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Analysis of Advance Placement Distance of the Gateway In-Street Sign on Increased Yielding Distance

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ANALYSIS OF ADVANCE PLACEMENT DISTANCE OF THE GATEWAY IN-STREET SIGN ON INCREASED YIEDLING DISTANCE

by

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The National Highway Traffic Safety Association (2018) reported approximately 6,000 pedestrians were fatally injured by vehicles in 2016, with an increasing trend in fatalities over the past decade. The gateway configuration of In-Street signs has been shown to produce an increase in the percentage of drivers yielding right-of-way to pedestrians; this study examined at what distance in advance of the gateway the configuration was most effective in inducing drivers to yield right of way further in advance of the crosswalk. This study also counterbalanced time of day across placement distances. Data were collected on all vehicles that passed through the intervention at a residential neighborhood with a steady flow of traffic on the distance drivers yielded in advance of the crosswalk for various placement locations. The In-Street signs were most effective at producing advance yielding in drivers when it was placed further in advance of the crosswalk.

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INTRODUCTION

The National Highway Traffic Safety Association (NHTSA) reported in 2016 that 5,987 pedestrian fatalities and 70,000 injuries resulting from traffic accidents occurred in the United States. Of those fatalities NHTSA reported that over a quarter involved motorists failing to yield right of way to pedestrians (NHTSA, 2018). From 2007 through 2016 pedestrian injuries have increased in proportion to traffic fatalities. In 2014, 4,910 traffic fatalities involving pedestrians occurred, with that number increasing to 5,376 fatalities in 2015 (NHTSA, 2018). Pedestrians now account for the largest proportion of traffic fatalities recorded in the past 25 years. The increasing trend in pedestrian fatalities since 2009 (NHTSA, 2018) stresses the importance to continue investigating new treatments and technologies to increase pedestrian safety, while increasing the efficiency of existing countermeasures.

During the first half of 2016, the Federal Highway Administration (FHWA) indicated that motor vehicle traffic on all roads have increased by 3.3% or 50.5 billion vehicle miles (FHWA, 2016). With higher volumes of motorists on the road the probability of pedestrian fatalities increase proportionality. The Fatality Analysis Reporting System (FARS) published by NHTSA in 2016 reported that 72% of pedestrian deaths occurred in travel lanes (i.e. non intersections, mid-block’s, highways, etc.). There are three theories that attempt to explain the increase in pedestrian fatalities. First, the growing use of smart phones to access wireless data while walking or driving which can be a significant source or distraction for both pedestrians and motorists. Second, the increase in pedestrian fatalities and injuries could be a result of the design of recent vehicles with less slope to the hood leading to greater trauma when pedestrians are struck. Third, an increase in the percentage of people walking. One way to reduce pedestrian crashes is to develop more effective methods of prompting motorists to yield to pedestrians at crosswalks.

Marked uncontrolled crosswalks are crosswalks have lines and signs marking the location of the crosswalk. An uncontrolled marked crosswalk is a crosswalk without stop sign or traffic signal. In 2005 Zeeger and colleagues found that after conducting a comprehensive analysis, no significant difference in crash rates at marked crosswalks at uncontrolled intersections and unmarked uncontrolled intersections (crosswalks with no lines or signs marking the location of the crosswalk. These uncontrolled crosswalks at uncontrolled intersections create additional threats to pedestrians including right of way problems and multiple threat accidents. Multiple threat accidents are an incredibly deadly form of pedestrian related accidents that occur on multilane roads when the pedestrian's view of the second lane, and a motorist's view of the pedestrian from that lane, are obscured by a vehicle that has yielded close to the crosswalk (Hochmuth & Van Houten, 2018).

