VISIBILITY OF TWO-WHEELED MOTORISTS APPROACHING LEFT TURNING VEHICLES UNDER NIGHTTIME CONDITIONS

by

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A thesis submitted to the faculty of
The University of North Carolina at Charlotte
in partial fulfillment of the requirements
for the degree of Master of Science in
Engineering

Charlotte

2014

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ABSTRACT

HEATH COREY SPIVEY. Visibility of two-wheeled motorists approaching left turning vehicles under nighttime conditions.
(Under the direction of DR. SRINIVAS S. PULUGURTHA)

The number of fatal crashes on United States roadways has declined substantially since 2002, yet the number of fatalities involving two-wheeled motorists has consistently increased over the same period. Examining incidents involving a two-wheel motor vehicle and a passenger vehicle indicates passenger car drivers often fail to recognize an oncoming two-wheeler and unintentionally violate their right of way. This reoccurring scenario has raised questions surrounding the visual performance capabilities of drivers. Numerous studies have investigated ways to increase the conspicuity of two-wheelers under daytime conditions, such as adding daytime running lights, but only a few have analyzed their conspicuity under nighttime conditions. The aim of this study was to evaluate the visibility of several hazards that drivers encounter at urban intersections under nighttime conditions, including passenger vehicles and two-wheeled motorists. The 30 participants who took part in this study interacted with a low fidelity simulator which presented a series of videos from a driver’s perspective while the vehicle was positioned in the permitted left turn lane at a signalized intersection. During each video the participant was instructed to determine whether a left turn maneuver was safe to make given the current traffic conditions. If a hazard was present, such as an oncoming vehicle or a pedestrian, participants were asked to identify the hazard. The response times for each participant were recorded, for a total of 627 responses.

The results indicate there is no significant difference in a driver's ability to recognize a two-wheeled motorist compared to a passenger vehicle at urban intersections where street lighting is installed. Therefore, the conspicuity issues for two-wheelers in daytime and nighttime conditions are not the same. Furthermore, the same treatments proposed for two-wheelers in daytime conditions may not be as beneficial or even needed during nighttime driving. However, analysis of other hazards revealed that as a hazard becomes more complex and is no longer emitting light, recognition time is extended. Future studies are proposed to determine if the same results hold true at rural intersections where artificial lighting is not provided.

ACKNOWLEDGEMENTS

As with many accomplishments in life, this research study could not be completed without the help and guidance of several important people. First, I would like to express my gratitude to Dr. Srinivas S. Pulugurtha for his direction, insight, and helpful comments which made the report better. I would also like to thank Dr. Martin R. Kane and Mr. David W. Naylor for agreeing to be members of my committee.

This study would not have been possible without the support of my employer, Brian K. Anders, president of DELTA [v] Forensic Engineering, Inc. Thank you for your financial contribution and your understanding of the time needed to complete such a project.

Finally, I would like to thank my wife, Brooke Spivey, for her emotional support during the study and willingness to provide helpful input along the way. Without your continuous encouragement, this report would not have been completed.

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CHAPTER 1: INTRODUCTION

In 2012, two-wheeled motorists were 26 times more likely to be involved in a fatal crash compared to passenger vehicle occupants. This is based on a fatality rate of 23.27 for two-wheeled motorists and 0.89 for passenger vehicles per 100 million miles traveled. A total of 4,957 two-wheeled motorists were killed in motor vehicle crashes in 2012, which represents 15 percent of all motor vehicle fatalities. However, two-wheelers only accounted for three percent of all registered vehicles and 0.7 percent of all vehicle miles traveled (National Highway Traffic Safety Administration, 2012). Although the number of fatalities on United States roadways has continued to decline since 2002 (Figure 1), the number of two-wheeled motorists' fatalities has increased every year with the exception of 2009.

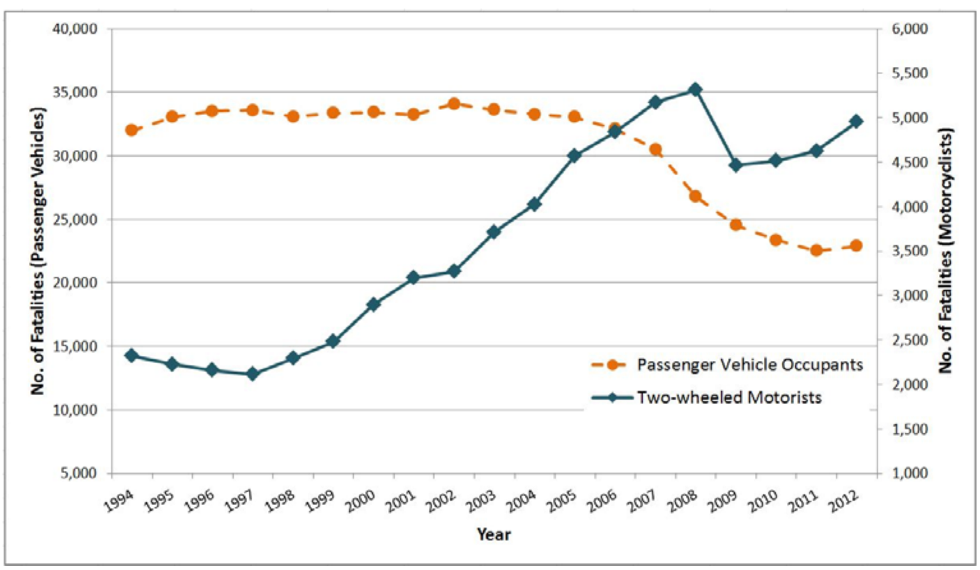


FIGURE 1: Motor vehicle fatalities from passenger vehicles and motorcycles[1]

[1] Source: NHTSA – Fatality Analysis Reporting System (FARS)

It is obvious two-wheelers offer much less protection to their operator than do passenger cars and trucks. Consequently, two-wheeled motorists are more likely to suffer incapacitating injuries when a collision occurs. Since protection on a two-wheeler cannot be changed considerably, safety improvements have focused on understanding why certain types of incidents occur.

The most reoccurring collision involving a two-wheeled motor vehicle is a passenger vehicle maneuvering into the path of an oncoming two-wheeler (Pai, Hwang, & Saleh, 2009). In 2012, there were 2,317 fatal crashes involving a two-wheeler and one other type of vehicle. In 41 percent of those crashes, the other vehicle was making a left turn while the motorcycle was going straight, passing, or overtaking the vehicle (National Highway Traffic Safety Administration, 2012).

