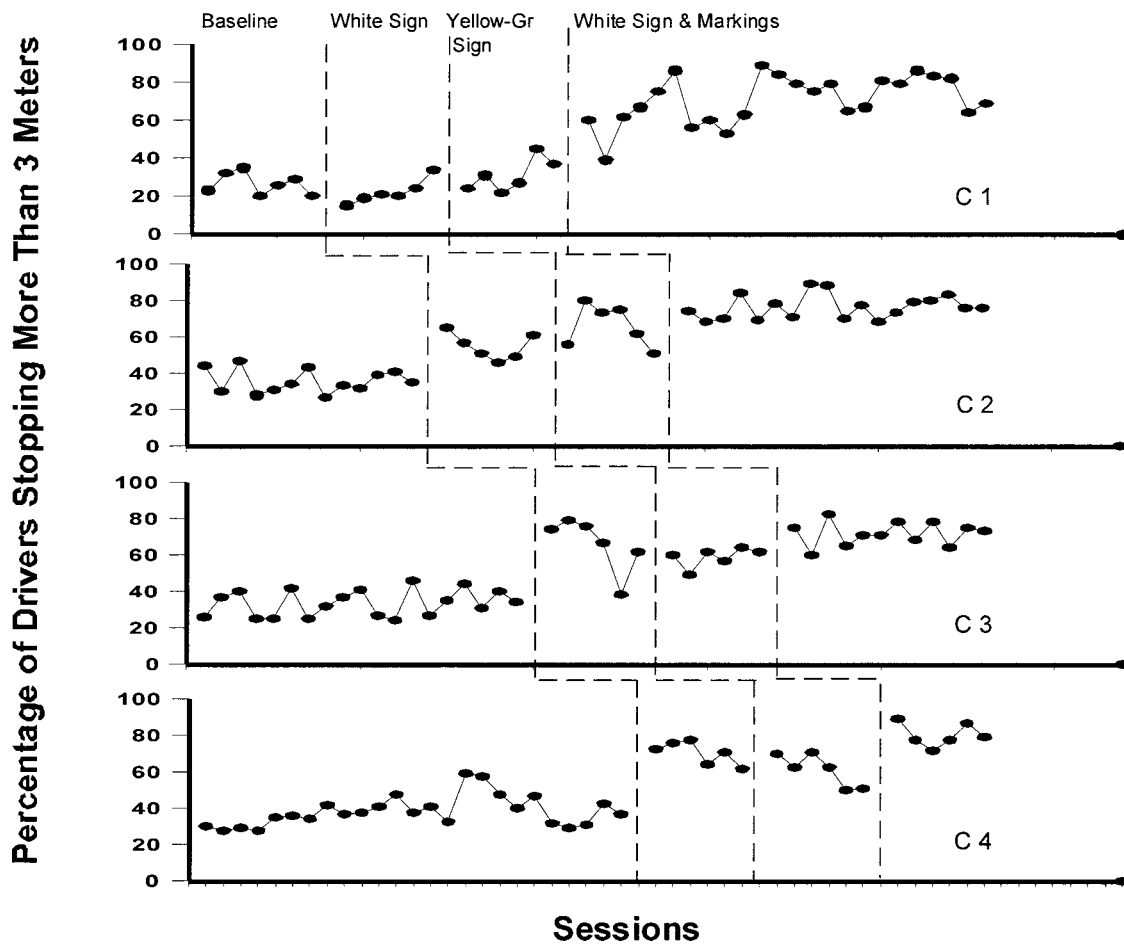


Figure 4. Percentage of drivers who yielded more than 3 m in advance of the crosswalk during each session of Experiment 1.

conflicts averaging 3.3% at C1, 3% at C2, 2.1% at C3, and 1.7% at C4. These represent overall conflict reductions between 74.2% and 89.8% compared with baseline.

Figure 4 shows the percentage of motorists who yielded more than 3 m from each of the four crosswalks. The introduction of the white sign alone or the yellow-green sign alone had no effect on this percentage at C1, but these signs were associated with increases in yielding more than 3 m at the remaining three crosswalks. The introduction of the white sign was associated with an increase in percentage of motorists yielding at least 3 m in advance of the crosswalk from 35.7% to 54.8% at C2, from 53% to 66% at C3, and

from 38.5% to 70.7% at C4, and the yellow-green sign was associated with little change in these percentages. The introduction of the white sign and markings was associated with increased yielding over 3 m at all four sites, with yielding averaging 72% at C1, 77% at C2, 71.5% at C3, and 80.5% at C4.