While no significant improvement over baseline yielding measures has been shown with marked crosswalk interventions, various other prompts have demonstrated effectiveness at increasing motorists yielding to pedestrians at uncontrolled locations. Van Houten (1988) analyzed the effects of advanced yield markings along with signs educating motorists where to yield. The treatment with the combination of prompts proved to be effective in increasing yielding distance and in reducing pedestrian motorist conflicts, however there was only a slight increase in motorist's behavior of yielding right of way to pedestrians (Van Houten 1988). A follow up study by Huybers, Van Houten, and Malenfant (2004) analyzed the individual and combined effects of each component of the previous treatment package and discovered that placing advanced yielding markings alone were more effective than a sign alone, and just as effective as advanced markings plus signs in reducing multiple threat conflicts between pedestrians and motorists as well as increasing the distance motorists yielded to pedestrians from the crosswalk (Huybers, Van Houten & Malenfant, 2004). This treatment has also been demonstrated to reduce pedestrian crashes in large scale national study (Zegeer et.al., 2017)

The R1-6 sign has proven to be another treatment that has been effective at prompting yielding right of way to pedestrians. The R1-6 in-street sign is a narrow rectangular sign (see Figure 1) with a yellow border surrounding a white interior that reads "State Law Yield to Pedestrians Within Crosswalk" using symbols and test (Federal Highway Administration, 2009). Bennett, Manal, and Van Houten (2014) analyzed if multiple signs could be configured in the road to create a "gateway" affect to increase efficacy of prompting yielding behavior in drivers. The gateway configuration consisted of placing signs on both edges of the roadway, with one sign in the centerline and other lane lines if present, to create a narrowing affect slowing down motorists and thus increasing the probability of yielding right of way to pedestrians. Bennett et al. (2014) found that the gateway configuration was effective at producing noticeably greater increases in yielding behavior of motorists over placing a single R1-6 sign on the centerline.

Ellis, Van Houten, and Kim (2007) investigated the effect of placing a single R1-6 directly at the crosswalk, and then in advance of the cross walk at 20 ft and 40 ft. The authors found that all three interventions produced a signification increase in yielding behavior in motorists over baseline measures. The authors then tried to place all three signs in the road on the centerline simultaneously (at the crosswalk, 20 ft. in advance of the crosswalk, and 40 ft.in advance of the crosswalk) and found that no significant increase in yielding over baseline against a single sign installed on the centerline (Ellis, Van Houten & Kim, 2007).

It has been demonstrated that the gateway treatment at marked crosswalks is an effective intervention at prompting motorists to yield right of way to pedestrians. Placement of the R1-6 sign at and advanced of the crosswalk has also been proven to be effective at increasing yielding right of way to pedestrians. While previous research on has evaluated placement of a single sign at various distance from the crosswalk and other studies have examination the effects of several other variables influencing the effectiveness of the gateway configuration, no research has been conducted on optimal sign placement in advance of the crosswalk results in facilitating motorists yielding further in advance of the crosswalk. It is has also not been determined if time of day affects overall efficacy of the R1-6 gateway configuration or the advance placement of signs from the crosswalk on increasing yielding behavior in motorists. The present study examined the efficacy of systematically varying the distance of the in-street gateway intervention placed in advanced of the crosswalk counterbalanced across various times of day.

METHOD

Participants

The participants of this study were any motorists traversing the crosswalks at the data collection site. No demographic data were taken on any of the motorists. A motorist would become a participant simply by using the road where the researchers were collecting data. Motorists did not have to meet any criteria other than being physically present and currently operating a motor vehicle. No information about the motorist's vehicles were recorded.

Setting

Only one site was used for this study, which took place at a crosswalk on a three lane road at a four-way intersection located on North Main St. at the intersection of West Bennett St. This crosswalk connects an elementary school and a church near the entrance of the city of Three Rivers, Michigan. The posted speed limit on North Main Street was 35 mph, there was no grade on the roadway. All data were collected on the northbound crosswalk on North Main St., and all data collection took place between the months of October and November of 2016.

Apparatus

The R1-6 Sign states includes a "Local Law, Yield to Pedestrians" plaque was mounted on temporary bases that were able to be easily manipulated and moved to various distances in the roadway depending on the condition of the experiment. All signs were double sided and placed in both the gutter pan as well lane lines to produce a gateway that drivers needed to travel through.