This collision scenario has been the topic of numerous research studies and is commonly referred to as the “looked-but-failed-to-see” phenomenon (Hills, 1980; Pai, Hwang, & Saleh, 2009). It involves a vehicle which is initially traveling in the opposite direction of a two-wheeler and is preparing for a left turn maneuver. The motorist violates the two-wheeler’s right-of-way and often reports they either did not see the vehicle or saw it after it was too late to avoid the collision. The contributing factors to these collisions often involve a motorist’s visual perception (i.e., what the left turning driver saw or should have seen and at what distance the hazard was easily identifiable). During litigation, it is often necessary to compare a driver’s recollection of what occurred to research studies in order to make a determination as to when a reasonably alert driver should have detected the hazard (Klein & Stephens, 1992). Motorists rely on visual cues such as the frontal surface area of a vehicle, identifying lights, and the pace at which the vehicle is approaching to determine when it is acceptable to complete a turn maneuver. Based on size alone, two-wheeled vehicles are less conspicuous compared to passenger vehicles and trucks. Add a cluttered environment, such as an urban street or a vehicle following a two-wheeler and the time necessary for detection is extended (Smither & Torrez, 2010).

Several relationships have been explored to help explain why motorists fail to see oncoming two-wheeled vehicles. The most common involves sensory and cognitive conspicuity (Rogé, Douissembekov, & Vienne, 2012). Sensory conspicuity refers to contrast, how well does a vehicle blend with the background scene because of its size, color, brightness, etc. This is also referred to as visual or attention conspicuity (Haferkemper, Sprute, Schiller, & Khanh, 2010). It is the ability of a vehicle to attract the visual attention of a driver based on its physical properties. Many studies have shown that daytime running lights help increase the visual conspicuity of two-wheelers (Smither & Torrez, 2010; Haferkemper, Sprute, Schiller, & Khanh, 2010; Shadeed, Gkritza, & Marshall, 2012). Additionally, a rider may choose to wear retro-reflective clothing or add additional lighting to their vehicle to increase conspicuity. Under nighttime conditions, conspicuity of a vehicle is largely provided by the vehicle's headlights because the other visual cues are not available to a driver unless street lighting is installed.

A number of researchers have suggested that the "looked-but-failed-to-see" phenomenon is not exclusively a result of sensory conspicuity (Rogé, Douissembekov, & Vienne, 2012; Hancock, Wulf, Thom, & Fassnacht, 1990). They propose a contributing factor to this type of collision deals with cognitive or search conspicuity. This refers to a driver's ability to detect an oncoming vehicle based on their past experiences and expectation of a hazard appearing. Driver expectancy is a very subjective term, because no one other than the individual knows what a person is expecting to encounter as they are driving. However, it is possible some drivers may have inappropriate expectations about what types of hazards are likely to be encountered based on their previous experience or infrequent exposure to certain hazards. For example, a motorist will likely be very attentive to pedestrians while traveling in an urban downtown environment but may not expect pedestrians to appear on the interstate. Research has shown that drivers with motorcycle riding experience detect two-wheeled motorists sooner than non-motorcycle motorists (Rogé, Douissembekov, & Vienne, 2012). Expectations of two-wheeled vehicles can change with the time of year. Typically, there is a higher volume of two-wheeled vehicles during the spring and summer months compared to winter time. Many states display messages on their variable message signs to alert drivers of the increased presence of motorcycles during this time.

Conspicuity also plays a role in the judgment of speed. During daylight hours drivers may use cues from both the vehicle and the environment to judge the speed of an oncoming vehicle, such as how quickly a vehicle passes a stationary object or the skip lines on a roadway. During nighttime conditions, the primary and potentially sole vehicle cue is the vehicle’s headlights. When a vehicle with two headlights is approaching, drivers may use the expansion rate of the headlights as an indication of speed (Olson, Dewar, & Farber, 2010). For example, if the headlights appear close together, the vehicle is far away; as the vehicle gets closer, the headlights appear to spread apart. Evaluating how quickly the headlights are spreading apart can be a cue to the driver as to the speed of the vehicle. Two-wheelers are normally traveling with only one operating headlamp, which may reduce a motorists' ability to judge its speed accurately. Research has shown that a single light provides poor cues to both location and speed. A change in the apparent size and brightness of a single light source is more difficult to detect than changes in the angular separation between two lights (Donne, 1990). Drivers may also have expectations as to how fast vehicles travel on a certain roadway. If an oncoming vehicle is traveling well above the posted speed limit and violates the expectation of the driver, it may influence when a driver begins what he or she believes is a safe turn maneuver.

The majority of published research on the recognition of two-wheeled motorists to date has focused on motorcycle conspicuity under daytime conditions. This was either in preparation for legislation requiring daytime running lights or conducting before and after studies on daytime running lights. A journal article by Chih-Wei Pai in 2011 performed an in depth comparison of 17 motorcycle right-of-way crash studies (Pai C. W., 2011). Only two of the research studies considered two-wheeled motorists traveling during nighttime conditions. By design humans do not function well in low light conditions. Illumination provided by a vehicle's headlights, fixed lighting installations, and often a combination of the two is needed for nighttime motor vehicle operation.

1.1 Study Objectives

This study aims to evaluate the nighttime visibility of ordinary two-wheeled vehicles by quantifying their detection and identification rate by way of a response time. The motivation for the study was to understand how drivers perceive two-wheeled motorists compared to passenger vehicles and to answer two key questions: Do the same issues exist in daytime conspicuity compared to nighttime? Will the same results be found in a nighttime study compared to the daytime studies?

1.2 Organization of Report

This report is divided into four remaining chapters. Chapter 2 presents a review of the most noteworthy literature related to two-wheeler conspicuity in both daytime and nighttime conditions. Methodologies are discussed in order to demonstrate how visibility has been measured in the past. Chapter 3 describes the methodology used in this study including site selection, video capturing and processing, recruitment tools, and the process used to capture response times. Chapter 4 presents the results and statistical significance of each scenario shown to the participants. Finally, Chapter 5 provides an in-depth discussion of the results and how they compare to prior research. It also provides recommendations for future studies to further understand nighttime visibility of two-wheeled motorists.

CHAPTER 2: LITERATURE REVIEW

Many of the methods used in this study have been accepted into peer reviewed publications in the past. A detailed description of the most influential and closely related studies is provided in this chapter. Previous research has attempted to quantify the conspicuity of motorcycles and other two-wheelers in various ways. They include analysis of crash reports, capturing response times to static images and video, and gap-acceptance studies.