Overall, neither sign alone was effective at C1, whereas both signs were equally effective at the remaining three crosswalks. The white sign plus markings were superior to the sign alone at all four sites. The purpose of the second experiment was to investigate the effectiveness of the advance yield markings without the addition of a sign.

EXPERIMENT 2

METHOD

Participants and Setting

The participants in Experiment 2 were motorists and pedestrians observed at two multilane crosswalks at uncontrolled locations in Halifax, Nova Scotia. As in Experiment 1, both sites were equipped with a Canadian RA 5 sign as well as right- and left-handed crosswalk signs. The first crosswalk (C5) on Kerney Lake Road crossed two lanes of traffic in each direction and formed a T intersection with Castle Hill Road, a minor road controlled by a stop sign. The second crosswalk (C6) on Brunswick Street crossed two lanes of traffic in each direction and formed a T intersection with Carmichael Street, a minor road controlled by a stop sign. Both streets were busy arterial roads.

Apparatus

The pavement markings used in this experiment were of the same material and measurements as those used in Experiment 1. The signs were the same as the white sign used in Experiment 1. Signs and advance yield markings were placed 10 m to 25 m in advance of the crosswalk.

Experimental Design

A multiple baseline across crosswalks design was used in this research with an ABC sequence of conditions. Following a baseline condition in which standard crosswalk markings were employed without any prompts to increase yielding farther in advance of the crosswalk, each crosswalk first received the advance yield pavement markings alone, then the advance yield markings plus white signs, in a staggered fashion across crosswalks. Signs and markings were placed 10 m in advance of the crosswalk on one side of the crosswalk. On the other side, the advanced yield markings were placed 15

m in advance of the crosswalk because placing them at 10 m would have located them in the middle of the intersecting street.

Procedure

The procedure was similar to that used in Experiment 1. Each weekday, two observers scored motorist and pedestrian behaviors during July and August of the following year (2002). Data were collected between 8:00 a.m. and 9:00 p.m. at C5 and from 11:30 a.m. to 12:00 p.m. and 3:00 p.m. to 5:00 p.m. at C6. At C5, observers collected data from a car parked in a lot perpendicular to the crosswalk.

Measures

The same pedestrian/motor vehicle conflict measure used in Experiment 1 was used in this experiment. Data collection was carried out in the same manner as in Experiment 1.

Interobserver agreement. Interobserver agreement was also carried out in the same manner as Experiment 1, and calculations were computed in the same way. Agreement was 100% for conflicts. Agreement on yielding for pedestrians averaged 94.5%, with a range of 83% to 100%. Agreement on yielding distance averaged 92%, with a range of 87% to 100%.

RESULTS AND DISCUSSION

The number of conflicts observed at the two crosswalks is shown in the top panel of Figure 5. During baseline, conflicts averaged 17.5% at C5 and 17.1% at C6. The introduction of the advance yield markings alone resulted in a decrease in the average percentage of conflicts to 5.8% at C5 and 5.0% at C6. The introduction of the sign was not associated with further changes at either crosswalk.

The middle panel of Figure 5 shows the percentage of motorists who yielded more than 3 m from the crosswalk. The introduc-