Design

This study utilized an alternating treatments design with a reversal. The alternating treatments embedded within the reversal design was added to explore and control for any effect that time of day might have on yielding. To counterbalance the order of distances from the cross walk by the time of day, a Latin Square (4x4) generator was used. The times of day represented were 10:00AM, 11:00AM, 12:00PM, 1:00PM, and 2:00PM, and no combination of conditions and time of day was repeated. One data point was collected at the top of each hour

Independent Variable

The current study examined the presence and location of the R1-6 Sign in the gateway configuration and the distance the gateway was placed in advance of the crosswalk. Placement of the gateway at five different distances (5ft, 10ft, 20ft, 30ft, 50ft) in advance of the crosswalk assigned using the Latin Square generator. These distances were measured from the nearest crosswalk line to the placement of the signs. All distances from the crosswalk were marked with tape throughout the entirety of the study to allow observers to score yielding distance of each vehicle.

Dependent Variable

The primary measures were the percentage of motorists who yielded to researchers crossing at a designated crosswalk and the distance they yielded in advance of the crosswalk. Researchers were between the ages of 19 and 31 years old. Five of the research assistants were male and one was female. Researchers were not required to wear a uniform or meet any specific physical criteria.

One trial consisted of one completed crossing by the researcher. The number of motorists who yielded and did not yield to the researcher crossing in the crosswalk were recorded. A total of twenty crossings (trials) were averaged for each data point. The total number motorists who yielded were added to the total number of motorists who did not yield. The total number of motorists who yielded was then divided by the total number of motorists to obtain the percentage of yielding. Yielding distance was measured using a TR Industrial 6 in. aluminum collapsible measuring wheel at the beginning of each trial which would record the number of feet traveled from the crosswalk per rotation of the wheel. Duct tap was then used to in the gutter pan to clearly mark the distances for research assistants to view from a distance.

Scoring Procedure

A trial would begin when a research assistant put his or her foot in a crosswalk and looked towards the direction of traffic. The location of the dilemma zone was calculated by using the engineering equation from the Institute of Transportation Engineers 1994 report titled "Determining Vehicle Signal Change and Clearance Intervals". The formula is: $y= t + ((v)/(2a +2Gg))$ where y is the length of the yellow interval, t is motorist perception reaction time (recommended as 1 second), v is the speed limit (feet per second), a is the safe deceleration rate (10 feet per second squared), g is gravitational acceleration (32 feet per second squared), and G is the approach grade, in this case 0%. The time was used to calculate the location of the dilemma zone by multiplying the time by the speed limit in feet per second. The calculated distance reflects the distance a motorist requires to react and stop safely if a pedestrian entered a crosswalk. The interventions occurred at locations with a posted speed limit of 35 miles per hour. Thus the dilemma zone used at the experimental sites began 183 feet in advance of the crosswalk.

The dilemma zone was marked on both sides prior to any data collection, and was always done in pairs of researchers, to ensure the safety of the other. A walking wheel was used to measure out the distance away from the crosswalk in the gutter pan of the road. Researchers wore reflective vests anytime the walking wheel needed to be used. If at any time a researcher felt uncomfortable measuring the distance of the dilemma zone due to traffic, they were instructed to step out of the road and wait until traffic cleared, but still kept the walking wheel on the same spot of the gutter pan. To ensure accuracy of the distances measured and collected, duct tape was placed at the following distances in advance of the crosswalk (5ft, 10ft, 20ft, 30ft, 50ft) in the gutter itself, and small metal sprinkler flags were placed in the grass on the curb. A flag was also placed at the dilemma zone if no easily identifiable landmark (lamppost, tree, driveway, etc.) was present at the dilemma zone.

If a car inside the dilemma zone yielded to a pedestrian that initiated a crossing, the car would still be scored as yielding. This was possible because the formula used to calculate the dilemma zone provides a generous distance for vehicles to stop. It is also possible to yield inside the dilemma zone when the vehicles are traveling under the speed limit. However, if the car did not yield within the dilemma zone, they would not be scored, as they did not likely have a safe amount of distance to safely yield.

This site was located on a two-way road, so only motorists approaching the first half of the roadway were scored until the researcher was able to reach the middle of the road (turning lane), and initiate the crossing procedure again. During all conditions, the researcher would approach the crosswalk and signal intent to cross by placing a foot in the gutter pan. Researchers were then instructed to wait at the crosswalk until a vehicle yielded to them, traffic cleared, or there was a large enough break in traffic for them to safely cross without any concern of being struck.

