



4-2012

Effects of Symbol Prompts and 3D Pavement Illusions on Motorist Yielding at Crosswalks

Nicole M. Cambridge

Follow this and additional works at: https://scholarworks.wmich.edu/masters_theses



Part of the Psychology Commons

Recommended Citation

Cambridge, Nicole M., "Effects of Symbol Prompts and 3D Pavement Illusions on Motorist Yielding at Crosswalks" (2012). *Master's Theses*. 48.

https://scholarworks.wmich.edu/masters_theses/48

This Masters Thesis-Open Access is brought to you for free and open access by the Graduate College at ScholarWorks at WMU. It has been accepted for inclusion in Master's Theses by an authorized administrator of ScholarWorks at WMU. For more information, please contact wmu-scholarworks@wmich.edu.



BF
9999
. C335

EFFECTS OF SYMBOL PROMPTS AND 3D PAVEMENT ILLUSIONS ON
MOTORIST YIELDING AT CROSSWALKS

by

Nicole M. Cambridge

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

Western Michigan University
Kalamazoo, Michigan
April 2012

Copyright by
Nicole M. Cambridge
2012

EFFECTS OF SYMBOL PROMPTS AND 3D PAVEMENT ILLUSIONS ON MOTORIST YIELDING AT CROSSWALKS

Nicole M. Cambridge, M.A.

Western Michigan University, 2012

Pedestrian safety remains a serious concern at busy non-signalized intersections in large metropolitan cities across the nation, because many drivers fail to stop or yield to pedestrians at marked crosswalks. Past evaluated devices either have obtained marginal effects during evaluation or are limited in availability, such as the High Intensity Activated Crosswalk (HAWK) beacon and the Rectangular Rapid Flash Beacon (RRFB), due to installation and maintenance costs. 3D pavement illusions have been previously studied in transportation application; however no formal evaluations have examined the effectiveness of 3D pavement illusions on motorist yielding behavior. A multiple baseline study was conducted across two uncontrolled crosswalks sites. Following a baseline condition, an in pavement “Look for Pedestrians” message marking was placed in advance of the crosswalk. Next, 3D pavement illusions were added to the pavement marking message. The pavement marking message increased yielding behavior and the initial installation of the 3D illusions were effective at increasing yielding further, however over time the novelty of the 3D pavement illusions reduced motorist yielding back to the previous pavement message only condition.

ACKNOWLEDGMENTS

I would like to take this time to acknowledge my appreciation to several individuals that contributed to the successful completion of this thesis. First, I would like to extend my thanks to my advisor and committee chair, Dr. Ron Van Houten for his guidance, support, and patience as I completed this research. The enthusiasm of Dr. Van Houten for exploring new approaches to solving real world problems has provided me a springboard for pushing the envelope in my own innovative and outside-the-box analytical approaches in my current work. Next, I would like to thank the members on my thesis committee, Dr. Brad Huitema, and Dr. Heather McGee for their encouragement and flexibility as I balanced school along with a full time career.

I would like to express my gratitude to my data collectors, Trevor Salimi and Patrick Marcotte, for enduring long data collection sessions in a multitude of weather elements, compiling numerous data sheets, and spending countless time at FedEx scanning datasheets for my analysis. I could not have asked for more professional and courteous colleagues to help in this endeavor.

Finally, I would like to offer thanks and appreciation to my family: Carl and Judy Cambridge, Shawn Cambridge, and LeRoy and Lucille Duwa, Matthew Polk, as well as my colleagues and friends: Justin Bryson, David Forsyth, Daniel and Christina Janek, Marco and Jessica Tomasi, Amber Watts, and Nicholas West for their support, patients, advice, and humor through this enduring process.

Nicole M. Cambridge

TABLE OF CONTENTS

ACKNOWLEDGMENTS	ii
LIST OF TABLES	v
LIST OF FIGURES	vi
INTRODUCTION	1
PURPOSE	5
METHOD	6
Setting	6
Participants	6
Materials	7
Walking Wheel	7
Pavement markings	7
3d Pavement Illusions	8
MEASURES	10
Dependent Variable	10
Independent Variable	10
EXPERIMENTAL DESIGN	11
PROCEDURES	13
Data Sheets	13
Participants Used in Collection Procedures	13

Table of Contents—continued

Natural Observation Crossings	13
Staged Crossings	14
Data Collection and Weather Conditioning	14
IoA and Integrity of the Independent Variables	14
RESULTS	15
DISCUSSION	20
CONCLUSION	23
REFERENCES	25
APPENDICES	
A. Installing 3D Pavement Markings and 3d Illusions to the Roadway	27
B. Data Sheet	29
C. Approval Letter from the Human Subjects Institutional Review Board (HSIRB)	31

LIST OF TABLES

1. Multiple baseline schedule across two sites..... 11

LIST OF FIGURES

1. Illustration of Phase 1: Pavement Marker.....	8
2. Design of ‘Thunder’ 3D Pavement Illusion Marker	9
3. Illustration of Phase 2: Pavement Marking Plus 3D Illusions	9
4. Percentage of All Motorists Yielding	17
5. Percentage of Motorists (excluding taxi cab drivers) Yielding	18
6. Percentage of Taxi Cab Drivers Yielding	19

INTRODUCTION

Crosswalks are sites of frequent interactions between vehicles and pedestrians. In 2010, there were 70,000 pedestrian injuries and 4,280 pedestrian deaths attributing from pedestrian-vehicle collisions across the United States (USDOT, 2012). These numbers have increases of 19.0% and 4.2% respectively from 2009 indicating that the need for continued research in the area of pedestrian safety. The primary approaches to pedestrian safety include traffic engineering modifications, traffic law enforcement, and pedestrian education. Unlike the difficulty in assessing the effects of enforcement and educational programs on pedestrian-vehicle crashes, it is possible empirically evaluate engineering methods.

