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Investigating Generalization of Motorist Yielding to the Gateway Prompt from the Treated Leg of the Intersection to the Untreated Adjacent Leg

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INVESTIGATING GENERALIZATION OF MOTORIST YIELDING TO THE GATEWAY PROMPT FROM THE TREATED LEG OF THE INTERSECTION TO THE UNTREATED ADJACENT LEG

by

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Pedestrian safety continues to be an important research topic, especially since recent data show a small increase in pedestrian fatalities (USGAO, 2015). There have been several interventions that prompt pedestrians, but especially motorists, to yield properly at uncontrolled crosswalks (Van Houten, 1988; Van Houten & Malenfant, 1992; Nasar, 2003; Crowley-Koch, Van Houten & Lim, 2008). One low-cost intervention that has been successful is the R1-6 in road yielding sign (Kannel, Souleyrette, & Tenges, 2003). When this sign is laid out purposefully across a crosswalk (called a gateway), it has resulted in substantial increases in yielding compared to baseline conditions. In addition to being an effective treatment, the gateway configuration is also cost effective, costing only $900 vs. $10,000 – $120,000 for more technological alternatives (Shurbutt, Van Houten, Turner & Huitema, 2009). This study assessed whether generalization of yielding behavior would occur if the gateway was used on one of the two crosswalks of the intervention site (i.e., whether motorists' yielding behavior at a non-gateway crosswalk would increase, decrease, or maintain if the other crosswalk had the gateway intervention installed). An alternating treatments and reversal design was used to determine the effects of generalization at an uncontrolled crosswalk in the Midwest. The results showed motorist yielding at generalization crosswalks was higher than baseline, but lower than crosswalks with the gateway installed. Additionally, driving through the gateway resulted in

higher motorist yielding at the generalization crosswalk. The findings may have implications for intervention design and city planning.

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INVESTIGATING GENERALIZATION OF MOTORIST YIELDING TO THE GATEWAY PROMPT FROM THE TREATED LEG OF THE INTERSECTION TO THE UNTREATED ADJACENT LEG

An historical review of pedestrian fatalities statistics in the United States shows a dramatic decrease in the number and percentage of fatalities. In 1927, 10,820 pedestrian fatalities comprised 41.9% of total traffic fatalities. The frequency increased until 1937, but then experienced a steady decrease with some variability through the 70's and 80's (Campbell, Zeeger, Huang, & Cynecki, 2004). The reasons for that decrease are numerous, with the largest reason likely being the most obvious: as more pedestrians became motorists, their direct exposure to traffic was reduced, resulting in less pedestrian activity overall, and thus fewer fatalities. Additional explanations for the decrease in pedestrian fatalities are: better travel infrastructure, routes and signs that prompt both pedestrian and motorist behavior, and driver education and training, to name a few. Despite the overall improvements in pedestrian safety in the United States, pedestrian fatalities and injuries now represent a growing percentage of all traffic fatalities and injuries. For example, pedestrian fatalities comprised 10.9 percent of all traffic deaths nationwide in 2004, but 14.5 percent in 2013 (USGAO, 2015).

Several reasons may explain why pedestrian fatalities occur and the behavior of both pedestrian and motorist is the most likely causal factor in accidents involving both parties. However, lack of knowledge of traffic laws involving pedestrian crossings may be another important factor. Mitman and Ragland (2007) studied pedestrian knowledge of right-of-way traffic laws at both marked (crosswalks that have visible street markings or demarcations) and unmarked crosswalks (crosswalks that lack any visible markings) as they pertain to both pedestrians and motorists. The authors surveyed 192 people in the San Francisco Bay area of California, a group composed of 133 pedestrians and 59 motorists. Those surveyed were given a panel showing 5 different crosswalk and intersection scenarios and were told to identify in which scenarios pedestrians had the right-of-way. Results of the survey showed that as the scenarios increased in complexity, the understanding of right-of-way laws decreased. Overall, pedestrians were correct 63% of the time, while the motorists were correct 55.6% of the time. This study lends evidence to the idea that knowledge of when or where to cross correctly could be a causal factor in pedestrian accidents and fatalities. However, it should be noted that pedestrian and motorist behavior are most likely influenced by how effortful a behavior is, and how long they have to wait.

In 2013, 4,735 pedestrian fatalities and approximately 66,000 pedestrian injuries occurred during street crossings in the United States (NHTSA, 2014). A potential explanation for these pedestrian fatalities and injuries is a lack of environmental stimuli that prompt motorists to yield to pedestrians in crosswalks. However, a comprehensive study by Zeeger, Stewart, Huang, Lagerwey, Feaganes, and Campbell (2005) found that marked crosswalks (crosswalks with a visual lane of travel for pedestrians) showed no statistical difference in crash rates than unmarked crosswalks at uncontrolled intersections. Uncontrolled crosswalks, and crosswalks at uncontrolled intersections (crosswalks with no yield, stop, or traffic signal), pose an additional "right-of-way" challenge.

Behavior Analytic Treatment Packages

Early behavioral research in pedestrian and motorist safety focused on treatment packages including several interventions: antecedent and feedback signage (e.g., Van Houten & Nau, 1983; Van Houten, Malenfant, & Rolider, 1985; Nasar, 2003), advance yield markings (e.g., Van Houten, 1988; Malenfant & Van Houten, 1989; Huybers, Van Houten, & Malenfant, 2004), enforcement (e.g., Van Houten & Nau, 1983; Van Houten & Malenfant, 2004), and prompts to motorists (e.g., Crowley-Koch, Van Houten, & Lim, 2011). The following studies use two or more of these interventions.

Van Houten and Nau (1983) used feedback signs and several variations of police enforcement in a series of studies to understand variables that influence vehicle speed on roadways and highways. The settings for all the studies were roadways outside of Dartmouth, Nova Scotia. The first study set out to determine if performance feedback signs displaying variable speeding criteria would affect speeding behavior. Data were collected during daylight hours on weekdays with a highway speed limit of 50 kph. Motorist speed was collected using a radar gun. The independent variable was a feedback sign that read: "DRIVERS NOT SPEEDING LAST WEEK ___%". The researchers used a modified reversal design where, after baseline, they posted strict speeding criterion (the percentage of drivers traveling less than 60 km/h on a random day from the preceding week), followed by a lenient speeding criterion (the percentage of drivers traveling less than 70 km/h on a random day from the preceding week) in an A-B-C-A-B-C-B format. Numbers posted on the sign from the strict phase ranged from 53%-58% and the lenient phase from 91%-96%. The results of this first study showed a stepwise reduction in vehicle speeding from the progression of baseline, to stringent, and then lenient posting criterion. The researchers were able to rule out sequence effects by showing an increase in speeding when returning to the final stringent criterion phase. When baseline was reinstated, vehicles' speeds rose to near baseline levels. The results showed that providing feedback using the more lenient criterion was more effective at decreasing vehicle speed than the stricter criterion. The authors suggested that using a criterion that encompasses 80-90% of drivers would be more effective. The authors also posited that the effects might derive from the implication that the cars are being watched by law enforcement. It is also possible that a social norming effect is present in these data. Such an effect suggests that fewer people will speed when they think most people are not speeding and that more drivers will speed when they think most drivers are speeding.