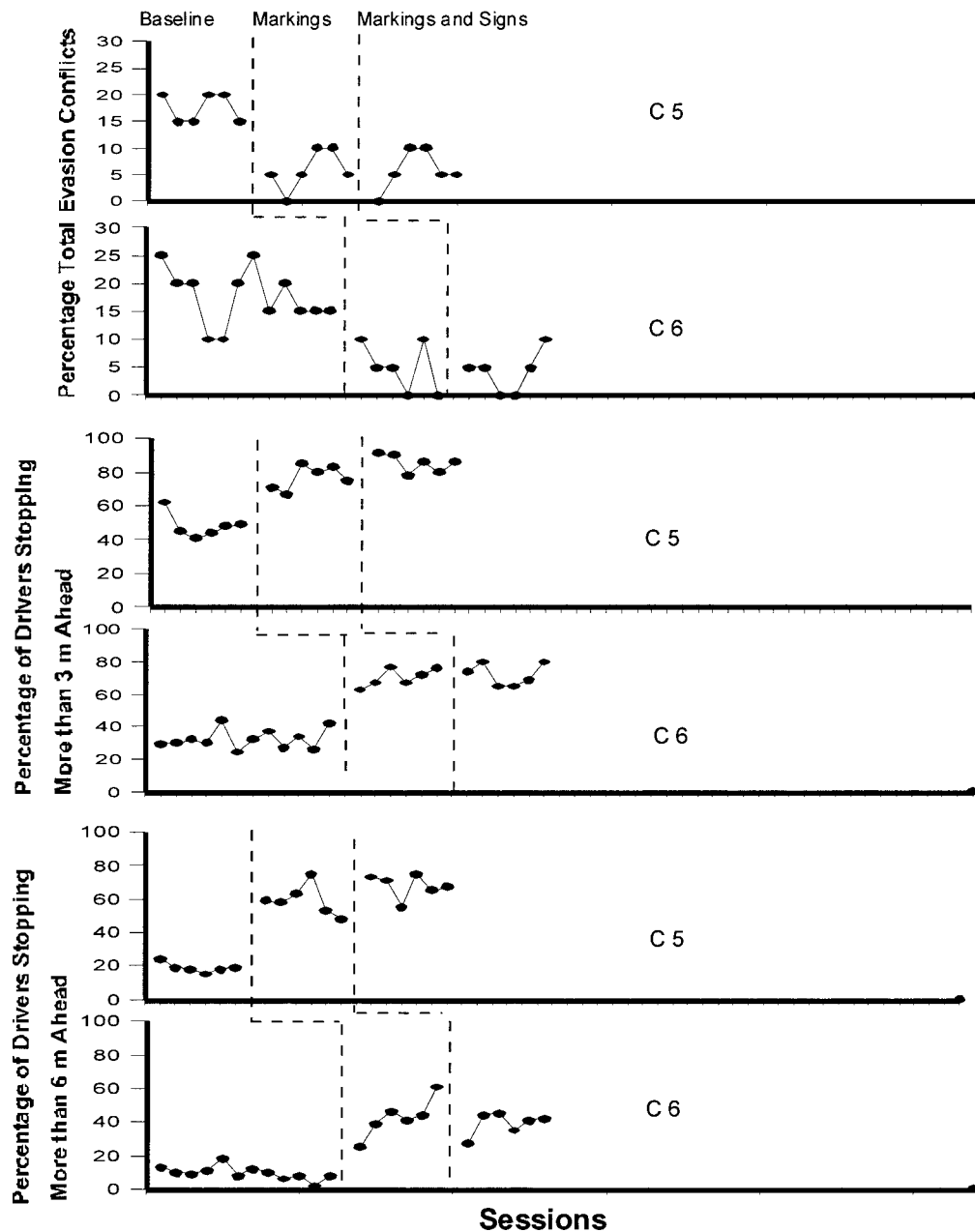


Figure 5. Percentage of total evasion conflicts (top panel) and drivers who yielded more than 3 m (middle panel) and 6 m (bottom panel) in advance of the crosswalk during each session of Experiment 2.

tion of the markings alone increased the percentage of motorists who yielded at least 3 m behind the crosswalk from 48.2% to 76.8% at C5 and from 32.2% to 70.3% at C6. During the markings and signs treatment, little change occurred in the percent-

age of motorists who yielded more than 3 m in advance of the crosswalk.

The bottom panel of Figure 5 shows the percentage of motorists who yielded at least 6 m in advance of the crosswalk. These results are similar to those for motorists who

yielded at least 3 m in advance of the crosswalk. Increases were seen at both crosswalk locations when the markings alone were introduced, with an increase from 18.8% to 59.3% at C5 and from 9.6% to 42.3% at C6. Little change was observed following the introduction of the signs at either site.

GENERAL DISCUSSION

The results of this research demonstrate that the “yield here to pedestrians” sign, when used alone, reduced the pedestrian/motor vehicle conflicts and increased the percentage of motorists who yielded in advance of the crosswalk at three of the four crosswalks studied in Experiment 1. Although the sign alone produced some reductions in conflicts and increases in yielding distance at three of the four crosswalks in Experiment 1, combining the sign with advance yield pavement markings produced further reductions in conflicts. The addition of the fluorescent yellow-green background to the sign did not produce a marked improvement in these results. These results support the findings of Clark, Hummer, and Dutt (1996), in which fluorescent yellow-green pedestrian signs did not decrease pedestrian/motor vehicle conflicts even though it increased visibility and legibility distance (e.g., Dutt *et al.*, 1996; Schnell, Bentley, Hayes, & Rick, 2001).