Retting et al (2003) reviewed evidence-based traffic engineering measures and found there to be three main categories to support the pedestrian in traffic designs; separating pedestrians from vehicles by time or distance, increasing pedestrian visibility, and reducing vehicle speeds. Due to regulations for crosswalk placement, it is difficult to separate vehicles and pedestrians by time or speed at crosswalk locations without the use of traffic signals or refuge islands. Pedestrian visibility interventions may also be limited in certain locations due to local, state, or federal traffic ordinances. Although speed reduction interventions can be effective, they often involve the use of costly traffic calming measures.

Although speed inventions may seem limited, Oxley et al. (2001) focused on determining cost-effective approaches to vehicle speeds in high pedestrian

environments. Three of these interventions included increased speed limit signs, painted colored crosswalk, and painted section within the median (painted island versus a raised island). The results of these studies found little difference in speed after the implementation of the countermeasures.

Another approach to increase driver yielding to pedestrians is the use of in roadway markings and beacons devices. The more effective interventions, such as the Rectangular Rapid Flash Beacon (RRFB) and the Hybrid Beacon (formally called the High-Intensity Activated Crosswalk or HAWK beacon), may be too costly for cities. The use of advance stop lines placed 50 feet in advance of crosswalks designed to increase yielding further in advance of the crosswalk has also shown to be associated with a small increase in overall yielding behavior (Van Houten, 1998; Van Houten & Malenfant, 1992).

Past studies have indicated that illusions have decreased motorist's speeding behavior; therefore, illusions may increase drivers' yielding behavior as well. Illusions have been demonstrated to reduce speeds in several studies (Griffen & Reinhardt, 1996; Maroney & Dewar, 1987). Maroney and Dewar (1987) concluded that transverse lines painted at progressively reduced distances project the illusion of increased speed, which can lead to a reduction in speed. This is similar to lining a lane with traffic cones placed progressively closer together along the edge of the road. The cones would project a narrowing lane, decreasing driver's speed, although no cones were actually place further into the lane. The initial results were effective with a subset of drivers, but after three weeks the effect on driver's speed diminished.

Griffen and Reinhart (1996) also reported that the behavioral mechanism behind the observed effects may have been an effect of a marking alert rather than an illusion of speed. If a warning or alerting effect from the illusions is the mechanism responsible for the speed reductions, it is likely that more prominent illusions, such as raised three-dimensional (3D) illusions on roadways, may prove even more effective than basic illusions. It is also possible that the effect of a 3D illusion will habituate based on data with other types of illusions.

In 2001, The Organization for Traffic Safety in South Holland County in the Netherlands researched the effects of two types of 3D illusions, mountain and block type illusions, on motorist speeding behavior. The study assessed nine sites and data were collected via surveys, traffic counters, and the use of a laser gun. The surveys indicated little or no significant differences in motorist speeding behavior. The results stated that it was unclear if any change in speed attributed to the 3D illusions.

Researchers conducted awareness surveys and 86.0% (out of 377 surveyed individuals) stated that they did notice the 3D illusions. When asked the type of reaction to the illusions, the majority stated that the illusions stood out each time (24.0%, 85 out of 353 responses) and the illusions reduced their speed (21.0%, 74 out of 353). Only 5.0% (19 out of 353 responses) viewed the illusion as an obstacle. Although there was no significant speed reduction noted within the parameters of the study, perception of reduced speed was high in comparison to examining motorist perception of the illusions.

Blomberg and Cleven (2006) assessed multiple illusion types as part of the *Heed the Speed* program and found significant speed reduction from “raised” roadway illusions. The results of the Heed the Speed program established that 3D pavement markings were associated with a 94.0% and a 24.0% increase in driver compliance with the posted speed limit at two independent sites, and a reduction of 62.0% and 40.0% in drivers traveling seven miles per hours (mph) over the speed limit. Blomberg and Cleven observed these reductions maintain for three to four months after installation. Unfortunately, no measurements of the long-term persistence of the effect were evaluated. The study continued to state that roadway illusions could be an effective marking for pedestrian safety if paired with an appropriate public prompt or message. Because increased speed enforcement was implemented along with public education, it is not clear whether the speed reductions would have occurred in the absence of these interventions.

As indicated in the Heed the Speed study, 3D illusions may be beneficial to pedestrian safety, as indicated by the statistically significant results, even though the illusions were not evaluated on long-term reduction in speeding behavior. As drivers reduce their vehicle speed, the frequency and the severity of pedestrian crashes should decrease.

The present study compared a pavement marking prompt to “look for pedestrians” alone with the pavement marking prompt plus a 3D illusion.

PURPOSE

The application of 3D illusions in the field of transportation safety may have the capability to influence motorist's behavior beyond reducing speed. One possible application is to add 3D illusions to uncontrolled crosswalks to potentially achieve an increase in motorist's yielding behavior. The desired behavioral outcome in the uncontrolled crosswalk application is different from the previous use of the 3D illusion that addressed speeding. By applying 3D pavement illusions prior to the advance of the crosswalk, motorists will likely reduce speed, and therefore should have more time to yield right-of-way to the pedestrian in a crosswalk.

The 3D pavement illusion is a novel and unique prompt, signaling the motorist to slow in high pedestrian areas to allow pedestrians to cross the street. The purpose of this study is to 1) evaluate the efficacy of an in pavement marking prompt to look for pedestrians, 2) the effect of adding a 3D pavement illusion to the pavement marking prompt and 3) to evaluate the maintenance of any changes produced by these treatments.

