Traffic Control Devices Pooled Fund Study

Evaluation of Selected Flashing Patterns

Final Report

January 2010

Prepared by:
H. Gene Hawkins, Jr.
Sarah Young

Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843-3135

This research project was sponsored by the Traffic Control Devices Pooled Fund Study, TPF-5(065). Members of the Pooled Fund Study Panel are as follows:

Johnny Bhullar, California Department of Transportation
Mark Wilson, Florida Department of Transportation
Kathy Zahul, Georgia Department of Transportation
Larry Gregg, Illinois Department of Transportation
Tim Crouch, Iowa Department of Transportation
Steven Buckley, Kansas Department of Transportation
John Smith, Mississippi Department of Transportation
Julie Stotlemeyer, Missouri Department of Transportation
Dan Waddle, Nebraska Department of Roads
Dave Partee, Nevada Department of Transportation
William Lambert, New Hampshire Department of Transportation (co-chair)
Doug Bartlett, New Jersey Department of Transportation
Barbara Abrahamer, New York State Department of Transportation
Ron King, North Carolina Department of Transportation
Ed Fischer, Oregon Department of Transportation
Jim Tenaglia, Pennsylvania Department of Transportation
Nick Boozer, South Carolina Department of Transportation
Doug Skowronek, Texas Department of Transportation
Tom Notbohm, Wisconsin Department of Transportation
Roger Wentz, American Traffic Safety Services Association
Lee Billingsley, Broward County, Florida Department of Transportation (retired)
John Fisher, Los Angeles, California Department of Transportation

Richard Seabrook, Federal Highway Administration, Federal Lands Highway
Ed Rice, Federal Highway Administration, Office of Safety
Scott Wainwright, Federal Highway Administration, Office of Operations (co-chair)
Amanda Emo, Federal Highway Administration, Office of Safety R&D
Bryan Katz, Science Applications International Corporation

The objective of the Traffic Control Devices Pooled Fund Study (TCD PFS) is to assemble a group composed of State and local agencies, appropriate organizations and the FHWA to 1) establish a systematic procedure to select, test and evaluate approaches to novel TCD concepts as well as incorporation of results into the MUTCD; 2) select novel TCD approaches to test and evaluate; 3) determine methods of evaluation for novel TCD approaches; 4) initiate and monitor projects intended to address evaluation of the novel TCDs; 5) disseminate results; and 6) assist MUTCD incorporation and implementation of results.

To join the TCD PFS, or for more information about the TCD PFS

- Contact Amanda Emo at (202) 493-3395 or contact Scott Wainwright at (202) 366-0857
- Visit www.pooledfund.org and search for study # TPF-5(065).

EXECUTIVE SUMMARY

The Traffic Control Devices Pooled Fund Study (TCD PFS) focuses on a systematic evaluation of novel TCDs addressing human factors and operations issues for each TCD idea. As part of the PFS effort, the Texas Transportation Institute (TTI) evaluated various types of flash patterns for potential application in flashing traffic signals. The flash patterns evaluated were:

- Pattern A (Steady): once on, stays on.
- Pattern B (5×0.10): 0.1 on, 0.1 off, 0.1 on, 0.1 off, 0.1 on, 0.1 off, 0.1 on, 0.1 off, 0.1 on, 0.1 off, 0.1 on, 0.1 off (5 flashes at 0.1 sec each separated by 0.1 sec dark intervals)
- Pattern C (3×0.10): 0.1 on, 0.1 off, 0.1 on, 0.1 off, 0.1 on, 0.5 off (3 flashes at 0.1 sec each separated by 0.1 sec dark intervals followed by 0.5 sec dark interval)
- Pattern D (2×0.25): 0.25 on, 0.25 off, 0.25 on, 0.25 off (2 flashes at 0.25 sec each separated by 0.25 sec dark intervals)
- Pattern E (1×0.50): 0.5 on, 0.5 off (1 flash at 0.5 sec followed by 0.5 sec dark interval) Standard flash pattern

The flashing patterns were evaluated through a laboratory study in which research participants were asked to identify the appearance of a simulated flashing beacons projected on a computer screen 25 feet wide by 8 feet tall. The beacons were projected against three backgrounds: black, gray, and a multi-colored moving background. The experiment also presented the beacons in three sizes which represented viewing distances of 100, 200, and 300 feet. Thirty individuals participated in the research study. In addition to looking for the beacon, research participants also were required to use a steering wheel to keep a tracking triangle between two moving lines at the bottom of the screen. Upon seeing the flashing beacon, research participants pulled a lever on the steering wheel, which recorded their response time.

The differences in the mean reaction times across all of the flashing patterns and all backgrounds are not statistically significantly different from one another at a 95 percent confidence interval. This makes it difficult to recommend any one pattern for implementation.

ACKNOWLEDGEMENTS

The authors of this report would like to thank the Traffic Control Devices Pooled Fund Study panel for their technical and financial support of the project. Particular appreciation is expressed to Sarah Young of TTI for leading the data collection effort and Ben Sutherland with the Texas A&M University Immersive Visualization Center for use of the visualization laboratory for the data collection. The authors would also like to thank Bryan Katz for his guidance and support of the project.

DISCLAIMER

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Page

1.0 INTRODUCTION

Gaining a driver's attention as he or she approach a pedestrian crossing can be a challenging undertaking. One step in gaining a driver's attention is to provide a detectable stimulus. Historically, one of the primary means of improving traffic control device detectability is through the use of an incandescent flashing beacon in or adjacent to the device. However, the use of traditional dynamic treatments, such as incandescent flashing beacons, may have limited effectiveness due to the intensity of the illumination element and the traditional temporal pattern of the flash.

The advent of LED technology in traffic signals provides many benefits and opportunities. One of the opportunities is the ability to implement different flash rates in beacons and other devices. Section 4L.01 of the Manual on Uniform Traffic Control Devices (MUTCD) indicates that different flash rates may be used for in-roadway lights. The "rapid flash" has been used for in-roadway lights at pedestrian crossings. Figure 1 illustrates the rapid flash pattern that has been used for in-roadway light applications. In this pattern, the element is illuminated for 0.1 seconds three times, with 0.1 seconds between each illumination. Then there is a 0.5 second dark period before the cycle repeats.

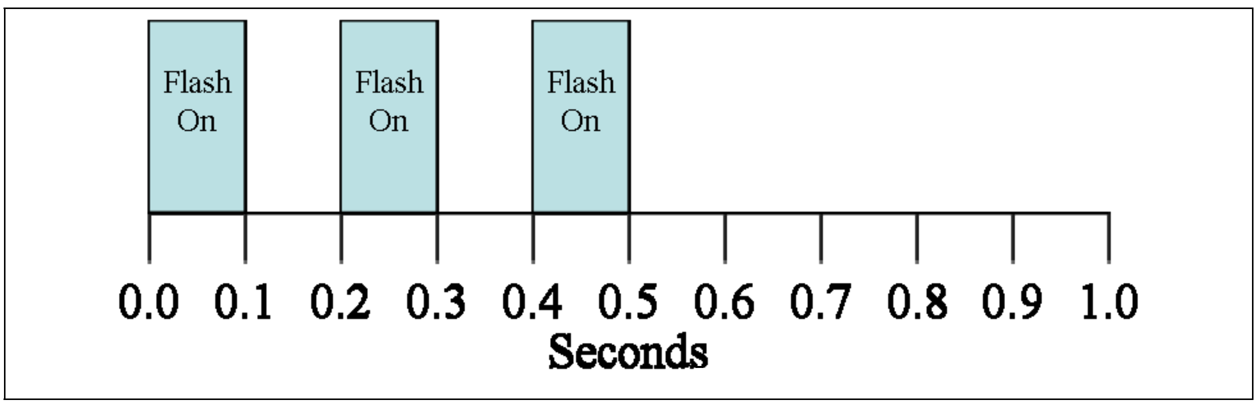

Figure 1. Stutter Flash Pattern

This flash pattern has becoming the defacto flash pattern for pedestrian crossing applications despite the fact that there has been little to no research as a traffic control device to establish whether this is the most effective pattern for in-roadway lights or any other traffic control device application. However, there has been related research addressing flashing stimuli, which is described in Chapter 2. In this proposed research, the researchers evaluated the detectability of various flashing patterns in a laboratory experiment to determine which type of flashing pattern was easiest to detect while engaged in a tracking task.

2.0 BACKGROUND

There is extensive information regarding the evolution, design, and use of flashing indications to solicit attention from subjects in various real and experimental scenarios. This chapter presents a brief summary of previous efforts in three areas: evolution of MUTCD guidelines for flashing indications, the potential for flashing indications to excite a photosensitive epileptic seizure, and general research related to the effectiveness of various flashing rates.