The second study set out to determine if the weekly feedback sign used in the first experiment would work on a limited access highway with a constant speed limit of 100 kph, and how far beyond the sign the effects would last. The participants were motorists traveling southbound on a 6km section of a 4-lane divided highway. Speed measurements were taken during weekday daylight hours using a radar gun at 4 different sites along the roadway: 1 km, 2 km, 4 km and 6 km past the feedback sign. The feedback sign was slightly different than the first experiment and read "DRIVERS NOT SPEEDING LAST WEEK__%, BEST RECORD __%.". The researchers used a reversal design alternating between baseline, where driver's speed was measured while the sign was covered with opaque black plastic, and a weekly posting condition in which the percentage of motorists who were travelling less than 109 kph was posted on the sign, as well as the highest percentage to date. The feedback sign was updated every Monday with data from a random day of the preceding week. Results of the second experiment showed that driver speed decreased during the feedback sign conditions when compared to baseline, and that the effects of the feedback sign deteriorated as the distance increased from the feedback sign location. The authors also noted that the feedback sign was more effective at decreasing the speed of higher speed motorists than those of lower speed motorists.

The third experiment compared the effects of the feedback sign to a parked, marked, unmanned police vehicle. A secondary purpose was to determine if the combined effects of the feedback sign and parked police car were more effective than either of the techniques alone. Participants were motorists travelling along a 2-lane, 2-way street with a posted speed limit of 50 kph. The roadway was chosen because of a history of traffic accidents. Vehicle speeds were measured with a radar gun and the police car used was a standard police cruiser from the traffic division that had “TRAFFIC DIVISION, DRIVE CAREFULLY” printed in white block letters on the trunk of the vehicle. The researchers used a modified reversal design switching between baseline (no police vehicle present), police car present, feedback sign posting, and a combination of both to determine the single and combined effects of the marked police car and the feedback sign. During the posted feedback phase the sign displayed the percentage of drivers travelling at 64 kph or less during the preceding week and the highest percentage recorded. The feedback sign was updated every Monday morning with data from a random day of the previous week. The results showed that the parked police car was effective at reducing speeding of motorists, and confirmed the effectiveness of the feedback sign at reducing speeds. However, the parked police vehicle was more effective at reducing motorists’ speeds than the feedback sign, and when the two interventions were combined there was no greater effect observed. The authors also noted that the effectiveness of the parked police vehicle diminished over time.

The fourth experiment’s purpose was to compare the effectiveness of the feedback sign to another speed enforcement technique: police aircraft patrols. The participants for the 4^{th} study were motorists travelling along a 5km 4-lane divided highway segment with a posted speed limit of 80 kph. This segment was chosen because of recent crash fatalities and the amount of speeding motorists observed. Speed measurements were taken at four different sections along the highway using a radar gun. The feedback sign was the same fashion as the one used in the second experiment and there were also air patrol warning signs that read “SPEED LIMIT ENFORCED BY POLICE AIRCRAFT” with a similar size and shape to that of the feedback sign. The speeds of motorists were sampled daily, similar to the previous experiments, Monday through Friday during daylight hours. The researchers employed a reversal design switching between baseline, feedback sign, air patrol, and a combination of air patrol and feedback sign phases to determine the single and combined effects of the independent variables. The air patrol condition consisted of 2 hour-long air patrols by helicopter in which a constable from the helicopter reported speeders to traffic police on the ground. These officers stopped violators and either gave them a warning or issued them a citation for speeding. When the feedback sign only condition was in effect the air patrol signs were covered, and vice versa. The results of the fourth experiments showed that both interventions alone were successful at reducing speed below baseline levels and that the combination of the feedback sign and air patrol was more effective than the feedback sign alone. The purpose of the last study was to compare the effectiveness of the feedback sign and standard enforcement to a treatment that consisted of giving warnings and informational fliers to speeding motorists rather than citations. The participants of this study were motorists on three different roads with speed limits of 50 kph, 50 kph, and 70 kph. The researchers used a multiple baseline across sites to compare the different treatments. Speeding data were collected using similar strategies from the previous studies. The warning flier given to speeding motorists offered information on historical accidents on the current road of travel and reasons why speeding was a catalyst in those crashes. The results of the study showed that the warnings and informational fliers were effective at reducing motorists' speed at all sites and that it was more effective than a standard enforcement procedure. The addition of the feedback sign to the warning and flier phase was more effective than either alone. The likely variable was the increase in certainty that a driver will be stopped when warnings are given because of the much larger proportion of drivers that could be warned than cited. Because a citation takes much longer to write than to give a verbal warning with a flyer, it was possible to stop ten times as many people when warnings are given.

Van Houten, Malenfant and Rolider (1985) evaluated a treatment package consisting of posted feedback, signs that prompt pedestrians to signal their intent to cross, and a warning enforcement program for motorists who failed to yield to pedestrians. The researchers chose high traffic crosswalks on two multi-lane roads with a recent history of pedestrian accidents in Dartmouth, Nova Scotia as the setting for their study. They studied both pedestrians and motorists who utilized these crosswalks using a multiple baseline design across sites in an A-B-C-D fashion. After baseline measures were taken, the treatment package phase (B) began which included (a) posting feedback on motorist yielding percentage, (b) signs tailored to the pedestrians at the beginning of the crosswalks that instructed them how to signal to motorists their intention to cross, and (c) enforcement (warnings). The posted signs presented feedback on the current percent yielding and highest yielding record to date of motorists yielding to pedestrians. These signs were updated every Monday with data from the previous week. The enforcement consisted of police officers acting as confederates in the crosswalks, crossing when other pedestrians were not present. When a motorist failed to yield to a pedestrian, a police officer pulled over the vehicle, wrote them a warning, and handed them a flier with information regarding the law and statistics for pedestrian accidents in that area. The next phase (C) was the “reward” condition. This consisted of enforcement officers pulling over motorists who had yielded to pedestrians and handing them a small bag with a pen, a bumper sticker, and note from the chief of police thanking them for their safe behavior. The final phase (D) was a follow-up that consisted of measuring behavior while the feedback and prompting signs were in effect but with the absence of enforcement. The intervention package (B) resulted in an increase in motorist yielding behavior from 22% and 12.5% to 51% and 33.4%, respectively. The introduction of the “reward” condition had little effect on yielding behavior. Additionally, the follow-up data showed that the results maintained after the enforcement condition was removed. The treatment package was also successful at increasing the prompting behavior of pedestrians from a near zero baseline to 13% for the treatment condition.

