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A Comparison of the Effect of In-Street Pedestrian Signs Alone, the Rectangular Rapid-Flashing Beacon Alone and Both Together on Yielding Behavior

Hana Sahar Manal

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A COMPARISON OF THE EFFECT OF IN-STREET PEDESTRIAN SIGNS ALONE, THE
RECTANGULAR RAPID-FLASHING BEACON ALONE AND BOTH TOGETHER ON
YIELDING BEHAVIOR

by

Hana Sahar Manal

A Thesis
Submitted to the
Faculty of The Graduate College
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Degree of Master of Arts
Department of Psychology
Advisor: Ron Van Houten, Ph.D.

Western Michigan University
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Rectangular Rapid-Flashing Beacon Alone and Both Together on Yielding Behavior

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A COMPARISON OF THE EFFECT OF IN-STREET PEDESTRIAN SIGNS ALONE, THE RECTANGULAR RAPID-FLASHING BEACON ALONE AND BOTH TOGETHER ON YIELDING BEHAVIOR

Hana Sahar Manal, M.A.

Western Michigan University, 2012

This study examined the effectiveness of a rectangular rapid-flashing beacon (RRFB) alone, in-street signs alone, and the RRFB plus in-street sign together on motorist yielding to pedestrians. Participants consisted of drivers in Oakland County, Michigan. Pedestrians were confederate data collectors. The target behavior was driver yielding. The two treatments utilized were the RRFB and the in-street sign. A reversal design was used in which the first set of conditions included baseline, the RRFB alone, two in-street signs alone and the combination of the two in-street signs with the RRFB. All of the treatments affected yielding in the predicted direction, except the two in-street signs were associated with a one-percentage point increase in yielding over the last RRFB data point. Visual analysis revealed that the only treatment that evoked yielding to a greater degree than the other treatments assessed was the combination of the RRFB with the gateway treatment (M=85%, SD=79%). Similarly, the level change from RRFB to the combination of the RRFB and gateway treatment was associated with a significant level change coefficient of .17667 (t=2.44, p=.011).

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CHAPTER I

INTRODUCTION

Between the years of 2005 and 2010, 775 pedestrians were killed in traffic accidents and 6,498 pedestrians were injured in Michigan (Michigan Department of Transportation [MDOT], 2012). While pedestrian crashes account for .4% of all motor vehicle crashes, pedestrian fatalities account for 12.7% of all traffic related fatalities. The discrepancy between these two figures is likely the result of the physical vulnerability of pedestrians.

In 2009, the Michigan fatality rate was below the national average. The national average of pedestrian fatalities for 2009 was 1.33 per every 100,000 citizens whereas the state average was 1.18. Currently, Michigan ranks 23rd highest in the United States for pedestrian fatalities (MDOT, 2012). Michigan has more pedestrian fatalities than the neighboring states of Illinois, Indiana, Ohio, and Pennsylvania (MDOT, 2012).

People between the ages of five and 24 represent the population subset most involved in pedestrian crashes. This age group is also over-represented regarding pedestrian crash statistics compared to their relative proportion of the population. The proportion of Michigan pedestrians struck within this age group is also elevated compared to the national average (MDOT, 2012).

Traffic volume related to location and seasonal factors affects the number of traffic related crashes, because greater vehicular travel is associated with greater

risk (Ewing & Dumbaugh, 2009). When comparing per capita vehicle related fatalities and miles traveled, the relationship is linear in nature for both urban and rural environments (Litman & Fitzroy, 2005). The same analysis revealed that in urban areas, each percentage increase in miles traveled is associated with a single percentage point increase in fatalities and in rural areas, each percent increase in miles traveled is associated with a 1.5 percent increase in traffic-related fatalities. Additionally, crash rates tend to be higher in high-density urban areas due to the heightened exposure; however, crash severity tends to be greater in rural areas due to the increased speed at which vehicles travel (Litman & Fitzroy, 2005).

Traffic speed is the final mediating factor. In general, higher speeds allow drivers less time to react to pedestrians or other potential hazards (Ewing & Dumbaugh, 2009). Lower traffic speeds are also associated with greater pedestrian safety in terms of likelihood of crash survival. When struck by a vehicle traveling 40 miles per hour, a pedestrian has a 15 percent chance of survival and this improves to a 55 percent survival rate if the vehicle is traveling at 30 miles per hour. If the vehicle is traveling at 20 miles per hour, the pedestrian has a 95 percent chance of survival (UK Department for Transport, 1997; Zegeer et al., 2002a).

Various technologies are utilized within North America to improve the percentage of time drivers yield to pedestrians. These treatments include countdown timers, flashing yellow arrows, overhead hybrid beacon signals, rapid-flashing and traditional beacons, and various supplemental in-street or sidewalk signs.

Countdown timers are traditional pedestrian signals that display a "walk" or "don't walk" signal for pedestrians as well as the number of seconds the pedestrians have to cross before the traffic will no longer be stopped by the active red light. The effects of countdown timers are robust in nature because the technology utilizes a legal red light to stop traffic when the countdown timer is activated. Eccles, Tao, and Mangum (2004) utilized a pre-test post-test design in which the effects of the countdown timer were determined by collecting eight to 10 hours of natural pedestrian crossings before the implementation of the technology and the same number of hours of data collection after the implementation at each of four separate sites. Eccles et al. reported that out of four sites, the countdown timer significantly reduced the number of pedestrian-vehicle conflicts from 37 conflicts before the intervention to seven after the intervention. While the use of countdown pedestrian signals is a powerful technology, they can only be implemented at a crosswalk controlled by a traffic signal.