Researchers began investigating daytime running lights on motorcycles as early as the 1970s. Hurt, Jr. and DuPont (Hurt, Jr. & DuPont, 1977) were sponsored by the National Highway Traffic Safety Administration to investigate motorcycle crash causation factors and to identify countermeasures. Their research is known as the most comprehensive and in-depth motorcycle study of its time. The research consisted of on-scene investigations of at least 900 motorcycle crashes and the acquisition of at least 3600 police traffic crash reports for comparison. A portion of their research focused on the human factor problems that are specific to motorcycle conspicuity. The authors report the most common crash investigated during their research was an intersection collision with an automobile violating the right-of-way of a motorcycle, usually by turning left in front of the oncoming motorcycle. The recognition of a motorcycle depends largely on the contrast between the motorcycle and its background. The countermeasure for this problem is to increase the contrast conspicuity of both the motorcycle and rider. The data collected during the study showed that motorcycles not using the daytime running lights were overrepresented in the crash population. The authors attribute the improved conspicuity of daytime running lights to the bouncing and flickering of a moving motorcycle's headlamp which made it more attention-getting in traffic.

One of the earliest researchers in the field of human factors relating to automobile crashes is Paul Olson. He is also one of the few authors to explore the conspicuity of two wheeled motor vehicles under nighttime conditions. In a 1981 study, Olson, Halstead-Nussloch, and Sivak (Olson, Halstead-Nussloch, & Sivak, 1981) evaluated several motorcycle conspicuity treatments and their ability to deter motorists from accepting short time gaps. Known as a gap-acceptance or gap-rejection study, the authors drove a motorcycle through a selected intersection with the normal flow of traffic at night. The subject vehicles in the study were not aware they were participating in a test. The authors documented whether the subject drivers "accepted" the gap provided by the motorcycle and a lead vehicle, thus merging into the traffic flow or if they "rejected" the gap by remaining stopped. One maneuver studied was a subject vehicle initially traveling the opposite direction of the motorcycle and making a left turn onto a side street. Gap times of three, four, and five seconds were evaluated between the motorcycle and the lead vehicle. The results showed a greater probability that motorists would accept shorter gaps from a motorcycle compared to a passenger vehicle. Adding a retro-reflective suit to the motorcycle rider had the most significant effect in reducing the probability of short gaps being accepted. Additionally, the difference between a motorcycle with no treatment and a passenger vehicle became more pronounced as the gap times increased. This led the authors to conclude that larger vehicles appear more threatening than motorcycles.

G. L. Donne conducted a number of motorcycle conspicuity studies in the mid-1980s, both under daylight and nighttime conditions. One particular nighttime study assessed the various headlamp arrangements on two-wheeled vehicles (Donne, 1990). Observers were seated in a stopped vehicle and asked to count random numbers on a display positioned directly in front of them. This was done to mimic the driving task and to occupy the participant's central field of vision. Next, participants were asked to indicate when they were aware of a test vehicle approaching in their peripheral vision at an angle of 60 degrees. The distance at which the approaching vehicle was identified by the participant was used as the measure of detectability of the lighting configuration. Both cars and motorcycles were used as test vehicles. The results showed that a motorcycle was always less readily detected than a passenger vehicle from a driver's peripheral vision, regardless of the motorcycle's lighting arrangement. Additionally, Donne found that lamp intensity and beam-pattern were major factors in detectability. He comments that the most effective way of increasing the light falling on a driver's eye is to simply increase the intensity of standard motorcycle headlamps rather than add additional lights.

In 2008, Crundall, Humphrey, and Clarke (Crundall, Humphrey, & Clarke, 2008) used static images to access motorcycle conspicuity. The authors hypothesized that either drivers fail to perceive the oncoming motorcycle, or they incorrectly judge that it is safe to pull out. To investigate their theories, the authors showed 17 participants static daytime pictures of a T-intersection containing a motorcycle, car, or clear roadway for 250 milliseconds each. The approaching vehicles could be at near, intermediate, or far distances from the intersection. The participants were instructed to press one of two buttons on a keypad to report whether traffic was present in the picture or not. The results revealed that motorcycles at far distances were spotted less than cars and correct response times were slower, demonstrating a problem with perceiving motorcycles. In a second experiment, 62 participants were given five seconds to view each picture before deciding whether it would be safe to pull out in front of an approaching vehicle. The results showed no difference between car and motorcycles given the extended time period. The authors conclude that perceptual errors can occur when a driver's decision is made quickly, but when information is fully processed by a driver, there is no difference between motorcycles and passenger vehicles.

The authors of a 2010 study focusing on the effect of daytime running lights by motorcycles choose to place participants on the edge of a roadway and capture their responses to passing vehicles (Haferkemper, Sprute, Schiller, & Khanh, 2010). The study compared the use of Light-emitting diode (LED) daytime running lights, low beam headlights, and no lights on the perception of motorcycles in oncoming traffic. Eight subjects were positioned on the edge of a busy highway and observed oncoming traffic. The participants were told the purpose of the study was to determine errors in counting vehicles. They were instructed to count all white and red cars as well as motorcycles as soon as they were recognized. The participants were provided a laptop to enter their responses, which also recorded the point in time for each count. A total of 23 motorcycles were driven by the participants in the flow of traffic. Detection distance results showed a significant difference between the use of no light and low beam headlight compared to several daytime running light configurations. The motorcycles outfitted with two daytime running lights were observed at the greatest distance. The authors conclude the higher contrast achieved by using daytime running lights leads to earlier detection of vehicles, thus leaving more time to make decisions.

