2004-13

Final Report

Deer Avoidance:

The assessment of real world enhanced deer signage in a virtual environment

Research

Technical Report Documentation Page

1. Report No. MN/RC-2004-13	2.	3. Recipients Accession No.
4. Title and Subtitle DEER AVOIDANCE: The assessment of real world enhanced deer signage in a virtual environment		5. Report Date January 2004 6.
7. Author(s) Curtis Hammond and Michael G. Wade		8. Performing Organization Report No.
9. Performing Organization Name and Address University of Minnesota Division of Kinesiology 1900 University Ave SE Minneapolis, MN 55455		10. Project/Task/Work Unit No. 11. Contract (C) or Grant (G) No. (c) 81655 (wo) 25
12. Sponsoring Organization Name and Address Minnesota Department of Transportation 395 John Ireland Boulevard Mail Stop 330 St. Paul, Minnesota 55155		13. Type of Report and Period Covered Final report 14. Sponsoring Agency Code
15. Supplementary Notes http://www.lrrb.org/PDF/200413.pdf		

16. Abstract (Limit: 200 words)

This study explores three techniques of signage in an attempt to reduce the incidence of vehicle/deer collisions on highways in Minnesota. A simulated environment was created along a stretch of U.S. Highway 23 near Marshall, Minnesota with participants chosen from the University of Minnesota and the surrounding community. The simulation consisted of a standard warning sign as well as a prototype of the experimental signage. The prototype was comprised of a beacon light attached to the top of the warning sign designed to flash when deer were present. During the simulation, participants were exposed to the standard signage as well as the new signage with and without the beacon flashing. The main objective was to determine whether the prototype signs would modify driver behavior such that they decreased their speed.

The study found that the prototype signage was effective in decreasing the speed of the participants when the beacon light was flashing. These results were consistent across the variations of age and gender. The results for the prototype signage with the beacon light turned off were essentially no different from the standard signage.

17. Document Analysis/Descriptors		18. Availability Statement	
Deer Simulation Human factors	Crash Signage Motion detection	No restrictions. Document available from: National Technical Information Services, Springfield, Virginia 22161	
19. Security Class (this report) Unclassified	20. Security Class (this page) Unclassified	21. No. of Pages 50	22. Price

Deer Avoidance:

The assessment of real world enhanced deer signage in a virtual environment

Final Report

Prepared by:

Curtis Hammond
Michael G. Wade
Division of Kinesiology, Human Factors Research Lab
University of Minnesota

January 2004

Published by:

Minnesota Department of Transportation
Research Services Section
Mail Stop 330
395 John Ireland Boulevard
St. Paul, Minnesota 55155-1899

Acknowledgements

Mn/DOT Personnel

Jason Alcott
Anne McLellan
Robert Weinholzer

HumanFIRST/CTS

Peter Easterlund
Curtis Olson
Nic Ward

School of Kinesiology, Human Factors Research Laboratory

Andrew Leidel
Patrick McKay
Michelle Pieper
Thomas Stoffregen
Tom Smith

Table of Contents

List of Tables

List of Figures

Executive Summary

This study sought to evaluate a new motion detection technology designed to reduce the incidence of vehicle/deer collisions on Minnesota highways. A prototype detection device was placed adjacent to highways and connected to a standard sign with a beacon light attached to the top, which flashed when deer presence was detected. The central research question was to determine whether these new flashing signs modified driver behavior such that they slowed down. Participants were recruited from the University of Minnesota and the community at large, forming two experimental groups of younger and older drivers distributed for both gender and driving experience (city vs. rural). The participants were asked to drive a course simulating the actual location of the new motion detection technology located on a stretch of U.S. Highway 23 near Marshall, Minnesota. During the simulation, test subjects were presented with standard signage, the new signage without the beacon flashing, the new signage with beacon flashing, and clusters of the new signage with beacon flashing located on both sides of the highway. The speed limit was posted at 55 miles per hour. Data were recorded for changes in speed, along with in-vehicle video analysis of the direction of the driver gaze, referred to in the report as scanning behavior. The actual driving time in simulation was approximately 30 minutes. Real-time data was collected for the entire session for purposes of analysis. The majority of drivers fixated on the road ahead and exhibited very little scanning behavior to either look for deer or to continue to search for deer in the surrounding environment, even though all drivers were presented with visual information suggesting that deer were present.

In terms of actual response to the signs, there was a significant response to the enhanced signage when it was flashing. This is reported as significant evidence in the analysis, and suggests that there is a mathematically reliable speed reduction within a 500 ft. approach to the enhanced flashing sign. The distance of 500 ft. from either side of the sign was chosen as the window of analysis in order to determine the impact of signage on vehicle velocity and driver behavior. The general conclusions were that the flashing sign did appear to reduce driver speed and that there were no discernable effects regarding the age of participants (the young group averaged 24 years of age and the older group 69 years of age). There were no noticeable gender effects (females N=25, male N=27) or differences due to driver experience, whether primarily city or primarily rural. Finally, there was no impact regarding the time of day during which the test occurred (daylight or dusk). In summary, we found that the VE simulation was sufficient to motivate drivers to perform as they would in the real world, with little atypical behavior due to the conditions of the testing protocol. Relative to the signage types, there was an overall decrease among the study participants driving speed in the proximity of the active enhanced signage. We recorded a decrease in the variability between each successive exposure to the active sign condition. A greater overall average speed and variance was demonstrated with the standard signage. The enhanced signage in the "off" position produced speeds that where essentially the same as the standard sign condition.

Overall, it would seem that the novel stimulus of a warning light flashing in the presence of deer along the highway does play a role in reducing road speed. Our data suggests that these results are a direct consequence of the flashing beacon and are not related to any of the characteristics of the participants in the study.

As an initial foray into experimentally determining the impact of new technology to address the problem of vehicle/deer collisions in the United States, it would be of interest to investigate further whether or not the presentation of deer in the simulated display would catch the attention of drivers such that if the deer appeared in the display concomitant with the presence of a sign, would this further increase driver awareness levels? In other words, while drivers did not appear to reduce their speed, is their level of attention and awareness of the potential presence of deer enhanced?

The vast majority of the literature relative to vehicle/deer collisions suggests that controlling deer is extremely difficult. The central challenge in employing enhanced technology to make drivers aware of the presence of deer will focus primarily on a human-centered approach, and on determining whether the awareness of drivers is sustained (or declines rapidly) if there are no other prompts to remind them that a particular area of highway is notorious for the presence of deer.

Chapter 1
Introduction

Each year in Minnesota alone there are about 5,500 reported deer/vehicle collisions, and about twice as many unreported, according to DNR data. These collisions result in personal injuries, costly vehicle damage, loss of wildlife, and three to five human deaths per year. Both traffic and deer volumes are increasing. In a non-injury crash, the estimated average vehicle damage is over $2,000. Although much of the damage incurred in deer-car collisions is from the collision itself, a substantial amount of damage results from evasive actions (Minnesota Department of Transportation News Release, June 12, 2001, and Underwood, G., Crundall, D., & Chapman, P., 1997). Drivers try to avoid hitting the deer and end up in a ditch or in an accident with another vehicle. With a vast network of roadways throughout the state, deer collisions are of concern to Minnesotans.

A variety of control methods have been developed in an attempt to reduce the number of collisions between deer and cars. Most of these devices are aimed at altering the behavior of the deer, in an attempt to keep them away from the roads.

Roadside reflectors redirect the light from headlights at a right angle to the road to create a red beam alongside the road. They are supposed to produce an optical fence, which will cause deer to stay away from the road when a car is present. The lenses are placed at regular intervals along the roadway to produce a constant beam. The reflectors are not effective during daylight hours, fog, or snow. They also must be continuously maintained, otherwise one reflector may not function and create a gap in the beam, through which deer may cross onto the road. Deer proof fences are one method that has proven effective. The fences physically constrain the deer from accessing the roadway. They are generally eight feet tall and run along the side of the road. However, fences cannot be placed along an entire roadway due to accessibility and cost restrictions. Where there is a gap in the fence, deer will pass through, and instead of preventing deer from crossing the roadway the locations of deer crossings are simply relocated. Installation of the fencing has a high initial cost, and the fences must be maintained in order to preserve their usefulness. An additional aspect of fencing is determining effective placement. In conjunction with fences, some locations install under or overpasses at gaps in the fence to direct the deer crossing away from traffic.

Varieties of sound emitting devices that can be mounted to the front of vehicles have been developed and are being sold commercially. These whistles produce a high-pitched siren when the car is in motion, many of which are air activated at speeds greater than 35 m.p.h.. The intended purpose of these whistles is to alert animals in the area of your presence, hopefully stunning them into stillness. However, the sound produced is at a frequency that some claim is not within the hearing range of deer. In addition, the whistles only produce a weak sound, which is often barely audible above the noise of the car itself.

The intended purpose of many technologies is to change the behavior of the deer, when in reality it is unknown how the deer will react to the device. Deer are wild animals and their actions cannot be predicted nor controlled. Instead, it may be prudent to focus on how we can better influence humans (the driver).

Human-centered efforts in regards to accident prevention focus upon public awareness and warning signs as well as active signage. Simply making drivers aware of the potential for danger may increase their level of caution and alertness while driving. However, current deer crossing signs do not seem to have an impact on driving behavior, unless reinforced by personal experience. Most people become immune to the signs, and these warnings become part of the scenery. In order to rectify this, active signage systems have been developed to gain driver attention in situations involving deer presence.