In a follow up study, Malenfant and Van Houten (1989) tested whether a similar intervention package would be effective for entire cities and not just certain crosswalk locations. The intervention package was similar to Van Houten, Malenfant, and Rolider (1985). The treatment package (safety program) consisted of five components: public posting, prompting of both motorist and pedestrian, police enforcement, advance stop lines (lines in the roadway that precede crosswalks and thus prompt motorists to stop well in advance of the crosswalks), and media attention/public education. The settings for this study were three Canadian cities in the Northeast. The apparatuses were virtually the same as in the previous study – large signs to provide prompts and feedback, as well as signs to prompt pedestrian behavior. The crosswalks in each city were chosen based on accident data, and complaints from residents. The study evaluated thirteen streets in the first city, fourteen in the second, and seven in the third city. A multiple baseline design across locations was used to determine treatment package effectiveness. This study engaged in more city-wide education and media attention including mailed flyers, informational posters near schools, and lessons plans for primary, elementary, and junior high schools. The city-wide safety program was effective at increasing motorist yielding to crosswalks

– from a 54%, 9%, and 44% baseline yielding percentage to 71%, 52%, and 65%, respectively. In addition to motorist yielding behavior, the researchers were able to obtain accident data from two of the three cities. The number of pedestrians struck in marked crosswalks with no traffic signal averaged 1.4/year during the 3.5 years before the intervention. Post-intervention, this number was reduced to .5/year for 2 years after the safety program for the first city, and 5.7/year to 2.5/year for the second city.

In a formative study, Van Houten (1988) used advance pavement markings and a sign prompting drivers to yield. The setting was two uncontrolled crosswalks that traversed a 6-lane, 50 km speed limit roadway in Dartmouth, Nova Scotia. The prompts used for the intervention consisted of pavement markings that were painted on the roadway in advance of the crosswalk, and large wooden signs that read "STOP HERE FOR PEDESTRIANS" with an arrow pointing to the advance line markings. The signs also used reflective material to increase visibility. The two main dependent variables were motorist yielding and pedestrian-motorist conflicts. Three types of scenarios can describe pedestrian-motorist conflicts. Type 1 conflicts involve a pedestrian or motorist engaging in evasive maneuvers to avoid contact (either abrupt braking or swerving for motorists, and pedestrians jumping or stepping back). Type 2 conflicts involve motorists who fail to yield to a pedestrian and pass less than a lane's distance from a pedestrian, but do not qualify as a type 3 conflict. Type 3 conflicts involve a secondary vehicle passing a primary vehicle that had yielded to a pedestrian, and in doing so, passing within one lane of the crossing pedestrian. A reversal design that either introduced or removed the prompts was used to determine the effectiveness of the treatments. Results of this study showed that the number of motorist-pedestrian conflicts decreased significantly and yielding behavior increased slightly. It also showed that motorists who did yield tended to yield further back from the crosswalk.

In a follow-up study, Van Houten and Malenfant (1992) used similar interventions at controlled crosswalks (compared to the uncontrolled setting in the previous study) to determine if the prompting sign alone was as effective as the sign with the advance yield markings. The settings for this study were two marked crosswalks in Nova Scotia. Both settings were multi-lane roads with a speed limit of 50 kph. Each roadway had advance markings in the form of a large "X" painted 50m on each side of the crosswalk. The sign in this study was replicated from Van Houten (1988): a large wooden sign with reflective tape that read "STOP HERE FOR PEDESTRIANS" with an arrow pointing to the crosswalk. The signs and markings intended to prompt motorists to yield further back from the crosswalk to avoid multiple threat scenarios. Multiple threat scenarios occur when a driver yields very close to the crosswalk, obscuring the pedestrian's view of the driver approaching in the next lane. Additionally, it obscures the hidden driver's view of the pedestrian beyond the stopped vehicle. These crashes usually occur with the vehicle traveling at high speed and are most often fatal. The dependent measures in this study replicated Van Houten (1988) – motorists yielding to pedestrians and pedestrian-motorist conflicts. A multiple-baseline design across settings was used to determine the effectiveness of the interventions. The baseline condition was followed by the prompting sign alone, then the sign plus the stop line. A follow-up condition with the absence of any treatment was conducted at the one-month and one-year marks after the study concluded. The results indicated that the sign alone was effective at increasing yielding, and the addition of the advance markings further increased yielding behavior. The results also showed that the interventions reduced all three types of motorist-pedestrian conflicts. All of these results were maintained at the one-month and one year-follow-ups.

Van Houten, McCusker, and Malenfant (2001) carried out another study to assess slight differences in treatments – signs prompting motorists to yield using signs with symbols instead of text. The settings were 3 multi-lane crosswalks in the Halifax region of Nova Scotia. Each site had pedestrian activated flashing amber beacons to alert motorists to imminent crossings. All of the selected sites had a history of pedestrian-motorist crashes involving the multiple-threat scenario. Data collection was conducted similarly to the above studies using natural crossings and various types of motorist-pedestrian crossings. The advance yield markings in this study consisted of small white triangles, 16 inches wide and 24 inches long, spaced 9 inches apart. The posted sign prompt consisted of a white sign with a red “yield” symbol and the words “Here” and “To”, with a black pedestrian symbol and arrow pointing to the advance markings. Similar to previous studies, a multiple baseline across settings was used to determine the effects of treatments. In subsequent phases of the study, the advance yield markings were moved further back and staggered across sites. The results of the study showed that the advance yield markings and yield sign reduced motorists-pedestrian conflicts at all sites. The interventions also resulted in motorists yielding further back from the crosswalks. Pedestrian yielding percentages increased slightly at all sites.

Van Houten, McCusker, Huybers, Malenfant, and Rice-Smith (2003) conducted a comparative study which utilized a variation of the white yield sign from Van Houten, McCusker and Malenfant (2001). This study used a more conspicuous fluorescent yellow-green yield sign. The setting for this study was 24 crosswalks in Nova Scotia with uncontrolled approaches (no stop signs or traffic lights). The settings were spread out over the regional area with 12 located in the Halifax Regional Municipality (HRM). The 12 crosswalks in HRM were multi-lane roads and the other crosswalks were multi-lane, 2-way and one-way roads. All sites had a speed limit of 50 kph. The measures and data collection procedure were identical to the previous study. The experimental design was a before-and-after with control group – sites with similar parameters were grouped in sets of four and then randomly assigned to a treatment with one group as control. The four treatment groups were (1) control, (2) advance yield marking with white signs, (3) fluorescent sign alone, and (4) advance yield marking with fluorescent signs. Results of the study confirmed the results of previous similar studies. Advance markings and yield signs decreased the number of motorist-pedestrian conflicts, increased yielding to pedestrians, and increased the yielding distance to pedestrians. An additional finding of this study was that the fluorescent yellow-green signs did not increase yielding more than the white signs.

Huybers, Van Houten, and Malenfant (2004) were interested in teasing out the individual variables of the previous similar studies to determine how much each of the components contributed to the success of the treatment packages. If large-scale implementation were to be completed, a cost-benefit analysis would be necessary. The researchers conducted a series of studies to determine the separate and combined effects of a sign with fluorescent yellow-green sheeting, with and without pavement markings and the effects of advance pavement marking without the prompt sign. Both studies were completed at multi-lane crosswalks in Halifax, Nova Scotia – four crosswalks for the first study and two crosswalks for the second study. The first study compared the white sign to the fluorescent sign, and the white-sign plus advance pavement markings using a multiple-baseline design across settings. The dependent measures were motorist-pedestrian conflicts and motorist yielding distance. The results of the first study showed that neither sign alone was effective at the first crosswalk but were equally effective at the other 3 crosswalks, and the white sign plus advance markings were more effective than the sign alone at all crosswalks. The second study investigated the effectiveness of the advance yield markings with the addition of the prompting sign. A multiple baseline design across settings was used to determine the effects. An ABC design was used with A as the baseline, B as the crosswalks with advance yield markings, and C added the prompting signs to the advance yield markings. The measures for the second study were the same as the first. The results showed decreases in pedestrian conflicts with the addition of the advance yield markings and increases in yielding differences. However, the addition of the signs did not change motorist behavior. This study showed that the markings were responsible for the effectiveness of the treatment.