METHOD

Setting

Data were collected at two uncontrolled marked crosswalks in the city of Chicago. Uncontrolled marked crosswalks were defined as painted crosswalks without traffic controls. These crosswalks were marked using continental markings. Researchers selected sites in the same neighborhood, approximately one mile apart, on parallel roads, having similar environmental conditions to minimize variability. Each road was thirty-seven feet wide, and located within a minimum block distance of 1,000 feet situated between consecutive intersections with traffic signals. Both sites were two-way streets with one lane in each direction for on-street parking, had high traffic volume, and had three or more pedestrian crashes within the last three years.

Participants

The data collection procedure was based on natural observation; therefore there was no formal recruitment of participants. Participants included motorists and pedestrians that approached the two crosswalk sites. When no pedestrians were present at a site, data collectors performed staged crossings following the safe crossing protocol. In this study, only the motorist's behaviors regarding interactions at the crosswalk sites were recorded.

Materials

Walking Wheel. Data collectors initially used a walking wheel to mark dilemma zones for the two sites. A signal time formula, as described by Van Houten and Malenfant (2004), was used to calculate the length of the dilemma zone. The dilemma zone is the threshold or minimum distance required for a vehicle to safely stop at given speed limit under dry pavement conditions. Both sites were located in a 30 mile per hour (mph) zone. Using the signal timing formula, the minimum distance required to complete a safe stop at 30 mph was recorded and measured out in both directions at each site. A landmark situated near the dilemma point in each direction marked the dilemma zone for recording at each site.

Pavement Marking Prompt. Following a baseline condition, an in-pavement message marking was placed in the travel lane in advance of the crosswalk. This pavement marking prompt was constructed from white retro-reflective standard U.S. Department of Transportation (DOT) thermal plastic material. The thermal material was affixed to the roadway using a torch. The pavement marking prompt contained the words “LOOK FOR” with a standard pedestrian symbol. An illustration of the marking is depicted in Figure 1.

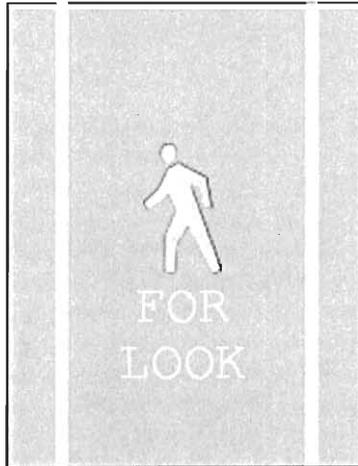
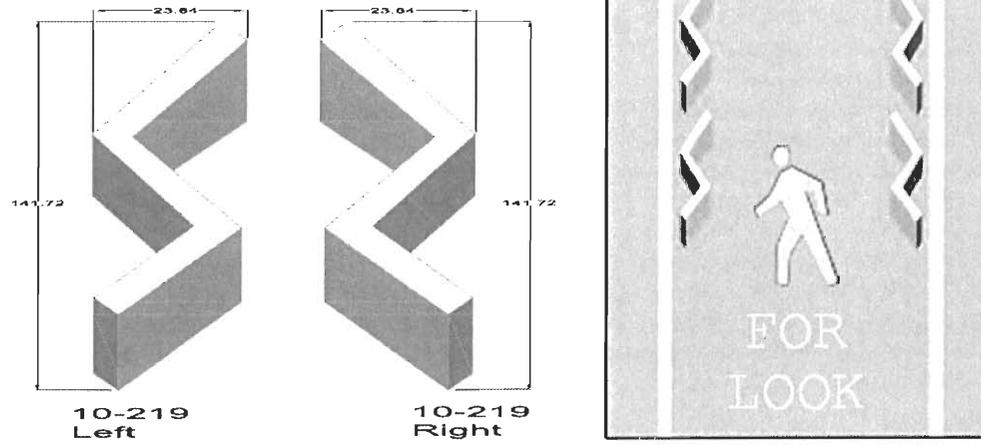


Figure 1: Illustration of Phase 1: Pavement Marker

3D Pavement Illusion. The 3D pavement illusion consisted of thermal plastic colored material that was arranged to produce a 3D effect suggesting a vertical deflection. A 3D illusion was placed on each side of inside lane directed above the “LOOK FOR” pavement message prompt. The 3D illusions were affixed in a mirror pattern onto the roadway using the same torch technique as previously mentioned. These markings are illustrated in Figures 2 and 3.



Figures 2: Design of ‘Thunder’ 3D Pavement Illusion Marker.

Figure 3: Illustration of Phase 2: Pavement Marking Plus 3D Illusions

Measures

Dependent Variable. The dependent variable was the percentage of motorists that yielded or failed-to-yield to a pedestrian in the crosswalk. Data collectors recorded the number of vehicles that yielded or failed to yield for each crossing. Yielding was defined as the motorist stopping or slowing down to permit a pedestrian to cross. Not yielding was observed as the motorist entering the crosswalk in front of the pedestrian, although sufficient time and distance would have allowed the vehicle to safely slow down or stop for the pedestrian in the crosswalk. The landmarks selected for the dilemma zone of each site determined if the motorist had sufficient time to yield when the pedestrian entered the crosswalk.

Motorists who had passed the dilemma point marker before the pedestrian entered the crosswalk were scored as yielding, but not failing-to-yield because they passed the marker indicating that there was sufficient time available to yield. Motorists who had not yet crossed the marker after the pedestrian placed a foot in the crosswalk were scored as yielding or not yielding because these motorists had sufficient distance to safely stop. For this study, a maximum of two cars (one in each lane) could be recorded as yielding for each crossing. An unlimited number of cars could be recorded as failing to yield at each crossing.