General Data Collection Procedure

In order to control potential confounding variables a variety of requirements were in place for researchers' crossing. Researchers were instructed not to stand close to each other near the cross walk, or in groups with other pedestrians. All crossing had to be made by a single researcher at a time. If a naturally occurring pedestrian began to attempt to cross the crosswalk with a researcher, or across the street from the researcher, the researcher was instructed not to count that crossing for that trial, but to continue to cross the street naturally. Researchers were not allowed to make any motions prior to motorist yielding such as waving at the motorists, signs of emotional discomfort or frustration, yelling, pointing, etc. This was done because previous research indicated that pedestrians can influence motorist yielding by engaging in various behaviors to indicate an intention to cross (Crowley-Koch, 2011). However, researchers were allowed to smile, nod, and/or wave thanks to the motorists after they successfully yielded to the researcher.

Researchers were given specific instructions and requirements when it came approaching the cross walk, crossing the street, and recording data. Researchers were told to adjust their speed in order to properly time their foot entering the cross walk when a car was just outside of the dilemma zone, but were not allowed to run toward the cross walk, or slow their pace in order to adjust any miscalculation that was made in timing. If a researcher ended up approaching the cross walk too early, and a motorist was still far outside of the dilemma zone, the researcher continued to cross the street and would not count that trial. The same instructions were given if the approach to the crosswalk was too slow. To remain inconspicuous to all motorists, researchers would identify a location on each side of the crosswalk that would appear typical for pedestrians to be located in. For this site, locations that were used to blend in included a park bench, the local church's steps, or further down the side walk out of direct sight of the motorists. For those researchers that were further down the road, a "spotter" researcher located in one of the other two locations would indicate when to start approaching the crosswalk. Researchers did not engage in conversation with actual pedestrians or motorists of traveling vehicles during the approach or while waiting.

All data were collected on clipboards and printed data sheets. Researchers would directly record the data after a crossing was complete if there were no motorist present after the crossing, otherwise they were instructed to continue to walk further down the sidewalk until they were out of sight to record their data. In order to appear as natural crossing pedestrians, researchers would conceal the clipboards by placing themselves between the line of sight of the motorist and the clipboard. The clipboard would be held at their side or behind their back until the crossing was complete.

Inter-Observer Agreement

Inter-observer agreement (IOA) was collected on more than 25% of all trials. Two independent observers would score a crossing during inter-observer trials. A researcher could cross and score while the other did not cross and remained stationary or both would score from the same position while a third researcher performed the crossing. Each event that was scored the same by both observers counted as an agreement and each event that had differing scores counted as a disagreement. The total percentage was calculated by dividing the total number of agreements on vehicles that yielded by the total number of agreements and disagreements ((Agreements) / (Disagreements + Agreements)) * 100 = % of Agreement]. The average IOA for yielding was 98%, with a range of 96% to 100 %. The average IOA for yielding distance was 93% with a range of 87% to 100%.

Research Assistant Training

Researcher training occurred entirely on site. Candidates were shown how to use the equipment to mark the dilemma zone by a senior researcher. It was not necessary to test comprehension and retention of these procedures because no errors were observed after an initial training session. A selected candidate would observe a previously trained researcher model the appropriate crossing and procedures. The candidate would then cross with the senior researcher and receive feedback until the candidate could consistently complete a crossing without any mistakes. Any mistake that was made by candidates would be immediately met with corrective feedback after a crossing was completed. The potential researcher and the trainer would score crossings together. Sometimes the senior researcher and candidate would score another researcher crossings or would cross together and score that trial. The person needed to obtain inter-observer agreement on 90% or higher for two data points (40 crossings) before being allowed to collect data. All candidates ended up meeting these requirements. Either the primary investigator or the graduate student assistant researcher conducted all training. A total of five different researchers collected data.

Results

The experiment began with a baseline condition that had a yielding average of 8%. Signs that were placed 5ft in advance from the crosswalk during the treatment conditions saw yielding increase to 50%. Signs placed 10ft in advance from the crosswalk during treatment conditions saw yielding increase to 56%. Signs placed 20ft in advance from the crosswalk during treatment conditions saw a drop in yielding to 55% during treatment conditions. Signs placed 30ft in advance of the crosswalk saw a decrease as well in yielding down to 54% during treatment conditions, and finally yielding decreased even further to 52% when signs were placed 50ft in advance of the crosswalk during treatment conditions. Once the signs were removed, the yielding average dropped back down to 3% during the return to baseline condition (see Figure 2). Total average IOA was 98.1%. The overall treatments indicate that signs placed 10ft in advance of the crosswalk were the marginally more effective at prompting yielding behaviors in motorists, while the 5 ft configuration was the least effective at prompting yielding behaviors in motorists. All configurations were more effective than both baseline conditions (See Table 1). However these differences were very small and were not behaviorally significant.