Washington State implemented a set of signs for research. The system consists of two lasers, one on each side of the road, and two deer crossing signs. An additional sign that reads "when flashing" has been added as well as solar powered strobes on top of the sign. When the line of the laser is broken it sets off the strobe light to notify drivers of the presence of an animal. The battery life of the laser is only one week, thus the system must be maintained regularly, introducing system operating cost. In addition, line of sight posed a problem. Sunlight distorted the laser and even lead to false activations. These obstacles, as well as theft of various parts of the equipment, make these systems problematic (Washington State Department of Transportation News Release, October 23, 2002).

Other states have researched the use of active deer warning signs, with minor alterations to the apparatus. A new system similar to those implemented and researched around the country was developed and is currently being tested in Minnesota. Trial signs have been set up along Highway 23 near Marshall, in southern Minnesota. However, rather than engage in extensive field research, the Minnesota Department of Transportation collaborated with the University of Minnesota to research the effectiveness of the new active signage via simulation. The study compared drivers' reactions to conventional and active deer warning signage.

This new system comprises an infrared (IR) beam set up along a 650 foot stretch of the highway, set back off the road 60 feet. The beam is three feet off the ground in order to avoid false activations by smaller animals. When the beam is broken it activates a flashing light on top of the deer crossing signs at each end of the 650 foot stretch. Drivers are notified of what the light means by an additional indicator on the deer crossing sign that states "when flashing". The lights flash for a predetermined period of time before turning off again.

Chapter 2
Methods

<u>Participants</u>

The sample population comprised 52 volunteer participants. The group consisted of 40 individuals with a mean age of 24 years, and 12 with a mean age of 69 years. Of the entire group, 27 were male and 25 were female; 35 considered themselves "city drivers" and 17 "rural drivers." Demographic data was recorded on the group relative to driving experience and their familiarity with simulation.

<u>Environment design: The Real World (RW)</u>

The simulated environment used for the Deer Avoidance project was modeled after an existing highway where the active signage is currently under assessment located near Marshall Minnesota (Fig. 2.1).

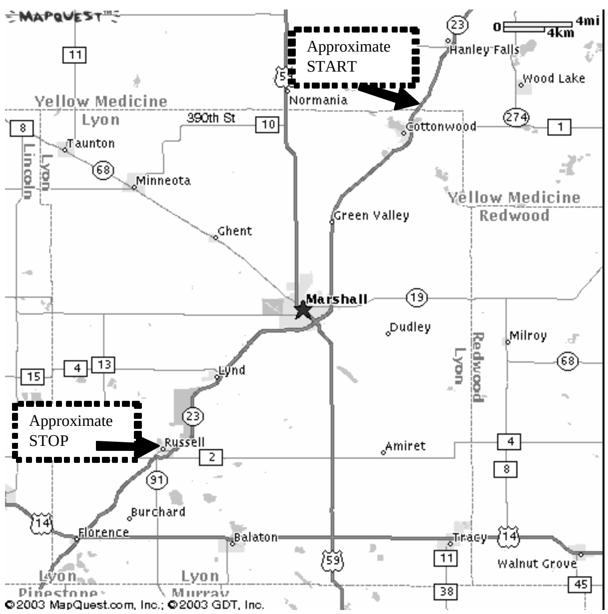


Figure 2.1 – Actual road used for VE layout

The road conditions and signage presented in the simulation trials are illustrated in Figures 2.2 and 2.4.

Figure 2.2 – Enhanced signage

Other RW components such as traffic and fauna were also present and will be discussed later.

Environment design: The Virtual Environment (VE)

VE Systems Specifications

The Virtual Environment for Surface Transportation Research (VESTR) is an immersive driving simulator. VESTR operates with a 2002 Saturn SC2 full vehicle cab donated by Saturn with controls and instrumentation including force feedback on the steering and power assist feel for the brakes. The visual scene was projected to a high-resolution five-channel 210-degree forward field of view (Figure 2.3) with rear and side mirror views provided by a rear screen and LCD panels. The software can generate any type of road environment, including precise reproductions of geo-specific locations, as was done with the Marshall, Minnesota region. Auditory and haptic feedback was provided by a 3D surround sound system, car body vibration, and a three-axis electric motion system (roll, pitch, Z-axis). These systems generated natural sound and motion cues to increase the perceived realism of the simulation.

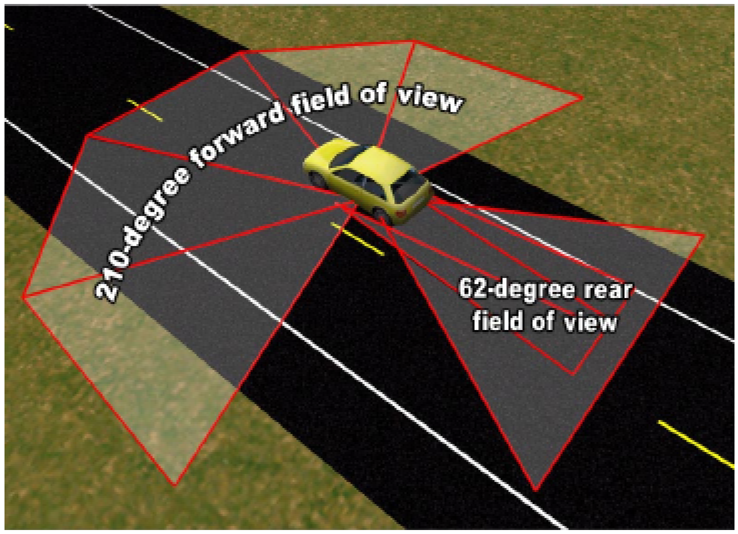


Figure 2.3 – Field of view of simulator auto

Figure 2.4 – VE State Highway 23 and RW State Highway 23

The similarities of the VE design (i.e. foliage, lighting, etc.) to the RW are demonstrated in figure 2.4. The VE totaled about 27 miles of road. There were no intersections with the highway. A deer was presented at the beginning of the trial and was located off-road and to the right near to the "tree line". This was done to indicate the potential presence of fauna. There were no deer present elsewhere in the VE. This was avoided in order to not produce a "game-like" environment with an abnormally high level of anticipation or perception of threat. Traffic was present in the environment. It consisted of a mix of vehicles and the occasional motorcycle. The traffic was predominantly present in the oncoming lane.

<u>Signage</u>

All deer signage was placed in the straight segments of the highway (see Fig. 2.1) as to rule out the effect on road speed, which might be produced by curves in the highway. All other non-deer related signage was randomly dispersed as to obscure the intent of the study. The VE was comprised of four basic scenarios with each condition (normal, enhanced-on, enhanced-off) repeated three times. The fourth scenario was a cluster of enhanced signage in the on state. We will discuss this later. Each condition stood alone within approximately 2-3 mile stretches in order to allow for complacency and temporal isolation from one another.

Figure 2.5 – Approximation of VE enhanced signage w/ rotating flasher (1Hz)

Enhanced signage has both an active and inactive state. The signage conditions were:

1. Active Warning (sign w/ flashers, flashing) (Fig. 2.5)
2. Inactive Warning (sign w/ flashers, not flashing) (Fig. 2.5)
3. Standard deer signage (Similar to Fig. 2.5 without the beacon)
4. Typical road signage mixed and interspersed between sign conditions 1, 2 & 3 (as appropriate for VE road conditions).

The first three conditions were considered to be the actual independent variables with the mixed signage (number 4) viewed as baseline. The enhanced signage (Condition 1) was also presented in a modified condition where the signs were presented as a cluster of several signs 650 feet apart as presented in the RW. This was not done with the other conditions (signage) since this would appear somewhat abnormal.

These conditions were presented under two simulated environment lighting conditions;

1. day
2. half-light (dusk/dawn)

Participants were randomly assigned to one of the environmental conditions.

Protocol

Upon arrival at the laboratory the participants were given a consent form and brief questionnaire to complete (Appendix A). The questionnaire was primarily demographic data (age, gender, rural vs. city driver, etc.) and addressed any medication or visual issues. The bulk of the questions served simply to obscure the purpose of the study. The participant then proceeded to the VE vehicle under the instructions of simply driving as normally as possible.

The trial took about 30 minutes depending on driving speed. After completing the trial the participants completed a brief post-test questionnaire addressing their experience (i.e. realism, expectations, comfort) and an open ended “describe anything else you’d like” type question.

Chapter 3
Results and Discussion

Results

Demographics

The sample population consisted of 52 volunteers (N=52) but in certain trial conditions some of the participant data was not used. For example, one subject had an average road speed of about 12-15 m.p.h. and another thought that 100+ m.p.h. was appropriate (a devoted video game player). These results were omitted from the analysis. This group was subdivided into several subgroups for analysis; young/old (N=40/12), male/female (N= 27/25), and city/rural (N=35/17). The overall mean age was 27 years. The mean age for the "young" group was 24 years and the mean age for the "older" (60+ years) group was 69 years. The sample population was derived primarily from University of Minnesota volunteer students and retirees.