Several researchers have used vehicle simulators to explore motorcycle conspicuity issues. Research by Smither and Torrez in 2010 evaluated the effects of age, gender, and motorcycle lighting conditions on one's ability to effectively detect a motorcycle under daytime conditions (Smither & Torrez, 2010). The 150 participants were shown three second videos of a motorcycle approaching an intersection. The test vehicle was positioned in a left-hand turning lane, as if to emulate the start of a left turn. A total of 12 motorcycle-present conditions and 12 motorcycle-absent conditions were shown in a randomized order to the participants. The motorcycle-absent conditions consisted clips showing a pedestrian, traffic cone, regular traffic, or an empty road. Each of the motorcycle-present conditions was presented four times for a total of 48 video clips. Between each clip, participants were shown a blank slide containing a "visual noise" background and a fixation point directly in the middle of the screen. This was done to capture the time for the participant to move their eyes from straight ahead to the location of the hazard. The videos were presented to the participants via a GE PatrolSim II+ driving simulator. The motorcycle traveled at a constant 25 MPH in the opposite lane of travel for all experimental conditions. The condition of the motorcycle consisted of headlight off, headlight on, and a modulated headlight. Participants were told the goal of the study was to identify potential hazards that might be encountered while driving. Analysis of the results indicated that a motorcycle with daytime running lights is detected faster than a motorcycle without daytime running lights. There was no significant difference in the participants' reaction times for motorcycles with daytime running lights compared to a motorcycle with a modulated headlight. The authors attribute this to the videos clips being recorded on a clear afternoon in a low-traffic environment. The results also show that when a vehicle is trailing a motorcycle, the time necessary for detection is extended. The authors conclude that a following vehicle causes a cluttered visual environment, thus lowering motorcycle conspicuity. The authors point out the need for further research that accounts for other environmental conditions, such as fog, and during twilight. Mean response times for participants in this study ranged from 0.940 seconds for a motorcycle alone with no headlight, to 1.030 seconds for a motorcycle with no headlight and a following vehicle with its daytime running lights activated.

Lastly, Rogé, Douissembekov, and Vienne conducted a study to determine the interaction between sensory and cognitive conspicuity of motorcycles under daytime conditions in early 2012 (Rogé, Douissembekov, & Vienne, 2012). The authors thought motorists who have a motorcycle license or have motorcycle driving experience may be more apt to identify a motorcycle quicker than non-motorcycle drivers. Their sample size consisted of 42 drivers, 21 motorcyclists and 21 non-motorcyclists. The participants were asked to perform driving tasks within a car-driving simulator, such as following a lead vehicle or navigating to a town based on road signs. During their driving, participants were asked to flash their headlights whenever a motorcycle was spotted. The motorcycle appeared from different points in their environment, such as an overtaking motorcycle, from oncoming traffic, or from the side during a turning maneuver. The results showed that all drivers detected the motorcycle at a much greater distance when the motorcycle appeared in front of them than when it appeared from behind. Car drivers who had a motorcycle license and who rode regularly detected the motorcycle when it was farther away. Finally, motorcycles with a high color contrast to their environment were detected from farther away for all drivers.

One can surmise from the research to date that various methods have been used to evaluate the visibility of two-wheelers. However, limited research has been conducted regarding the visibility of motorcycles and other two-wheelers under nighttime conditions. The nighttime research conducted is outdated due to the advancement of two-wheelers since the 1980s. Additionally, the introduction of high-definition video has allowed low-light video to be captured closer to reality than ever before. As previously discussed, the methodology used in this study is similar to previous research in daytime conditions and allows for a comparison of the results.

CHAPTER 3: METHODOLOGY

A review of prior research was extremely helpful in preparation for this study. Comments from authors and observations from their methodology influenced how this nighttime study was constructed.

2.1 Selecting Intersections

Two intersections in Charlotte, North Carolina were selected for use in the study. Both are urban intersections with very similar characteristics in geometry and layout, with a posted speed limit of 35 MPH on the main thoroughfare. Each have street lighting and are controlled by a traffic signal which allows for permitted left turning traffic. Additionally, both intersections have a restricted sight line, such that oncoming traffic cannot be seen at a great distance. The first intersection is South Tryon Street and Griffith Street (hereafter referred to as Griffith St. intersection). Video was captured from a driver's point of view as the test vehicle was preparing for a left turn maneuver from northbound South Tryon Street onto westbound Griffith Street. The driver's perspective is shown in Figure 2. This intersection served as the main intersection for the study, accounting for 76% of the videos shown to participants. The second intersection is West Boulevard and Barringer Drive (hereafter referred to as Barringer Dr. intersection). The test vehicle at this intersection was preparing for left turn from westbound West Boulevard onto southbound Barringer Driver. The driver's perspective is shown in

Figure 3. The perspective at each intersection is the same among all experimental conditions.

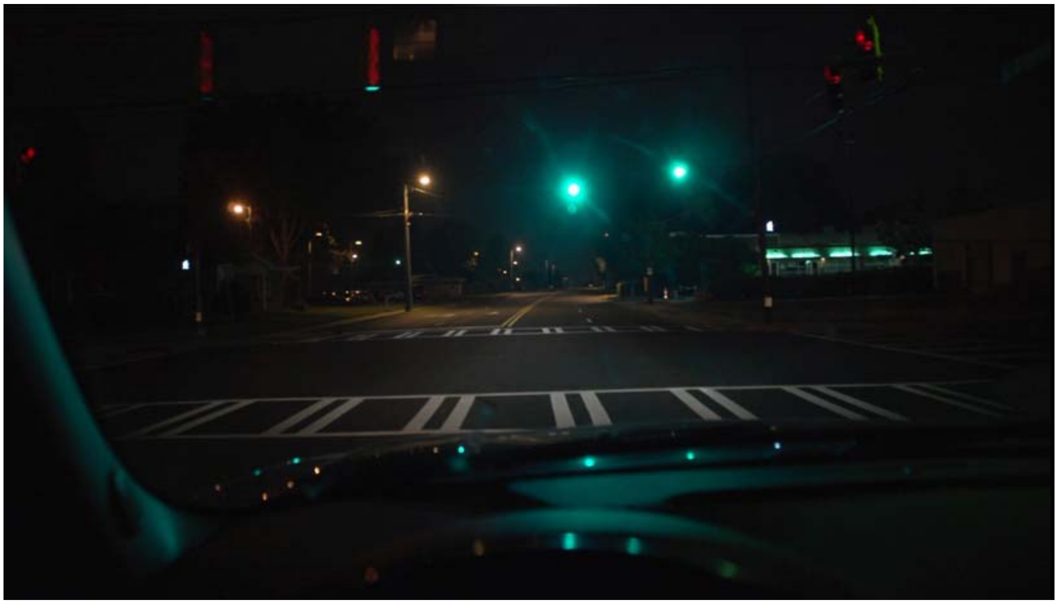


FIGURE 2: Driver's view at Griffith St. intersection

FIGURE 3: Driver’s view at Barringer Dr. intersection

2.2 Video Recording and Processing

The study used real time video of live traffic conditions at each intersection, captured in High Definition MEPG-4 AVCHD with a resolution of 1920 x 1080 using a

Sony NEX-FS100U Camcorder. This camera is ideal for low-light nighttime video recording due to its single Super 35 mm image senor. The recording took place over two nights in June 2014, hours after sunset. The weather conditions were clear and dry both evenings. Prior to recording, the camera was calibrated using a contrast board, shown in Figure 4. This technique is similar to research by Thomas Ayres (Ayres, 1996) and James Sprague (Sprague, Shibata, & Auflick, 2014). It is used to capture the observer's ability to detect contrast differences between an object and its background. The investigator views a contrast board filled with gray scale numbers and symbols from inside the test vehicle. The numbers provide varying levels of contrast, which may or may not be visible under the current lighting condition. Likewise, the symbols provide a second measure of contrast detection. The board is held at a distance similar to the specified target. The number of visible numbers and symbols were recorded. A symbol is considered visible if the observer can detect which direction the arrow is pointing. The camera settings are then adjusted to match what the observer could actually perceive. This was done from the left, middle, and right side of the test vehicle with the low beam headlights activated.