Independent Variables. There were two independent variables. The first was the placement of the pavement marking prompt containing the message “LOOK FOR” and the pedestrian symbol prior to the crosswalk in both directions. The second

variable was the addition of the 3D illusion to the previous pavement marking prompt.

EXPERIMENTAL DESIGN

This study utilized a multiple baseline experimental design across two sites. Following a baseline condition, an in-pavement “Look for Pedestrians” prompt marking was placed in the travel lane in advance of the crosswalk. Next, 3D pavement illusions were added to the pavement marking prompt. In a multiple baseline design, a treatment site is compared with a control site that is subsequently treated. The staggered treatment approach controls for other variables that may have been correlated with the treatment at the first site, while later replicating the effect at the second site. It is possible to control for community wide variability that may have been responsible for the treatment effect through staging the treatment across sites. Through longitudinal data collection, it is possible to record that the variation is closely associated with the treatment introduction at both sites. This design is diagrammed below in Table 1.

	Phase 1	Phase 2	Phase 3	Phase 4	
Site 1	Baseline	Pavement marking prompt	Pavement marking prompt & 3D illusion	Pavement marking prompt & 3D illusion (6 month follow-up)	
Site 2	Baseline		Pavement marking prompt	Pavement marking prompt & 3D illusion	Pavement marking prompt & 3D illusion (6 month follow-up)

Table 1: Multiple baseline schedule across two sites

In all conditions, the start of a crossing or trial began when a pedestrian placed one foot inside the crosswalk and the approaching vehicle was beyond or at the dilemma point denoted by the previously determined landmark. In the baseline condition, motorist yielding behavior was recorded as pedestrians crossed the original uncontrolled marked crosswalk. During the pavement marking prompt condition, the “LOOK FOR” and PEDESTRIAN SYMBOL were placed onto the roadway in front of the crosswalk. In the following phase, the 3D illusions were placed slightly above the pavement marking prompt adjacent to the marked crosswalk. The final condition, a follow-up phase, continued to assess longitudinal effects from the pavement marking prompt plus the 3D illusions condition approximately six months after the markings and 3D illusions were initially installed.

PROCEDURES

Date Sheets

Each data sheet contains twenty crossings or trials. The average yielding compliance across the thirty-five trials was recorded as the yielding behavior for that session.

Participants Used in Collection Procedures

During sessions where only one data collector was present, only naturally observed pedestrians served as the pedestrian for each crossing. In sessions where two recorders were present, either naturally observed pedestrians or a research assistant (staged crossings) could serve as the pedestrian for each crossing. Staged crossings were only used in two conditions; 1) no pedestrians present or 2) the pedestrian was not actively approaching the crosswalk.

Natural Observation Crossings

In natural observational trials, one or two data collectors scored driver behavior. Data collectors observed in close proximity to the crosswalk within sight of the dilemma points. Motorist behavior was recorded independently if two data recorders were present at the session to assess for inter-observer agreement (IOA). A trial started when a pedestrian approached the crosswalk as a vehicle approached the dilemma zone (denoted by landmark) in the baseline, pavement marking prompt, pavement marking plus 3D illusions, or follow-up phase. If the vehicle yielded, the pedestrian then could cross the street safely and the vehicle would be scored as

yielding. If the first vehicle did not yield, succeeding vehicles were recorded until a vehicle yielded or a gap occurred in traffic allowing the pedestrian to cross. If a vehicle was in the opposite lane, yielding was also recorded for that motorist and any subsequent motorists.

Staged Crossings

Staged crossings were only able to be used if two data recorders were present. The collectors alternated as the confederate while the other one recorded the crossings. The same recording procedure for yielding and non-yielding was used during confederate crossings.

Data Collection and Weather Conditions

Research assistants recorded sessions several days per week at each site. Data were not collected in rainy conditions due to changes in stopping distances for wet pavement. Observation sessions ranged from 20 minutes to 90 minutes.

IOA and Integrity of the Independent Variables

The standard practice for IOA is to obtain a minimum of 80.0% agreement across 20.0% of all observed sessions. Data collectors conducted IOA for 20.0% of the observations sessions. The data records for the two observers were compared on a crossing-by crossing basis. Recording an agreement for yielding occurred when both observers recorded the same number of cars yielding for that particular crossing. Scoring an agreement for failing-to-yield occurred when both observers recorded the same number of cars as not yielding for that particular crossing. IOA percentage was calculated using the formula: agreements divided by the sum of the agreements plus

disagreements, multiplied by 100. Mean agreement for non-taxi cab drivers was 92.0%, with a range of 85.0% to 100%. IOA was calculated for 20.0% of sessions and obtained an average agreement of 93.0% on participating vehicles that were taxi cabs.

RESULTS

Figure 4 shows the mean percentage of motorists who yielded to pedestrians during each of the three conditions; baseline, pavement marking prompt, and pavement marking prompt plus 3D illusions, along with the six-month follow-up phase across the two sites. Motorists from site 1 started with an averaged yielding baseline of 31.0% while site 2 was slightly higher with an average of 34.0%. The pavement marking prompt phase increased yielding at both sites. There was a 20.0% increase in yielding at site 1, increasing yielding to an average of 51.0%. The introduction of the pavement marking prompt at site 2 produced an 11.5% increase bringing the average to 45.5%. The addition of the 3D illusions only showed marginal change increasing the averages to 53.3% and 48.8% respectively. The follow-up phase was conducted six months after the initial 3D installation at both sites. While site 1 maintained an average yielding of 53.0%, site 2 decreased 5.3%, dropping the average yielding back to 43.5%, which is slightly lower than the initial pavement marking prompt marking condition in phase 1.