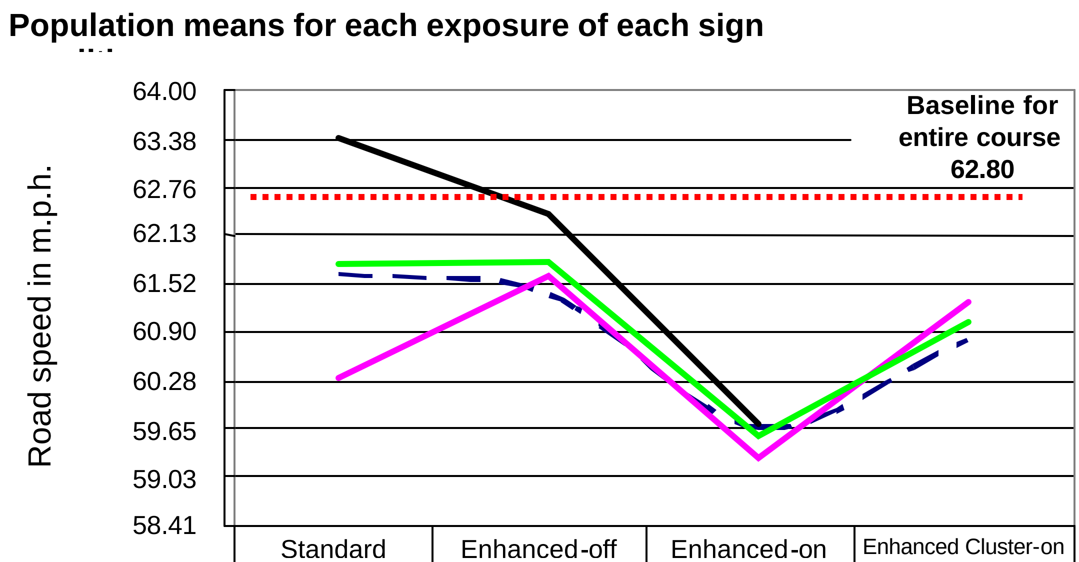
Scanning behaviors

Video of the participants scanning behavior was analyzed for any decrease or increase in scan levels. Scoring was done in the regions approaching and soon after the locations of the deer warning signage. Scoring was done using an abbreviated Likert scale (1-2-3) with a score of two as the midpoint. A score of one (1) indicated a decrease in scanning level (Table 3.1), which would include actions such as looking down for an extended time period at the instrument cluster, or other distractions. A score of two (2) would indicate normal forward-looking driving behavior with some glancing about. A score of three (3) would indicate increased vigilance by the driver indicative of scanning the roadsides or an increased focus on extravehicular objects (signage, deer, trees, etc.). Out of a group of forty-seven participants (N=47) the scores were surprisingly consistent with only eight (8) recorded incidences of increased scanning out of 517 (11x47) scores. The group average scanning scores of are presented in Table 3.1.

Table 3.1 – Average scanning level of participants for sign condition exposure

Signage Type	Average Score
Normal Signage	2.0
Enhanced signage (off)	2.0
Enhanced signage (flashing)	2.1
Enhanced signage (flashing)	2.0
Normal signage	2.1
Enhanced signage (off)	2.0
Enhanced signage cluster (flashing)	2.1
Enhanced signage (off)	2.0
Enhanced signage (flashing)	2.0
Normal signage	2.0
Enhanced signage cluster (off)	2.1

Notation was made from the video analysis as to any external influences which may have played a role in changes in scanning behavior. Of the 8 noted increases in scanning behavior, six were due to attempts at passing a virtual vehicle in front of the test car, one was due to a noisy distraction outside the simulator and another incident which was not identified. No difference was found based on experience level (age).



	Standard	Enhanced-off	Enhanced-on	Enhanced Cluster-on
Series 1	61.63	61.38	59.66	60.78
Series 2	60.59	61.62	59.27	61.28
Series 3	63.41	62.41	59.71	
mean (SD)	61.87 (**5.16**)	61.80 (**4.80**)	59.55 (**4.66**)	61.03 (**3.75**)

Figure 3.1 – Mean and standard deviations (SD) of road speed for signage condition.*

Figure 3.1 illustrates the mean performance measures in response to the signage conditions. As can be seen, the enhanced signage in the “on” condition (flashing) produced the lowest mean speeds and variability in both the single sign and sign cluster configuration.

Figure 3.1 presents a graphic of the drivers’ behavior throughout the experiment. At the bottom of the Figure 3.1, data showing the overall average and variability of speed scores for each of the four conditions tested are presented. The enhanced-on condition (beacon flashing) produced the lowest mean speed (59.55) and a lower (but not the lowest) variability score (4.66). The enhanced cluster-on produced an average speed of 61.03 m.p.h., compared with 59.55 m.p.h. for the enhanced-on sign, but the variability was slightly less in the cluster condition (3.75 vs. 4.66).

*See Appendix C for complete data

The average speed for the standard signage across the series was 61.78 m.p.h., which is essentially the same as the enhanced-off signage (beacon not flashing). For the enhanced cluster-on condition (four signs with flashing beacons), the speed was a little more than 61 m.p.h. The only condition producing a significant reduction in speed was the enhanced-on signage. Analysis of variance testing the overall effects of the four signage conditions produced a significantly lower speed for the enhanced-on signage ($F_{3,7}=4.15$, $P<.05$). See Appendix C for complete analysis.

Even though the range of scores across the four sign conditions was only 2.25 m.p.h., the slowest recorded average driving speed was in the enhanced-on condition, and the fastest average driving speed was in the enhanced-off position. A difference of 2.25 m.p.h. was sufficient to make that the difference mathematically reliable. There were no reliable differences between the speeds recorded for the normal signage condition compared to either enhanced-off or enhanced cluster-on conditions, although the two slowest conditions were the enhanced-on and the enhanced cluster-on. Standard signage produced the highest variability of driver speeds. All enhanced signage conditions reduced speed variation.

On-road performance

Comparisons between the characteristics of the participant group were unremarkable. Age, gender, driving experience, and time of day were of no real consequence, and when subjected to statistical analysis revealed no significant differences.

Discussion

Scanning behaviors

Eye movements are generally accepted to be governed by attention (Underwood G, Crundall D, Chapman P. 1997). The surprisingly consistent scanning behaviors exhibited expose a potential weakness in using eye-tracking as an indicator of level of attention or complacency.

It is a separate issue to determine where one is looking versus on what one is focusing. Simply because one’s eyes are directed at point A, there is no indication from this as to whether point A is the focus of attention.

The road speed of the trials was posted at 55 m.p.h. with a moderate mix of traffic. This combination of attentional load has been associated with an effect referred to “tunnel vision” (Bartmann, Spikers and Hess, 1991) and may explain the results of this study. Bartmann, Spikers, and Hess (1991) reported;

> “..An additional variable that affected perceptual behavior was traffic load. It was observed that as speed increased the driver fixated driving task relevant objects more often. On the basis of the results it is argued that the often-postulated "tunnel vision" effect of driving speed should be regarded as a consequence of focal attention to driving task relevant objects.”

Numerous studies have referenced variations on this effect. They have ranged from attentional loads based on cell phone conversations to general traffic attention levels. Due to the nature of this study we feel that this goes a long way to explaining the absence of any real variation in scanning behaviors relative to perceived threat/complacency levels. This leaves us with performance measures such as road speed or anticipatory movement (i.e. hovering over the brake) as indicators of perceived threat.

An increase in foveal demand tends to decrease extra-foveal attention, yet this does not vary with either experience or eccentricity (Crundall D, Underwood G, 1998; Crundall D, Underwood G, Chapman P, 1998; Crundall D, Underwood G, Chapman P, 1999).

Though there is some evidence equating lateral scanning increase with experience (Ball KK, Beard BL, Roenker DL, Miller RL, Griggs DS, 1988), no increase was noted in our "older" population. Once again this is possibly due to the increased task load associated with being in a virtual environment and an unfamiliar vehicle.

On-road performance

On-road performance by most participants appeared to be "normal" by observed behaviors (Table 3.1). One participant immediately treated the trials as a game-like experience which was evident by his accelerating to almost 110 m.p.h. and continuing at similar speeds throughout the trial. He commented "It's not real, is it? I knew I couldn't get hurt." This is an issue in virtual situations. The data were not used. At the other end of the spectrum, an older participant rarely exceeded 20 m.p.h. and exhibited other strange behaviors which led us to believe it to be unlikely that he was still driving. His data was also not used.

On the whole, participants indicated a general agreement that the simulated experience felt very normal and that traffic interactions were on par with the real world. When asked about the test itself only one person out of 47 guessed correctly that they were aware of the purpose of the study. This individual failed to detect the deer at the start of the trial, however, of the 47 subjects asked, 29 recalled that there was a deer at the start of the trial but made no real note of it.

Road speeds were, as one might expect in the real world, at an average speed in excess of the posted speed by 5-10 m.p.h. As indicated in Figure 3.1, driving speed was more variable for the normal signage condition. The average decrease in road speed is also evident. It should be noted however that this equates to only a small decrease in speed with the enhanced signage (2.25 m.p.h.). This could still be a critical factor in an accident scenario requiring a rapid response. An observed oddity in Figure 3.1 is the small increase in the road speed in the clustered sign condition (59.55 vs. 61.03). This is only a 1.48 m.p.h. difference and could possibly be due to the fact that it occurred near the end of the trial and was a result of impatience. It may also be that the sequence produces a "safe zone" effect without the actual visible presence of the deer.

The lack of significant differences in the population between the groups may not be all that surprising due to the inherent contrived nature of the simulation. The daytime condition vs. the dawn/dusk condition possibly lacked the level of contrast needed to promote an increased awareness of the signage. The city/rural condition might have been an issue of "how" rural.

Living near the Twin Cities and yet still being classified (self-classified) as rural may be a bit ambiguous. The exposure to deer may still vary widely.

With alpha set at .05 (a five percent probability of our results being due to chance) it may well be that under real world conditions (and hence RW threats) the enhanced signage might produce a stronger response as measured by road speed. In simulation, our effects may possibly be conservative.