Flashing Yellow Arrows are also installed at controlled crosswalks, and therefore require the same type of infrastructure as the countdown timer. The flashing yellow arrow is a left turn signal that when flashing indicates to drivers that they must yield to oncoming cars or pedestrians before proceeding with the left-hand turn.

Another tool that can be installed at a crosswalk where no traffic signal is present is the high-intensity activated crosswalk (HAWK) as either an overhead or side-mounted pedestrian beacon. The HAWK is arranged in a triangular fashion with two red lights on top and a yellow light on the bottom to alert the driver that a

pedestrian has activated the beacon and then a short, solid red phase followed by a

flashing red phase to allow the pedestrians to cross. According to Fitzpatrick and

Park (2009), after statistically analyzing state-wide crash data using the before-and-

after empirical Bayes evaluation, the HAWK contributed to a 51% decrease in

pedestrian crashes and a 29% decrease in total crashes within the state of Arizona.

Although the HAWK effectively incorporates a red light as a conditioned stimulus to

evoke a stopping response, the HAWK is an expensive technology and is not always

appropriate on streets where there are a lot of traffic signals because the HAWK will

cause additional stopping that can back-up traffic when placed too close to a traffic

signal.

One relatively inexpensive technology is the use of a yellow rectangular

rapid-flashing beacon (RRFB) that is usually mounted on the cautionary pedestrian

sign erected at crosswalks, and typically requires no electronic wiring when

powered by solar panels. By pressing one of the buttons on either side of the road,

both RRFBs are activated by radio-frequency transmission. RRFBs are designed to

alert drivers that a pedestrian has activated the mechanisms by rapidly flashing in

an irregular flash pattern. This device employs high intensity strobe flashes, which

have an irregular pattern like those on emergency vehicles.

In a three-year long community intervention, the implementation of RRFBs

produced a statistically significant increase in yielding over baseline levels

(Shurbutt, Van Houten, Turner, & Huitema, 2009). In a separate study, RRFBs were

added at two multilane crosswalks within the community of Miami-Dade County,

Florida. In order to demonstrate experimental control, a reversal design was utilized

at each site, alternating phases with and without the activation of the RRFB technology (Van Houten, Ellis, & Marmolejo, 2008). Overall, this study in Miami improved yielding to pedestrians and reduced evasive action on the part of the pedestrian or vehicle as well as the percentage of pedestrians trapped in the center of the roadway during a crossing. When the RRFB was not activated, yielding percentages for staged crossings averaged 2.5%. During phases when the RRFB was activated, the yielding percentage improved to an average of 66% for staged crossings and 92% for local pedestrians (Van Houten et al., 2008).

The RRFB has been associated with higher yielding percentages than the less expensive and less effective counterpart, the traditional beacon. The traditional beacon is a side-mounted yellow flashing beacon that flashes in a steady sequence instead of an irregular fashion. Shurbutt et al. (2009) found that while the RRFB was associated with 78% of drivers yielding to pedestrians, the traditional beacon evoked yielding percentages that averaged 16%.

Another inexpensive technology is the use of the "Yield to Pedestrian in Crosswalk" in-street signs (R1-6) that are short breakaway signs placed on the yellow line separating two opposing lanes of traffic. They can significantly increase the percentage of motorists yielding to pedestrians in marked crosswalks at uncontrolled locations (without a traffic signal or stop sign) (Ellis, Van Houten, & Kim, 2007). Ellis et al. (2007) utilized a single in-street sign placed at distances of immediately before the crosswalk, 20 feet in advance of a crosswalk, and 40 ft in advance of the crosswalk in between two lanes of traffic at a two-lane road in Miami Beach, Florida. In addition to the single sign treatment, three signs together were

also evaluated by placing one sign at the crosswalk, one 20 feet in advance of the crosswalk, and one sign placed 40 feet in advance of the crosswalk. This study revealed that installing the in-street sign at the crosswalk was as effective if not more effective than the additional treatments including placing signs at various distances preceding the crosswalk or the three signs together placed perpendicular to the crosswalk at 0 feet, 20 feet, and 40 feet distances. Ellis et al. asserted that in-street signs can be more effective than other pedestrian technologies because these signs are directly in the field of view of the motorist and are located within close proximity to the crosswalk. Fitzpatrick, Turner, and Brewer (2007) found that overall, in-street signs were associated with 90% overall motorist compliance during an extensive observational study incorporating both natural and staged pedestrian crossings at 42 different sites utilizing nine different pedestrian technologies. However, these signs were only evaluated on two lane streets with one lane in each direction. The only evaluated technologies associated with high yielding on roads with more than one lane in each direction in this study were the mid-block and half signals such as the overhead HAWK signal beacon.

Although Ellis et al. (2007) found that including multiple signs at specific distances further from the crosswalk did not further improve the effectiveness of a single sign placed at the crosswalk, in-street signs can be utilized as traffic-calming measures when placed in ways to create the illusion of lane narrowing for approaching drivers. Another study conducted by the Center for Transportation Research and Education (CTRE) (2007) utilized two treatments at a two-lane road in order to narrow the lanes and reduce the speed of traffic. Gateway treatments