2.1 MUTCD GUIDELINES

Flashing indications have been used with traffic signals from the early days of traffic signals in the first quarter of the twentieth century. It appears that the first effort to standardize flashing indications on a national level occurred in the 1935 MUTCD. This was the first edition of the MUTCD. Section 388 of the 1935 MUTCD stated that the flashing rate shall be continuous at a rate not less than 50 nor more than 70 times per minute. It further stated that the illuminated period shall be at least as long as the dark period (1). In the 1948 MUTCD, the flashing rate was changed to not less than 50 nor more than 60 times per minute (2). This is the flash rate that is still specified in the MUTCD today for flashing indications. The 2003 MUTCD contains the following standard for the use of a flashing indication (Section 4D.11) (3):

> *The light source of a flashing signal indication shall be flashed continuously at a rate of not less than 50 nor more than 60 times per minute. The illuminated period of each flash shall be not less than half and not more than two-thirds of the total flash cycle.*

The 2000 MUTCD introduced the use of in-roadway lights with the ability to use a flashing rate that is not continuous. The 2003 MUTCD contains the following standard for the use of a flashing indication in in-roadway lights (Section 4L.02) (3):

> *The flash rate for In-Roadway Warning Lights at crosswalks shall be at least 50, but not more than 60, flash periods per minute. The flash rate shall not be between 5 and 30 flashes per second to avoid frequencies that might cause seizures.*

Part of the reason for providing the ability to use a different flashing pattern with in-roadway lights was the fact that the use of LED lights provided the ability to flash an indication at a more rapid rate than was practically feasible with the type of incandescent light source used in traffic signal beacons and signal heads. LEDs provide the ability to cycle the indication on and off more rapidly. The language in the MUTCD excluding a flash rate between 5 and 30 flashes per second (5-30 Hz) was based on pertinent literature gathered by FHWA staff during the rulemaking process.

Although not identified in the MUTCD language, the flash pattern implemented with the in-roadway lights was a rapid-flash pattern with three flashes of 0.1 second duration, separated by 0.1 seconds, then followed by a 0.5 second dark period (see Figure 1). This pattern provided an overall flash rate of 60 flashes per minute and six flashes per second. However, it appears that there is no research basis for selecting this flashing pattern.

2.2 PHOTOSENSITIVE EPILEPSY

Photosensitive epilepsy (PSE) is an extremely rare condition that affects approximately one in every 5,000 people in the general population (4). Contrary to popular belief, the percentage of the epileptic population that is also prone to photosensitive responses is also remarkably low. Current research places this figure at anywhere between three to five percent (5). For as extensive as the medical investigation has been in this field, the percentage range remains extremely wide, exposing the truly obscure and uncertain nature of photosensitive epilepsy. Medically speaking, PSE is a "… condition characterized by seizures in patients who show photoparoxysmal responses on electroencephalography (EEG) elicited by intermittent photic simulation" (6). In other words, PSE occurs in response to what could be thought of as an "overload" of visual stimulus – rapid fluctuations in a light source, repeated oscillations of an object, and particular geometric designs have all been known to provoke epileptic seizures. In daily life, these stimuli can translate to strobe lights, sunlight coming through a tree canopy or glistening off of a body of water, escalators, or even Venetian blinds.

On a positive note, there are many things that are indeed well-documented and confirmed about PSE. It has clearly been proven to be genetically influenced, and it is more common in females than males (7). It is also significantly more prevalent in children, with the principal ages of susceptibility ranging between five and fifteen years (6).

With the rise of LED technology and its applications, beacon traffic signals have become a possible topic of interest among the transportation community. In particular situations, such as an extraordinarily dark location or an extremely busy intersection, reflectivity and standard incandescent beacons are often not enough to capture a driver's attention. To combat this issue, the concept of the rapid flash indication has developed.

The possible advantages of this technological upgrade are obvious. Important messages will be more likely to be received by drivers on the road, consequently making an overall safer traffic situation. Additionally, the longer life and efficiency of an LED will save a notable amount in labor and energy costs in the long-run. However, a clinical evaluation of the effects of a rapid flash indication were beyond the scope and resources of this research effort. The researchers addressed the concerns of PSE on the research subjects by excluding individuals that indicated PSE symptoms.

Light sources that trigger an epileptic seizure, as mentioned before, can either be natural or artificial. With the advent of television, computers, and video games, however, artificial sources of light have rapidly become the primary source, despite the equally adverse potential of natural light.

Perhaps the most popular example of this trend occurred in 1997, "...when 685 children had an epileptic seizure during a highly contrasted scene involving flashing colors in the cartoon show 'Pocket Monsters'" (8). Although many of the victims' symptoms were attributed to a physical response to mass hysteria, an impact of this magnitude on the public serves as a reminder of the care that must be taken when dealing with mechanisms that can be fatally sensitive to certain portions of the public (8).

Upon further examination, researchers have discovered a distinct set of factors that influence the possibility of bringing on a seizure. In no particular order of priority, they include: the frequency of the stimulus, the intensity of the stimulus, the amount of the viewer's field of vision that is exposed to the stimulus, whether the person's eyes are closed, open or blinking, and the background illumination. Sensitivity most commonly exists in the range of five to thirty Hertz (flashes per second) (5). Although this range accounts for at least ninety five percent of the potentially harmful frequencies, extreme cases ranging between three and sixty Hertz have been documented (7). Unfortunately, little qualitative data exists with regard to the factor of a victim's field of vision. All that is known for sure is that the chance of seizure has a positive correlation with the percentage of a viewer's field of vision that is occupied by the stimulating source. This relationship has clearly demonstrated itself through time, as "… more than 60 percent of [European] epileptic photosensitive patients experience their first photosensitive seizure while watching television (6).

Consideration has also been taken for the hypothesis of certain wavelengths of light being more prone to result in seizure than others. As reported by Verrotti, "A superior susceptibility of photoparoxysmal responses to red light was observed in some photosensitive patients but not in others" (6). This finding allows for an increased degree of flexibility in terms of which particular wavelengths could possibly be used in rapid-rate beacons.

2.3 PREVIOUS RESEARCH ON FLASHING RATES

The concept of using a rapid flash to attract attention is not a new one. Luminance and motion transients are known to be effective at capturing attention due to the fact that the visual system is sensitive to abrupt onset, luminance flicker, and rapid motion (9). There is a range of studies and basic information that indicate the appropriate flash rates for gathering a subject's attention. An older study recommended flash rates of 3-10 Hz using a constant rate and found that 4 Hz was the best (10). However, other research has indicated that lower frequency flash rates may not be abrupt enough, as one study found that a frequency of 17 Hz was more attention-capturing than frequencies of 2, 4, or 8 Hz (11). A white paper on warning signal design found a practical limitation on multiple flash patterns, indicating that flashes separated by times in the range of 30-80 msec can cause signal detectability to decrease by as much as 50 percent (12).

A recent study evaluated the potential to use a rapid flash stimulus in the Center High Mount Stop Lamp to improve reaction times (13). In this study, the authors conducted two laboratory experiments in a simulated driving task to measure brake reaction time. The second experiment added a loading task, which was not present in the first experiment. The stimuli were either a steady indication or a 20 cycles per second rapid flash. The results indicated that the 20 Hz stimuli were more attention-capturing than the continuous light (13). Another simulation study by a different author found that reaction times improved when brake lights flashed at a rate of 4 Hz (14).

3.0 EXPERIMENTAL DESIGN AND DATA COLLECTION

This laboratory study measured drivers' ability to detect a flashing stimulus by measuring the response time to various flashing patterns presented across a large screen. In additional to the different flashing patterns, the stimuli were also of different sizes and were presented in three different visual environments: monochromatic black background, monochromatic gray background, and an in-motion colored background. In the experiment, research participants faced a 25 foot wide by 8 foot tall screen upon which the simulated beacons were projected in a variety of locations. While looking for the beacon, research participants were also required to use a steering wheel to keep a tracking triangle between two lines randomly moving across the bottom of the screen. Research participants were instructed to pull a lever on the steering wheel when the beacon appeared. The program recorded the reaction time of each participant along with other pertinent information associated with each individual run. This portion of the report provides additional details about the specific elements of the experimental design and data collection effort.

3.1 EXPERIMENTAL SETUP

The key elements of the experimental set-up included the facility where the experiment was conducted, the beacons evaluated, the background they were presented against, and the participant loading task.

3.1.1 Facility

Researchers conducted this study in the Immersive Visualization Center (IVC) at Texas A&M University. The IVC provides advanced visualization capabilities to researchers at Texas A&M. Based on a semi-rigid, rear projected, curved screen, the IVC facilitates the imaging of very large datasets from a diverse set of disciplines. This particular configuration is the first such installation in the Western Hemisphere. The screen has the following specifications: 25×8 foot semi-rigid curved screen (12 foot radius), 3 projectors, and RT display management. The system is driven by a workstation running Linux. The IVC is housed in facilities provided by the Department of Geology and Geophysics and is operated by the Institute for Scientific Computation. Figure 2 is a photograph of the IVC facility.