Chapter 4
Conclusions and Future Considerations

Conclusions

The central objective of this project was to test, via simulation, new deer avoidance signage as a possible improvement aimed at reducing auto/animal collisions. The new (enhanced) sign technology was tested in three configurations and compared to the standard deer signage currently in use. The new signage incorporated a flashing beacon triggered by the presence of deer. We compared the standard signage to the new signage with three variations: flashing beacon “off”, flashing beacon “on”, and a cluster of four signs with the flashing beacon on. We simulated a section of highway in southern Minnesota where the new signage is in use. The simulation took into account the general layout of the highway, the length of the highway, and the essential landscape. Our conclusions are as follows:

1. There were no reliable differences in the characteristics of the participants in the study. Namely, there were no age differences between the young group (averaging 24 years of age) and the older group (averaging 69 years of age). There were no differences between males and females, and no differences regarding whether their driving experience had been primarily city or rural. Time of day (daylight or reduced visibility) also provided no reliable differences.

2. The standard signage currently in use recorded the highest average road speed and highest variability. The average road speed for the standard signage during the experiment was 61.87 m.p.h., with a standard deviation of ± 5.16 m.p.h. This was essentially the same as the results for the enhanced signage with the beacon not flashing, although the variability of the road speed was slightly less (mean speed = 61.8 m.p.h., standard deviation was ± 4.8 m.p.h.).

3. The enhanced signage with the beacon flashing (indicating the presence of deer) recorded the lowest road speed for the participating drivers. This average speed was 59.55 m.p.h., which was significantly lower than with either the standard signage or the enhanced signage without the beacon flashing. The absolute difference was 2.25 m.p.h. (approximately 3.3 ft/sec). Our results suggest that even a modest speed reduction of 2.25 m.p.h., although statistically significant, perhaps does not seem large in the “real world”, but in terms of approaching an area where deer are present it does provide added time to respond to a possible auto/animal collision. For example, at a speed of 60 m.p.h. (88 ft/sec) a reduction of 2.5 m.p.h. down to 57.5 m.p.h. (84.3 ft/sec) would provide an alert driver with added time to react to a possible collision incident.

4. Scanning behaviors of drivers recorded by the in-car video system were unremarkable (see Table 3.1). All drivers fixated on the road ahead with minimal active scanning. This result is in agreement with past research that suggests "eye movements are generally accepted to be governed by attention" (Underwood and Everatt, 1992). These results are further supported by other research (Chapman, P.R., Underwood, G., 1998; Crundall D, Underwood G, Chapman P, 1998). Whereas the task loads of the RW and VE

environments are different, the demand characteristics are likely more similar than dissimilar. The perceived threat of oncoming traffic is not high in either condition. As drivers, we tend to generally ignore oncoming traffic in a RW environment unless it exhibits unusual behavior (e.g. swerving etc.). Also, in keeping with RW behaviors there was little scanning involved in the driving task when the environment contains little external stimuli (walls of trees, open fields, etc.).

In summary, we found that the VE simulation was sufficient to motivate drivers to perform as they would in the real world with little atypical behavior due to the conditions of the testing protocol. Relative to the signage types, there was an overall decrease among the study participants' driving speed in the proximity of the active enhanced signage. We recorded a decrease in the variability between each successive exposure to the active sign condition. A greater overall average speed and variance was demonstrated with the standard signage. The enhanced signage in the "off" position produced speeds that were essentially the same as the standard sign condition.

Future Considerations

Overall, it would seem that the novel stimulus of a warning light flashing in the presence of deer along the highway does play a role in reducing road speed. Our data suggests that these results are a direct consequence of the flashing beacon and are not related to any of the characteristics of the participants in the study.

It would be of interest to modify the conditions of the trial to include deer in flashing areas in a marginally conspicuous manner, such as presenting a deer carcass on the roadside. Our study presented deer in the more normal manner, that is, there's a sign for deer but no deer present. It would be interesting to get feedback from participants as to whether or not they saw the deer. This would be indicative perhaps of increased awareness levels regardless of the driver actually taking action by slowing.

From almost all the literature, controlling the deer is challenging. To focus on the driver/road system seems a more rational approach. If the RW trials of the system prove to be effective over time, then this would support a driver centered approach for any number of future human-centered strategies.

If further research is contemplated, we recommend the following be incorporated in a simulated roadway display:

a. Deer carcass displayed on roadside to reinforce the presence of deer in the area.

b. Redesign deer signage to incorporate LED's around the perimeter of the sign to signal deer presence as an alternative to a "flashing" warning light (Figure 4.1)

Figure 4.1 – Deer signage with LED's

References

Underwood, G., Crundall, D., & Chapman, P. (1997). Visual attention while performing driving and driving-related tasks. In G. B. Grayson (Ed.), Behavioural Research in Road Safety 7 (pp. 60-73). Crowthome, UK: Transport Research Laboratory.

Bartmann, A., Spijkers, W., & Hess, M. (1991). Street environment, driving speed and field of vision. In A. G. Gale (Ed.), Vision in Vehicles 3: Proceedings of the 3rd International Conference (pp. 381-389). Aachen, Germany: Elsevier.

Crundall, D., Underwood, G. (1998). Effects of experience and processing demands on visual information acquisition in drivers. *Ergonomics* 41(4), 448–458.

Crundall, D., Underwood, G., & Chapman, P. (1998). How much do novice drivers see? The effects of demand on visual search strategies in novice and experienced drivers. In G. Underwood (Ed.), Eye Guidance in Reading and Scene Perception (pp. 395-418). Oxford: Elsevier.

Crundall, D., Underwood, G., Chapman, P. (1999). Driving experience and the functional field of view. *Perception* 28(9), 1075–1087.

Ball, K.K., Beard, B.L., Roenker, D.L., Miller, R.L., Griggs, D.S. (1988). Age and visual search: expanding the useful field of view. *Journal of the Optical Society of America* 5(12): 2210–2219.

Underwood, G. & Everatt, J. (1992) The Role of Eye Movements in Reading: Some Limitations of the Eye-Mind Assumption. in E. Chekaluk & K.R. Llewellyn (Eds.) The Role of Eye Movements in Perceptual Processes. Elsevier Science Publishers B.V.

New Deer Alert System May Lessen Motorist-Deer Collisions in Minnesota. Minnesota Department of Transportation. June 12, 2001. http://www.dot.state.mn.us/d8/newsrels/01/0612deeralertsystem.html

Deer Laser Warning Beacon Test Begins on US 97A. Washington State Department of Transportation. October 23, 2002. http://www.wsdot.wa.gov/regions/northcentral/communication/102302-Deer_Laser_Test.htm

Additional References (by category)

Scanning/Attention

Castiello, U., Umilta, C. (1992). Splitting focal attention. *Journal of Experimental Psychology: Human Perception and Performance* 18: 837–848.

Chan, H.S., Courtney, A.J. (1993). Effects of cognitive foveal load on a peripheral single-target detection task. *Perceptual and Motor Skills* 77: 515–533.

Chapman, P.R., Underwood, G. (1998). Visual search of driving situations: Danger and experienced. Perception 27: 951–964.

Chapman, P.R., Underwood, G. (2000). Forgetting near accidents: The roles of severity, culpability and experience in the poor recall of dangerous driving situations. *Applied Cognitive Psychology* 14: 31–44.

Christianson, S. (1992). Emotional stress and eye witness memory: A critical review. *Psychological Bulletin* 112: 284–309.

Cnosson, F., Rothengatter, T., Meijman, T. (in press). Strategic changes in task performance in car drivers as an adaptive response to task demands. Transportation Research Part F.

Cooper, P.J., Pinili, M., Chen, W. (1995). An examination of the crash involvement rates of novice drivers aged 16 to 65. *Accident Analysis and Prevention* 27: 89–104.

Driver JS, Bayliss GC. (1989). Movement and visual attention: the spotlight metaphor breaks down. Journal of Experimental Psychology: *Human Perception and Performance* 15: 448–456.

Williams, L.J. (1982). Cognitive load and the functional field of view. *Human Factors* 24: 683–692.

Williams, L.J. (1985). Tunnel vision induced by a foveal load manipulation. *Human Factors* 27: 221–227.

Williams, L.J. (1988). Tunnel vision or general interference? Cognitive load and attentional bias are both important. *American Journal of Psychology* 101: 171–191.

Zwahlen, H.T. (1993). Eye scanning rules for drivers: How do they compare with actual observed eye scanning behavior. Transportation Research Record 1403: 14–22.

Animal centered: Physical control

Bashore, T.L., Tzilkowski, W.M. & Bellis, E.D. (1985). Analysis of deer-vehicle collision sites in Pennsylvania. *Journal of Wildlife Management 49:769-74.*

Bellis, E.D., Graves, H.B. (1976) Highway Fences as Vehicle/Deer Collision Deterrents. *Penn State Univ. Univ. Park, Inst for Res on Land and Water Resources, Rep Num FHWA-PA-74-9*

Bellis, E.D., Graves, H.B. (1978) The Effectiveness of Deer Flagging Models as Deterrents to Deer Entering the Highway Right-of-Ways. *Penn State Univ. Univ. Park, Inst for Res on Land and Water Resources, Rep Num FHWA-PA-78-12*

Falk, N.W., Graves, H.B., & Bellis, E.D. (1978). Highway right-of-way fences as deer deterrents. *Journal of Wildlife Management.42:646-650.*

Feldhamer, G.A., Gates, J.E., Harman, D.M., Loranger, A.J. & Dixon, K.R. (1986). Effects of interstate highway fencing on white-tailed deer activity. *Journal of Wildlife Management 50:497-503.*

Knight, J. E., Swensson, E.J., & Sherwood, H. (1997). Elk use of modified fence-crossing designs. Wildlife Society Bulletin 25:819-822.