Nasar (2003) used a novel approach to prompting to achieve increased yielding at uncontrolled crosswalks on a college campus located in the Midwest. Confederates acted as pedestrians in an ABA reversal design where baseline consisted of crossings with no prompts. The intervention consisted of signs that confederates displayed as a prompt, and consequence for yielding or non-yielding motorists. For example, if a motorist approached the crosswalk and yielded to the confederate, the confederate would raise a sign that read “Thanks for Stopping” with a picture of a “thumbs up”. If the motorist failed to yield to the confederate, then a research assistant 15 yards past the intersection would show the motorist a sign that read “Please Stop Next Time” with a “thumbs down” picture. Yielding data were collected at 2 intersections - the treatment crosswalk and one downstream from the treatment intersection, to understand if generalization of the treatment effect would occur. Researchers did not track to see if the same cars were yielding at the downstream intersection. Results indicated that the prompt was effective at increasing yielding slightly at both the treatment and generalization crosswalk. Although effective, the intervention may not be practical or sustainable given that it requires an individual to assess the situation and display the prompt and deliver the consequence.

Enforcement studies have continued in areas with high pedestrian fatalities and low motorist yielding. Van Houten and Malenfant (2004) conducted a pedestrian safety study in Miami Beach, Florida at two corridors with an historically high frequency of crashes. Both contained unmarked crosswalks connecting the city to beaches. Eight crosswalks in these corridors were used for the enforcement study with 12 other surrounding crosswalks used to measure possible generalization of intervention effects. Elaborating on the previous enforcement studies, confederates acted as pedestrians at all eight treated crosswalks to collect yielding data. The researchers used a multiple baseline design across locations to determine the effectiveness of the enforcement variable followed by a maintenance phase to determine any lasting effects. The intervention for this study was a 2-week intensive enforcement operation— plainclothes police officers acted as pedestrians and gave warnings and citations to motorists who failed to yield to the confederate pedestrians in the designated crosswalks. If the motorist was a flagrant violator and put pedestrian lives in danger they were cited; most motorist who failed to yield were given a warning with an informational flyer detailing pedestrian safety statistics and asking for their help in keeping the crosswalks and pedestrians safe. Police also issued a press release during the second week of enforcement, which gained traction in local media. Results showed that an intensive enforcement system was successful at increasing yielding at those locations. Additionally, the researchers found the yielding gains made in the intervention phase were maintained up to one year after the enforcement phase had ended. Finally, the authors found generalization of yielding behaviors had occurred in other crosswalks that did not receive the enforcement intervention.

In a follow up study, Van Houten, Malenfant, Huitema, and Blomberg (2013) showed that a similar enforcement intervention over the course of a year proved effective at increasing motorist yielding to pedestrians. Uncontrolled crosswalks in the city of Gainesville, Florida were the setting for the study. Researchers randomly assigned 12 crosswalks to “enforcement” or “control” conditions. Data were collected in a similar manner to other pedestrian right-of-way studies. Confederates acting as pedestrians used the dilemma zone (a method to calculate the appropriate distance and time to yield) to initiate crossings and collect data on motorist yielding. The enforcement intervention was similar to Van Houten and Malenfant (2004), but with four two-week enforcement waves over a year, and with more publicity surrounding the enforcement initiatives (radio ads, flyers, university outreach, and feedback signs). The results show that the combined use of enforcement and publicity slowly yet dramatically increased driver yielding behavior at both treated and untreated crosswalks. Follow-up data collected four years later showed that the effects increased even further, indicating a “tipping point effect” (Van Houten, Malenfant, Blomberg, Huitema, and Hochmuth, (in press).

Prompts for Pedestrians

In addition to marking the environment with signs and lights as prompts for motorists to yield to pedestrians, Crowley-Koch, Van Houten, and Lim (2008) showed that pedestrians could use hand signals to prompt their intent to cross. The settings for the study were uncontrolled crosswalks at 10 different socially significant locations (crosswalks that linked hospitals, connected pedestrian parks and trails) in Chicago and West Michigan. The hand signals used by confederate crossers were two different variations of hand gestures that are commonly known as "stop", "halt" or "slow down" – similar to a traffic police officer showing the palm of their hand to approaching cars. Compared to baseline, both variations of the hand signal were more effective at prompting motorists to yield. One limitation of this approach is the requisite need for pedestrians to initiate this behavior when crossing. However, this pedestrian behavior could be achieved with prompts such as signs and pavement markings at the edge of each crosswalk or in the road as part of the crosswalk. Additionally, prompts or signs could be positioned for motorists notifying them that pedestrians may use these hand signals to convey their intent to cross.

Technological Interventions

Given the advancement in technology in the last few decades it should not be a surprise that researchers have started to use more advanced technology to prompt motorists to yield to pedestrians at both uncontrolled and controlled crosswalks. Van Houten, Retting, Van Houten, Farmer, and Malenfant (1999) conducted another study at intersections in Florida that used modern lighting technology to prompt pedestrians. The researchers were interested in decreasing serious motor vehicle-pedestrian conflicts at controlled intersections, especially when vehicles turn left on a green light. The researchers scored actual pedestrians crossing at these intersections and observed pedestrians checking for motor vehicle threats after getting the "walk" signal. The intervention for this study was a pair of enhanced LED eyes attached to a lighted "walk" sign, which signaled the pedestrian to look for turning vehicles during their crossing. A multiple baseline was employed to test the apparatus. The LED eyes sign was effective at increasing the pedestrian behavior of looking for oncoming traffic as they crossed through the intersections and the benefits were sustained over a six-month period. Also, because of the increase in pedestrian vigilance behaviors, the number of motorist-pedestrian conflicts decreased.

Van Houten and Malenfant (2000) tested a similar device at two different novel locations in St. Petersburg, Florida: a vehicle exit at an indoor parking garage, and a mid-block crosswalk. The garage exit posed a difficult situation for motorists and pedestrians. As the motorists turned left onto a one-way street they focused their attention to the right to determine a safe gap to enter into traffic. Parking structure management had installed a convex mirror and signage to alert motorists to pedestrians entering their path from the left. The mid-block crosswalk connected two bus stops on a 4-lane road with a speed limit of 30 mph and an average daily traffic (ADT) of 10,000. The crosswalk was marked with advance yield markings and signs prompting motorists to yield in advance of the crosswalk, so as not to obstruct pedestrian field of view. Data were collected on natural occurrences of pedestrian crossings during the weekday working hours. Observers scored drivers yielding to pedestrians and pedestrian-motorist conflicts. Observers also scored whether pedestrians were stranded in the middle of the mid-block crosswalk, and if motorists looked for pedestrians from the left when leaving the parking garage. The intervention consisted of a set of animated LED eyes situated between two pedestrian symbols. A reversal design was used to test the efficacy of the garage exit sign. The results showed that looking for pedestrians and yielding to pedestrians increased when the “eyes” sign was present, and that a decrease in these behaviors occurred when returning to baseline. The mid-block setting used an alternating treatments design. The introduction of the “eyes” sign led to an increase in driver yielding from baseline and a decrease in pedestrians stranded at the centerline. The data also showed a decrease in vehicle speed as exiting vehicles approached the garage exit when pedestrians were present.