3.1.2 Beacons

Simulated beacons were projected onto the screen with variations in size, location, and flashing pattern. Each of these characteristics is described in more detail in the following sections. In all cases, the simulated beacons were an amber color consistent with the standard color for a yellow signal indication. The beacon was sized to represent a visual angle equivalent to that of a 12-inch beacon (the standard size) viewed at 100, 200, and 300 feet. The beacons were randomly presented in one of eight locations on the screen.


Figure 2. Immersive Visualization Center where Experiment was Conducted

3.1.2.1 Beacon Color

The color of the beacon stimuli was selected to represent the standard color of an amber LED beacon. The color of the beacon was selected to be in the center of the x,y color box defined by the ITE specification for vehicle traffic control signal heads (15). The appropriate x,y value was determined to be x=0.562 and y=0.430. This was converted to an RGB value (Red = 255, Green = 175, and Blue = 0) using an on-line color calculator so that the proper color would be presented with the projection system (16).

3.1.2.2 Beacon Size

The beacon size on the screen was calculated to represent a 12-inch diameter beacon viewed at distances of 100, 200, and 300 feet. The corresponding angular size of the beacon was 0.573°, 0.286°, and 0.191° for 100, 200, and 300 feet, respectfully.

3.1.2.3 Beacon Location

The beacon was presented in eight different positions on the screen. These eight positions are indicated in Figure 3 and were selected at random during the presentation of the stimuli.

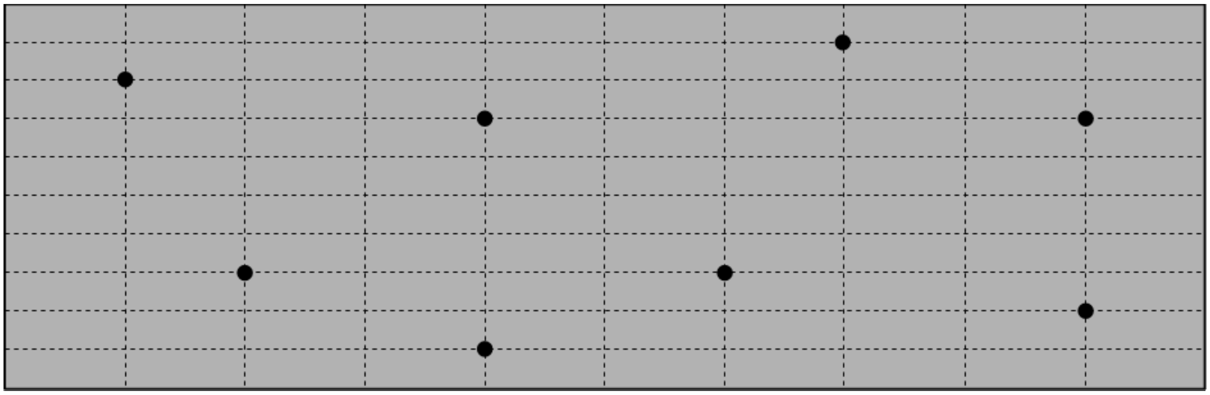

Figure 3. Locations for Beacon Stimuli

3.1.2.4 Beacon Flash Pattern

Beacons patterns were presented in a random order using one of five predefined flashing patterns listed below and illustrated in Figure 4. Patterns B, C, and D represent rapid flash patterns. Pattern C represents the only stutter flash pattern. Pattern A represents a steady indication and Pattern E represents the current standard flash pattern for traffic signals.

- Pattern A (Steady): once on, stays on.
- Pattern B (5×0.10): 0.1 on, 0.1 off, 0.1 on, 0.1 off, 0.1 on, 0.1 off, 0.1 on, 0.1 off, 0.1 on, 0.1 off, 0.1 on, 0.1 off (5 flashes at 0.1 sec each separated by 0.1 sec dark intervals)
- Pattern C (3×0.10): 0.1 on, 0.1 off, 0.1 on, 0.1 off, 0.1 on, 0.5 off (3 flashes at 0.1 sec each separated by 0.1 sec dark intervals followed by 0.5 sec dark interval)
- Pattern D (2×0.25): 0.25 on, 0.25 off, 0.25 on, 0.25 off (2 flashes at 0.25 sec each separated by 0.25 sec dark intervals)
- Pattern E (1×0.50): 0.5 on, 0.5 off (1 flash at 0.5 sec followed by 0.5 sec dark interval) Standard flash pattern

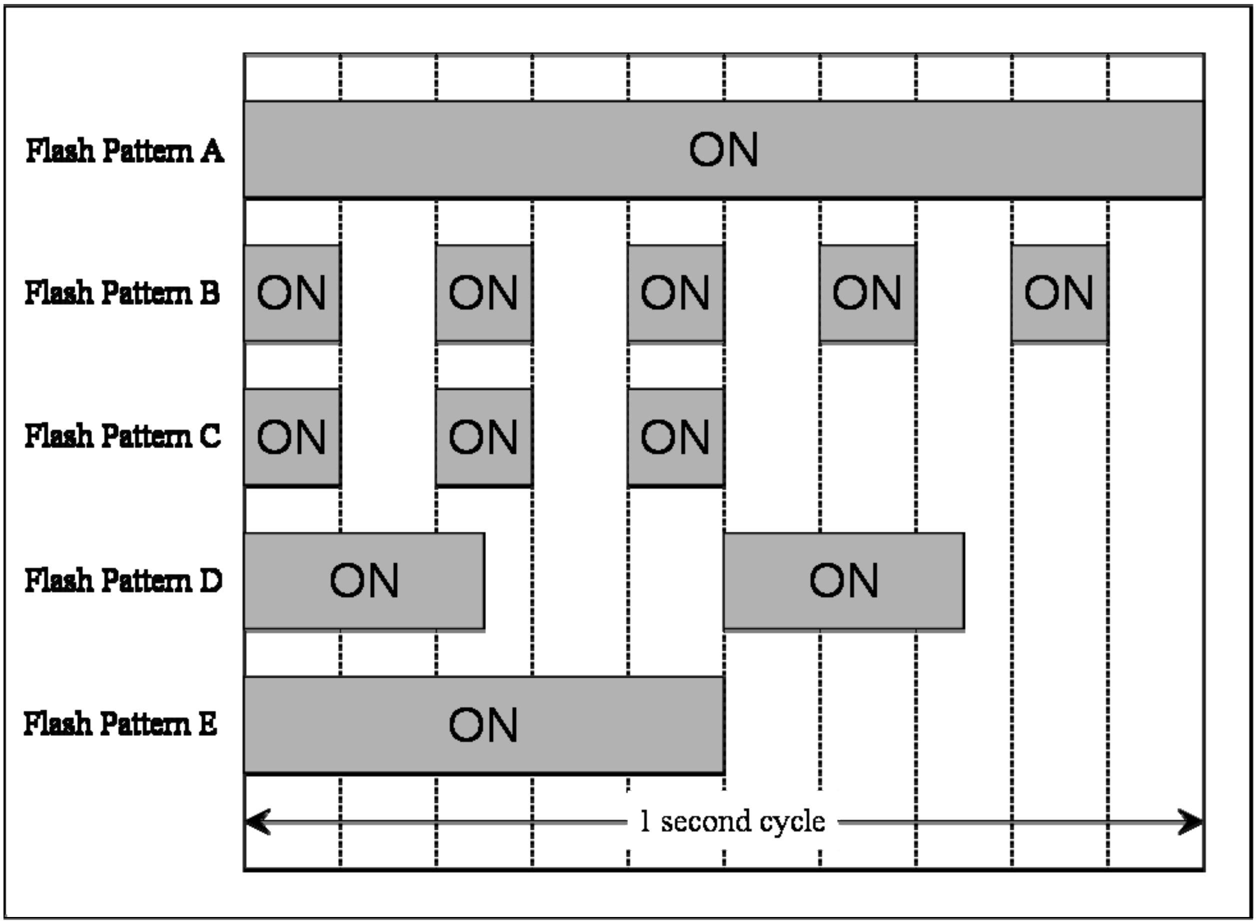

Figure 4. Illustration of Beacon Flash Patterns

3.1.3 Backgrounds

The flashing beacons were presented against three backgrounds: black, gray, and a multi-colored moving background. The color elements of the moving background shifted constantly in a manner similar to that used as the moving background (skin) in a computer media player. These backgrounds are presented in Figure 5, Figure 6, Figure 7, and Figure 8. Figure 7 and Figure 8 also provide an illustration of the difference between the 300 foot beacon size (Figure 7) and the 100 foot beacon size (Figure 8). In each of these figures, the beacon stimulus is circled to make it easier to find in the figure.