From 2005 to 2007, taxi cabs were involved in a significant amount of pedestrian crashes. Taxi cabs accounted approximately 25.0% of crash during this

period. The data collectors noted on the data sheet if a vehicle was a taxi cab. Figures 5 and 6 separate these data into two categories: motorists excluding taxi cab drivers and taxi cab drivers. Figure 5 shows the mean percentage of motorists (excluding taxi cab drivers) who yielded to pedestrians during each of the three conditions: baseline, pavement marking prompt, and pavement marking prompt plus 3D illusions, along with the follow-up phase across the two sites. Motorists (excluding taxi cab drivers) from site 1 averaged a baseline yielding percent of 30.0% while site 2 motorists averaged closely to site 1 with an average of 28.4%. The pavement marking prompt phase increased at both sites to average yielding of 42.0% and 46.4%, respectively. The addition of the 3D illusions did show a 10.0% increase at site 1, however site 2 did not show similar results, as the 3D illusions were only associated with an increase in yielding of 1.4% between phase 2 and phase 3. The follow-up phase was conducted six months after the initial 3D installation at both sites. While site 1 maintained an average yielding of 51%; only a 1.0% difference from the initial illusion phase, site 2 decreased yielding from 48.0% in phase 2 to obtaining a mean of 40.0% in the follow-up phase.

Figure 6 shows the mean percentage of taxi cab drivers who yielded to pedestrians during the four conditions across both sites. Taxi drivers averaged a baseline yielding percent of 27.0% at site 1 and 40.3% at site 2. The pavement marking prompt phase increased yielding to pedestrians at both sites to an average yielding of 54.7% and 44.7%, respectively. The 3D illusions only produced an increase in yielding behavior in taxi cab drivers for site two with a 7.8% increasing

bringing the average yielding for taxi cab drivers up to 52.5%. The follow-up phase produced mixed results regarding taxi cab drivers' yielding behavior. Site 1 jumped from a mean of 51.0% to 58.0% while site 2 slightly increased from a mean of 52.5% to 55.9%.