come in many forms, and one method CTRE utilized was the peripheral transverse marking in the form of parallel bars painted near the shoulder line and lane line in order to give drivers the perception that their vehicle is increasing in speed, which can prompt them to slow as they approach a reduced speed limit zone. Additionally, the lanes were narrowed by painting both the shoulders and the center island in order to increase the feeling of constraint which can prompt drivers to reduce their speed. CTRE found the transverse markings to be moderately effective at reducing traffic speeds. However, the lane narrowing did not produce an effect. Although the gateway effects of the painted shoulder and center median treatments did not significantly alter driver behavior, the current study utilized the in-street signs to create a lane narrowing effect by placing either two or four signs at the crosswalk to test the effectiveness of a partial barricade to give the illusion that the drivers were approaching a section of road with narrowed lane widths. The lane narrowing effect produced by the in-street signs is similar to the choker method, a curb extension that narrows a lane by extending the sidewalk in a triangular format on each side of the street requiring the driver to slightly turn the vehicle in order to maneuver the partial barricade. Both the in-street sign and the choker method physically narrow the lane in order to initiate reduced speeds needed to negotiate the lane narrowing. The choker has been associated with a 14% decrease in traffic speeds for single lanes and a 4% reduction in speeds for two lane sites (Institute of Transportation Engineers, 2012).

The purpose of the current study was to assess the effectiveness of a rapid-flashing beacon within a township setting, which has an RRFB installed at the site.

The RRFB alone was compared to the in-street sign alone, and the RRFB plus the in-street sign condition together. The study also evaluated the use of several in-street signs at the lane lines and the edge of the road to produce a gateway treatment. The RRFB was evaluated because unlike the robust effects of technologies like the HAWK and the countdown timer, the RRFB is associated with modest motorist yielding percentages, about 80% at most uncontrolled crosswalks with multiple lanes in each direction (Shurbutt et al., 2009). Because the RRFB involves an expenditure of about $14,000, the current study sought to compare the effectiveness of the RRFB with the in-street sign which also is associated with modest yielding although far less expensive than the RRFB at about $200 per sign. The current study also sought to compare the RRFB with various configurations of in-street signs in order to determine if utilizing a single in-street sign for each lane or utilizing a four-sign traffic gateway could prove more cost effective than the RRFB. Additionally, the current study compared the two technologies separately as well as combined in order to determine if a significant increase in yielding would occur when combining the in-street sign with the RRFB, potentially garnering support for the use of the RRFB only when combined with the in-street sign.

It was hypothesized that the in-street sign (the single sign for each of the two traffic lanes and the four signs utilized to create a gateway effect) would produce significant effects over baseline levels of yielding performance, and the RRFB was proposed to improve yielding over the in-street sign alone; however the gateway treatment alone was hypothesized to improve yielding over the RRFB, and the

combination of the RRFB and in-street sign was hypothesized to result in the

greatest yielding percentages.

CHAPTER II

METHOD

Participants and Setting

Data were collected on Grand River Avenue, an extension of Lyon Center
Road within South Lyon township located in Oakland County, Michigan. The
crosswalk on Grand River Avenue crosses one lane in the westbound direction and
one lane in the eastbound direction as well as a turning lane in the center.
Pedestrians utilizing this crosswalk site were mainly joggers crossing the street in
order to use a jogging trail through the South Lyon area. Due to a sharp curve on
both the eastbound and westbound sides of Grand River Avenue, the posted speed
was 25 mph for both sides of the road. An advance warning sign with a visual
depiction of a crossing pedestrian was posted by the township 30 feet in advance of
the crosswalk on both sides of the street.

Grand River Avenue has low levels of traffic, averaging about four cars per
minute. Data were collected during the months of February and March and once a
weather effect was detected, the researcher limited data collection to days that were
partially cloudy and average spring temperatures around 50 degrees Fahrenheit in
order to control for weather as a confounding variable. During the one sunny and
warm day when data were collected, the in-street sign gateway and baseline
percentages were much higher than percentages on cloudier days, which caused
data for that day to not generalize to the rest of the data in the study. After this

point, data were only collected on partially cloudy days with temperatures around 50 degrees Farenheit. Participants were drivers on Grand River Avenue.

Measures

The pedestrians were two confederates trained on proper crossing protocol. Proper crossing protocol involved placing one foot in the crosswalk before the targeted vehicle was within the dilemma zone. The dilemma zone was calculated using the following formula used to time the yellow phase of a traffic signal:

$$y = t + \frac{v}{2a + 2Gg}$$

where,

y = length of yellow interval calculated to the nearest .1 second

t = perception or reaction time of the driver, usually set at 1.0 second

v = the approaching vehicle's velocity in feet per second

a = deceleration rate usually set at 10 feet/second^2

G = acceleration attributed to gravity which is set at 32 feet/second^2

g = the grade of approach in percentage format divided by 100 (Institute of Transportation Engineers, 1985).

This formula indicates the time required for a vehicle to stop and is converted to a distance by multiplying the time by the posted speed limit. This provides the distance a driver should be in advance of the crosswalk in order to safely stop at the time the pedestrian initiates the crossing. Yielding behavior was only scored if the pedestrian initiated the crossing when the car was just beyond the dilemma zone mark. For streets with speed limits marked at 25 mph, the dilemma

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zone is marked at 102 feet, so the staged pedestrian initiated the crossing when the car was just beyond 102 feet. The dilemma zone was measured using a measuring wheel and marked using orange sprinkler flags placed in the grass along the street to indicate the point at which the vehicle must be to initiate the staged pedestrian cross.

Training occurred at the site between the lead researcher and the research assistant by first explaining the dilemma zone, how to place a foot in the crosswalk in order to initiate a yield, and how to determine yielding distances while crossing. Training involved explaining crossing protocol and then completing sets of 20 unofficial crossings together until 85% inter-observer agreement was obtained.