Lehnert, M. E., & Bissonette, J.A. (1997). Effectiveness of highway crosswalk structures at reducing deer-vehicle collisions. *Wildlife Society Bulletin 25:809-818.*

Ludwig, J., & Bremicker, T. (1983). Evaluation of 2.4-m fences and one-way gates for reducing deer-vehicle collisions in Minnesota. *Transportation Research Record 913:19-22.*

McKnight, T.L. (1969). Barrier fencing for vermin control in Australia. *Geographical Review 59:330-347.*

Animal centered: Behavioral control

Beauchamp, D.E. (1970). Deer mirror evaluation. *California Department of Fish and Game. 8.*

Bruinderink, G.W.T.A., & Hazebroek, E. (1996). Ungulate traffic collisions in Europe. *Conservation Biology 10:1059-1067.*

Carr, W.P., Penland, S., Schafer, J.A. (1985) Effectiveness of Wildlife Warning Reflectors in Reducing Deer-Vehicle Accidents in Washington State. *Transportation Research Board, Iss 1010, pp 85-88.*

Ford, S.G., Villa, S.L. (1993) Reflector Use and the Effect They Have on the Number of Mule Deer Killed on California Highways. *FHWA Rep.# FHWA/CA/PD-94/01, Rep No. 53-626004.*

Gladfelter, L. (1984). Effect of wildlife highway warning reflectors on deer-vehicle accidents. *Iowa Highway Research Board Project HR-210. Iowa Department of Transportation. 11pp.*

Ludwig, J., & Bremicker, T. (1983). Evaluation of 2.4-m fences and one-way gates for reducing deer-vehicle collisions in *Minnesota. Transportation Research Record* 913:19-22.

Reeve, A.F., & Anderson, S.H. (1993). Ineffectiveness of Swareflex reflectors at reducing deer-vehicle collisions. *Wildlife Society Bulletin 21:127-132.*

Romin, L.A., & Dalton, L.B. (1992). Lack of response by mule deer to wildlife warning whistles. *Wildlife Society Bulletin 20:382-384.*

Shafer, J.A., & Penland, S.T. (1985). Effectiveness of Swareflex reflectors in reducing deer-vehicle accidents. *Journal of Wildlife Management 49:774-776.*

Singer, F.J., & Doherty, J.L. (1985). Managing mountain goats at a highway crossing. *Wildlife Society Bulletin 13:469-477.*

Swarovski, A.G. (1997). Roadside Reflectors-Do They Work? *Road Management & Management Journal, May 12, 1997.*

Waring, G.H., Griffs, J.L., & Vaughn, M.E. (1991). White-tailed deer roadside behavior, wildlife warning reflectors, and highway mortality. *Applied Animal Behaviour Science 29:215-223.*

Williamson, L. (1980). Reflectors reduce deer-auto collisions. *Outdoor News Bulletin 34:2.*

Wood, P., & Wolfe, M.L. (1986). Do white-tailed deer avoid red? An evaluation of the premise underlying the design of Swareflex wildlife reflectors. *Transportation Research Record 1075:35-43.*

Zacks, J.L. (1985). An investigation of Swareflex wildlife warning reflectors. *Federal Highway Administration Report FHWA-MI-RD-85-04, Washington, D.C. 53 pp.*

Zacks, J.L. (1986). Do white-tailed deer avoid red? An evaluation of the premise underlying the design of Swareflex wildlife reflectors. *Transportation Research Record 1075:35-43.*

Human centered approaches and other:

Allen, R.E., & McCullough, D.R. (1976). Deer-car accidents in southern Michigan. *Journal of Wildlife Management 40:317-325.*

Anon. Deer Vehicle Collision Reduction Working Group Conference, *Final report, Wis. Dept of Trans.*

Bellis, E.D. & Graves, H.B. (1971). Deer mortality on a Pennsylvania interstate. *Journal of Wildlife Management 35:232-237.*

Carbaugh, B., Vaughan, J.P., Bellis, E.D., & Graves, H.B. (1975). Distribution and activity of white-tailed deer along an interstate highway. *Journal of Wildlife Management 39:570-581.*

Case, R.M. (1978). Interstate highway road killed animals: a data source for biologists. *Wildlife Society Bulletin 6:8-13.*

Conover, M.R., Pitt, W.C., Kessler, K.K., DuBow, T.J., & Sanborn, W.A. (1995). Review of Human Injuries, Illnesses, and Economic Losses Caused by Wildlife in the United States. *Wildlife Society Bulletin* 23:407-414.

Conover, M.R. (1997a). Monetary and intangible valuation of deer in the United States. *Wildlife Society Bulletin 25:298-305.*

Hughes, W.E., Saremi, R. (1990) Investigation of Crashes with Animals, *Highway Safety Information Systems Vol. 20.*

Pojar, T.M. (1975) Effectiveness of Lighted, Animated Deer Crossing Sign. *Journal of Wildlife Mgmnt, Vol. 39, 1. pp 87-91.*

Pojar, T.M., Presence, R.A., Reed, D.F., & Woodward, R.H. (1975). Effectiveness of a lighted, animated deer crossing sign. *Journal of Wildlife Management 39:87-91.*

Pojar, T.M., Reed, D.F., Resigh, T.C. (1972) "Deer Crossing" Signs May Prove Valuable in Reducing Accidents and Animal Deaths. *Highway Research News, Hwy Res Board, Iss 46 pp20-23.*

Puglisi, M.J., Lindzey, J.S., & Bellis, E.D. (1974). Factors associated with highway mortality of white-tailed deer. *Journal of Wildlife Management 38:799-807.*

Putman, R.J. (1997). Deer and road traffic accidents: options for management. *Journal of Environmental Management 51:43-57.*

Reed, D.F., Beck, T.D.I., & Woodard, T.N. (1979). Methods of reducing deer-vehicle accidents: benefit-cost analysis. *Wildlife Society Bulletin 10:349-354.*

Romin, L.A., & Bissonette, J.A. (1996). Deer-vehicle collisions: status of state monitoring activities and mitigation efforts. *Wildlife Society Bulletin 24:276-283.*

Stout, R.J., Stedman, R.C., Decker, D.J., & Knuth, B.A. (1993). Perceptions of risk from deer-related vehicle accidents: implications for public preferences for deer herd size. *Wildlife Society Bulletin 21:237-249.*

Suchy, W.J. (1998). Simpson Poll: attitudes about deer and deer management options. *Iowa Department of Natural Resources In House Report. 6 pp.*

Appendix A

[Pre/Post test questionnaire]

University of Minnesota Human Factors Driving Simulation Study

Pre-test Survey/Questionnaire

As stated in your instructions, all data are confidential.

Q1.

Name	
Age	
Gender	**M / F**
Phone Number	

Q2. Do you currently have a valid driver's license? (Circle one.)

1. **Yes**

2. **No**

Q3. Years driving experience (likely to be age-16=_). Number of years ____________.

Q4. Do you have any visual impairments?

1. **Yes** If Yes please describe.-______________________________________
2. **No**

Q5. Are you currently taking any medications?

1. **Yes** If Yes please describe.-_______________________________________

2. **No**

Q6. Have you experienced dizziness in the past (whether driving or not) (circle one.)

	Yes	**No**	(If you answered yes, what caused the dizziness?)
a. 5 years?	1	2	______________________________
b. 1 year?	1	2	______________________________
c. 6 months?	1	2	______________________________

Q7.

Do you experience nausea in any of the following situations?	YES	NO	If YES describe situation (where, how often, etc.).
Driving a car.	1	2	
Riding in a car as a passenger.	1	2	
During plane trips.	1	2	
Carnival rides.	1	2	
Other. (Watching TV, movies, etc.)	1	2	

Q8. Please answer Y or N and the frequency (Circle one response for each item.)

Do you experience-	always	sometimes	rarely	never
Claustrophobia (fear of closed spaces)	1	2	3	4

Acrophobia (fear of heights)	1	2	3	4
Driving fatigue	1	2	3	4
Panic attacks while driving.	1	2	3	4
Driving aggression (anger while driving)	1	2	3	4

Time on Road

Q9. Do you consider yourself a city or rural driver? (circle one)

CITY / RURAL

POST-test Questionnaire: Part I

Please rate your simulator experience (circle one number).

NOTE: Numbers omitted in this appendix (1-9 scale)

Q1. How would you rate the physical comfort of your simulator experience?

Not at all comfortable. Very comfortable.

Q2. How nervous did you feel during your simulator experience?

Very nervous. Not at all nervous.

Q3. How realistic did you find the visual display?

Not at all realistic. Very realistic.

Q4. How realistic did the simulator feel physically?

Not at all realistic. Very realistic.

Q5. How difficult or easy was it for you to learn to use the simulator?

Very difficult. Very easy.

Q6. How well did you adapt to the simulator?

Never got use to it. Quickly became use to it.

Q7. How closely did your simulator experience meet your expectations?

Not very closely Very closely

Please feel free to explain any extreme scores (1, 2 or 8, 9) you may have had:

Q8. Did you experience any nausea during the experiment?

1. **Yes**

2. **No** (If *No*, skip to **Q9**)

a. If *Yes*, at what point during the experiment did it occur (early, midway, late)?

____

b. If *Yes*, was it caused by a specific situation that you can remember?

____

c. If *Yes*, what (if anything) did you do to ease the sensation?

____

Q9. Describe the general experience or any other comments you may have about your simulator experience (if any).

____

____

____

____

____

____

____

____

____

____

____

____

Appendix B

[Raw Data: Mean scores at each sign condition]

As indicated on the first page, each block (3 cells) indicates the mean for the road section bordering each sign by approximately 500 feet on each side.

The R, M, F, S, letters represent the signage condition.

R- Normal

M- Enhanced, off

F- Enhanced, flashing

S- Enhanced, cluster (flashing)

The first three rows on each page are subject identifiers and overall mean speed and standard deviations.