Two new technologies have proven effective at increasing yielding at marked crosswalks. The first is a Rectangular Rapid Flashing Beacon (RRFB). This device flashes rapidly at intervals similar to emergency vehicles. The second is a Pedestrian Hybrid Beacon (PHB). This device has a yellow and a red signal phase and is located either on the roadside, or on masts that reach over the roadway in advance of intersections with crosswalks (MUTCD, 2009).

Van Houten, Ellis, and Marmolejo (2008) tested the RRFB. The researchers conducted the study at two multi-lane uncontrolled crosswalks, with speed limits of 35 and 40 mph, in the Miami-Dade County of Florida. Both sites had advance yield markings 30 ft. prior to the crosswalks with signage that read “Yield Here to Pedestrians”. The intervention for this study consisted of LED flashers (two 6-inch by 2.5-inch devices placed 9 inches apart) attached to a standard pedestrian warning sign. The intervention was tested using a reversal design in which the LED flashers were turned off or uninstalled (baseline) and turned on or installed (intervention phase). The LED signs were successful at increasing yielding during intervention phases with a marked decrease during returns to baseline. Not only did the LEDs increase yielding during treatment conditions, they decreased evasive conflicts and pedestrians trapped in the roadway. Additionally, the intervention increased the distance at which motorists yielded to pedestrians.

Shurbutt, Van Houten, Turner, and Huitema (2009) evaluated the use of the RRFB at four multi-lane crosswalks in St. Petersburg, Florida. All locations had posted speed limits of 35 mph and ADT counts between 8,596 and 19,192. The participants consisted of motorists and pedestrians in natural circumstances. The beacons were mounted on top of the yellow diamond pedestrian crossing signs at the crossing locations. Four signs with beacons were placed at each crosswalk. The devices were linked with radio frequency transmitters so all beacons would activate when one was triggered. The devices also notified pedestrians through audible messages and a lighted prompt that activated the beacon, advising them to wait for cars to stop before crossing. Several measures were taken during this study: (a) driver yielding to pedestrians, (b) motorist-pedestrian conflicts, (c) pedestrian trapped at centerline, (d) yielding distance, (e) driver passed or attempted to pass stopped vehicle, and (f) car behind yield car slams on brakes. A reversal design was used to determine the efficacy of the RRFB. The results showed that the beacon significantly increased yielding at all sites. Furthermore, it increased the distance at which motorists yielded, and drastically decreased the number of vehicles passing or attempting to pass. The researchers noted that the beacon's effectiveness could be attributed to the fact that it was a novel stimulus. However, follow-up data showed that high levels of yielding remained two years post-study. The cost for this device is estimated to be between $12,000 and $20,000 per crosswalk installation.

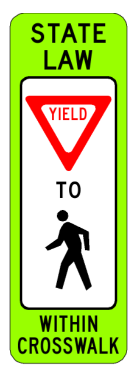
A typical PHB installation includes: An overhead red-yellow-red beacon facing both directions, stop sign(s) on the minor street, a marked crosswalk on the major approach, a pedestrian pushbutton with information placard, and pedestrian prompts ("Walk" or "Don't Walk"). The PHB typically operates as follows: (1) The overhead beacon is dark until activated by a pedestrian; (2) a pedestrian activates the beacon by pressing a pushbutton; (3) a flashing yellow indication is given to vehicles as a clearance phase while pedestrians see a "DON'T WALK" sign; (4) a steady red indication is given to vehicles while pedestrians see a "WALK" signal; (5) as the flashing "DON'T WALK" starts, a flashing red is given to vehicles which communicates to drivers that they may proceed with caution if pedestrians have cleared the crossing; and (6) after the pedestrian clearance the beacon returns to dark mode. The researcher's principle measure was crashes before and after the installation of the PHB device. The results of the study showed a 13.8% reduction in total crashes, a 13% reduction in severe crashes, and a 59.2% reduction in pedestrian crashes. Although this treatment has proven to be highly effective, it is relatively costly (estimated cost for an installation around $120,000). The cost has tended to limit its application.

Zeeger, Lyon, Srinivasan, Persaud, Lan, Smith, Carter, Thirsk, Zeeger, Ferguson, Van Houten, and Sundstrom (2017) conducted a large-scale crash modification factors (CMF) study to determine the reduction in crash risk under four treatments. The four treatments evaluated in the study were the RRFB, the PHB, a pedestrian refuge island (PI), and advance yield markings (AS). These treatments have been covered above, except for PIs. Pedestrian refuge islands, also referred to as center islands or pedestrian islands, are raised areas that provide protection to pedestrians crossing multi-lane roads. They allow pedestrians to cross one lane of traffic at a time, so they can maintain their focus on one direction of travel at a time. This enables pedestrians to wait until a safe gap is provided in each direction without standing on the yellow centerline. The researchers used multiple methods to identify the 14 cities selected for this study – the final database included 499 treatment sites and 476 comparison sites. Comparison sites were similar to treatment sites except that no treatment was present, and efforts were made to select comparison sites that were similar to treatment sites in lanes of travel, traffic volume, and other setting factors. The treatment sites were mostly four or more lane roads because of the likelihood for pedestrian crashes. Data for pedestrian crashes were provided by local and state agencies. A series of statistical analyses were carried out to compare treatment settings to comparison settings. The results of the study showed that PHBs were associated with the greatest reduction of pedestrian crash risk (55% reduction), followed by RRFBs (47%), PIs (32%) and AS (25%).

R1-6 Sign

Another antecedent intervention proven to be effective at evoking motorist yielding to pedestrians in crosswalks is the use of a street sign, typically installed on the centerline of a 2-lane road. Kannel, Souleyrette, and Tenges (2003) explored this technique at a few key uncontrolled intersections in Cedar Rapids, Iowa. The locations were varied in terms of urban environment, and motorist and pedestrian volume at the crosswalks. The researchers measured three dependent variables: vehicle speed changes, percentages of “first vehicles” that yield to pedestrians, and percentage of aborted or hurried crossings. They compared these variables before and after in-street “Yield to Pedestrians” signs were installed at the three locations. The results found an increase in yielding to pedestrians as well as a small decrease in speed at most of the crosswalks. The researchers received many positive reactions to the implementation of the signs and no accidents or injuries occurred at any of the sites during the experiment.

These signs, known as “R1-6” signs (MUTCD, 2006), are rectangular and narrow with a yellow border surrounding a white interior that reads “State Law Yield to Pedestrians Within Crosswalk”. The sign uses a combination of symbols and words to display the prompt (see Figure 1). Ellis, Van Houten, and Kim (2007) assessed various sign placements (e.g., signs placed at the crosswalk, 20 and 40 feet in advance) and found that placement at the crosswalk was marginally more effective than placing the signs at a distance. The results from these studies indicated that signs significantly increase motorist yielding compared to baseline conditions.