Dependent Variable and Experimental Design

The dependent variable of interest was the percentage of drivers yielding to pedestrians. Each data sheet had two columns to score yielding and non-yielding driver behavior. Data collectors were trained to score each driver as either yielding or not yielding when the pedestrian had a single foot in the crosswalk (see Appendix A). A yield was defined as stopping for the pedestrian or markedly slowing the vehicle to allow the pedestrian to cross. The vehicles in the lane closest to the pedestrian were targeted, although a yield in the far lane was scored if the car was beyond the dilemma zone when the pedestrian stepped into the crosswalk. Yielding percentages were calculated by dividing the total number of cars yielding by the number yielding and not yielding.

Additionally, data collectors classified yielding distance as less than ten feet, between ten and 20 feet, between 20 and 30 feet, and beyond 30 feet. The distances

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were measured using a measuring wheel and marking the distances with orange sprinkler flags. The data collectors were trained to mark whether a yield had occurred, and if a yield did occur, to also mark the distance at which the yield occurred. The distance was defined as the number of feet the car was from the crosswalk when the pedestrian was directly in front of the yielding vehicle.

There are other variables on the data sheet that were scored but were not analyzed for the purposes of the study. Evasive action on the part of the pedestrian and/or the vehicle was included on the data sheet. Evasive action for the pedestrian included jumping out of the way of a vehicle or running to avoid being struck when correct crossing protocol was followed. Evasive action for a vehicle included slamming on the brakes or swerving to avoid either the pedestrian or a yielding vehicle. "Pedestrian trapped in center" was marked when a pedestrian was trapped in the turning lane because the cars in the second lane did not yield appropriately. A driver "passing a stopped vehicle" would also have been marked in the event a vehicle used the turning lane to pass a yielded vehicle rather than stopping behind the yielding vehicle. Additionally, "natural crossings" were marked for actual pedestrians utilizing the crosswalk with the appropriate technology for the condition, although this did not occur for the current study.

<center>Experimental Design</center>

An ABCDAEBEBF reversal design was employed in this experiment (A=Baseline, B=RRFB, C=Single sign for each lane (2 lanes), D=RRFB+Single sign for each lane, E=Gateway treatment (four signs total placed in roadway with two near the lane line and two in the gutter), F=RRFB+Gateway treatment).

Table 1

GANT Chart Showing the Condition in Each Phase

Condition	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Baseline	■				■
RRFB		■			
2 In-street Signs			■		
RRFB + 2 Signs				■	
Gateway Treatment					
RRFB + Gateway					

Condition	Phase 6	Phase 7	Phase 8	Phase 9	Phase 10
Baseline					
RRFB		■		■	
2 In-street Signs					
RRFB + 2 Signs					
Gateway Treatment	■		■		
RRFB + Gateway					■

During the baseline condition the staged pedestrian did not utilize either the RRFB or the in-street technology, and the pedestrians crossed without activating the RRFB. The advance yield signs installed by the city remained in place. In the RRFB alone condition the pedestrian pressed the button to activate the RRFB but the in-street sign was not installed (see Figure 1).

During the in-street sign condition alone a single in-street sign for each of the two lanes was installed within the turning lane on the lane line immediately post the crosswalk, but the pedestrian did not press the button to activate the RRFB (see Figure 2).

Figure 1. Condition B: RRFB on Grand River Avenue

Figure 2. Condition C: Two In-street Signs on Grand River Avenue

During the RRFB plus in-street sign condition the RRFB was activated for each crossing and the in-street sign for each lane remained in the roadway (see Figure 3). After a return to baseline the treatments were evaluated a second time with the order

RRFB and two in-street signs

Figure 3. Condition D: RRFB and Two In-street Signs

in which the RRFB and in-street signs were introduced reversed as well as an increase in the number in-street signs used to create the gateway effect.

The gateway treatment incorporated four signs, two placed in the same spots as the single sign for each lane of traffic and then two additional signs placed on each gutter pan in order to give the illusion of narrower lane widths (see Figure 4). The RRFB plus gateway treatment incorporated the RRFB technology with the four in-street signs (see Figure 5). Additionally, three baseline probes were collected

within the reversal in order to test for weather effects and determine the reliability

of data collected on sunny days when compared to data collected on cloudier days.

Four in-street signs

Figure 4. Condition E: Gateway Treatment

Four in-street signs plus the RRFB

Figure 5. Condition F: RRFB Plus Gateway Treatment

Independent Variables

One treatment for this experiment was the side-mounted rectangular rapid-flashing beacon with two LED flashers attached to each side of each RRFB on the east and westbound streets (see Figure 1). Each RRFB was dual-indicated, meaning that there were two LED flashers on each side of the RRFB. The LED flashers were 2.5 inches tall and six inches wide. The LED flashers were placed nine inches apart and flashed in an irregular wigwag flashing sequence. The two signs on either side of the crosswalk were linked by radiofrequency transponders, so activating either side of the technology activated the LED flashers on both sides. Each RRFB also included an audible message when a pedestrian approached, instructing the pedestrian to press the red button in order to cross the street. A written sign on each RRFB instructed the pedestrian to first press the button, check for traffic, place a foot in the crosswalk, and thank the driver by waving upon yielding. Advance crosswalk warning signs in the shape of a diamond and with a visual depiction of a crossing pedestrian were also utilized 30 feet in advance of each RRFB because those were previously installed by the township.

Additional in-street signs were utilized in this study. The signs used were three feet in height and on the side facing the traffic read "Local Law Yield to Pedestrians in Crosswalk." During the first series, two signs were used for the eastbound and westbound traffic by placing the signs on the white lines between the travel lane and the turning lane immediately behind the crosswalk (see Figure 2). During the second series, four signs were used by placing each sign on the lines

between the travel lanes and the turning lane on both the eastbound and westbound sides as well as on both of the gutter pans (see Figure 4).