Means are last column on final page.

Missing values are those removed due to interference of road speed in the signage data acquisition areas by road traffic resulting in aberrant acceleration/deceleration data.

		25.11.9h	dusk13.1	9.10.12h	26.11.12	25.11.12	dusk15.1	dusk15.1	dusk15.1	dusk15.1	dusk15.1	dusk14.1
	overall	83.92	121.63	93.62	81.54	92.42	89.76	91.65	110.15	99.38	97.78	81.00
		6.95	17.26	6.47	5.21	8.34	12.79	5.84	14.89	7.62	11.20	5.41
mean	R	95.56	101.54	95.67	86.45	97.42	99.75	92.59	105.06	98.77	91.87	91.73
sd		7.82	16.88	5.07	6.72	14.71	17.09	3.86	8.21	7.02	17.73	13.54
kurt		-1.21	-0.22	2.55	-0.15	-1.23	-1.54	-0.42	-1.23	-1.14	-0.74	-0.69
	M	85.60	109.69	90.87	90.92	81.24	79.94	85.56	106.56	97.79	91.06	80.25
		3.19	18.46	5.80	2.41	2.24	2.91	8.00	8.94	2.17	13.47	2.20
		-0.61	-0.91	-0.22	-0.30	0.15	0.13	0.00	-1.17	-0.37	-1.53	2.51
	F	79.82	109.85	95.76	82.92	88.14	79.24	91.74	92.40	94.54	94.94	80.03
		3.84	14.74	6.46	4.15	11.82	12.10	4.64	12.09	7.44	8.37	2.58
		-0.13	2.47	0.63	-0.60	1.31	-0.25	-0.04	-0.49	4.38	-0.83	-0.95
	F	80.81	108.16	95.05	79.36	91.61	92.04	90.54		98.61	99.45	80.01
		5.02	20.55	2.05	5.47	2.99	11.72	4.30		3.26	1.26	2.58
		0.91	-0.80	0.89	-0.64	-1.37	-1.53	0.92		0.11	-0.68	-0.82
	R	79.99	127.87	90.75	79.65	90.54	79.65	93.43		97.46	93.84	80.06
		4.61	6.33	5.94	4.09	1.98	3.00	3.54		4.91	10.65	1.90
		-0.26	-0.41	-0.41	0.84	0.46	-0.67	0.50		1.16	-0.53	-0.72
	M	80.64	123.44	95.53	79.82	95.47	79.79	92.53	109.07	100.50	99.74	79.67
		2.32	16.45	1.29	3.60	10.28	3.08	6.20	16.90	2.29	2.59	2.73
		0.33	1.65	-0.07	-0.79	3.47	-0.61	-0.05	-0.82	-0.24	2.91	0.94
clusterr	S	79.86	112.53	95.39	80.51	93.50	80.87	91.74		95.47	83.03	80.15
		2.83	0.48	1.37	3.48	3.68	2.15	4.27		7.95	5.77	2.99
		-0.08	-0.74	-0.52	-0.76	0.79	0.41	1.87		-0.24	1.55	-0.24
	M	80.13	127.36	88.92	79.83	91.42	80.79	87.94		102.31	100.63	79.31
		2.03	11.66	9.09	4.14	3.07	3.38	7.22		0.83	5.88	2.66
		-0.62	1.65	0.72	-0.46	-0.96	1.38	-1.18		-1.01	3.56	-1.04
	F	79.97	103.10	96.92	81.63	94.31	84.88	93.84	103.13	87.49	101.44	81.32
		3.31	10.69	2.53	3.14	7.31	13.27	4.10	8.95	4.32	4.59	3.16
		0.12	2.76	6.62	2.35	0.18	-1.49	1.10	-1.14	0.83	1.94	-0.81
	R	80.83	125.59	98.09	80.65	95.72	97.16	94.78	100.26	107.14	107.59	80.82
		3.31	10.70	2.50	3.14	7.31	13.27	4.11	14.30	4.31	4.59	3.15
		0.12	2.76	6.34	2.34	0.18	-1.49	1.09	-1.51	0.84	1.94	-0.81
clusterr	S	93.10	125.55	85.36	79.54	94.85	93.51	92.14	108.62	98.40	99.14	79.51
		5.75	10.71	7.80	3.85	8.74	9.50	6.88	10.67	6.23	12.51	2.12
		3.38	2.75	-0.95	0.67	0.32	0.97	-0.04	0.28	-1.21	-1.14	0.94

dusk13.1	24.11.8h	17.10.13	17.10.14	17.10.15	20.10.15	25.11.11	20.10.16	20.10.14	dusk26.1	dusk25.1	dusk25.1	dusk24.1
114.079	81.098	101.170	89.708	93.995	110.711	79.804	117.416	127.529	79.857	81.259	81.479	80.793
10.705	3.865	9.151	7.432	8.986	14.750	6.675	15.281	14.750	6.718	5.982	6.363	5.100
114.337	83.505	99.690	93.242	90.803	111.711	71.939	120.903	115.364	67.530	95.947	91.819	90.287
10.411	2.881	8.377	7.741	7.845	14.546	6.776	19.258	9.265	8.171	12.019	10.244	9.065
4.484	2.684	-0.563	-0.481	-1.135	-0.495	-0.574	0.083	2.126	-1.279	-1.588	-1.203	-0.984
112.538	87.056	84.414	96.150	88.778	108.830	76.541	124.314	116.307	81.253	80.372	87.093	82.803
13.264	2.205	8.529	4.315	10.609	17.030	9.194	17.606	9.328	7.706	2.656	6.847	4.990
-0.393	-0.942	1.577	1.536	-1.240	-1.033	-1.164	0.062	0.972	-1.084	-0.728	-0.854	-0.714
100.195	83.492	95.462	90.847	92.817	102.250	83.758	116.263	119.822	86.587	80.061	78.627	79.978
9.149	3.011	1.988	4.054	2.018	3.942	7.820	12.809	16.157	6.623	1.709	9.554	4.458
0.860	0.030	-0.894	1.518	2.343	2.953	-0.640	2.196	0.886	-0.916	-0.331	6.446	-0.333
107.769	80.233	98.892	85.892	88.763	96.854	80.521	112.430	119.833	79.884	79.494	81.806	79.654
10.761	4.685	6.207	5.664	9.596	12.089	4.404	10.324	8.183	5.702	3.285	4.263	3.022
1.539	1.167	2.059	2.258	-0.628	-1.098	0.699	0.702	5.321	-0.520	-0.344	0.544	-0.057
115.361	79.479	99.699	87.949	98.845	102.210	83.622	116.313	131.573	82.007	80.923	80.183	79.923
6.465	4.374	1.801	6.454	1.916	1.062	4.267	9.609	5.213	5.693	2.497	2.832	3.157
1.006	-0.904	3.707	0.113	-0.796	-1.472	-0.787	0.386	0.727	-0.674	-0.463	0.288	0.434
107.465	80.435	104.417	94.996	87.045	105.431	80.614	114.061	131.396	79.954	79.524	79.902	79.741
16.112	2.913	4.935	2.249	8.101	7.609	3.332	8.931	8.427	4.546	2.463	4.240	3.817
-1.616	-0.746	3.932	-0.984	-1.331	1.911	-0.155	-0.318	3.254	-0.989	-0.171	-0.638	-0.372
104.806	80.199	100.975	90.602	90.074		79.885	115.552		79.419	78.091	79.982	79.686
3.269	2.801	4.428	5.767	8.866		3.542	9.823		3.942	4.348	2.577	3.147
1.946	0.041	0.039	2.207	-1.657		-0.308	1.118		-0.490	0.561	-0.129	-0.091
116.199	78.819	102.996	80.128	98.430	120.096	79.778	115.994	137.622	79.416	81.928	79.479	79.642
5.239	3.321	8.498	5.111	4.220	9.090	4.198	11.153	12.806	4.772	4.136	5.251	3.483
0.607	-0.601	2.217	-0.595	4.806	3.297	0.237	1.352	5.423	-0.859	-0.104	0.033	-0.881
106.243	80.373	89.446	92.221	94.387	103.615	79.589		133.310	81.998	80.290	80.781	80.244
11.969	3.042	4.159	7.079	8.876	5.024	3.960		20.075	5.028	2.286	3.857	3.756
2.681	0.082	2.916	0.251	-0.959	-0.346	-0.250		-0.049	-0.906	0.009	-1.037	-0.744
121.141	80.953	104.278	95.328	99.202	113.636	80.831	96.419	139.999	78.188	80.383	80.522	80.501
11.971	3.041	4.159	7.078	8.872	5.033	3.957	8.631	20.058	5.024	2.286	3.857	3.756
2.681	0.086	2.914	0.256	-0.952	-0.348	-0.247	0.370	-0.036	-0.903	0.008	-1.037	-0.744
119.125	79.702	99.521	90.920	101.540	105.519	79.485	96.394	116.399	81.683	79.552	79.974	79.404
1.052	2.504	4.582	6.883	2.295	3.899	4.098	8.642	9.360	4.238	2.933	3.456	3.489
-0.731	-0.167	5.538	-0.558	-0.976	-1.466	-1.113	0.356	0.965	0.213	-0.684	-0.802	-0.773