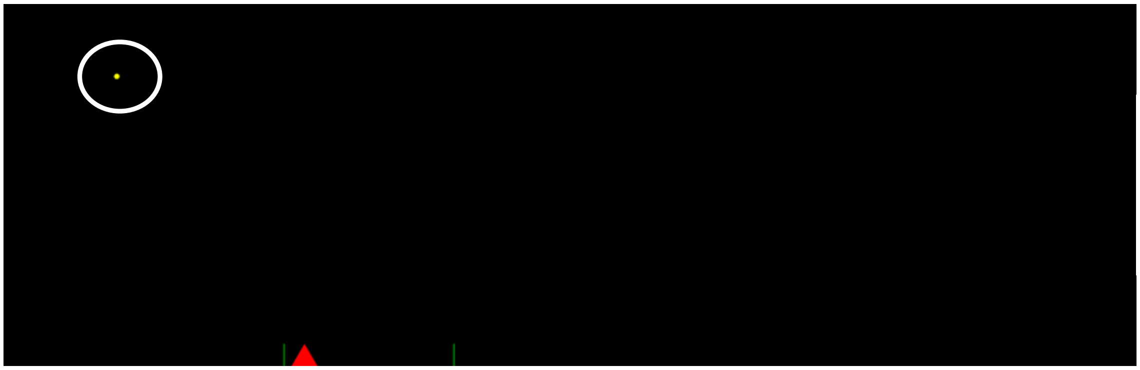

Figure 5. Black Background

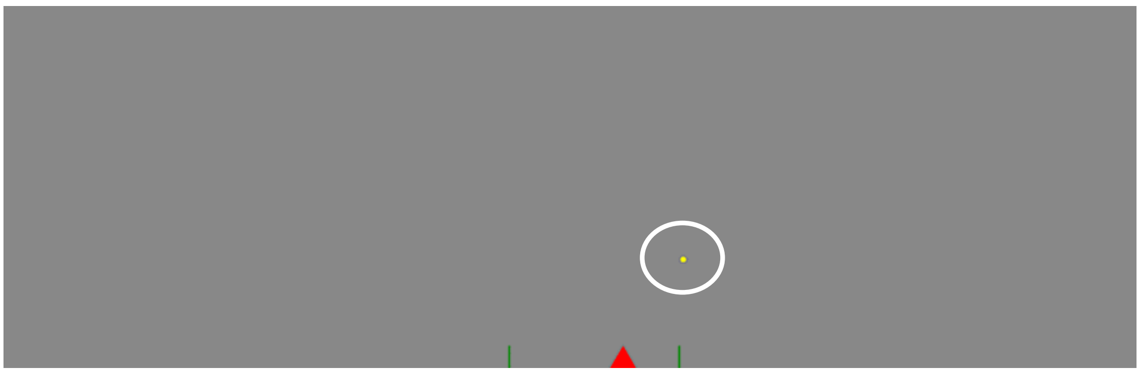

Figure 6. Gray Background

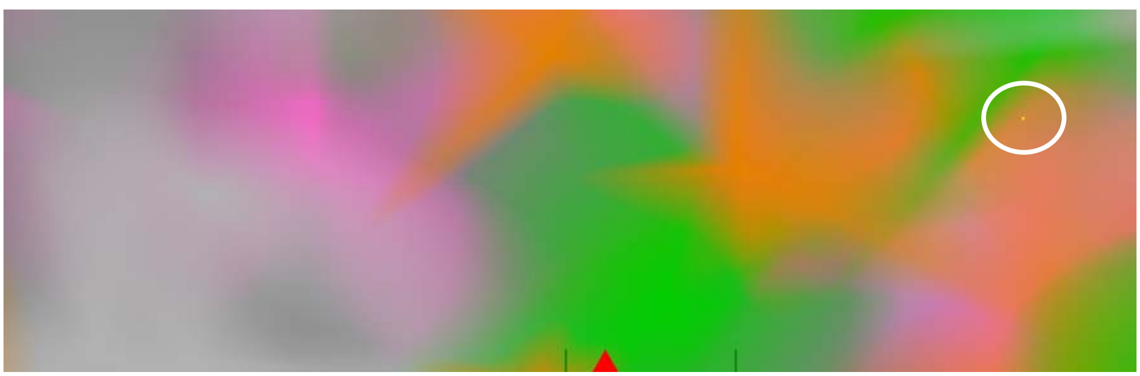

Figure 7. Multi-Colored Moving Background – Image 1

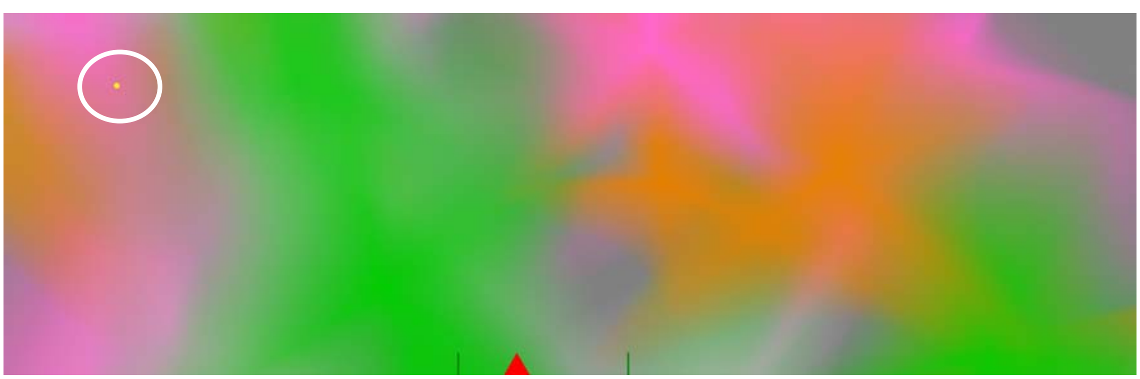

Figure 8. Multi-Colored Moving Background – Image 2

3.1.4 Participant Loading Task

The original experimental set-up used only a simple push button for research participants to indicate when the beacon appeared and did not include any type of task loading. In pilot testing, researchers found the task of locating the beacon too simple and so they revised the experimental design to add a task loading effort that would require research participants to focus their attention on something other than the appearance of the beacon.

The loading task required research participants to use a steering wheel to keep a triangle between two lines that moved across the bottom of the screen in a random manner. Figure 5 through Figure 8 illustrate the triangle and the tracking lines. Repeated pilot efforts were required to determine the most appropriate distance between the tracking lines – 15 percent of the screen width (3.75 feet).

The steering wheel used in the experiment was a Force Feedback Wheel, as illustrated in Figure 9. The wheel used a clamp to secure it in place and minimize shifting during use. The steering wheel and participant were placed approximately 12 feet from the screen. Research participants were able to guide the direction of a constantly moving triangle at the bottom of the screen by using the steering device. Research participants were asked to keep the triangle within two moving lines to their best ability. The steering wheel was also equipped with levers on the underside which participants would pull in response to seeing a flashing beacon appear on the screen. Figure 10 presents the overall set-up used for the experiment.

Figure 9. Steering Wheel Used in Experiment

Figure 10. Experimental Set-Up

3.1.5 Experimental Procedure

The experimental program consisted of three files, each holding a script to display 360 simulated flashing beacons per background. To discourage driver fatigue, each file was split into two separate files to allow the participant recovery time. The six files were approximately 7 minutes long each, dependent on how quickly the participant responded to each beacon. Participants were provided a practice run to familiarize them with the task and to ensure that they were comfortable with the equipment. The flashing simulated beacons appeared one at a time until the participant indicated he or she saw it by pulling the lever on the steering device. While there were determined locations for the beacon to appear, the computer generated the beacons in random order.

3.1.6 Participant Demographics

A total of 34 research participants from the Bryan-College Station area participated in the study. Recruiting was done by phone, using a local participant pool which included past research participants. Research participants were compensated $20 for the first set and $22 for the second set for their participation at the completion of the testing. Of the 34 research participants recruited, three participants had unusable data due to technical difficulties, and one participant was compensated but not run due to a history of seizures. This provided a total of 30 participants with usable data. The demographic sample of research participants is shown in Table 1.

Table 1. Participant Demographics

Age Group	Male	Female	Total
18-24	1	3	4
25-34	2	2	4
35-44	1	4	5
45-54	0	4	4
55-64	2	2	4
65-74	1	2	3
75+	4	2	6
Total	11	19	30

Participants were instructed to meet the researcher at a designated parking spot on campus and were then accompanied to the IVC. Once in the lab, the participant was read the study protocol and asked to complete a consent form followed by a short demographic questionnaire which collected information on gender, age, seizure history, visual acuity, and contrast sensitivity. The visual characteristics were collected using standard static visual acuity (Snellen) and contrast sensitivity (Vistech) screening tests.