Table 1: Overall average motorist yielding for each condition measured.

Condition	Condition Averages
A – Baseline	7.54
B – 5ft	50.09
C – 10ft	55.87
D – 20ft	55.44
E – 30ft	54.04
F – 50ft	52.30
A – Baseline	2.94

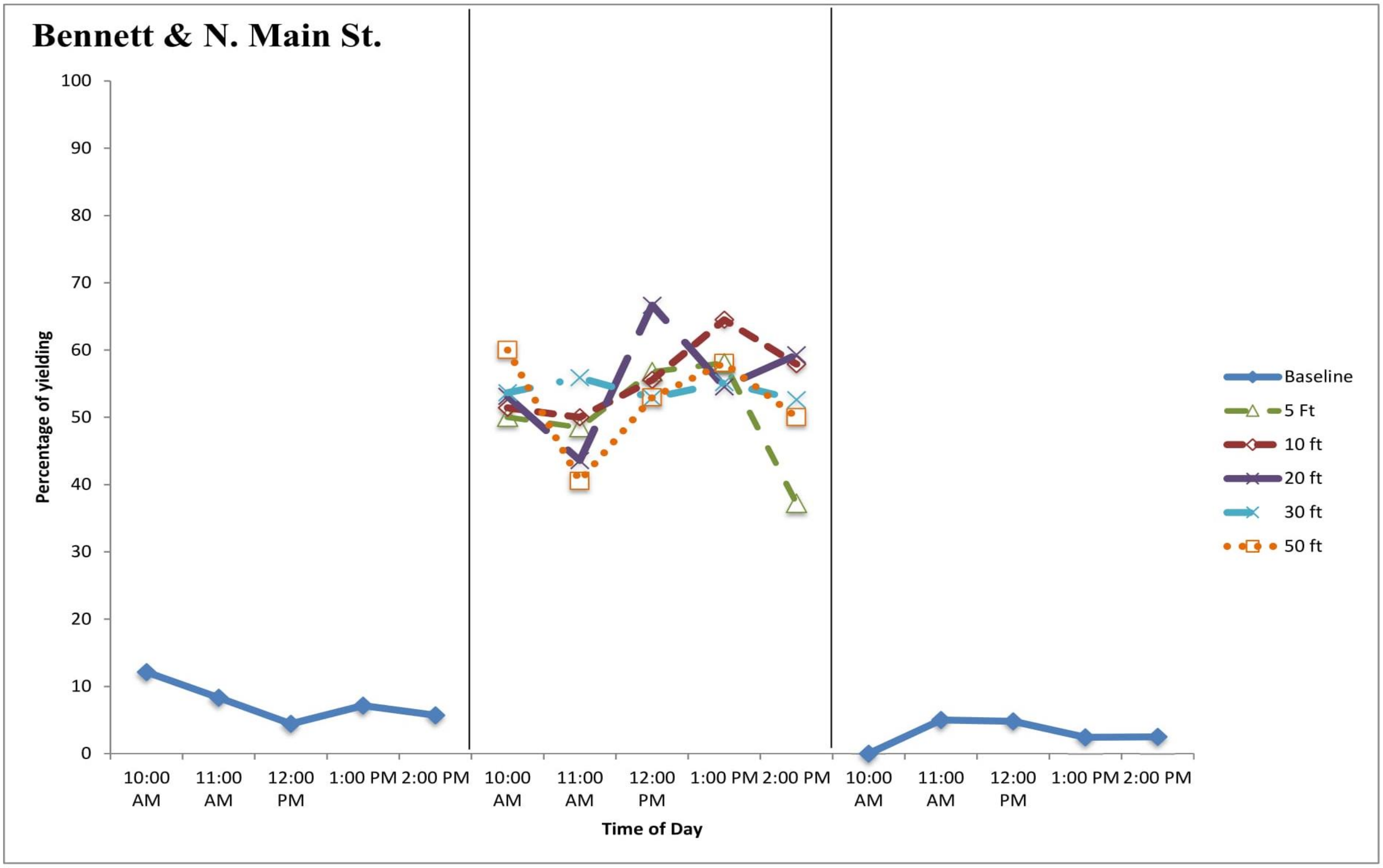

Figure 1: Overall Results

Yielding distance during each condition is shown in Figure 2. When signs were placed 5ft in advance of the crosswalk, motorist who yielded would yield at least 5ft in advance of the crosswalk 65% of the time. When signs were placed 10ft in advance of the crosswalk, motorist who yielded would yield at least 10ft in advance of the crosswalk 60% of the time. When signs were placed 20ft in advance of the crosswalk, motorist who yielded would yield at least 20ft in advance of the crosswalk 45% of the time. When signs were placed 30ft in advance of the crosswalk, motorist who yielded would yield at least 30ft in advance of the crosswalk 50% of the time. When