The results of Experiment 1 also indicated that the addition of advance yield pavement markings was associated with a further decrease in conflicts and a further increase in motorist yielding distance. These results rule out the possibility that the lack of effectiveness of the yellow-green sign was due to a floor effect for conflicts or a possible ceiling effect for yielding farther behind the crosswalks. The present results suggest that although signs made with yellow-green sheeting may be more easily recognizable, greater compliance does not necessarily follow. It is

possible that the motorists were attending more to the fluorescent yellow-green sheeting than to the message of the sign that was printed on it.

It is possible that the sign alone did not improve safety at C1 because motor vehicles on Duke Street were more inclined to park near the signs (a no-parking zone). Because these vehicles were primarily large trucks and buses, they obscured the view of the signs and pedestrians. Although no formal data were collected on yielding when vehicles were parked next to the sign, informal observation suggested that drivers were less likely to yield in advance of the crosswalk when large vehicles were parked by the sign.

In Experiment 2, advance yield markings alone were as effective as the markings with a sign at decreasing pedestrian/motor vehicle conflicts and increasing motorist yielding distance. These studies in combination demonstrate that yield markings are the essential component in decreasing pedestrian/motor vehicle conflicts and increasing motorist yielding distance. However, this conclusion needs to be tempered because it is possible that signs may have facilitated the initial understanding of the yield markings. They had previously been applied at a number of other locations in Halifax, and hence many motorists may have seen the sign and markings used together. However the use of temporary signs would likely produce similar results and reduce the cost of this effective safety treatment. Our findings show that prompting motorists to yield farther back from the crosswalk increases pedestrian safety and are consistent with the findings of other studies (e.g., Van Houten, 1988; Van Houten & Malenfant, 1992; Van Houten *et al.*, 2001, 2003).

One reason why pavement markings used alone produced a larger effect than the sign alone may relate to the location of the prompt. There are several reasons why position may influence the efficacy of the

prompts. First, although both signs and markings are located in the driver's view, it is likely that drivers spend more time scanning the roadway in front of them than the side of the road. This makes it more likely that they will see a prompt placed in the roadway. Second, roadway markings are likely to be visible at a greater distance than the sign because of their relative size. Third, it is possible that markings in the road may better control stopping location than signs at the side of the road because the driver must attend to the roadway while stopping and the relative position of the sign rapidly approaches the side of the road as the driver approaches it, making it unlikely that the driver would continue to look to the side while driving. For prompts to be effective, they should be timed to occur before the desired behavior is to be emitted. One factor that can facilitate good timing is the location of the prompt (Van Houten, 1998). Placing the prompt on the roadway helps to ensure that it will be seen by the driver and come to control the location where the behavior is emitted. These findings support the assertion (Van Houten) that prompts should be located to facilitate good timing and that prompts should be located so as to guide the desired behavior.

Future research should examine whether the use of advance yield markings alone work as well in communities that have not had a history of the signs used with the markings, and whether the signs work as well at crosswalks at full intersections as they do at crosswalks at T intersections.

The use of advance yield markings along with the symbol sign have recently been incorporated in the Federal Highway Administration's *Manual of Uniform Traffic Control Devices*. This manual specifies what treatments may and may not be used, and the inclusion of this treatment in the manual will facilitate the use of this intervention.

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STUDY QUESTIONS

1. What was the basis for the authors' suggestion that prompting is a more cost-effective road safety strategy than is providing feedback to drivers?
2. What is a pedestrian/motor vehicle conflict, and why is it a common dependent variable in road safety research?
3. Briefly describe the three prompt conditions used in Experiment 1.
4. What were the dependent variables, and how were they operationally defined?
5. Summarize the results of Experiment 1.
6. What conditions were compared in Experiment 2, and what results were obtained?
7. How did the authors account for the difference in effectiveness between signs and pavement markings?
8. In what way were the two experiments complementary in providing a component analysis of the interventions of interest?

Questions prepared by Natalie Rolider and Erin M. Camp, University of Florida