R1-6

Figure 1. R1-6 Yield to Pedestrians roadway sign.

Although R1-6 signs have proven to be highly effective when used on 2-lane roads, they have shown less favorable results when placed on the centerline of roads with more than one travel lane in each direction (Turner et. al., 2004). One way to increase the efficacy of the R1-6 sign on multi-lane roads is to install multiple signs, creating a gateway effect at the crosswalk (Bennet, Manal, & Van Houten, 2014). In this study, data were collected at two sites with multiple lanes of travel in two Michigan cities. The researchers measured both motorists who yielded, and those who failed to yield to pedestrian confederates crossing in uncontrolled crosswalks. The researchers compared the placement of one R1-6 sign in the center of an uncontrolled crosswalk to multiple R1-6 signs placed throughout the crosswalk (at each side of the edge of the street, at the start of the crosswalk, and at the centerline) along with a baseline condition. The multiple sign placement throughout the crosswalk, called a “gateway”, was more effective at increasing motorist yielding to pedestrians than a single sign alone. The researchers hypothesized that the gateway created a narrowing effect on the roadway, which may have increased yielding as well as provided visual cues that delineate the crosswalk boundaries. Bennett, Manal, and Van Houten (2014) compared the PHB and the RRFB to the use of in-road R1-6 gateway in-street sign configuration. Results indicated that the gateway intervention produced similar effects to both the PHB and RRFB at uncontrolled locations. The gateway intervention costs significantly less than the technical solutions of the RRFB and PHB – around $300 per R1-6 sign.

Gateway crosswalks, which have been marked on both sides of the intersection, have proven to be a cost effective intervention, resulting in increased motorist yielding at uncontrolled crosswalks. One important question yet to be answered is whether installing a gateway at only one of the two crosswalk legs would be as effective in prompting drivers to yield at both crosswalk legs. If a significant amount of generalization occurs between two sites when only one leg is treated, the treatment would only cost half as much. The purpose of this study was to determine if the effects of a gateway crossing would generalize to a non-intervention crosswalk at the same intersection.

Method

Participants and Setting

The study was conducted in the city of Three Rivers, Michigan. Participants were motorists traveling on Main Street as they crossed the intersection of Bennett Street while pedestrians were using the crosswalks. The North-South traffic (Main St) was comprised of three lanes (two lanes with a middle turn lane) and a posted speed limit of 30 mph (48 kph). The East-West traffic (Bennett St) comprised 2 lanes with stop signs on the side road, and a speed limit of 25 mph (40 kph). There were two crosswalks at the intersection connecting two churches, a park, and an elementary school (see Figures 2 and 3).

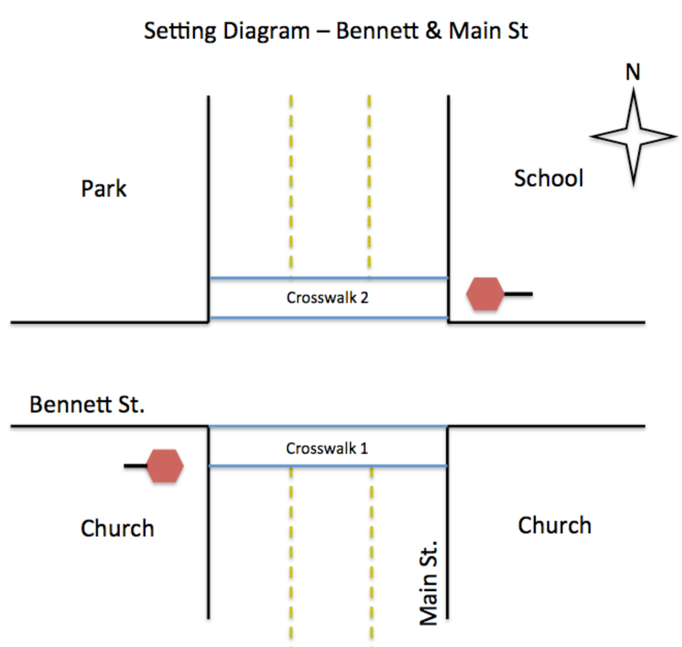


Figure 2. Intersection of Bennett St. and Main St.

Figure 3. Photograph of Intersection - Bennet St. and Main St.

Dependent Variables

The primary dependent variable for this study was the percentage of motorists yielding to pedestrians. Motorist yielding can be determined by establishing a dilemma zone in which the driver has enough time to yield after a pedestrian places their foot in the crosswalk. This dilemma zone was calculated using a formula used by traffic engineers to calculate yellow signal time at a signalized intersection (Institute of Traffic Engineers, 1989), which takes into consideration driver reaction time, posted speed, safe deceleration rate, and the grade of the road. The zone was identified by bright tape or flags placed on the road and curb. Motorists who were outside the zone were scored as “yielding” or “not yielding” as they had sufficient time to slow to allow pedestrians to cross. Motorists who had entered the dilemma zone before the pedestrian placed a foot in the crosswalk could still be scored as yielding since it is possible to still react, but could not be scored as not yielding due to the diminished time to respond safely. The formula used for calculating the dilemma zone is: $y = t + v/2a+2Gg$ where t is the perception and reaction time in seconds, v is the speed of approaching vehicles in feet per second (posted speed limit used); a = the deceleration rate; G is the acceleration due to gravity; and g is the grade of the approach. The distance of the dilemma zone was 104 ft. at this location.

Independent Variable

The independent variable was a series of signs spread out through one crosswalk, also known as a gateway in-street sign configuration. The signs followed the perimeter of the crosswalk on the approach side of the crosswalk. The signs (see Figure 1) were the R1-6 in-street yielding sign. The signs were placed on sturdy bases at the intersection of the lanes of travel and the crosswalk as well as both sides of the street. See Figure 4 for depiction.

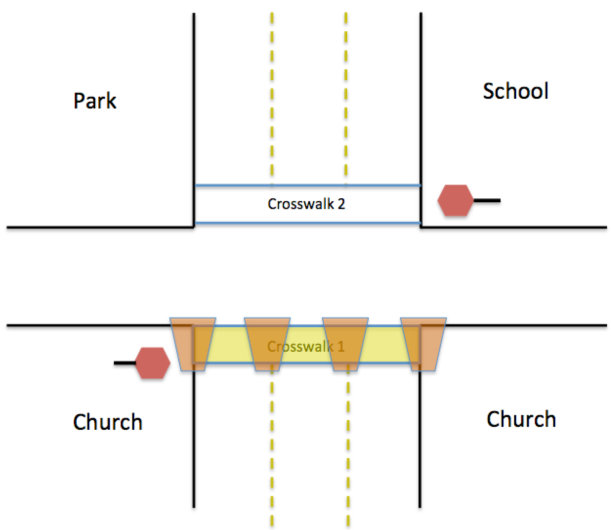


Figure 4. Placement of R1-6 roadway signs in the Gateway configuration at experimental setting.