3.2 SEIZURE RISKS

As described in the background chapter, literature has identified that rapid flashing stimuli can instigate a seizure in individuals with photosensitive epilepsy (PSE). Of all persons who have been diagnosed as epileptic, between three and five percent are known to be of the photosensitive type. Symptoms usually first appear during childhood or adolescence, with a peak at the beginning of puberty, and few people have PSE after the age of 20.

Research has shown that not all flashing lights or visual patterns will trigger a seizure, even in individuals who are photosensitive. The rate of the flashing light, the duration of the flashing, and the intensity of the light all play a part. A flash at a frequency of between 15 and 20 flashes per second is most likely to cause a seizure. The rapid flashing warning beacons in general use in the U.S. flash at a rate of 3 flashes in one-half second (6 Hertz) and there have been no reports of seizure episodes that the researchers are aware of.

To manage the risk of a seizure, the researchers took the following steps:

- Only research participants age 20 and over were recruited.
- Potential participants were screened as part of the recruiting effort and individuals with any type of epilepsy were not used in the experiment.
- The flashing rate of any stimuli was limited to 8 or fewer flashes in one second.

4.0 DATA ANALYSIS AND RESULTS

After data collection was completed, it was collated and processed for analysis. The processing included removing data that was incomplete or corrupted (206 runs). Additional Individual runs were removed from the overall data set or the data was modified for the following reasons:

- There were 367 runs where the participant indicated the presence of a beacon when one was not present. These were removed from the data set.
- There were 57 runs where the participant never indicated the presence of a beacon even though one was visible. These were removed from the data set.
- There was one run where the data failed to record. This was removed from the data set.

The result was a set of data that consisted of 10,169 lines. Each line represented one run in the laboratory set-up. Each line of the data set included the following information:

- Participant number
- Run order for that participant
- Participant age
- Participant's visual acuity in left eye
- Participant's visual acuity in right eye
- Participant's contrast sensitivity
- Response time (continuous data), seconds
- Background (Black, Gray, or Moving)
- Simulated distance (100, 200, or 300 feet)
- Flash code letter (or flash pattern, see Table 2)
- Stimulus X location (horizontal location of stimulus, ranges from 0.0 to 1.0)
- Stimulus Y location (vertical location of stimulus, ranges from 0.0 to 1.0)
- Tracking triangle location (horizontal location of triangle representing the loading task, ranges from -35.17 to 9.39, but modified to values from 0 to 1)
- Separation (calculated from the collected data to define the separation in feet between the stimulus and loading task)
- Percent outside task lines (the percent of the run time that the triangle was outside of the lines that represented the loading task)

Table 2. Flash Codes for Flash Patterns

Code	Pattern	Description
A	1.0 on (steady indication)	Steady
B	0.1 on, 0.1 off, 0.1 on, 0.1 off, 0.1 on, 0.1 off, 0.1 on, 0.1 off, 0.1 on, 0.1 off, 0.1 on, 0.1 off (5 flashes at 0.1 sec each separated by 0.1 sec dark intervals)	5×0.10
C	0.1 on, 0.1 off, 0.1 on, 0.1 off, 0.1 on, 0.5 off (3 flashes at 0.1 sec each separated by 0.1 sec dark intervals followed by 0.5 sec dark interval)	3×0.10
D	0.25 on, 0.25 off, 0.25 on, 0.25 off (2 flashes at 0.25 sec each separated by 0.25 sec dark intervals)	2×0.25
E	0.5 on, 0.5 off (1 flash at 0.5 sec followed by 0.5 sec dark interval) Standard flash pattern	1×0.50

The 10,169 line data set was analyzed in several different ways. The following sections give the basic results for the analysis on variations of the total data set. For each analysis, researchers calculated the average response time for a given flash pattern for a specific background and size of stimulus.

4.1 FULL DATA SET

The first analysis was done for the entire cleaned data set of 10,169 lines (defined as Set 1). This analysis includes all the valid data collected for the experiment. No valid data was removed for this analysis even if the data represented unrealistic response times. Figure 11 presents the 95 percent confidence interval for the full data set of 10,169 lines. In this an all succeeding confidence interval plots, the line inside the circle represents the mean value and the upper and lower limits indicate the 95^{th} percentile confidence interval. Figure 12 presents a plot of individual values of the response times which illustrates this relationship.

The mean response times in seconds are presented in Table 3 and the sample sizes are presented in Table 4. Table 5 presents several descriptive statistics for the entire data set of 10,169 lines. The descriptive statistics are the minimum, median, and maximum values for the response time in seconds. A comparison of the data reveals that the mean values shown in Table 3 are significantly greater than the median values shown in Table 5, indicating that the data distribution is skewed. It is clear from the maximum values that some research participants took very long to find the stimulus. This is also indicated in the frequency distribution shown in Table 6.

The Analysis of Variance (ANOVA) for the full data set of 10,169 lines and broken-up subsets of the full data set for different backgrounds and distances are presented in the Appendix. The ANOVA indicates that no one flashing pattern has a statistically significant faster response time than any other flashing pattern at a 95 percent confidence level. The confidence interval plots shown in the ANOVA results in the Appendix are the same as those shown in Figure 11.

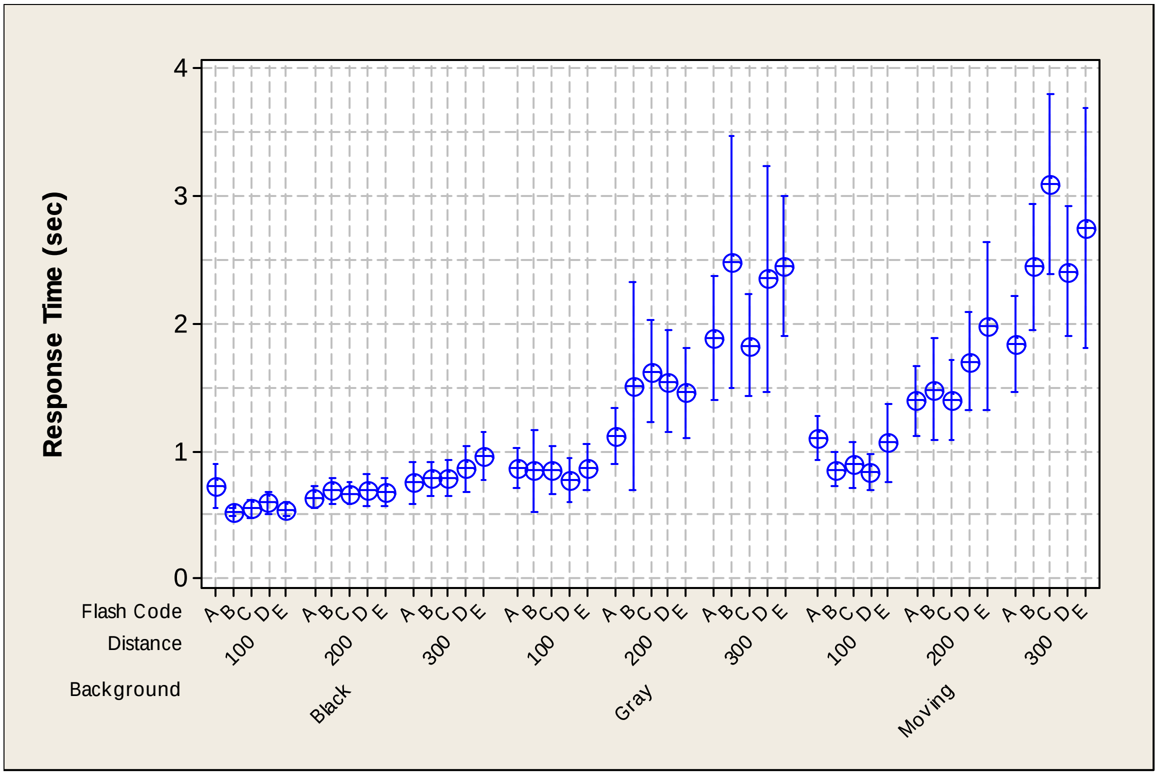

Figure 11. 95 Percent Confidence Interval Plot of Response Time for the Full Data Set (10,169 Lines)