Data Collection

Oakland County is approximately two hours from Kalamazoo, so data collection occurred in daylong segments between sunrise and sunset. The observers took breaks approximately every three data points because a single data point generally took about 45 minutes to collect. The data were collected on data sheets (see Appendix A). One data sheet contains 20 crossings and represents a single percentage yielding point. A minimum of three data points were collected for each condition if the average variability between data points was less than 15 percentage points. Additional points were collected if the average variability from the first three points was greater than 15% until the data stabilized at a level with average variability over three data points being less than 15 percentage points.

Data Analysis

A traditional visual inspection of the data was performed in which the level and the variation in the data were carefully inspected (Parsonson & Baer, 1986). In addition to visual analysis, level change and slope change statistics based on a model discussed in Huitema (2011) were also employed to determine the significance of each change within the reversal design. The model also provides an overall measure of change for the entire study, p-values for each change calculated, and a standardized effect size.

In order to determine the necessity of the slope change statistic, a model selection procedure was first performed in which the full regression model and reduced model were compared to reveal if the slope change was a relevant parameter within the model. The overall slope-change statistic was used to statistically determine if the introduction and withdrawal of the treatments affected the steepness of the slope of the dependent variable percentages whereas the overall level-change statistic was used to statistically determine if the introduction and withdrawal of the treatments changed the level of the dependent variable percentages.

The level change predictions in Table 2 were organized before data collection began and were utilized within this analysis. It was hypothesized that baseline would result in the lowest percentage of yielding. The two in-street signs alone would result in moderate levels of yielding and the RRFB would result in higher levels of yielding than the in-street sign condition. The combination treatment incorporating the RRFB and the two in-street signs were predicted to yield the highest levels of yielding for this series. The predictions for level changes were positive, negative and positive, respectively, for each of the three conditions in the first set of conditions (baseline to RRFB, RRFB to in-street signs, and in-street signs to combination treatment). Additionally, it was hypothesized that the transition from the combination treatment to the next series' baseline would result in a negative level change.

The same method for predicting the level changes was used for the second set of conditions within the reversal design. However, because the in-street

condition incorporated a gateway treatment, it was predicted that the gateway treatment effect would be greater than that of the RRFB. The prediction for level changes were positive, negative, positive, negative, positive (baseline to gateway treatment, gateway treatment to RRFB, RRFB to gateway treatment, gateway treatment to RRFB, and RRFB to the combination of the RRFB and gateway treatment). Due to the addition of the four sign gateway treatment in the second set of conditions, the level change between the RRFB and the four in-street sign condition for the second series of phases was hypothesized to not be as pronounced as the level change between the two in-street signs and RRFB condition from the first series.

Table 2

Predicted Signs for Level Changes for Adjacent Phases

Comparison Phases	Signs for Predicted Direction of Change
A, B	+
B, C	-
C, D	+
D, A	-
A, E	+
E, B	-
B, E	+
E, B	-
B, F	+

Inter-observer Agreement

Inter-observer agreement was assessed within each condition. One data sheet was completed by each observer independently. A single agreement

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constituted an identical yielding and non-yielding number for each of the 20 observations on the single data sheet. Once the staged pedestrian entered the crosswalk, there was an unlimited opportunity for non-yielding which was scored and at the most two opportunities for yielding since once a yield occurred, the pedestrian would cross the street. At least one data point (20 0bservations) within each condition was simultaneously collected by both observers to fulfill inter-observer agreement (IOA) requirements of at least 85%. IOA for yielding agreements were calculated by dividing the number of total agreements by the total number of disagreements and agreements and multiplying this number by 100 to convert the IOA to a percentage.

Inter-observer agreement on yielding occurrence averaged 99% (range 98% to 100%) during baseline, 100% during the RRFB phases, 100% during the two in-street size phases, 99% (range 98% to 100%) during the RRFB and two in-street sign phases, 100% during the gateway treatment phases, and 100% during the combination of the RRFB and gateway treatment phases.

RESULTS

Figure 6 shows the percentage of drivers yielding during baseline and during each of the five different treatments. During both sets of conditions, there was an increase in yielding associated with the introduction of each treatment after baseline for the introduction of both the RRFB and the in-street sign gateway treatment (RRFB 1 M=69%, SD=8.9%; signs gateway 1 M=8.7%, SD=7%). During the first set of conditions, there was a slight difference when comparing the effects of the RRFB with the two in-street signs (RRFB 1 M=69%, SD=8.9%; two in-street signs M=76%, SD=7%). However, there was not a marked difference between the two in-street signs and the combination of the two in-street signs with the RRFB (two in-street signs M=76%, SD=7%; in-street signs+RRFB M=78%, SD=9.6%).
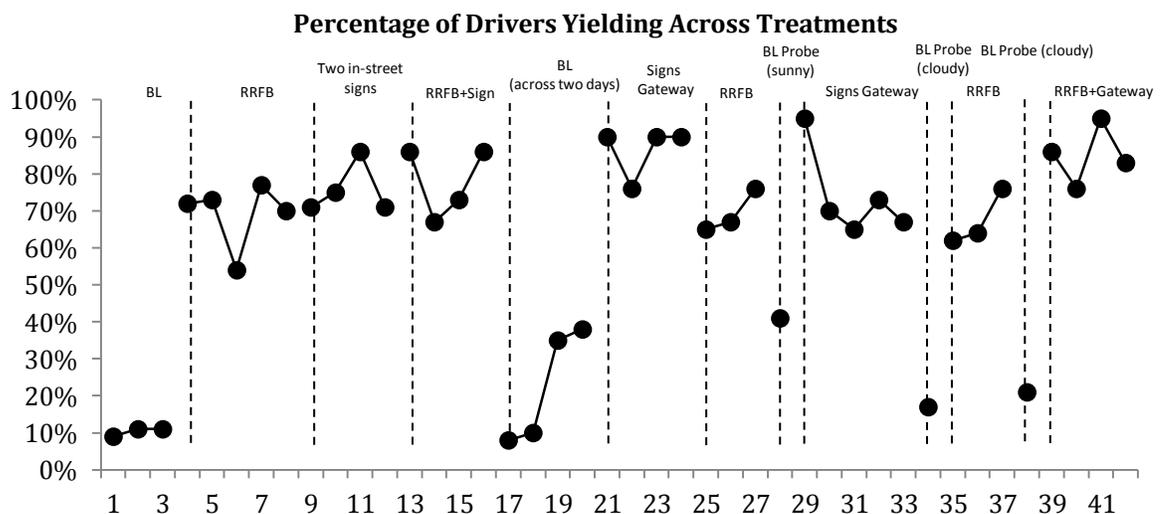