Data Collection

The protocol for this study followed the same established procedures used for previous studies (e.g., Bennett et al., (2014)). Research assistants acted as confederate pedestrians and crossed the street to determine if motorists would yield right-of-way during different conditions. Dilemma zones (see above) were established to determine at what point the confederates should cross the street, as well as which motorists were counted as "yielding" or "not yielding". Each trial, or staged crossing, began when a confederate put his or her foot into the crosswalk and faced the direction of traffic displaying their intent to cross. Another research assistant nearby surreptitiously collected the data. Each session consisted of 20 trials, or crossings. The percentage of drivers yielding to pedestrians was calculated by dividing the number of drivers yielding to pedestrians by the number of drivers yielding to pedestrians plus the number of drivers not yielding to the pedestrians. Each session counted as one data point. All data were collected during daylight hours. No sessions were conducted during precipitation, as a wet roadway would influence stopping distance and would therefore impact the dilemma zone distances as well as pedestrian safety.

Inter-observer Agreement. Inter-observer agreement (IOA) data were collected on 64% of trials. Inter-observer agreement was conducted by having an additional observer in a nearby location independently score the same crossings as the primary observer. An agreement was tallied whenever both observers scored a trial exactly the same and a disagreement was scored whenever the two observers scored a trial differently. IOA was calculated by dividing the number of agreements by the agreements plus disagreements and then multiplying by 100.

Experimental Design

An A-B-C-A-C design was used to assess the effects of the R1-6 gateway on motorist yielding behavior. First, a baseline (A) condition was conducted to establish yielding percentages in the absence of any intervention. Following the baseline condition, crossings at the crosswalk treated with the gateway prompt were scored. Immediately following this sub-phase, and leaving the gateway intervention intact at the initial crosswalk, crossings were completed and observed on the non-intervention crosswalk, (the generalization crosswalk). These two sub-phases make up the (B) intervention phase, as the experimental condition remained the same, but confederate pedestrians were observed using the intervention crosswalk and then the generalization crosswalk. The B phase was then followed by multi-element phase (C), where the pedestrians alternated trials between the gateway crosswalk and the generalization crosswalk. The multi-element phase was followed by a return to baseline, and then a short return to multi-element. By alternating between A, B, and C phases, the level of yielding for each condition, as well as the level of yielding generalization to non-intervention crosswalks could be determined.

Results

Driver Yielding Behavior

The yielding results are presented in Figure 5 below. Yielding averaged 3% during baseline, 62% at the intervention crosswalk, and 38% at the generalization crosswalk. During the first multi-element phase, the IV crosswalk resulted in an average of 56% yielding compared to an average of 39% for that of the generalization crosswalk. The return to baseline was an average of 1% and the final multi-element phase resulted in 58% for the intervention crosswalk and 29% for the generalization crosswalk. These results indicate that the side of the intersection treated with the Gateway intervention showed the largest increase in yielding behavior. The generalization crosswalk showed a modest increase in yielding behavior. The gateway crosswalk was the most effective at increasing yielding, compared to the other two experimental conditions.

Driver Yielding as a Function of Passing Through the Gateway vs. Through No Treatment

Drivers approached the crosswalks in two possible ways: drivers approaching from one direction traversed the generalization crosswalk first, and then passed through the gateway. Drivers approaching from the opposite direction passed through the crosswalk treated with the gateway first, and then passed through the generalization crosswalk. This presented a way to measure whether first passing through the gateway crosswalk influenced motorist yielding at the generalization crosswalk. The results of this analysis showed that 63.8% of the drivers who passed though the gateway crosswalk yielded at the generalization crosswalk.

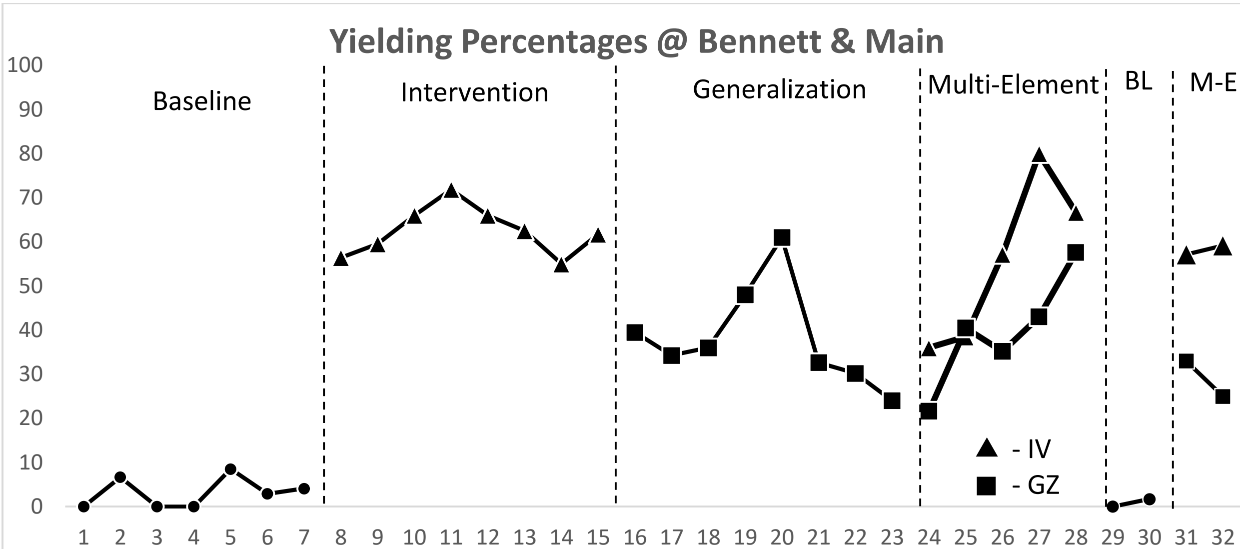


Figure 5. Yielding percentages at the intervention site.

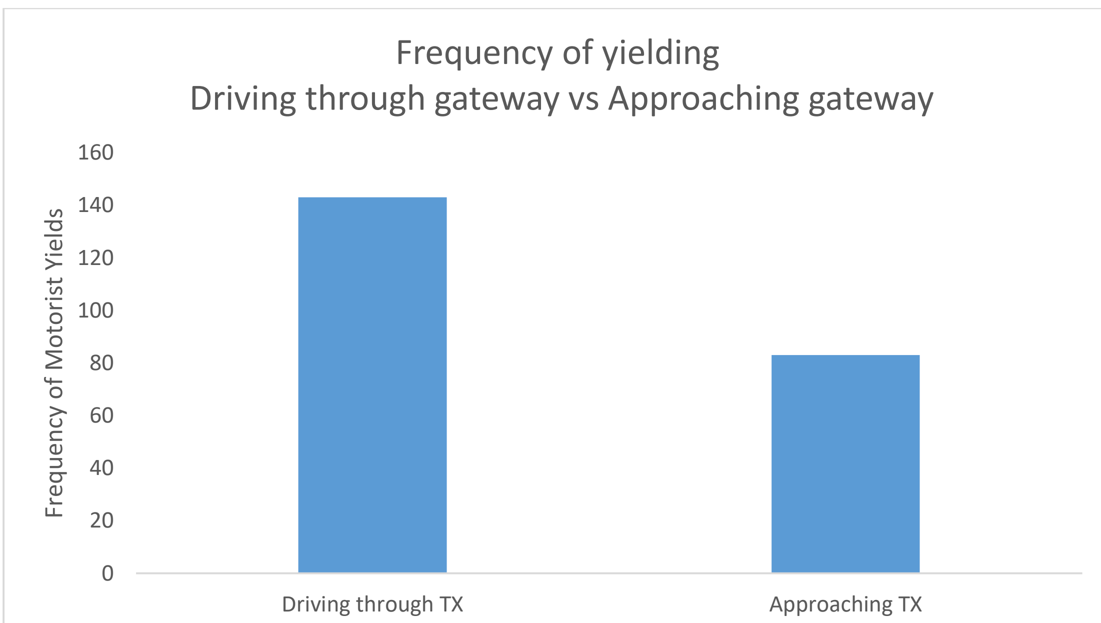


Figure 6. Yielding comparison between passing through the gateway vs. approaching gateway.