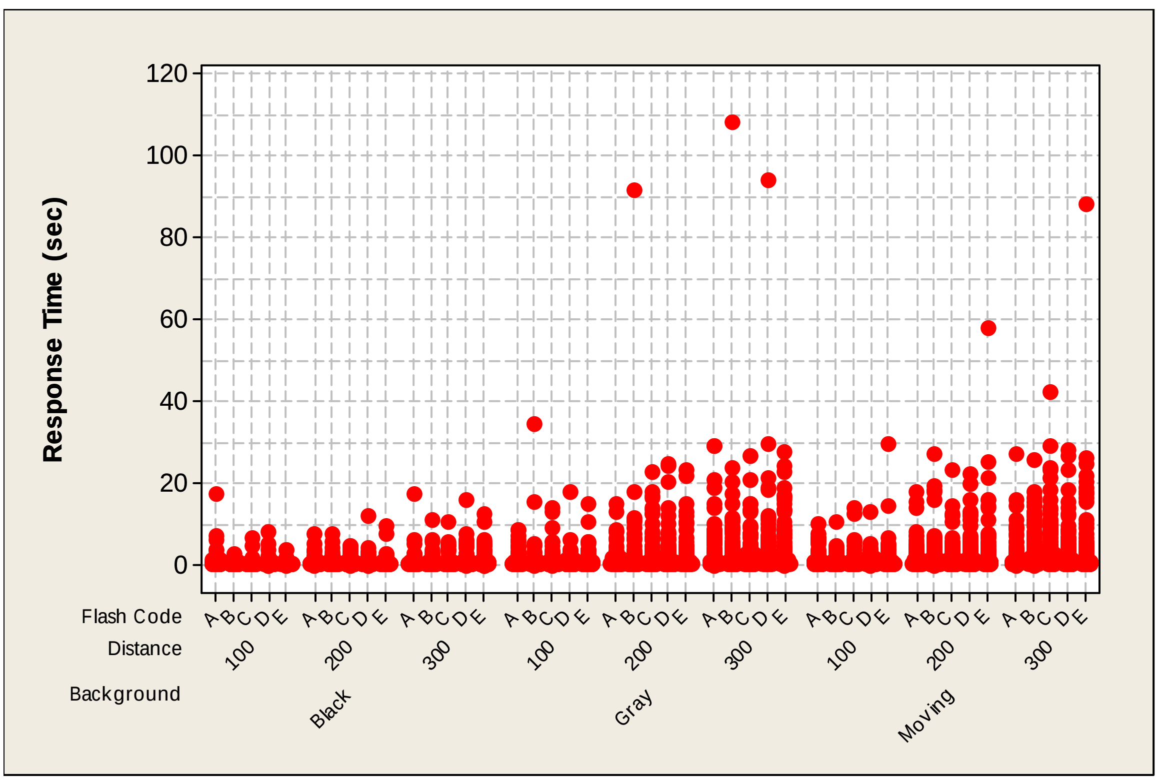

Figure 12. Individual Value Plot of Response Time for the Full Data Set (10,169 Lines)

Table 3. Mean Response Time (sec) for Entire Data Set (10,169 Lines)

Background	**Black**			**Gray**			**Moving**		
Distance (ft)	**100**	**200**	**300**	**100**	**200**	**300**	**100**	**200**	**300**
Flash Pattern A	0.7205	0.6297	0.7430	0.8647	1.1100	1.8800	1.0942	1.3930	1.8380
Flash Pattern B	0.5140	0.6838	0.7784	0.8380	1.4990	2.4860	0.8506	1.4790	2.4410
Flash Pattern C	0.5445	0.6631	0.7792	0.8407	1.6230	1.8210	0.8851	1.3990	3.0860
Flash Pattern D	0.5903	0.6898	0.8584	0.7659	1.5440	2.3480	0.8336	1.7000	2.4050
Flash Pattern E	0.5362	0.6737	0.9493	0.8676	1.4500	2.4470	1.0600	1.9800	2.7450

Table 4. Sample Size for Entire Data Set (10,169 Lines)

Background	**Black**			**Gray**			**Moving**		
Distance (ft)	**100**	**200**	**300**	**100**	**200**	**300**	**100**	**200**	**300**
Flash Pattern A	223	221	227	228	234	230	229	225	219
Flash Pattern B	219	225	223	236	230	234	225	224	215
Flash Pattern C	224	219	217	236	232	233	228	223	208
Flash Pattern D	229	222	225	227	232	234	222	224	223
Flash Pattern E	220	224	232	234	233	234	224	221	222

Table 5. Descriptive Statistics for Response Time (sec) for Entire Data Set (10,169 Lines)

Back-ground	Distance (ft)	100			200			300		
	Statistic	Min	Median	Max	Min	Median	Max	Min	Median	Max
Black	Flash Pattern A	0.218	0.486	17.546	0.070	0.478	7.615	0.221	0.512	17.439
	Flash Pattern B	0.261	0.448	2.958	0.282	0.494	7.773	0.154	0.509	11.255
	Flash Pattern C	0.233	0.456	6.793	0.028	0.480	4.681	0.277	0.516	10.577
	Flash Pattern D	0.067	0.460	8.265	0.056	0.506	12.210	0.118	0.525	16.171
	Flash Pattern E	0.033	0.462	3.887	0.311	0.518	9.785	0.015	0.521	12.602
Gray	Flash Pattern A	0.270	0.501	8.739	0.300	0.621	14.871	0.026	0.690	29.357
	Flash Pattern B	0.025	0.508	34.748	0.224	0.599	92.006	0.350	0.714	108.339
	Flash Pattern C	0.042	0.522	13.852	0.296	0.610	22.716	0.313	0.745	26.875
	Flash Pattern D	0.300	0.501	18.222	0.288	0.586	24.861	0.333	0.802	94.309
	Flash Pattern E	0.295	0.505	15.095	0.291	0.600	23.282	0.016	0.721	27.761
Moving	Flash Pattern A	0.326	0.648	10.284	0.134	0.678	18.032	0.031	0.881	27.322
	Flash Pattern B	0.290	0.554	10.616	0.065	0.623	27.110	0.032	1.038	25.858
	Flash Pattern C	0.282	0.568	13.839	0.301	0.669	23.167	0.340	1.192	42.272
	Flash Pattern D	0.043	0.554	13.259	0.303	0.805	22.582	0.359	1.061	28.329
	Flash Pattern E	0.291	0.555	29.720	0.302	0.678	58.290	0.309	0.865	88.592

Table 6. Frequency Distribution of Response Time (sec) for Entire Data Set (10,169 Lines)