Figure 6. Percentage of Drivers Yielding Across Treatments

During the second set of conditions, the signs gateway treatment seems to have a marked effect when compared to the preceding RRFB condition (signs gateway M=87%, SD=7%; RRFB M=69%, SD=5.9%); however, as the baseline probe reveals, yielding was considerably higher on sunny days and therefore the baseline data and gateway treatment data were associated with higher percentages when collected on the sunny day (signs gateway sunny M=87%, SD=7%; signs gateway cloudy M=74%, SD=12%). Once weather as an environmental variable was controlled for, the gateway treatment stabilized to mimic the percentages associated with the initial two in-street sign data, showing that additional in-street signs did not produce greater yielding percentages (signs gateway cloudy M=74%, SD=12%; two in-street signs M=76%, SD=7%). While the RRFB alone, the two in-street signs, and the in-street sign gateway treatments were associated with similar levels of yielding (RRFB M=69%, SD=5.9%; two in-street signs M=76%, SD=7%; signs gateway cloudy M=74%, SD=12%), the last phase incorporating the RRFB and the gateway treatment produced higher levels of yielding than the RRFB or the in-street signs gateway alone (RRFB+signs gateway M=85%, SD=7.9%).

A model comparison for a reversal design was calculated to determine whether the slope change parameters included in the full model were necessary within the model used to analyze the reversal design (Huitema, 2011). The data analysis revealed that Model II was the appropriate model, meaning that the justification for including the overall slope change was not strong (F=1.44, p=.23). A Durbin Watson statistic was calculated before choosing the second model to make sure that the Model II assumption of independent errors was met. The calculated

Durbin Watson statistic of 2.17 revealed that the residuals were uncorrelated and the assumptions were met for the original least squares method. Table 3 shows the original predicted direction for each level change and the observed level change for each phase change.

Table 3

Predicted and Observed Signs for Level Changes for Adjacent Phases

Comparison Phases	Signs for Predicted Direction of Change	**Signs for Observed Direction of Change**
A, B	+	+
B, C	-	+
C, D	+	+
D, A	-	-
A, E	+	+
E, B	-	-
B, E	+	+
E, B	-	-
B, F	+	+

Table 4 shows the calculated level change coefficients as well as the t-values and p-values for each level change. As is evident, the B-A level change and the E-A level change are both significant because these are associated with the change from the baseline phase to an intervention phase (B-A LC=.58867, t=8.5, p=.000; E-A LC=.63750, t=9.5, p=.000). Additionally, the A-D level change is significant because this is associated with the negative change from the combination of the two in-street signs and RRFB condition to the second baseline condition (LC=-.55250, t=-8.24, p=.000). There are no significant differences between the level changes of the various technologies tested in the first set of conditions.

In the second set of conditions, the level change associated with the change from the gateway treatment to the RRFB condition is significant, however these data were observed on a very sunny day when yielding overall was higher for baseline as well (LC=-.17167, t=-2.37, p=.013). When the gateway treatment was tested on cloudy, cool days, the level changes associated were not significant, providing evidence for the fact that weather variables can affect yielding levels. The final level change associated with the change for the RRFB to the gateway treatment and RRFB combination was a associated with significant level change, showing that combining these two treatments is significantly better than the RRFB alone (LC=.17667, t=2.44, p=.011)

Table 4

Level Change Coefficient, Standard Error Coefficient, T-value, P-value, and Standardized Effect Size

Phases	Level Change Coefficient	Standard Error Coefficient	t-value	p-value	Standardized Effect Size
B-A	.58867	.06927	8.50	.000*	6.21
C-B	.06550	.06363	1.03	.312	.690
D-C	.02250	.06707	.34	.37	.237
A-D	-.55250	.06707	-8.24	.000*	-5.82
E-A	.63750	.06707	9.50	.000*	6.72
B-E	-.17167	.07245	-2.37	.013*	-1.81
E-B	.04667	.06927	.67	.253	.492
B-E	-.06667	.06927	-.96	.172	-.703
F-B	.17667	.07245	2.44	.011*	1.86

CHAPTER IV

DISCUSSION

The results of this study show that pedestrian technologies such as the RRFB and the in-street sign have moderate effects on driver yielding over baseline levels of yielding and that combining the maximum number of in-street signs with the RRFB creates an even greater effect. The results indicate that there is not a marked difference between the RRFB and the in-street sign nor is there a greater improvement in yielding when the RRFB is combined with two in-street signs. However, the results show that the combination of the RRFB with the four in-street sign gateway treatment produces greater yielding than the RRFB alone, the two in-street signs alone, or the gateway treatment alone.