dusk20.1	dusk17.1	dusk17.1	dusk16.1	dusk17.1	dusk16.1	dusk24.1	dusk20.1	dusk17.1	dusk20.1	dusk17.1	13.10.13	13.10.10
98.931	94.369	114.545	92.807	124.290	81.806	97.613	112.905	118.782	141.721	116.189	116.520	100.860
5.537	4.064	18.644	7.130	14.316	5.686	13.412	10.274	7.004	21.402	18.275	11.812	8.468
97.735	86.844	106.116	89.985	113.868	95.081	110.442	108.795	118.743	128.626	116.921	101.241	95.915
2.314	6.388	27.336	15.293	13.001	2.198	14.254	7.172	9.320	16.422	11.796	8.543	2.391
-0.666	-1.617	-0.975	-1.025	1.978	0.442	3.427	2.095	4.530	-0.315	3.077	1.011	-0.156
96.058	93.375	99.443	86.186	125.790	86.715	104.427	109.869	119.805	149.087	116.702	107.687	103.145
5.213	1.123	19.953	9.057	9.847	5.863	11.775	4.999	4.068	16.368	14.211	8.204	8.287
6.581	-0.203	-1.270	-0.418	2.422	-1.165	-0.562	1.490	4.241	0.640	1.152	2.992	3.795
97.422	96.269	100.546	90.377	103.559	80.030	94.510	106.850	117.154	129.259	116.868	115.259	100.613
1.440	3.363	5.437	3.419	13.732	2.746	16.440	8.441	6.254	16.451	3.986	4.441	10.167
0.094	1.345	-0.194	3.257	3.471	-0.561	-0.243	-0.286	4.312	-1.464	1.329	-0.243	-0.022
96.806	93.808	111.072	92.593	109.232	80.202	95.880	102.285	117.793	144.735	88.456	115.575	98.887
7.945	1.695	6.924	2.712	20.855	5.422	8.106	14.816	12.857	24.760	17.072	9.890	13.769
0.972	-1.253	1.142	1.181	-1.722	3.840	-0.498	-0.831	3.158	-1.298	1.192	3.486	-1.067
99.481	92.792	107.511	88.466	121.666	80.153	83.944	114.598	120.579	155.482	97.784	120.588	97.787
1.596	4.215	17.654	8.986	10.577	3.527	7.588	3.512	4.489	18.363	22.138	4.658	2.101
0.373	1.946	-0.229	0.273	4.667	3.530	0.552	0.153	4.324	-0.164	-1.687	2.089	-0.678
97.988	93.928	117.639	95.357	126.657	79.925	97.467	111.970	116.610	143.413	126.314	112.289	94.730
8.157	2.228	7.119	2.296	7.965	2.131	8.791	11.082	8.305	24.828	3.475	14.937	5.890
0.268	-0.661	0.296	-0.991	3.749	-0.150	-0.289	-0.134	4.457	0.307	1.714	0.160	2.830
97.880	94.563	105.921	94.454	104.328	79.571	91.856	102.606	118.231	139.263	126.075	102.043	100.060
6.417	2.175	14.705	4.577	7.281	1.467	6.681	4.421	5.319	11.345	5.925	7.867	1.813
1.166	0.358	1.527	2.617	4.889	0.245	-0.569	-0.708	3.913	-0.659	5.922	1.704	0.181
100.235	96.400	122.844	94.571	128.600	79.095	100.661	118.905	121.134	124.633	114.132	126.810	100.636
0.850	2.765	17.544	2.213	12.498	4.539	13.315	8.426	3.460	20.689	18.360	4.458	8.422
-0.152	-0.685	0.869	0.344	3.670	-1.025	-0.959	2.234	2.023	-0.617	-0.583	-0.493	3.201
102.515	96.877	101.544	94.888	100.296	81.212	96.307	117.659	119.252	136.419	113.225	114.907	100.556
5.815	1.505	23.518	5.449	6.795	4.550	6.108	10.620	2.396	9.512	13.602	5.407	5.146
5.255	-0.578	-0.848	2.195	3.378	0.126	-0.132	1.294	0.672	-1.310	4.539	1.144	2.851
100.753	96.640	128.886	93.546	139.422	80.611	98.782	115.667	118.417	136.351	126.083	118.946	103.008
5.815	1.506	23.522	5.450	6.831	4.549	6.103	10.599	2.397	9.516	13.603	5.407	5.168
5.255	-0.585	-0.850	2.194	3.395	0.128	-0.131	1.316	0.668	-1.311	4.539	1.144	2.843
99.780	94.267	122.485	94.699	113.909	79.705	97.908	120.956	119.247	124.617	98.096	112.259	101.073
7.135	2.460	0.330	2.287	13.019	2.449	11.185	6.170	2.398	9.522	3.482	14.916	10.522
2.210	-0.103	-1.156	-0.986	1.971	-0.454	1.196	-1.557	0.662	-1.311	1.649	0.165	-0.280

15.10.10	15.10.13	14.10.13	16.10.13	15.10.14	15.10.15	16.10.11	17.10.11h8	
101.512	106.823	85.200	92.657	112.295	104.726	95.653	98.480	99.787
12.420	9.595	9.853	11.836	24.391	21.737	9.864	11.275	
98.318	105.173	92.644	102.340	96.803	99.313	97.747	96.918	99.179
18.412	14.739	14.928	15.625	19.700	9.756	5.585	8.262	10.859
-1.799	-0.770	-1.144	-1.298	-1.665	-0.952	-0.468	1.163	-0.001
103.673	114.978	99.527	106.353	117.625	80.206	96.294	101.857	98.772
14.818	7.622	6.072	7.902	15.260	3.036	8.819	4.936	8.255
-1.050	3.255	0.345	-1.622	0.322	4.000	0.464	-0.690	0.409
105.654	102.612	84.688	87.239	112.884	80.062	98.314	100.969	96.015
9.004	7.308	5.342	11.534	11.673	2.837	3.461	9.618	7.303
0.701	2.687	-0.812	0.910	1.282	-0.651	-0.294	0.976	0.783
98.269	105.304	81.466	85.047	82.266	107.605	85.630	96.223	95.382
9.853	11.851	4.438	2.279	5.855	8.143	8.017	10.993	8.083
-0.372	0.883	-0.912	1.789	4.068	4.047	-1.036	-1.318	0.547
98.384	106.633	80.596	94.481	89.197	89.533	98.070	81.211	97.051
14.599	8.859	4.775	9.402	20.518	11.937	9.827	6.279	6.770
-0.900	2.739	-0.272	-1.191	2.227	-1.477	1.227	11.337	0.690
102.419	107.902	85.756	80.017	104.338	101.156	101.237	104.318	99.169
10.117	4.931	9.961	1.971	19.735	17.046	3.087	5.313	7.217
0.748	2.489	1.587	-0.006	-1.556	-1.614	-0.622	-0.179	0.464
113.458	109.530	89.577	80.150	124.620	108.588	90.324	90.220	96.086
4.452	3.563	2.897	2.780	17.262	14.287	7.556	9.916	5.480
-1.132	0.317	-1.109	0.119	0.059	-0.854	3.024	-1.526	0.590
91.518	103.516	86.450	89.847	129.882	120.714	97.834	101.119	100.425
12.751	9.439	6.738	9.751	20.292	18.647	4.017	9.554	7.727
-1.173	3.606	-0.262	-0.988	0.518	-0.264	-0.278	0.790	0.608
102.175	104.481	79.075	99.571	130.483	118.322	83.815	99.601	97.811
4.592	8.543	3.550	1.600	17.511	17.610	7.666	6.843	7.109
-0.839	1.162	0.042	0.618	2.482	-0.403	-0.671	0.215	0.803
102.790	106.301	80.644	89.863	121.735	121.087	86.358	105.912	102.040
4.602	8.557	3.544	1.600	17.510	17.614	7.663	6.839	7.263
-0.828	1.151	0.025	0.618	2.482	-0.404	-0.664	0.222	0.779
100.060	109.229	78.969	100.121	101.425	104.927	102.263	103.073	98.622
9.667	10.343	4.025	2.180	10.716	22.747	4.376	3.353	6.566
-0.405	3.114	-0.806	2.252	4.444	-0.570	-0.749	0.233	0.340

Appendix C

Individual signage performance (m.p.h.) and group Analysis of Variance

Individual signage performance (m.p.h.) and group Analysis of Variance (ANOVA): Performance differences relative to sign type.						
Participants, coded		**Sum of Squares**	**df**	**Mean square**	**F**	**Sig.**
VAR00001	Between Groups	574.824	3	191.608	5.039	**.036**
	Within Groups	266.151	7	38.022		
	Total	840.974	10			
VAR00002	Between Groups	3692.988	3	1230.996	12.562	**.003**
	Within Groups	685.945	7	97.992		
	Total	4378.933	10			
VAR00003	Between Groups	1123.629	3	374.543	16.318	**.002**
	Within Groups	160.672	7	22.953		
	Total	1284.302	10			
VAR00004	Between Groups	357.988	3	119.329	5.185	**.034**
	Within Groups	161.085	7	23.012		
	Total	519.072	10			
VAR00005	Between Groups	382.953	3	127.651	6.374	**.021**
	Within Groups	140.184	7	20.026		
	Total	523.137	10			
VAR00006	Between Groups	334.182	3	111.394	3.003	**.104**
	Within Groups	259.683	7	37.098		
	Total	593.864	10			

Individual signage performance (m.p.h.) and group Analysis of Variance (ANOVA): Performance differences relative to sign type.						
Participants, coded		**Sum of Squares**	**df**	**Mean square**	**F**	**Sig.**
VAR00007	Between Groups	109.242	3	36.414	1.343	**.336**
	Within Groups	189.840	7	27.120		
	Total	299.082	10			
VAR00008	Between Groups	416.076	3	138.692	34.196	**.001**
	Within Groups	20.279	5	4.056		
	Total	436.355	8			
VAR00009	Between Groups	80.865	3	26.955	1.095	**.432**
	Within Groups	123.049	5	24.610		
	Total	203.914	8			
VAR00010	Between Groups	32.108	3	10.703	.277	**.840**
	Within Groups	270.242	7	38.606		
	Total	302.350	10			
VAR00011	Between Groups	604.177	3	201.392	5.934	**.025**
	Within Groups	237.580	7	33.940		
	Total	841.757	10			
VAR00012	Between Groups	3245.530	3	1081.843	113.524	**.000**
	Within Groups	66.707	7	9.530		
	Total	3312.238	10			