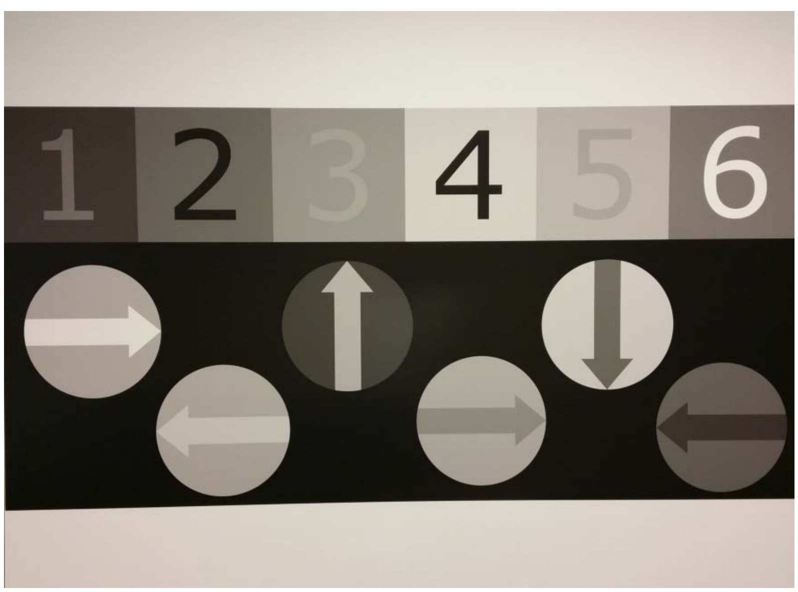


FIGURE 4: Contrast board used to calibrate nighttime video

The camera was mounted inside a 2007 Chevrolet Avalanche as close to the driver's height of eye as possible, as shown in Figure 5. The goal of the nighttime recording was to capture five scenarios encountered during a normal left turn maneuver:

1. No Hazard Present (e.g., clear roadway)
2. Approaching Passenger Vehicle (e.g., car, pickup, or SUV)
3. Approaching motorcycle
4. Approaching motor scooter
5. Pedestrian crossing within crosswalk

During each video the test vehicle was driven into the proper lane to make a left turn with the left turn signal activated. The recording did not begin until the vehicle was at a complete stop without intruding the intersection. Videos of a clear roadway and oncoming passenger vehicles were recorded at each intersection. These videos were recorded strictly by chance with traffic moving unimpeded. Only videos with one passenger vehicle in the frame at a time were used in the study.

FIGURE 5: Sony NEX-FS100U camcorder mounted at a driver's height of eye

In order to record the motorcycle, scooter, and pedestrian movement assistance was required. The motorcycle used in the study is a blue 2006 Kawasaki ZX-6R 636 equipped with a low beam PIAA H7 Xtreme White Plus 55-W headlight bulb. The motorcycle was driven at constant speed of 35 MPH during its approach to the Griffith St. intersection, once in the right and left lane. The scooter used is a 2012 Donfang DF50, equipped with 50cc engine and a 35-W low beam headlight bulb. The scooter was driven in the right lane at a constant speed of 30 MPH toward the Griffith St. intersection, due to its limited top speed. The scooter was also equipped with an aftermarket switch capable of disabling the front headlight. One approach of the scooter traveling without a front headlight was recorded. The operators of the motorcycle and scooter were wearing flat black protective clothing and helmet. Finally, the pedestrian in the study is a white male wearing khaki colored shorts with a dark gray short sleeve shirt. The pedestrian crossed perpendicular to the left turning vehicle within the near-side and far-side crosswalks, and once parallel to the turning vehicle in the side street crosswalk.

2.3 Video Post-Processing and Playback

The nighttime footage was edited and post-processed into 21 video clips using Adobe Premiere Pro and Adobe After Effects. The order of the videos remained the same for each participant. Table 1 identifies the intersection and provides a description of each video. The length of each video is six seconds regardless if a hazard is present or not present. When a hazard is present, the video corresponds with the hazard reaching the potential point of impact after five seconds. For example, a vehicle traveling 35 MPH would be approximately 257 feet from the intersection at the start of the video and would reach a point which intersects the left turning vehicle after five seconds, as shown in

Figure 6. This five second time to impact is the same regardless of the oncoming vehicle's speed. Thus, a vehicle traveling slower than 35 MPH would be closer to the intersection at the start of the video.

The participants watched and responded to the videos on a 32 inch flat panel LCD television which was placed approximately 34 inches from the participant.

TABLE 1: Order of videos and hazard description

Video No.	Intersection	Description
1	Griffith St	No Hazard
2	Griffith St	Passenger Car, Right Lane
3	Griffith St	Motorcycle, Right Lane
4	Barringer Dr	Passenger Car, Left Lane
5	Griffith St	No Hazard
6	Griffith St	Pedestrian, Parallel
7	Griffith St	Motorcycle, Left Lane
8	Barringer Dr	No Hazard
9	Griffith St	Passenger Car, Left Lane
10	Griffith St	Scooter, Right Lane
11	Griffith St	No Hazard
12	Barringer Dr	No Hazard
13	Griffith St	Scooter, No Headlight
14	Griffith St	Passenger Car, Right Lane
15	Griffith St	Pedestrian, Far Crosswalk
16	Griffith St	Scooter, Left Lane
17	Griffith St	No Hazard
18	Griffith St	Pedestrian, Near Crosswalk
19	Barringer Dr	Passenger Car - Left Lane
20	Barringer Dr	No Hazard
21	Griffith St	Motorcycle, Right Lane