During each RRFB phase, the average yielding was 69%. This is in agreement with the results of Van Houten et al. (2008) which showed average yielding to be 66% for staged pedestrians when the RRFB was activated. However, other studies report the RRFB to be associated with much greater yielding percentages (Shurbutt et al., 2009; Federal Highway Administration [FHA], 2010). The FHA reported that two-beacon RRFBs like the ones utilized by the current study were associated with an increase in yielding from 18% at baseline to 81% during the treatment condition. Initially, the FHA attributed the higher RRFB yielding levels to participant reactivity since the RRFB was a novel stimulus, however, the effects maintained during one

and two year follow-up data collections showing that the increase in yielding was not solely due to the novelty of the stimulus.

The results of the in-street sign conditions are not consistent with the findings of Fitzpatrick, Turner, and Brewer (2007) which revealed that in-street signs were associated with a 90% overall yielding at two-lane roads. However, the current study revealed higher yielding associated with the in-street sign than other studies. The Bay Ridge Consulting (2005) study reported that in the first year of implementation the in-street signs evaluated at three crosswalks were associated with 19% yielding and this increased the second year to 39% yielding. It is possible that because the current site had a turning lane in between to two opposing lanes of traffic and therefore two in-street sings had to be utilized on either side of the turning lane, that the two signs made driver yielding more frequent than the single sign utilized in the Bay Ridge Consulting (2005) study.

Ellis, Van Houten, and Kim (2007) found that adding additional in-street signs at further distances of 20 feet and 40 feet from the crosswalk did not further improve yielding over a single in-street sign placed at the crosswalk. Additionally, the results of the current study indicate that the four sign gateway treatment did not improve yielding over the two sign treatment when weather as an environmental variable was controlled.

Overall, the results were unexpected and revealed that the RRFB and the in-street signs are equally as effective at improving driver yielding over baseline levels. Additionally, the combination of the RRFB and the two in-street signs did not prove to be more effective although the combination of the RRFB and the gateway

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treatment did evoke the highest yielding levels of the entire study. The results of this study have implications for traffic engineering and city planning because pedestrian technologies are expensive. While the RRFB did improve yielding over baseline levels, the in-street signs were associated with the same levels of yielding and are a fraction of the cost of the RRFB. If more rural communities utilized in-street signs as a cost-effective pedestrian intervention, this could save lives over time.

The main difficulty encountered in this study was determining if the weather was suitable for data collection. Because the weather had a large effect on yielding percentages, the researcher also had to standardize the general weather throughout the study, which limited days and sometimes times when data collection was possible. The first in-street sign gateway condition resulted in high levels of yielding as a result of the nice weather and the fact that more pedestrians were out with children. For this reason, the average yielding of 87% for that condition on that day is not generalizable to the rest of the study since the other phases were not collected on sunny days. It is not appropriate to say the gateway treatment evoked higher levels of yielding without noting that the only significant data for this condition were collected on a sunny day completely different from the other days data were collected. However, the RRFB data collected on the sunny day did not show improvements over RRFB data collected on cloudy days. The in-street signs are made of retro-reflective material and this makes them even more salient on sunny days because of the additional reflection of the sun off of the sign. The RRFB may seem diluted on sunny days because the LED flashers are washed out when the sun

is bright. This study therefore may reveal that the in-street sign is as effective as the RRFB on cloudy days and even more effective than the RRFB on sunny days.

Gender of the data collectors also presented a problem because although all data collectors were trained in a similar manner, it often appeared that the female data collectors were able to evoke higher levels of yielding. Due to the limited number of data collectors, it was not possible to control for gender, and therefore it is possible that some of the data is more variable than they would be if the same person or the same gender collected each point.

Participant reactivity was also a concern because South Lyon Township is not a heavily populated area and therefore the same people tend to drive through the crosswalk area throughout the day. In order to control for this issue, the data collectors would stagger the times as well as the days during which they would collect data. However, due to the limited number of drivers in the area, it was not possible to standardize the days or the times during which data was collected, and days or times could be variables that also affect yielding levels.

This study indicates that overall, there is not a marked difference between the effectiveness of an RRFB and in-street signs (both the two in-street sign condition and the gateway condition) on driver yielding for two-lane rural roads when weather as a variable is held constant. However, the RRFB and the gateway treatment together improved yielding over either of the other technologies alone. Although the RRFB and the in-street signs (both the two in-street signs and the gateway treatment) evoked similar levels of yielding, the in-street signs are far less expensive than the RRFB. The durability of the in-street signs should be evaluated

over time to determine if they are more cost effective than the RRFB. Further research can also look at the source of effectiveness of the in-street signs by comparing signs that read "Local Law Yield to Pedestrians in Crosswalk" with blank signs that just create a gateway effect to determine if the source of the effectiveness comes from the actual prompt on the sign or the lane narrowing effect. Additionally, a community intervention could be effective in a small township setting in order to educate drivers on what constitutes a crossing pedestrian and how to effectively adhere to the RRFB and in-street signs. Finally, this study should be replicated on larger, multi-lane streets to determine if the RRFB and in-street signs are equally effective and if the combination of the RRFB and the gateway treatment evokes similar levels of yielding.