IOA Results

Inter-observer agreement was completed on 64% (25 out of the 39) of the trials. The average score for IOA was 98% agreement with a range from 91.4%-100%.

Discussion

Implications and Applications of This Research

The results indicate that the generalization phase was successful at increasing yielding over baseline conditions. This research also indicates that traveling through a roadway prompt at one crosswalk influences driver yielding at the next crosswalk on the other side of the intersection. Additionally, this may be a more cost effective intervention than inundating each crosswalk in a city or residential area with gateway prompts.

Previous research (Bennet, Manal, & Van Houten, 2014) has noted that the gateway produces a narrowing effect in the roadway, which may be the reason that drivers slow and yield. This may explain why the yielding at the generalization crosswalk was higher when motorists travelled through the gateway first. On the other hand, this may explain why drivers approaching the gateway yielded less: i.e., their speed could have been higher. In addition, the gateway might have drawn more attention to the treated crosswalk, so it is possible that motorists approaching the gateway were focused on the signs across the roadway and less on the pedestrian waiting to cross.

Applications of this type of intersection design are numerous. First, this type of set up would be ideal for a “Main Street” setting where there is a downtown area with a high pedestrian and vehicle traffic count with several crosswalks. The gateway intervention could be set up at the first intersection of each way of travel, therefore creating a corridor of safe crosswalks for that stretch of road. In a similar fashion, a staggered approach to the gateway prompt could be effective in similar environments. For example, if driving through a gateway prompt increases the chances that motorists will yield at the next crosswalk, it might be feasible to have every other crosswalk display the gateway prompt and still garner socially acceptable yielding from motorists.

This intervention could also be combined with other effective interventions. Similar to Crowley-Koch, Van Houten and Lim (2011), combining gateway prompts with prompts for pedestrians to signal their intent to cross could increase the yielding percentages. This approach may seem more equitable as the prompts are given to both parties involved in the interaction –i.e., the participants, both the pedestrian and the motorist are being asked to do something. Furthermore, given the effectiveness of enforcement interventions (Van Houten & Nau, 1983), an enforcement component could be added to further increase the likelihood of yielding. A communication campaign explaining the format and changes to crosswalks and the crossing process could also have an impact on how quickly yielding to pedestrian increases at the start of the intervention. Additionally, publicly posted feedback on the percentage of yielding could be added as part of a treatment package to further increase the likelihood of motorist yielding to pedestrians. This feedback would allow the community to see the effects of the intervention and would act as a prompt for yielding behavior of motorists and pedestrians as well as reinforcement for past behavior.

Limitations

This research was conducted in a single location in the suburban Midwest, so care must be taken when applying the generalization of these effects to other types of settings. Different speeds and roadway types may yield different results. Lower speed roads may result in higher yielding rates because there is less effort to stop the automobile at slower speeds, the driver has more time to see the pedestrian, and more time to react to potential crossings. It was noted by confederate pedestrians that, although the speed limit of the experimental site was 35 mph, many autos seemed to be traveling at faster rates. Additionally, because confederates were used as pedestrians, a more naturalistic study may yield different results. However, previous studies have shown that naturally occurring pedestrians are associated with somewhat higher levels of yielding because they often cross more aggressively than is prudent (Van Houten, Ellis & Marmolejo, 2008; Van Houten, Malenfant, Huitema & Blomberg (2013). Research assistants noted that motorists began to ask questions about the gateway signs and the overall experiment, which may have impacted the results of the study over time. In the first multi-element phase, both conditions have an upward trend that may indicate motorist learning, i.e., the community may have had enough exposure through the previous treatment phases that they may have caught on to the fact that their behavior was being measured. Additionally, other previous pedestrian prompting research studies that were conducted in the surrounding area may have influenced driving yielding at this research site. Although baseline showed poor yielding, it is possible that once an intervention was erected, the members of the community may have associated these signs/prompts with previous studies and therefore would have had experience with those stimuli resulting in higher levels of yielding.

The R1-6 signs were not permanent structures in the roadway and were erected during experimental sessions and then taken down when data collection was complete. This may have signaled to the motorists that they were being observed. Additionally, the average pedestrian traffic at this intersection was unknown, and therefore the increase in pedestrian traffic during measurement phases could have tipped off motorists that data collection was occurring, thereby altering their behavior. Early data sampling for both crosswalks with the gateway in effect showed similar yielding results, so it was determined that the generalization crosswalk and the gateway crosswalk would not change during the course of the study. This consistency may have drawn more attention to the crosswalk with the gateway installed, therefore increasing yielding behavior. Switching the gateway and generalization crosswalks throughout the study may have yielded slightly different results.

Implications for Further Research

Since this research was conducted at a single intersection, further research could determine at what distance or how many consecutive crosswalks it would take for the generalization results to reach baseline levels. This research could help determine optimal gateway prompt setups for heavy traffic areas with multiple intersections with crosswalks.

Additionally, future research could determine ways to increase yielding at non-intervention crosswalks. It is possible that the addition of antecedents or consequences to the gateway prompt may increase generalization behavior. As stated above, the gateway prompt produces a narrowing effect of the road that may increase yielding at such sites. It is possible that generalization crosswalks could have similar narrowing antecedents without using actual signs, such as pavement markings. It is also feasible that additional antecedents on the first gateway prompt could notify motorists that all subsequent crosswalks within the city limit/village/county/road are of similar design or carry similar consequences. Crosswalk design choices such as adding colors or pavement markings could increase the probability of generalization. Adding reinforcement to yielding at generalization crosswalks could also increase motorist yielding behavior. These reinforcers could include stimuli such as "thank you" waves from pedestrians, or feedback on yielding percentages through changeable signs.

APPENDIX: HSIRB APPROVAL LETTER

Date: October 21, 2013

To: Ron Van Houten, Principal Investigator
Miles Bennett, Student Investigator for dissertation

From: Amy Naugle, Ph.D., Chair

Re: HSIRB Project Number 13-10-28

This letter will serve as confirmation that your research project titled "Comparison of Alternative Pedestrian Crossing Treatment" has been **approved** under the **exempt** category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note: This research may **only** be conducted exactly in the form it was approved. You must seek specific board approval for any changes in this project (e.g., ***you must request a post approval change to enroll subjects beyond the number stated in your application under "Number of subjects you want to complete the study***)." Failure to obtain approval for changes will result in a protocol deviation. In addition, if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

Reapproval of the project is required if it extends beyond the termination date stated below.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: October 21, 2014

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