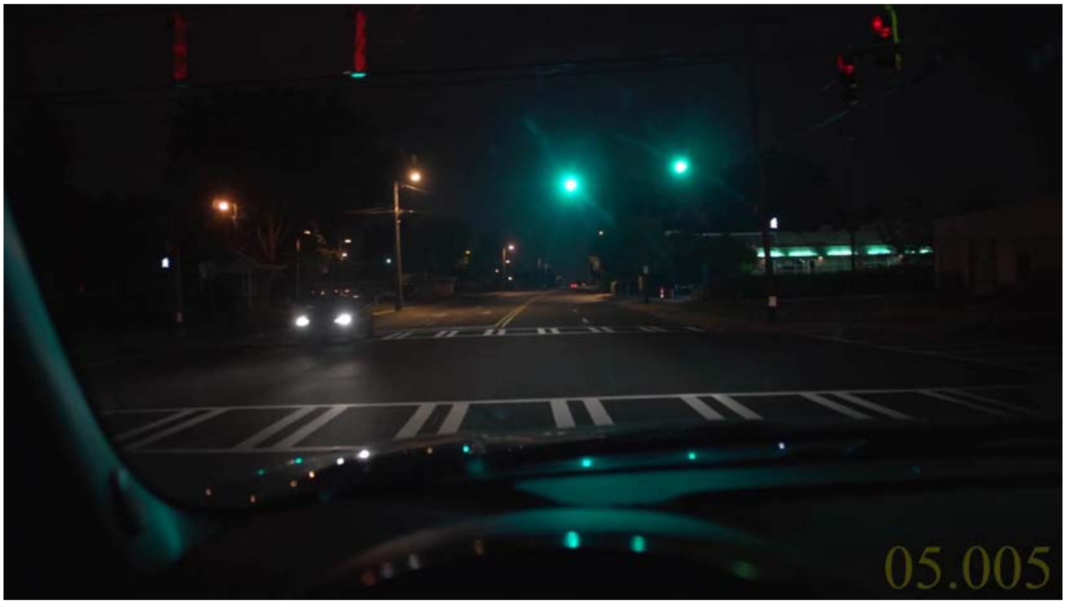


FIGURE 6: A passenger vehicle at the potential point of impact

2.4 Procedure

Two test locations were used during the study and both utilized the same test equipment. Both were business offices in which the windows were blacked out and lights were shut off during the study. The participants sat in a chair directly in front of the television monitor, as shown in Figure 7. A small video camera was placed over the participant's left shoulder to capture their responses during the study. Each participant was tested individually.

FIGURE 7: Experiment setup

The purpose of the study, to evaluate a motorist's visibility during nighttime driving, was explained to each participant. If the subject agreed to participate they would be compensated $15 at the conclusion of the study. The participant was first given an informed consent document which explained the inclusion criteria and confidentiality of the collected data. Participants who did not meet the inclusion criteria or needed corrective lenses but did not have them available were dismissed from the study. Participants were then asked to complete a questionnaire which included questions related to their age, gender, driver's license endorsements, driving experience, crash history, and risk of nighttime driving. The informed consent and questionnaire are available in Appendix A and B, respectively.

Next, the participants were shown a PowerPoint presentation (Appendix C) to familiarize themselves with the equipment and given the following instruction:

You are asked to watch a series of videos from a driver's perspective of a vehicle at an intersection. Each video will last approximately five seconds. During each video you will be asked to determine whether a left turn is safe to make given the current traffic conditions. If you determine the maneuver can be made safely, you should press the green button to indicate your decision that all is clear, similar to pressing the accelerator pedal in your vehicle. On the other hand, if you detect a hazard that would impede your ability to make the turn safely, you should press the red button to indicate your decision not complete the maneuver and that you have identified a hazard. You will then be prompted to identify out loud the detected hazard.

The participants did not know what hazard would appear, if any, or where the hazard would be located. The participants were provided two input buttons, the right button was lit green and the left lit red. After each input, green or red, a screen appeared and asked the participant "Was there a hazard present?" The screen included icons and text of the four available options: passenger vehicle, motorcycle/scooter, pedestrian, or nothing (Figure 8). A clock was placed in the lower right hand corner of the screen with a 10 second countdown to the start of the next video.

All participants were shown five daytime practice videos to confirm they were interacting with the equipment correctly. The investigator then encouraged any final questions before the study began. When the participant indicated he or she understood the objective, the nighttime videos began. A clock with 0.000 second precision appeared in the lower right-hand corner of each video to document when the participant entered an "all clear" or "hazard present" decision.

FIGURE 8: Answer screen shown after each video

2.5 Participants

A total of 30 participants took part in the study (17 male, 13 female). The participants were in one of five age range groups, the lowest range was 18 to 24 years, while the highest range was 51 to 60 years. The age range with the highest number of participants was the 51 to 60 group with a total of nine individuals. Recruitment tools included a flyer distributed in a local business park (Appendix D), a craigslist ad, and word of mouth. All participants were found in the greater Charlotte area and included several teachers from Fort Mill High School in Fort Mill, South Carolina.

Inclusion criteria for participation were persons between the age of 18 and 70 years old with a valid United States driver's license, normal or corrected-to-normal vision, spoke English, and had available transportation to the testing site. Participants were also excluded from the study if they were under the influence of a controlled substance, alcohol, or any medication that would prevent them from operating a motor vehicle. Only individuals who met all the inclusion and exclusion criteria were involved in the study.

CHAPTER 4: ANALYSIS AND RESULTS

4.1 Questionnaire Responses

None of the 30 participants had ever participated in a driving study before and only two participants had a motorcycle endorsement. All participants had at least five years driving experience and averaged 20 to 25 years of experience. Participants were asked, "Of the miles you drive per week, what percentage of these miles is driven at night?" The category with the largest number of responses was 10 to 20 percent, representing 36.7 percent of the sample population. Participants were then asked, "Do you think nighttime driving is any more dangerous than daytime driving?" 27 of the 30 (90%) participants answered yes, and 19 (63%) participants believed they were more attentive while driving at night compared to daylight driving. When asked about their crash history, 4 (13.3%) participants had never been involved in a crash while they were the driver, 6 (20%) had been involved in one crash, 6 (20%) in two crashes, 10 (33.3%) in three crashes, 3 (10%) in four crashes, and 1 (3.3%) in five or more crashes. The vast majority of participants, 80 percent, had never been involved in a crash at night while they were the driver.