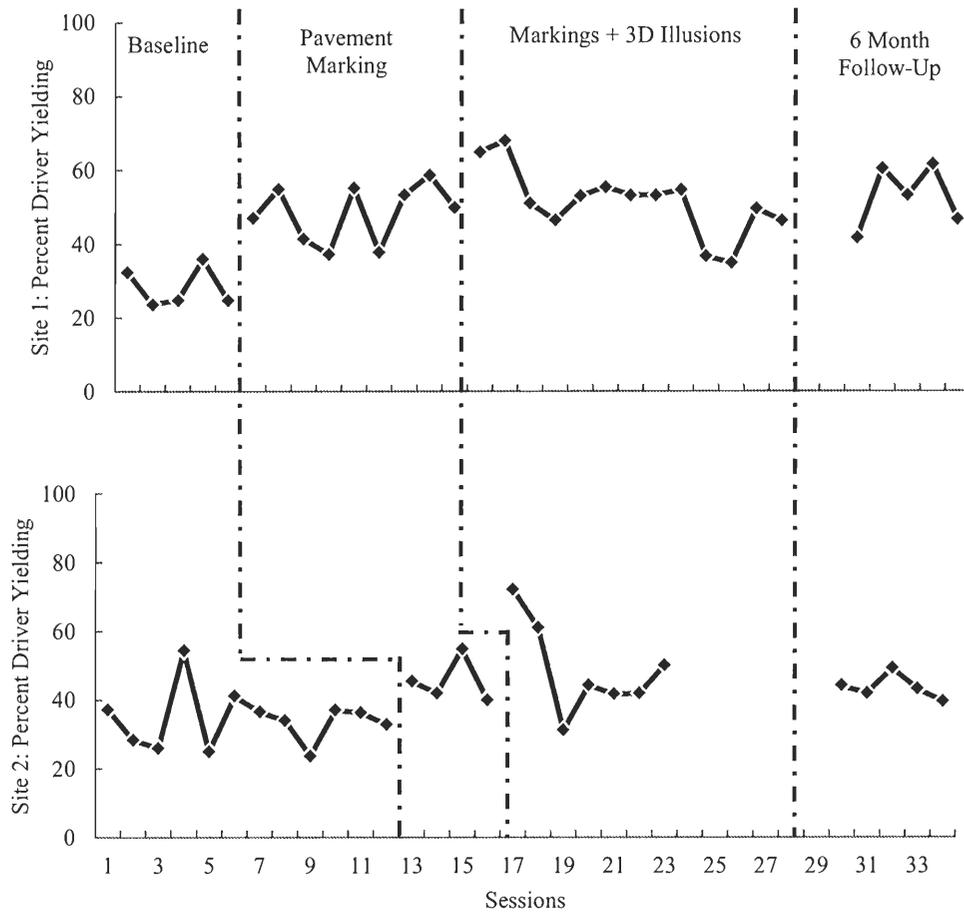


Figure 4: Percentage of All Motorists Yielding

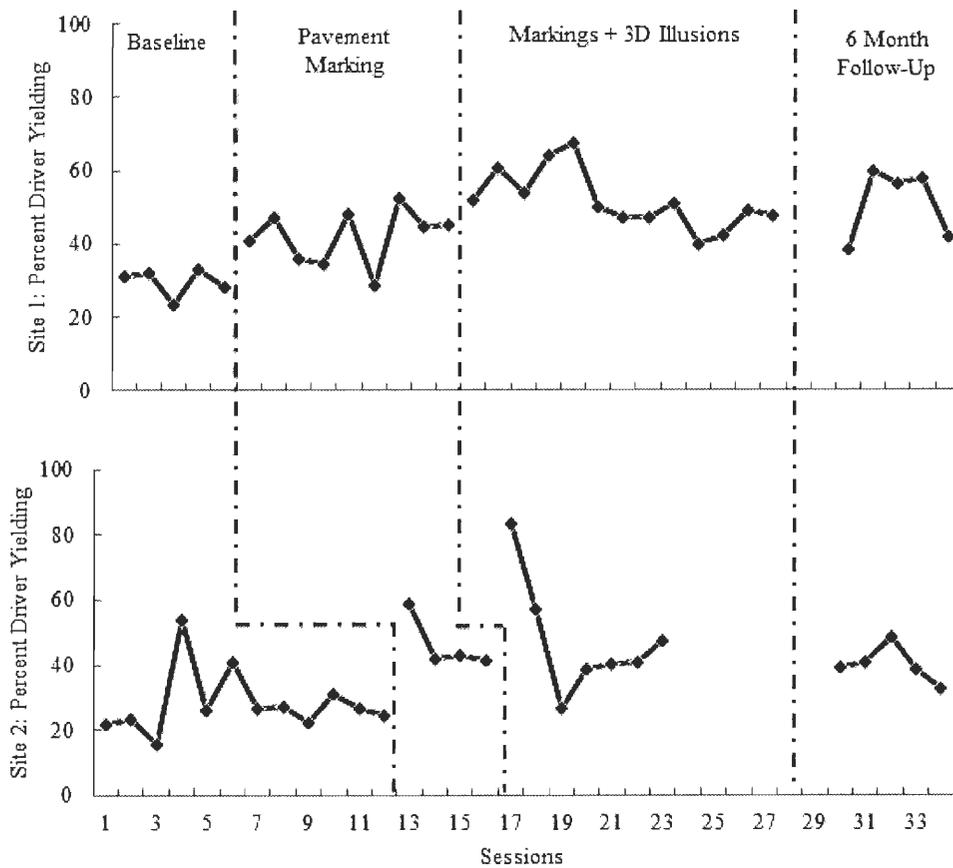


Figure 5: Percentage of Motorist (excluding taxi cab drivers) Yielding

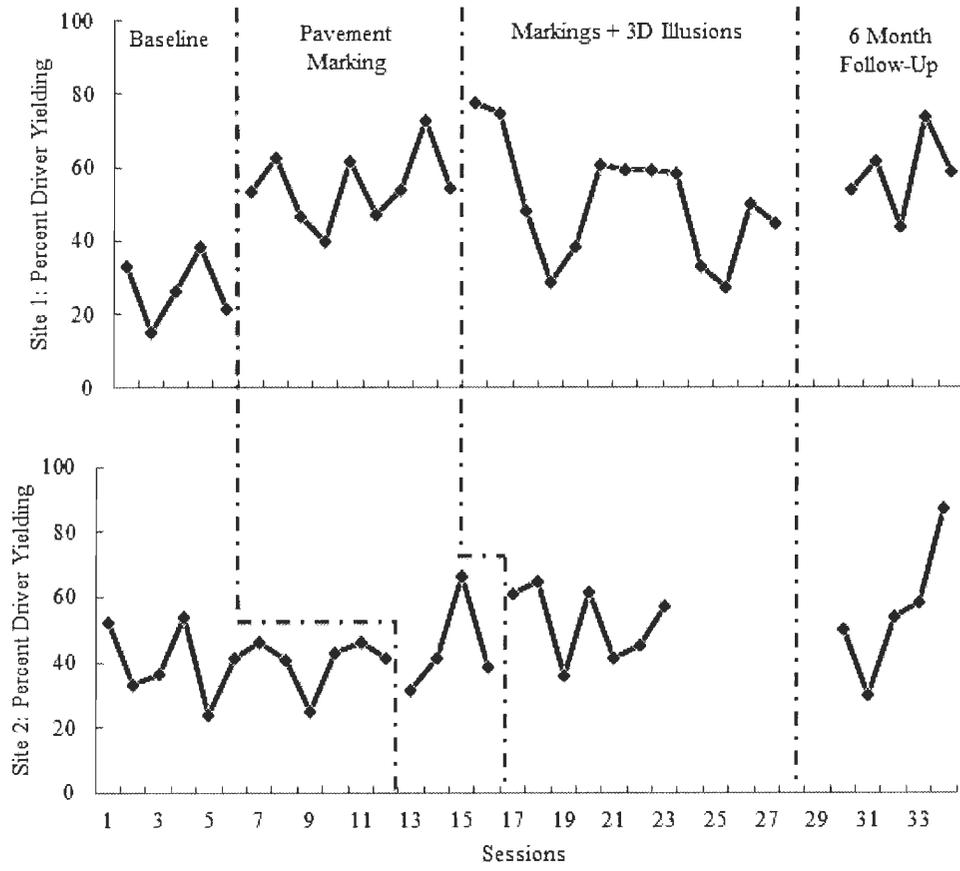


Figure 6: Percentage of Taxi Cab Drivers Yielding

DISCUSSION

Overall, the pavement marking prompt alone condition produced an increase in the percentage of drivers yielding to pedestrians and the 3D illusions seemed to add little to the effect of the prompt. The pavement marking prompt intervention may have produced better results over the 3D illusions because the novelty of the “raised” illusion wore off as motorists figured out that the illusion was not raised and would not harm their vehicle. The purpose behind the staged implementation of the two types of pavement markings were: to evaluate the pavement marking prompt independently from the 3D illusion and to attempt to create a pairing between the pavement prompt and the 3D illusion. Over time, motorists that traveled this particular stretch would learn that the illusion was not raised. By placing the 3D illusion with an in pavement marking prompt, it hoped that 3D markings would develop control of the rule(s) of “look for pedestrians, slow down or stop for pedestrians.” The data did not support the development of rule-governed behavior in this experiment.