Appendix A

Data Sheet

| Location: | Maple and Farmington Maple East | | | | | | | | | | |

| Describe condition: BL | | | W/O light | | | | | | | | |

| | Date: 7-12-11 | | | | start time: 4:00 | | | | Stop time: 6:30 | | |

	Staged Crossings	Cars Not Yielding	Cars Yielding	Distance Cars yielded from crosswalk				Evasive Action		Ped Trapped in Center	Driver Passed Stopped Veh
				<10 ft	>10<20	>20<30	> 30 ft	Ped	Veh		
1			2	2							
2			1		1						
3			2		2						
4			1	1							
5			1	1							
6		2									
7			1		1						
8		1	1	1							
9		3									
10		4									
11		3									
12			1	1							
13			2		2						
14		1	1		1						
15			2		2						
16		2									
17		1	2		2						
18			2		2						
19		3									
20		1	1	1							

	Natural Crossings	Cars Not Yielding	Cars Yielding	Distance Cars yielded from crosswalk				Evasive Action		Ped Trapped in Center	Passed Stopped Veh
				<10 ft	>10<20	>20<30	> 30 ft	Ped	Veh		
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
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14											
15											

Appendix B

HSIRB Approval Letter

WESTERN MICHIGAN UNIVERSITY

Date: May 12, 2011

To: Ron Van Houten, Principal Investigator
Hana Manal, Student Investigator

From: Amy Naugle, Ph.D., Chair
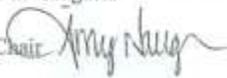
Re: HSIRB Project Number 11-05-13

This letter will serve as confirmation that your research project titled "Evaluating Pedestrian Safety Improvements" has been **approved** under the **exempt** category of review by the Human Subjects Institutional Review Board. *The waiver of informed consent meets the provisions set forth in 45 CFR 46.116 of the Code of Federal Regulations and is granted.* 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 that you may **only** conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. 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.

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

Approval Termination: May 12, 2012

REFERENCES

Bay Ridge Consulting (2005). WFB in-street yield to pedestrian sign effectiveness

study 2005 results. Retrieved from

overthebarsinmilwaukee.files.wordpress.com/2010/09/wfb-report.pdf.

Center for Transportation Research and Education. (2007). Gateway traffic calming

in Union, Iowa. Retrieved from

www.intrans.iastate.edu/pubs/t2summaries/tc-union.pdf.

Eccles, K. A., Tao, R., & Mangum, B. C. (2004). Evaluation of pedestrian countdown

signals in Montgomery County, Maryland. *Transportation Research Record:*

Journal of the Transportation Board, 1878, 36-41*.*

Ellis, R., Van Houten, R., & Kim, J. L. (2007). In-roadway "Yield to Pedestrians" signs:

Placement distance and motorist yielding. *Transportation Research Record,*

2002, 84–89. doi: 10.3141/2002-11

Ewing, R., & Dumbaugh, E. (2009). The built environment and traffic safety: A

review of empirical evidence. *Journal of Planning literature, 23(4),* 347-367.

doi: 10.1177/0885412209335553

Federal Highway Administration (2010). Effects of rectangular rapid-flashing

beacons on yielding at multilane uncontrolled crosswalks. *Pedestrian and*

Bicyclist Safety, FHWA-HRT-10-043.

Fitzpatrick, K., & Park, E. S. (2009). Safety effectiveness of HAWK pedestrian

treatment. *Transportation Research Record: Journal of the Transportation*

Research Board, 2140, 214-223. doi: 10.3141/2140-24

Fitzpatrick, K., Turner, S., Brewer, M. A. (2007). Improving pedestrian safety at

unsignalized intersections. *ITE Journal,* 77(5), 34-41.

Huitema, B. E. (2011). *Analysis of single-case reversal designs, in the analysis of

covariance and alternatives: Statistical methods for experiments, quasi-

experiments, and single-case studies* (2nd ed.). Hoboken, NJ: John Wiley & Sons,

Inc.

Institute of Transportation Engineers. (1985). Determining vehicle change intervals

a proposed recommended practice. *ITE (RP-016)*, 5.

Institute of Transportation Engineers. (2012). Traffic calming measures- choker.

Retrieved on April 3, 2012, from http://www.ite.org/traffic/choker.asp.

Litman, T., & Fitzroy, S. (2005). *Safe travels: Evaluating mobility management

traffic safety impacts.* Victoria, BC: Victoria Transport Policy Institute.

Michigan Department of Transportation (2012). *Pedestrian and Bicycle Crash Data

Analysis: 2005-2010.* unpublished manuscript.

Parsonson, B.S. & Baer, D.M (1986). The graphic analysis of data. In: A. Poling and

R.W. Fuqua (Eds.), *Research Methods in Applied Behavior Analysis.* Plenum

Press, New York, 157-186.

Shurbutt, J., Van Houten, R., Turner, S., & Huitema, B. (2009). Analysis of effects of

LED rectangular rapid-flash beacons on yielding to pedestrians in multilane

crosswalks. *Transportation Research Record, 2140*, 85-95. doi:

10.3141/2140-09

UK Department for Transport. 1997. *Killing speed and saving lives.* London: UK

Department of Transport.

Van Houten, R., Ellis, R., & Marmolejo, E. (2008). Stutter-flash light-emitting-diode

    beacons to increase yielding to pedestrians at crosswalks. *Transportation*

    Research Record, 2073, 69-78. doi: 10.3141/2073-08

Zegeer, C. V., Seiderman, C., Lagerwey, P., Cynecki, M., Ronkin, M., and Schnieder, R.

    (2002). *Pedestrian facilities users guide-Providing safety and mobility.*

    Report No. FHWA-RD-102-01. Washington, DC: Federal Highway

    Administration.