4.2 Summarized Data

Each of the 30 participants was shown 21 videos, allowing for a total of 630 responses. The data from each participant is provided in Appendix E. On only three occasions (0.05%) did the video time out without an input from the participant, thus 627 responses were available for analysis. The accuracy rate was high, 93 percent of responses were correctly input for “all clear” or “hazard present.” Of the 45 incorrect responses, 21 (47%) were from video number 15, in which a pedestrian crossed perpendicular to the test vehicle in the far crosswalk; therefore the pedestrian was not technically in the travel path of a left turn maneuver. However, most participants pressed the red button to indicate they saw the pedestrian rather than proceeding with the turn. Additionally, 8 (18%) of the incorrect responses came from one participant.

Considering all responses, the mean response time was 1.763 seconds with a standard deviation of 0.716 seconds. The minimum response time was 0.367 seconds and the maximum was 5.172 seconds.

4.3 Data Preparation

In order to satisfy the assumptions of parametric statistics tests, the response time data was evaluated for normality using Minitab 17 statistical software (Minitab Inc., 2013). Figure 9 shows the distribution of response times, along with the cumulative frequency. The data has a slight positive skew (1.27) and kurtosis (2.18). This is a common distribution associated with response time studies (McCormack & Wright, 1964; Smither & Torrez, 2010). Consequently the data set was transformed using a logarithmic transformation (Log10) to more closely resemble a normal distribution. Following the transformation, the data was checked for normality using three tests offered by Minitab: Anderson-Darling, Ryan-Joiner, and Kolmogorov-Smirnov. Table 2 shows the results of each test. Two of the three tests rejected the null hypothesis that the data is normally distributed. Therefore, an outlier test was performed in Minitab, which showed that the maximum response time of 5.127 seconds, was an outlier. The data point was removed and the normality tests were run again. Table 2 shows all three tests have a probability value greater than or equal to 0.05.

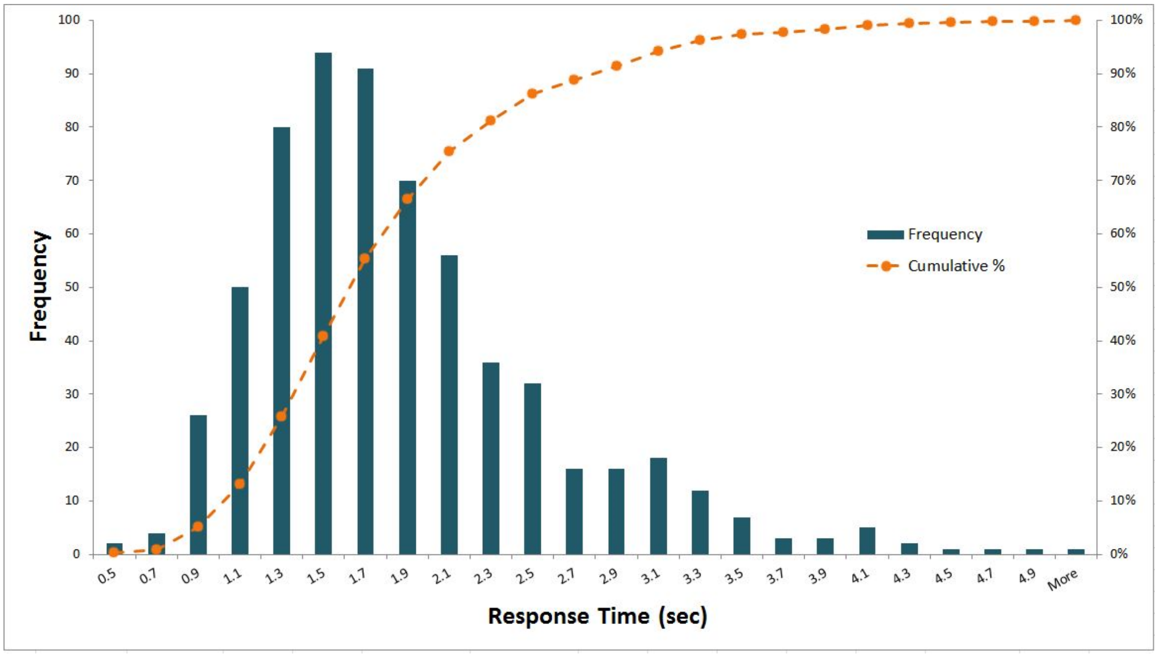


FIGURE 9: Histogram of all response times

TABLE 2: Normality tests

	Log10 Transformation	Log 10 Transformation with outlier removed
Anderson-Darling	0.045	0.063
Ryan-Joiner	0.073	0.070
Kolmogorov-Smirnov	0.038	0.047

The distribution of the transformed response times with the outlier removed is shown in Figure 10, which has a skewness of 0.00 and kurtosis of 0.32. A two-sample t-test was then performed for each category of interest. The null hypothesis in each test was there is no significant difference in the means. The means are considered significantly different when the probability value is less than 0.05.