signs were placed 50ft in advance of the crosswalk, motorist who yielded would yield at least 50ft in advance of the crosswalk 80% of the time (See Figure 3).

The overall treatments indicate that signs placed 50ft in advance from the crosswalk produced the safest motorists yielding distance (50ft in advance of the crosswalk) 80% of the time, while signs placed 20ft in advance from the crosswalk produced motorist yielding 20ft from the crosswalk 45% of the time (See Table 2).

Table 2: Overall percentage of drivers yielding in advance of the crosswalk

Condition	Yielded in Advance of Crosswalk
5ft	65%
10ft	60%
20ft	45%
30ft	50%
50ft	80%

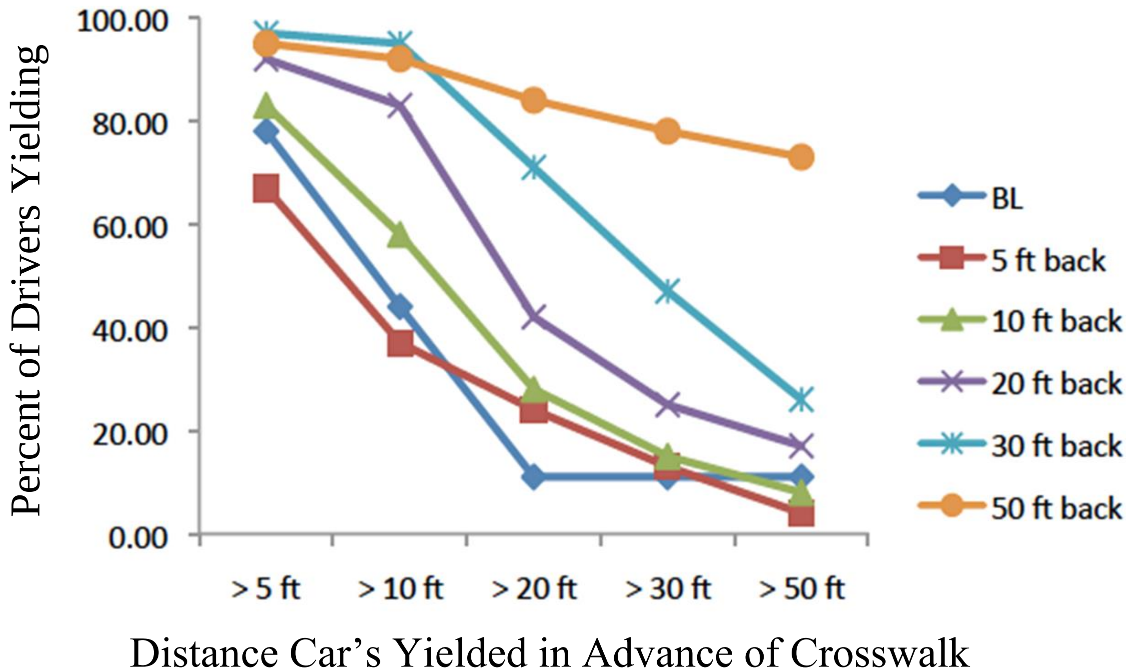

Figure 2: Distance of cars yielding from crosswalk

Figure 3 shows the distribution of stopping distances for each gateway placement distance. These data show that yielding distance falls off rapidly for all distances except for the 50ft placement distance.