Individual signage performance (m.p.h.) and group Analysis of Variance (ANOVA): Performance differences relative to sign type.						
Participants, coded		**Sum of Squares**	**df**	**Mean square**	**F**	**Sig.**
VAR00013	Between Groups	1895.934	3	631.978	24.440	**.000**
	Within Groups	181.011	7	25.859		
	Total	2076.945	10			
VAR00014	Between Groups	954.057	3	318.019	8.243	**.011**
	Within Groups	270.063	7	38.580		
	Total	1224.120	10			
VAR00015	Between Groups	127.180	3	42.393	1.261	**.359**
	Within Groups	235.424	7	33.632		
	Total	362.604	10			
VAR00016	Between Groups	75.422	3	25.141	1.234	**.367**
	Within Groups	142.582	7	20.369		
	Total	218.005	10			
VAR00017	Between Groups	795.211	3	265.070	6.741	**.018**
	Within Groups	275.267	7	39.324		
	Total	1070.478	10			
VAR00018	Between Groups	1304.651	3	434.884	23.880	**.001**
	Within Groups	109.268	6	18.211		
	Total	1413.919	9			

Individual signage performance (m.p.h.) and group Analysis of Variance (ANOVA): Performance differences relative to sign type.						
Participants, coded		**Sum of Squares**	**df**	**Mean square**	**F**	**Sig.**
VAR00019	Between Groups	3231.180	3	1077.060	18.489	**.001**
	Within Groups	407.788	7	58.255		
	Total	3638.967	10			
VAR00020	Between Groups	896.417	3	298.806	2.408	**.166**
	Within Groups	744.636	6	124.106		
	Total	1641.054	9			
VAR00021	Between Groups	4781.109	3	1593.703	40.595	**.000**
	Within Groups	235.550	6	39.258		
	Total	5016.659	9			
VAR00022	Between Groups	50.239	3	16.746	.633	**.617**
	Within Groups	185.109	7	26.444		
	Total	235.348	10			
VAR00023	Between Groups	44.331	3	14.777	.823	**.522**
	Within Groups	125.737	7	17.962		
	Total	170.069	10			
VAR00024	Between Groups	22.333	3	7.444	.655	**.605**
	Within Groups	79.560	7	11.366		
	Total	101.893	10			

Individual signage performance (m.p.h.) and group Analysis of Variance (ANOVA): Performance differences relative to sign type.						
Participants, coded		**Sum of Squares**	**df**	**Mean square**	**F**	**Sig.**
VAR00025	Between Groups	978.236	3	326.079	168.504	**.000**
	Within Groups	13.546	7	1.935		
	Total	991.782	10			
VAR00026	Between Groups	93.233	3	31.078	2.887	**.112**
	Within Groups	75.342	7	10.763		
	Total	168.575	10			
VAR00027	Between Groups	944.766	3	314.922	3.482	**.079**
	Within Groups	633.039	7	90.434		
	Total	1577.804	10			
VAR00028	Between Groups	903.066	3	301.022	7.805	**.012**
	Within Groups	269.972	7	38.567		
	Total	1173.038	10			
VAR00029	Between Groups	2908.939	3	969.646	18.992	**.001**
	Within Groups	357.390	7	51.056		
	Total	3266.328	10			
VAR00030	Between Groups	1445.567	3	481.856	12.686	**.003**
	Within Groups	265.887	7	37.984		
	Total	1711.453	10			

Individual signage performance (m.p.h.) and group Analysis of Variance (ANOVA): Performance differences relative to sign type.						
Participants, coded		**Sum of Squares**	**df**	**Mean square**	**F**	**Sig.**
VAR00031	Between Groups	1014.995	3	338.332	6.268	**.021**
	Within Groups	377.849	7	53.978		
	Total	1392.844	10			
VAR00032	Between Groups	885.511	3	295.170	22.423	**.001**
	Within Groups	92.145	7	13.164		
	Total	977.656	10			
VAR00033	Between Groups	237.745	3	79.248	1.809	**.233**
	Within Groups	306.581	7	43.797		
	Total	544.327	10			
VAR00034	Between Groups	1235.440	3	411.813	4.044	**.058**
	Within Groups	712.777	7	101.825		
	Total	1948.217	10			
VAR00035	Between Groups	1010.009	3	336.670	3.243	**.090**
	Within Groups	726.691	7	103.813		
	Total	1736.700	10			
VAR00036	Between Groups	147.632	3	49.211	.265	**.849**
	Within Groups	1298.823	7	185.546		
	Total	1446.454	10			

Individual signage performance (m.p.h.) and group Analysis of Variance (ANOVA): Performance differences relative to sign type.

Participants, coded		Sum of Squares	df	Mean square	F	Sig.
VAR00037	Between Groups	526.385	3	175.462	10.520	**.005**
	Within Groups	116.755	7	16.679		
	Total	643.140	10			
VAR00038	Between Groups	2.367	3	.789	.053	**.983**
	Within Groups	104.961	7	14.994		
	Total	107.327	10			
VAR00039	Between Groups	71.558	3	23.853	.902	**.487**
	Within Groups	185.120	7	26.446		
	Total	256.677	10			
VAR00040	Between Groups	1032.531	3	344.177	10.921	**.005**
	Within Groups	220.611	7	31.516		
	Total	1253.143	10			
VAR00041	Between Groups	359.661	3	119.887	1.659	**.261**
	Within Groups	505.954	7	72.279		
	Total	865.615	10			
VAR00042	Between Groups	1362.059	3	454.020	2.588	**.135**
	Within Groups	1227.855	7	175.408		
	Total	2589.914	10			

Individual signage performance (m.p.h.) and group Analysis of Variance (ANOVA): Performance differences relative to sign type.						
Participants, coded		**Sum of Squares**	**df**	**Mean square**	**F**	**Sig.**
VAR00043	Between Groups	223.785	3	74.595	.186	**.902**
	Within Groups	2802.252	7	400.322		
	Total	3026.037	10			
VAR00044	Between Groups	215.556	3	71.852	.567	**.654**
	Within Groups	887.579	7	126.797		
	Total	1103.135	10			
VAR00045	Between Groups	264.347	3	88.116	1.199	**.378**
	Within Groups	514.266	7	73.467		
	Total	778.613	10			

Exposure (sequence)

Means by signage type were calculated since no significance was found between each of the exposures to signage (Table 3.2a-3.2d) (in m.p.h.).

Table 3.2a
Analysis of variance (ANOVA):
Single factor all subjects standard signage (m.p.h.)

Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
sign 1/3	44	2713.83	61.67	88.87
sign 2/3	43	2603.70	60.55	182.81
sign 3/3	44	2803.00	63.70	193.01

ANOVA

Source of Variation	*SS*	*df*	*MS*	***F***	***P-value***	***F crit***
Between Groups	358.29	2	179.14	**1.15**	**0.31**	**3.06**
Within Groups	19799.2	128	154.68			
Total	20157.5	130				

Table 3.2b
ANOVA: Single Factor All Subjects Enhanced Signage – OFF (m.p.h.)

Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
sign 1/3	45	2761.83	61.37	150.12
sign 2/3	45	2772.94	61.62	163.18
sign 3/3	44	2745.66	62.4013	198.29

ANOVA

Source of Variation	*SS*	*df*	*MS*	***F***	***P-value***	***F crit***
Between Groups	41.06	2	20.53	**0.12**	**0.88**	**3.06**
Within Groups	22311.9	131	170.32			
Total	22352.9	133				

Table 3.2c
ANOVA: Single factor all subjects enhanced signage – flashing (m.p.h.)

Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
sign 1/3	45	2761.83	61.37	150.12
sign 2/3	45	2772.94	61.62	163.18
sign 3/3	45	2734.97	60.77	138.53

ANOVA

Source of Variation	*SS*	*df*	*MS*	***F***	***P-value***	***F crit***
Between Groups	41.06	2	20.53	**0.12**	**0.88**	**3.06**
Within Groups	22311.9	131	170.32			
Total	22352.9	133				

Table 3.2d
ANOVA: Single factor all subjects enhanced signage – flashing (cluster sequence) (m.p.h.)

Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
sign 1/3	42	2507.62	59.70	140.59
sign 2/3	45	2757.64	61.28	118.15

ANOVA

Source of Variation	*SS*	*df*	*MS*	***F***	***P-value***	***F crit***
Between Groups	86.80	1	86.80	**0.67**	**0.41**	**3.95**
Within Groups	86.80	85	128.98			
Total	11050.00	86				

By individual performance:

Some participants (n=22, ~50%) demonstrated significant differences in performance relative to signage types. See Sig. (significance) for $p < .05$.

By Population Sample Averages:

A significant difference was found between signage type (p=.05)

Table 3.3
ANOVA for performance by sign type (m.p.h.)

Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
Normal	3.000	85.33	61.77	3.89
Mod-off	3.000	185.39	61.79	0.46
Mod-on	3.000	178.63	59.54	0.09
Cluster	2.000	122.05	61.03	0.20

ANOVA

Source of Variation	*SS*	*df*	*MS*	***F***	***P-value***	***F crit***
Between Groups	16.21	3.000	5.40	**4.15**	**0.054**	**4.34**
Within Groups	9.10	7.000	1.30			
Total	25.32	10.000				