Similar to a stop sign, individuals can travel to another country, not be fluent in the native language, and still manage to respond properly to a stop sign in another country. Through parents, driver’s education class, or a department of motor vehicles (DMV), individuals pair the word ‘STOP’ with a red octagon. When approaching a red octagon in the roadway with script that does not read the English word ‘STOP’,

the individual refers to the governed rule of stopping prior to the sign as learned behavior and will stop prior to the stop sign.

Through the results, it is unlikely that the pairing of the 3D illusion with the “look for pedestrians” pavement prompt ever created an association between the illusions and the “look for pedestrians” prompt. The idea was for drivers to pair the thunder symbol with reducing speed and actively scan the roadway for pedestrians, thereby maintaining or increasing yielding behavior even after the novelty of the illusion wore off.

The six-month follow-up data were similar to the data collected in the marking prompt message plus 3D illusion condition. This suggests that the pavement markings, 3D illusions, or combination produced a long-term positive effect by maintaining a higher level of motorists yielding compared to the baseline yielding level.

It was difficult to determine empirically which stimulus maintained or increased yielding behavior starting in the 3D illusion phase, however vehicles were initially noted to avoid or straddle the illusions as the vehicle approached the crosswalk, supporting the initial data in phase 3. Unfortunately, applied research comes with potential risks, such as the coordination of many parties to successfully install roadway markings. The limitations in site selection may have been a factor in the difference in yielding behavior between the two sites. It is possible that the drop off in yielding at site 2 was due to differences in foot traffic between the two sites. Timeline modifications in the two installation phases and unforeseen inclement

weather were other factors limiting the number of data points that were collected in each condition. Due to these constraints, data collectors periodically recorded a session in close succession to the previous session. Additional data points in each condition may have provided less degree of variability in each condition giving more stability and possibly more consistent results in each phase across the two sites.

Alternating with the illusions first and the pavement prompt second in one of the sites may have determined if the 3D pavement markings truly produce higher results or if the effect of the illusions were masked by effect of the pavement marking prompt.

The majority of sessions were conducted between 4:00 pm and 8:00 pm in the late afternoons and early evenings, to minimize variability due to difference in traffic volume. However, data collectors conducted some sessions between 8:00 pm and 11:00 pm in the afternoons and evenings due to conflicts in data collector's schedules and inclement weather. It is also possible that the novelty of the illusions did not produce significant effect on the habitual travelers that cross one or both of the sites in their daily commute. Larger and longer vehicles, such as buses, may have contributed to the little to no effect the 3D illusions added to the pavement marking prompt on motorists. Although no data were recorded on the visibility of the illusions, these longer vehicles may have covered these markings up for following vehicles, reducing or eliminating its visibility to motorists that are approaching the crosswalk.

CONCLUSION

In conclusion, the addition of the 3D illusions did not produce significantly more yielding to pedestrians when added to the simple pavement marking prompt. Although the illusions may have produced little increase in yielding behavior, a clear difference in yielding occurred between baseline and the initial pavement marking prompt installation. The results of these pavement interventions indicate that a simple pavement marking prompt may be the more efficient choice in locations where posted signs and costly beacons may not be available interventions. A pavement marking prompt can also be a good alternative for posted prompts hidden by large objects, such as trees, building awnings, and bus stops that prevent drivers from seeing the prompt.

In addition, any possible slight benefit of the 3D illusions is also offset by the upfront costs in terms of custom design and installation. Four sets of thermal plastic pavement markings were \$1,787.68 compared to \$4,736.64 for the four set of 3D pavement illusions used in this study. Although the thermal plastic materials is slated to outlast fading when compared to paint, the removal of these devices requires additional effort as the device has to be grinded out of the road instead blasted away as a painted marking.

Future evaluation of the 3D pavement illusion would be able to provide more in-depth analysis as to the mechanics of the “raise” illusion to maximize the effectiveness of the illusion. A logical next step would be to evaluate the effect of a

stand-alone illusion compared to a stand-alone pavement prompt or posted sign.

Future research could include a longitudinal cost benefits analysis on the use of thermal plastic pavement interventions (symbols, messages, illusions) in comparison to using painted interventions as well as comparing various pairings of different prompt interventions, such as a more direct prompt as “yield to pedestrian”, “stop for pedestrians”, or “state law yield to pedestrians” with an illusion.