Discussion

Overall Yielding

Baseline had a combined average of 5% of motorists yielding and was consistently stable across all phases. Data collected from a previous study near Bennett and N. Main Street saw an average yielding percentage in baseline of approximately 6%, further adding to the data’s consistency. The overall averages of the distances measured in this study were 50% at 5ft, 56% at 10ft, 55% at 20ft, 54% at 30ft, and 52% at 50ft, with a combined average of 54%. This number is stable with data that has historically been collected in the city of Three Rivers (54%), and is likely due to the size of the city, and the similarity of motorists passing through the site. The road selected for this study was Bennett and N. Main street, a road off US Highway 131 leading into the city of Three Rivers. Most cars were still decelerating from highway speeds when they traversed the crosswalk, which could account for the lower percentage yielding averages of collected at this site than what have been historically collected at previous sites across West Michigan, which has been supported by Schmidt and Tiffin (1969). This further adds support to the conclusion that the gateway configuration of the In-Street R1-6 sign is effective at increasing and maintaining stable yielding behaviors in motorist. Regardless of where the gateway configuration is placed in advance of the crosswalk yielding percentages will remain stable across distances.

Drivers Yielding in Advance of Crosswalk

A secondary variable that was measured in this study was the distance motorists yielded in advanced of the crosswalk, with the highest percentage of yielding at 50 ft in advance of the crosswalk (80%) being generated when signs were placed 50ft in advance from the crosswalk, and the lowest percentage of yielding at 50 ft being generated when signs were placed 5ft in advance from the crosswalk. This shows that of all cars that yielded when signs were placed 50ft in advance of the crosswalk, 80% of the time motorists would be yielding 50ft away from the crosswalk. This effect remained consistent with all sign placement variations (see Figure 2) with respect to their placement in advance of the crosswalk. This finding suggests that when salient prompts have been placed in advance of the crosswalk, motorist have a better chance of reacting to these prompts. In the case of the gateway in-street sign configuration, having the signs placed 50ft in advance of the crosswalk allows the motorist to yield to the pedestrian further away from the crosswalk than when the signs were not present. This has the potential to reduce close stops at the cross walk, and the incidence of multiple threat crashes.

General Discussion

This study has shown that the In-Street gateway configuration of the R1-6 sign maintains its effectiveness when placed in advance of the crosswalk. This not only has intrinsic benefits to the pedestrians utilizing the crosswalks (reduced probability of a multiple threat crash) but has economic benefits as well. Some of the sites across West Michigan that utilize the R1-6 In-Street Gateway configuration are located in industrial areas that are frequently trafficked by fright trucks, or other commercial vehicles. Previous literature suggested that the R1-6 In-Street Gateway configuration should be located at the crosswalk itself, and when commercial vehicles that have a wider turning radius utilizes those intersections, signs have been struck and damaged. While the R1-6 has been designed to be struck, over the course of multiple impacts the R1-6 will need to be replaced. This process is expedited when a larger commercial vehicle strike the signs. This study demonstrated that the In-Street Gateway configuration is effective when placed in advance of the crosswalk while still maintaining its effectiveness, increased yielding at industrial sites across West Michigan can place the sign configuration in locations conducive for commercial vehicles.

An overall limitation of this study was that all trials were conducted on a three lane road. While placing signs in advance of the crosswalk was effective at prompting drivers to yield in advance of the crosswalk this study was unable to analyze the effect this sign placement would have on roadways with four or more lanes, to specifically reduce multiple threat crashes. Future studies should analyze the effects the distance of sign placement in advance of the crosswalk at wider multi-lane roads. Another limitation of this study was times of day that were measured. All crossings completed in this study were done between the hours of 10:00 am-2:00 pm. NHTSA (2015) stated that the most pedestrian related fatalities occur between the hours of 6:00 pm-9:00 pm. A replication of this study conducted within the timeframe of 6:00 pm-9:00 pm at night on a four lane road could be a beneficial step to reducing the total number of pedestrian related fatalities.

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