Range	Freq	Range	Freq	Range	Freq	Range	Freq	Range	Freq
0.0 - 0.1	16	>4.4-4.5	15	> 8.8 - 8.9	4	>13.2-13.3	2	> 19.5 - 19.6	1
>0.1 - 0.2	8	>4.5-4.6	21	> 8.9 - 9.0	3	>13.3-13.4	0	> 19.7 - 19.8	1
>0.2 - 0.3	79	>4.6-4.7	18	> 9.0 - 9.1	4	>13.4-13.5	1	> 20.1 - 20.2	1
>0.3 - 0.4	1460	>4.7-4.8	14	> 9.1 - 9.2	3	>13.6-13.7	1	> 20.3 - 20.4	1
>0.4 - 0.5	2346	>4.8-4.9	11	> 9.2 - 9.3	2	>13.7-13.8	4	> 20.5 - 20.6	1
>0.5 - 0.6	1667	>4.9-5.0	8	> 9.3 - 9.4	2	>13.8-13.9	3	> 21.1 - 21.2	2
>0.6 - 0.7	983	>5.0-5.1	8	> 9.4 - 9.5	4	>13.9-14.0	1	> 21.2 - 21.3	1
>0.7 - 0.8	636	>5.1-5.2	10	> 9.5 - 9.6	2	>14.0-14.1	2	> 21.5 - 21.6	2
>0.8 - 0.9	439	>5.2-5.3	7	> 9.6 - 9.7	2	>14.1-14.2	3	> 21.8 - 21.9	1
>0.9 - 1.0	269	>5.3-5.4	7	> 9.7 - 9.8	3	>14.2-14.3	0	> 22.1 - 22.2	1
>1.0 - 1.1	195	>5.4-5.5	7	> 9.8 - 9.9	0	>14.3-14.4	0	> 22.5 - 22.6	1
>1.1 - 1.2	142	>5.5-5.6	9	> 9.9 -10.0	1	>14.4-14.5	2	> 22.7 - 22.8	1
>1.2 - 1.3	103	>5.6-5.7	11	>10.0-10.1	2	>14.5-14.6	1	> 22.9 - 23.0	1
>1.3 - 1.4	111	>5.7-5.8	8	>10.1-10.2	4	>14.6-14.7	3	> 23.1 - 23.2	1
>1.4 - 1.5	126	>5.8-5.9	9	>10.2-10.3	1	>14.7-14.8	0	> 23.2 - 23.3	2
>1.5 - 1.6	113	>5.9-6.0	7	>10.3-10.4	2	>14.8-14.9	2	> 23.5 - 23.6	1
>1.6 - 1.7	117	>6.0-6.1	8	>10.4-10.5	1	>14.9-15.0	2	> 23.8 - 23.9	2
>1.7 - 1.8	74	>6.1-6.2	6	>10.5-10.6	4	>15.0-15.1	4	> 24.2 - 24.3	1
>1.8 - 1.9	69	>6.2-6.3	7	>10.6-10.7	3	>15.3-15.4	3	> 24.5 - 24.6	1
>1.9 - 2.0	60	>6.3-6.4	2	>10.7-10.8	2	>15.4-15.5	1	> 24.7 - 24.8	1
>2.0 - 2.1	47	>6.4-6.5	5	>10.8-10.9	3	>15.5-15.6	1	> 24.8 - 24.9	1
>2.1 - 2.2	24	>6.5-6.6	11	>10.9-11.0	4	>15.7-15.8	1	> 25.2 - 25.3	1
>2.2 - 2.3	24	>6.6-6.7	5	>11.0-11.1	2	>15.8-15.9	3	> 25.8 - 25.9	1
>2.3 - 2.4	38	>6.7-6.8	6	>11.1-11.2	1	>16.1-16.2	3	> 26.4 - 26.5	1
>2.4 - 2.5	57	>6.8-6.9	9	>11.2-11.3	2	>16.2-16.3	1	> 26.8 - 26.9	2
>2.5 - 2.6	53	>6.9-7.0	1	>11.3-11.4	2	>16.5-16.6	2	> 27.1 - 27.2	1
>2.6 - 2.7	39	>7.0-7.1	6	>11.4-11.5	1	>16.6-16.7	2	> 27.3 - 27.4	1
>2.7 - 2.8	42	>7.1-7.2	2	>11.5-11.6	0	>16.7-16.8	1	> 27.7 - 27.8	1
>2.8 - 2.9	31	>7.2-7.3	1	>11.6-11.7	1	>16.8-16.9	1	> 28.3 - 28.4	1
>2.9 - 3.0	29	>7.3-7.4	4	>11.7-11.8	1	>16.9-17.0	1	> 29.1 - 29.2	1
>3.0 - 3.1	28	>7.4-7.5	4	>11.8-11.9	1	>17.3-17.4	1	> 29.2 - 29.3	1
>3.1 - 3.2	16	>7.5-7.6	5	>11.9-12.0	3	>17.4-17.5	2	> 29.3 - 29.4	1
>3.2 - 3.3	16	>7.6-7.7	7	>12.0-12.1	3	>17.5-17.6	1	> 29.7 - 29.8	2
>3.3 - 3.4	22	>7.7-7.8	4	>12.1-12.2	1	>17.8-17.9	1	> 34.7 - 34.8	1
>3.4 - 3.5	28	>7.8-7.9	6	>12.2-12.3	2	>17.9-18.0	1	> 42.2 - 42.3	1
>3.5 - 3.6	30	>7.9-8.0	3	>12.3-12.4	1	>18.0-18.1	2	> 58.2 - 58.3	1
>3.6 - 3.7	29	>8.0-8.1	4	>12.4-12.5	2	>18.1-18.2	2	> 88.5 - 88.6	1
>3.7 - 3.8	19	>8.1-8.2	0	>12.5-12.6	1	>18.2-18.3	1	> 92.0 - 92.1	1
>3.8 - 3.9	17	>8.2-8.3	5	>12.6-12.7	1	>18.3-18.4	2	> 94.3 - 94.4	1
>3.9 - 4.0	21	>8.3-8.4	2	>12.7-12.8	2	>18.5-18.6	1	>108.3 - 108.4	1
>4.0 - 4.1	13	>8.4-8.5	7	>12.8-12.9	2	>18.6-18.7	1		
>4.1 - 4.2	12	>8.5-8.6	0	>12.9-13.0	3	>18.7-18.8	1		
>4.2 - 4.3	12	>8.6-8.7	4	>13.0-13.1	0	>18.8-18.9	2		
>4.3 - 4.4	5	>8.7-8.8	3	>13.1-13.2	3	>18.9-19.0	1		

Note: Frequencies shown in 0.1 second consecutive ranges to 15.0 seconds and only for those categories with frequencies > 0 for response times over 15.0 seconds.

5.0 CONCLUSIONS AND RECOMMENDATIONS

This experiment attempted to identify a flashing pattern for beacons that could be more effective at getting drivers' attention than the current rapid flash pattern of three 0.1 second flashes followed by a half second dark period. To assess the beacon performance, the researchers analyzed a wide range of combinations of the resulting total data set. Based on the analysis described in the previous chapter, the researchers offer the following conclusion:

- No one flashing pattern had a statistically significant (at 95%) faster response time than any other across all scenarios.

REFERENCES

1. *Manual on Uniform Traffic Control Devices for Streets and Highways*. American Association of State Highway Officials, National Conference on Street and Highway Safety. Washington, D.C., November 1935, reprinted September 1937.
2. *Manual on Uniform Traffic Control Devices for Streets and Highways*. Public Roads Administration. Washington, D.C.: August 1948.
3. *Manual on Uniform Traffic Control Devices for Streets and Highways*. U.S. Department of Transportation, Washington, D.C., 2003.
4. Harding, Graham. Photosensitive Epilepsy. London: Mac Keith Press, 1994.
5. "Information on Epilepsy: Photosensitive Epilepsy." NSE: Information on Epilepsy: Photosensitive Epilepsy. September 2002. <http://www.epilepsynse.org.uk/pages/info/leaflets/photo.cfm>.
6. Verrotti, Alberto. "Photosensitivity and Epilepsy." Journal of Child Neurology 19 (2004): 571.
7. Harding, G. and S. Seri. "Photosensitive Epilepsy." Epilepsy Action: Photosensitive Epilepsy. 28 October 2005. <http://www.epilepsy.org.uk/info/photo.html>.
8. Bosch, Xavier. "Visually Induced Epilepsy Explained." The Lancet 355 (2000): 728.
9. Franconeri, S. L., Hollingworth, A., & Simons, D. J. Do new objects capture attention? Psychological Science, 16, 2005, pp. 275–281.
10. Woodson, W. E., & Conover, D. W. Human engineering guide for equipment designers (2nd ed.). Berkeley, CA: University of California Press, 1964.
11. Dougherty, R. F., Smith, A., Verardo, M. R., & Mayer, M. J. Visual search for flicker: high temporal frequency targets capture attention. Investigative Ophthalmology and Visual Science, 37, S296, 1996.
12. Theodore E. Cohn. Integration by the Human Eye: Implications for Warning Signal Design. Working Paper. UCTC No. 207, University of California Transportation Center, 1993.
13. William P. Berg, Eric D. Berglund, Adam J. Strang, Matthew J. Baum. Attention-capturing properties of high frequency luminance flicker: Implications for brake light conspicuity. Transportation Research Part F 10, 2007, pp. 22–32.
14. Elschner, H. (1992). Optimization of rear signals in cars and trucks. Research project of Daimler-Benz, Inc. Unpublished study cited in Gail, Lorig, Gelau, Heuzeroth, & Sievert, 2001 [Gail, J., Lorig, M., Gelau, C., Heuzeroth, D., & Sievert, W. Optimization of rear signal pattern for reduction of rear-end accidents during emergency braking maneuvers. Bundesanstalt fur Straßenwesen, Bergisch Gladbach (Germany). Heft F39. Report No.: 3897018179/0943-9307, 2001.]
15. Purchase Specification for Vehicle Traffic Control Signal Heads - Light Emitting Diode (LED) Circular Signal Supplement, Institute of Transportation Engineers, Washington, D.C., June 8, 2005.
16. Easy RGB Color Calculator, http://www.easyrgb.com/index.php?X=CALC, Accessed March 24, 2007.

APPENDIX: STATISTICAL ANALYSIS OF FULL DATA SET

The information in this appendix presents the Analysis of Variance (ANOVA) for the full data set of 10,169 lines of data. The ANOVA analysis was done with a confidence interval of 95 percent.

FULL DATA SET, ALL BACKGROUNDS, ALL DISTANCES (10,169 LINES)

```
Source          DF        SS    MS     F       P
Flash Code       4      76.2  19.0  1.93  0.102
Error        10164  100105.2   9.8
Total        10168  100181.3
S = 3.138   R-Sq = 0.08%   R-Sq(adj) = 0.04%

                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level     N   Mean  StDev  ---+---------+---------+---------+------
A      2036  1.142  2.055  (--------*--------)
B      2031  1.286  3.895            (--------*--------)
C      2020  1.283  2.610           (---------*--------)
D      2038  1.308  3.202             (--------*--------)
E      2044  1.413  3.572                    (--------*--------)
                           ---+---------+---------+---------+------
                            1.05      1.20      1.35      1.50
Pooled StDev = 3.138
```

BLACK BACKGROUND ONLY, ALL DISTANCES (3,350 LINES)

```
Source         DF        SS     MS     F      P
Flash Code      4     2.301  0.575  0.63  0.644
Error        3345  3075.187  0.919
Total        3349  3077.488
S = 0.9588   R-Sq = 0.07%   R-Sq(adj) = 0.00%

                            Individual 95% CIs For Mean Based on
                            Pooled StDev
Level    N    Mean   StDev  --+---------+---------+---------+-------
A      671  0.6982  1.1399        (-----------*-----------)
B      667  0.6597  0.7566  (-----------*-----------)
C      660  0.6610  0.7781  (-----------*-----------)
D      676  0.7122  1.0440           (-----------*-----------)
E      676  0.7235  1.0101             (-----------*-----------)
                            --+---------+---------+---------+-------
```