REFERENCES

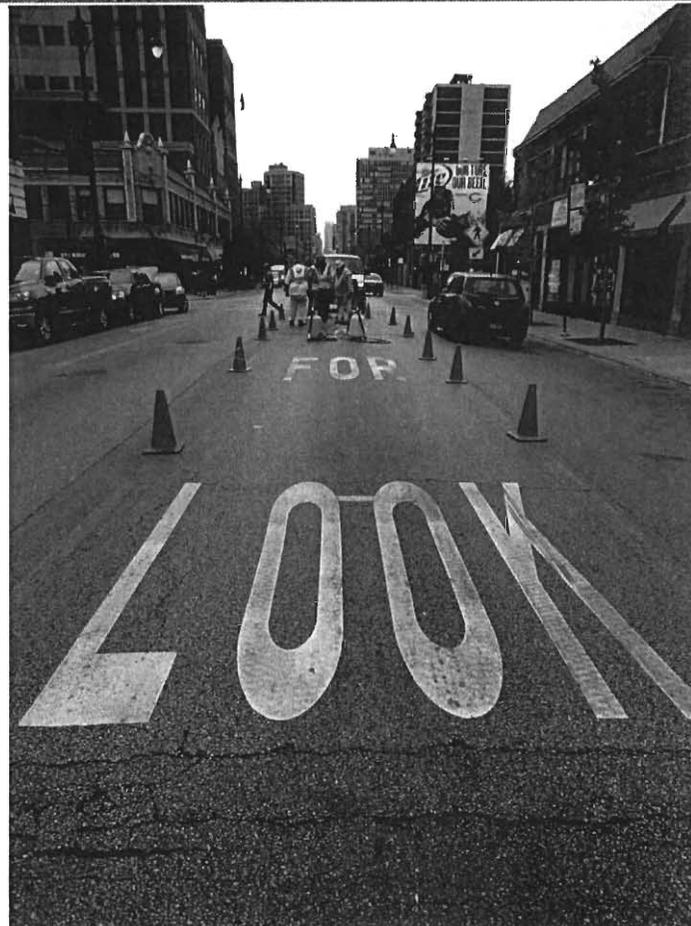
- Blomberg, RD & Cleven, AM. (2006). Pilot test of Heed The Speed, a program to reduce speeds in residential neighborhoods. DOT HS 810 648. Washington, DC: *National Highway Traffic Safety Administration*.
- Griffin, L.I. III, & Reinhardt, R.N. (1996). A review of two innovative pavement patterns that have been developed to reduce traffic speeds and crashes. Washington, DC: *AAA Foundation for Traffic Safety*, p 59.
- Huybers, S., Van Houten, R., & Malenfant, L. (2004). Reducing conflicts between motor vehicles and pedestrians: The separate and combined effects of pavement markings and a sign prompt. *Journal of Applied Behavior Analysis*, 37, 445–456.
- Maroney, S., Dewar, R. 1987. Alternatives to enforcement in modifying the speeding behavior of drivers. *Transport Res. Rec.* 1111, 121-126.
- Organization for Traffic Safety, S-Holland County. 3D Roadmarking Research Results of the Effects of 3-Dimensional Roadmarking Final Report. 03 May 2001.
- Oxley, J., Corben, B., & K Diamantopoulou, K. (2001). Some Cost effective approaches to moderate vehicle speeds in high pedestrian activity environments. *Accident Research Center*.
- Retting, R.A. Freguson, S.A. & McCartt, A.T. (2003) A Review of Evidence-Based Traffic Engineering Measures Designed to Reduce Pedestrian-Motor Vehicle Crashes. *American Journal of Public Health*. 93. 1456-1463.

- Shurbutt, J., Van Houten, R., Turner, S. & Huitema, B. (2009). An Analysis of the Effects of Stutter Flash LED Beacons to Increase Yielding to Pedestrians Using Multilane Crosswalks. *Transportation Research Record*. No. 2073, 69-78.
- Skinner, B. F. (1957). *Verbal behavior*. Englewood Cliffs, NJ: Prentice Hall.
- U.S. Department of Transportation. (2012). Traffic safety facts, 2010 (DOT HS 811 552). Washington, DC: Author. Retrieved from <http://www-nrd.nhtsa.dot.gov/Pubs/811552.pdf>
- Van Houten, R. (1988). The effects of advance stop lines and sign prompts on pedestrian safety in a crosswalk on a multilane highway. *Journal of Applied Behavior Analysis*, 21, 245–251.
- Van Houten, R., & Malenfant, L. (2004). Effects of a driver enforcement program on yielding to pedestrians. *Journal of Applied Behavior Analysis*, 37, 351–363.
- Van Houten, R. & Malenfant, L. (1992). The Influence of signs prompting motorists to yield 50 feet (15.5 m) before marked crosswalks on motor vehicle-pedestrian conflicts at crosswalks with pedestrian activated flashing lights. *Accident Analysis and Prevention*, 24, 217-225.
- Van Houten, R., Malenfant, L., & Rolider, A. (1985). Increasing driver yielding and pedestrian signaling with prompting, feedback, and enforcement. *Journal of Applied Behavior Analysis*, 18, 103–110

Appendix A

Installing Pavement Markings and 3D Illusions to the Roadway

Below are two illustrations of the installation of the pavement marking and 3D illusions to the roadway



Appendix B

Data Sheet

Below is an example of a data sheet

Recorder: _____ PRIMARY IOA

Date: _____ BL TR WEATHER: _____

Location: _____

Start Time: _____ End Time: _____

Enforcement Follow-up

Unsignalized Xing	# Peds Xing	Cars Not Yielding		Cars Yielding		Yielding distance		Evasive Action		Ped Trapped in Center	Driver passed Stopped Veh	Veh Brake Hard
		Reg	Taxi	Reg	Taxi	< 30ft	> 30ft	Ped	Veh			
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												

Unsignalized Xing	# Peds Xing	Cars Not Yielding		Cars Yielding		Yielding distance		Evasive Action		Ped Trapped in Center	Driver passed Stopped Veh	Veh Brake Hard
		Reg	Taxi	Reg	Taxi	< 30ft	> 30ft	Ped	Veh			
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												

% yield Overall		% < 30 ft		% E.A. Veh		% Driver pass
% Yield Taxi		% E.A. Ped		% Ped over		% Veh. brake hard

Appendix C

Approval Letter from the HSIRB

Approval Letter from the HSIRB

WESTERN MICHIGAN UNIVERSITY



Human Subjects Institutional Review Board

Date: March 7, 2012

To: Ron Van Houten, Principal Investigator
Nicole Cambridge, Student Investigator for thesis

From: Amy Naugle, Ph.D., Chair *Amy Naugle*

Re: HSIRB Project Number 12-02-70

This letter will serve as confirmation that the change to your research project titled "Effects of 3D Pavement Illusions on Motorists Yielding at Crosswalks" requested in your memo dated March 4, 2012 (change title to Effects of Symbols and 3D Pavement Illusions on Motorists Yielding at Crosswalks) has been approved by the Human Subjects Institutional Review Board.

The conditions and the duration of this approval are specified in the Policies of Western Michigan University.

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: February 29, 2012