Black Background, Distance = 100 Feet (1,115 lines)

```
Source        DF       SS     MS     F      P
Flash Code     4    6.079  1.520  2.72  0.029
Error       1110  620.637  0.559
Total       1114  626.717
S = 0.7478   R-Sq = 0.97%   R-Sq(adj) = 0.61%

                            Individual 95% CIs For Mean Based on
                            Pooled StDev
Level    N    Mean   StDev  -----+---------+---------+---------+----
A      223  0.7205  1.3462                   (-------*-------)
B      219  0.5140  0.2616  (-------*-------)
C      224  0.5445  0.5406    (-------*--------)
D      229  0.5903  0.6830        (-------*-------)
E      220  0.5362  0.3817   (--------*-------)
                            -----+---------+---------+---------+----
                               0.48      0.60      0.72      0.84
Pooled StDev = 0.7478
```

Black Background, Distance = 200 Feet (1,111 lines)

```
Source        DF       SS     MS     F      P
Flash Code     4    0.498  0.125  0.21  0.935
Error       1106  667.604  0.604
Total       1110  668.102
S = 0.7769   R-Sq = 0.07%   R-Sq(adj) = 0.00%

                            Individual 95% CIs For Mean Based on
                            Pooled StDev
Level    N    Mean   StDev  -----+---------+---------+---------+----
A      221  0.6297  0.6753  (--------------*-------------)
B      225  0.6838  0.7597          (--------------*-------------)
C      219  0.6631  0.6418       (--------------*-------------)
D      222  0.6898  0.9337           (--------------*-------------)
E      224  0.6737  0.8351         (-------------*--------------)
                            -----+---------+---------+---------+----
                               0.560     0.630     0.700     0.770
Pooled StDev = 0.7769
```

Black Background, Distance = 300 Feet (1,124 lines)

```
Source        DF       SS    MS     F      P
Flash Code     4     6.29  1.57  1.01  0.401
Error       1119  1742.94  1.56
Total       1123  1749.23
S = 1.248   R-Sq = 0.36%   R-Sq(adj) = 0.00%

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level    N   Mean  StDev   -+---------+---------+---------+--------
A      227  0.743  1.273   (----------*---------)
B      223  0.778  1.016     (----------*----------)
C      217  0.779  1.050     (----------*----------)
D      225  0.858  1.383          (----------*----------)
E      232  0.949  1.443                 (---------*---------)
                           -+---------+---------+---------+--------
                          0.60      0.75      0.90      1.05
Pooled StDev = 1.248
```

GRAY BACKGROUND ONLY, ALL DISTANCES (3,487 LINES)

```
Source        DF       SS    MS     F      P
Flash Code     4     51.7  12.9  0.82  0.513
Error       3482  54954.3  15.8
Total       3486  55005.9
S = 3.973   R-Sq = 0.09%   R-Sq(adj) = 0.00%

                          Individual 95% CIs For Mean Based on Pooled StDev
Level    N   Mean  StDev    +---------+---------+---------+---------
A      692  1.285  2.496    (----------*-----------)
B      700  1.606  5.932                (-----------*-----------)
C      701  1.425  2.706         (-----------*-----------)
D      693  1.561  4.513               (----------*-----------)
E      701  1.588  3.124                (-----------*----------)
                            +---------+---------+---------+---------
                          1.00      1.25      1.50      1.75
Pooled StDev = 3.973
```

Distance = 100 Feet (1,161 lines)

```
Source        DF       SS    MS     F      P
Flash Code     4     1.55  0.39  0.14  0.966
Error       1156  3127.72  2.71
Total       1160  3129.26
S = 1.645   R-Sq = 0.05%   R-Sq(adj) = 0.00%

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level    N   Mean  StDev  ---+---------+---------+---------+------
A      228  0.865  1.197        (--------------*-------------)
B      236  0.838  2.475       (-------------*-------------)
C      236  0.841  1.472       (-------------*-------------)
D      227  0.766  1.316  (-------------*-------------)
E      234  0.868  1.409         (-------------*-------------)
                          ---+---------+---------+---------+------
                           0.60      0.75      0.90      1.05
Pooled StDev = 1.645
```

Distance = 200 Feet (1,161 lines)

```
Source        DF       SS    MS     F      P
Flash Code     4     36.6   9.2  0.66  0.621
Error       1156  16059.7  13.9
Total       1160  16096.3
S = 3.727   R-Sq = 0.23%   R-Sq(adj) = 0.00%

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level    N   Mean  StDev  ----+---------+---------+---------+-----
A      234  1.110  1.701  (-----------*-----------)
B      230  1.499  6.295          (-----------*------------)
C      232  1.623  3.125              (-----------*-----------)
D      232  1.544  3.117            (-----------*-----------)
E      233  1.450  2.796         (-----------*-----------)
                          ----+---------+---------+---------+-----
                            0.80      1.20      1.60      2.00
Pooled StDev = 3.727
```

Distance = 300 Feet (1,165 lines)

```
Source        DF       SS    MS     F      P
Flash Code     4     95.6  23.9  0.80  0.524
Error       1160  34601.8  29.8
Total       1164  34697.4
S = 5.462   R-Sq = 0.28%   R-Sq(adj) = 0.00%

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level    N   Mean  StDev   -+---------+---------+---------+--------
A      230  1.880  3.723    (----------*-----------)
B      234  2.486  7.686              (----------*-----------)
C      233  1.821  3.105   (----------*-----------)
D      234  2.348  6.924           (-----------*-----------)
E      234  2.447  4.274             (-----------*----------)
                           -+---------+---------+---------+--------
                          1.20      1.80      2.40      3.00
Pooled StDev = 5.462
```

MOVING BACKGROUND ONLY, ALL DISTANCES (3,332 LINES)

```
Source        DF       SS    MS     F      P
Flash Code     4     91.1  22.8  1.89  0.110
Error       3327  40185.9  12.1
Total       3331  40277.0
S = 3.475   R-Sq = 0.23%   R-Sq(adj) = 0.11%

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level    N   Mean  StDev   -+---------+---------+---------+--------
A      673  1.436  2.188   (--------*--------)
B      664  1.578  2.863        (--------*-------)
C      659  1.754  3.446              (-------*--------)
D      669  1.648  2.919          (--------*--------)
E      667  1.926  5.203                   (--------*--------)
                           -+---------+---------+---------+--------
                          1.20      1.50      1.80      2.10
Pooled StDev = 3.475
```

Distance = 100 Feet (1,128 lines)

```
Source        DF       SS    MS     F      P
Flash Code     4    13.66  3.41  1.51  0.198
Error       1123  2544.55  2.27
Total       1127  2558.21
S = 1.505   R-Sq = 0.53%   R-Sq(adj) = 0.18%

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level    N   Mean  StDev  --------+---------+---------+---------+-
A      229  1.094  1.346              (---------*--------)
B      225  0.851  1.006   (---------*--------)
C      228  0.885  1.375    (---------*---------)
D      222  0.834  1.084  (---------*---------)
E      224  1.060  2.334             (---------*---------)
                          --------+---------+---------+---------+-
                                0.80      1.00      1.20      1.40
Pooled StDev = 1.505
```

Distance = 200 Feet (1,117 lines)

```
Source        DF       SS    MS     F       P
Flash Code     4     55.9  14.0  1.34  0.254
Error       1112  11636.2  10.5
Total       1116  11692.1
S = 3.235   R-Sq = 0.48%   R-Sq(adj) = 0.12%

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level    N   Mean  StDev  ------+---------+---------+---------+---
A      225  1.393  2.107  (----------*---------)
B      224  1.479  3.056    (----------*----------)
C      223  1.399  2.398  (----------*----------)
D      224  1.700  2.887          (----------*---------)
E      221  1.980  4.966                 (----------*---------)
                          ------+---------+---------+---------+---
                              1.20      1.60      2.00      2.40
Pooled StDev = 3.235
```

Distance = 300 Feet (1,087 lines)

```
Source        DF       SS    MS     F       P
Flash Code     4    183.5  45.9  2.03  0.089
Error       1082  24498.8  22.6
Total       1086  24682.3
S = 4.758   R-Sq = 0.74%   R-Sq(adj) = 0.38%

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level    N   Mean  StDev  ---+---------+---------+---------+------
A      219  1.838  2.832  (--------*--------)
B      215  2.441  3.645           (--------*--------)
C      208  3.086  5.173                    (--------*--------)
D      223  2.405  3.853          (--------*--------)
E      222  2.745  7.078               (--------*--------)
                          ---+---------+---------+---------+------
                           1.40      2.10      2.80      3.50
Pooled StDev = 4.758
```