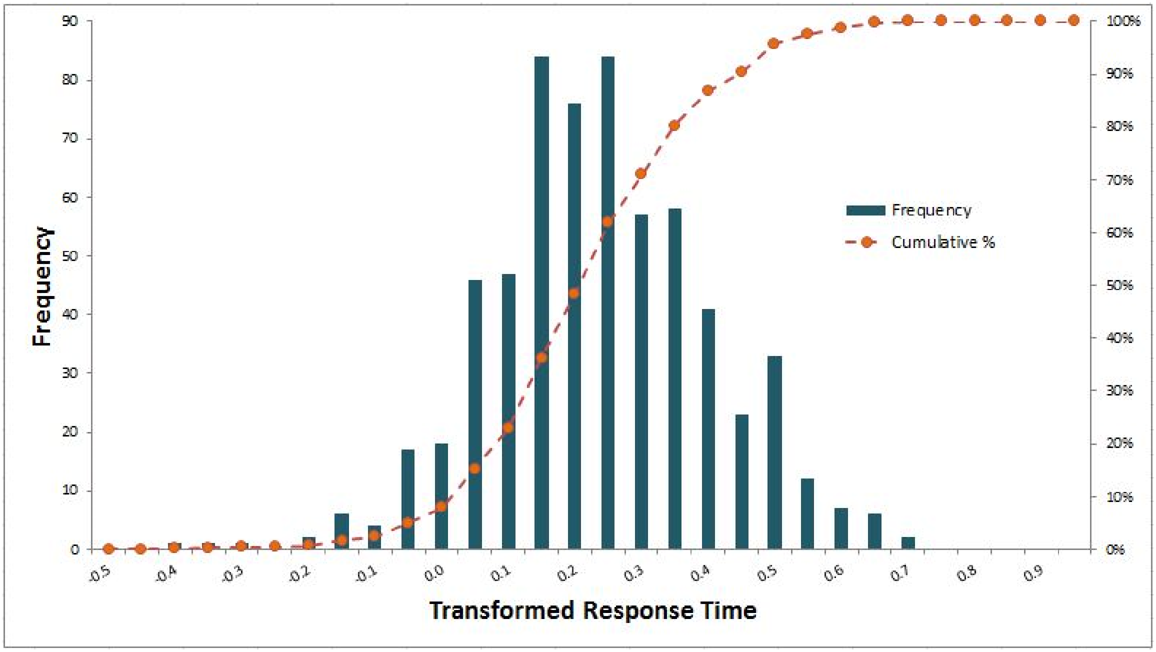


FIGURE 10: Histogram of transformed response times

4.4 Intersection Comparison

Next, the Griffith St. and Barringer Dr. intersections response times were compared to each other. This was done to confirm that each intersection had similar characteristics and could be used in the same sample. Table 3 shows a breakdown of each intersection. When analyzing the same hazard type at each intersection, there was no significant difference. A t-test for passenger vehicle hazards returned t(148) = -0.74, p = 0.458. The same test for no hazard present returned t(205) = -1.58, p = 0.117.

TABLE 3: Intersection comparison

Intersection	No. of Responses	Mean (sec)	Std. Dev. (sec)
Griffith St.	480	1.726	0.689
Passenger Car	90	1.487	0.529
No Hazard	120	1.932	0.800
Barringer Dr.	147	1.885	0.785
Passenger Car	60	1.549	0.454
No Hazard	87	2.117	0.878

4.4 Response Time by Gender

The response time by gender is shown in Table 4. The mean response time for males was 0.229 seconds faster than females, while males accounted for 355 of the 627 responses. The two groups differed significantly, $t(624) = 4.60$, $p < 0.001$.

TABLE 4: Mean response time by gender

Gender	No. of Participants	No. of Responses	Mean (sec)	Std. Dev. (sec)
Female	13	272	1.893	0.714
Male	17	355	1.664	0.701
Total	30	627		

4.5 Response Time by Hazard Type

The hazard types were separated into seven categories as shown in Table 5, including no hazard. Figure 11 displays the mean response time along with error bars representing plus and minus one standard deviation. Passengers vehicles had the lowest average response time (M = 1.512, SD = 0.499), while the highest average response time resulted when no hazard was present (M = 2.010, SD = 0.865). Considering only the scenarios in which a hazard was present, pedestrians had the highest average response time (M = 1.978, SD = 0.865).

TABLE 5: Mean response time by hazard type

Hazard Type	No. of Responses	Mean (sec)	Std. Dev. (sec)
Passenger Vehicles	150	1.512	0.499
All two-wheelers with headlight	150	1.545	0.468
Motorcycle	90	1.548	0.500
Scooter with headlight	60	1.540	0.419
Scooter without headlight	30	1.773	0.472
Pedestrian	90	1.978	0.865
No Hazard	207	2.010	0.837

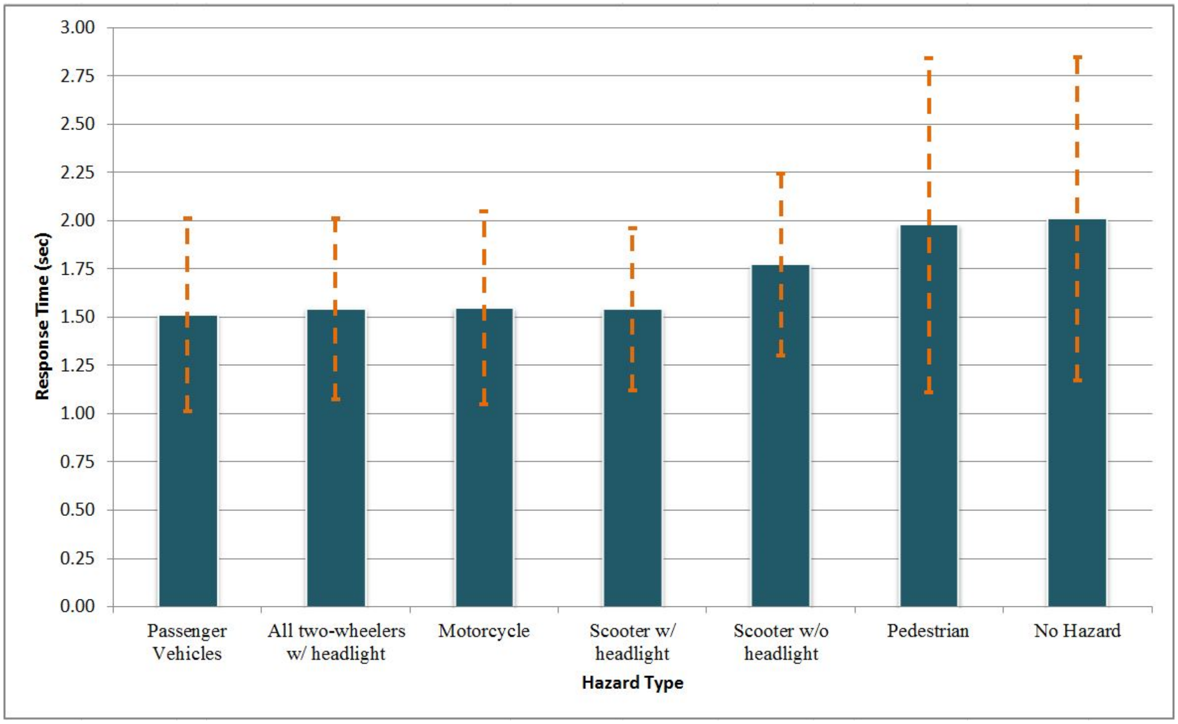


FIGURE 11: Mean response time by hazard type

A t-test was performed to compare the means of passenger vehicles and two-wheelers. Results revealed no significant difference between the two $t(298) = -0.81$, $p = 0.421$. Similarly, there was no significant effect between motorcycles and scooters, $t(148) = -0.16$, $p = 0.874$, although scooters had a slightly lower mean response time. Comparing a scooter with a headlight and a scooter without a headlight showed the lengthened response time when the scooter's headlight was off reached significance, $t(88) = -2.35$, $p = 0.021$. Finally, there was also a significant effect found when comparing a clear roadways (i.e. no hazard) and a hazard present, $t(624) = 5.67$, $p < 0.001$ (Table 6).

TABLE 6: Mean response time by hazard present

Presence	No. of Responses	Mean (sec)	Std. Dev. (sec)
Clear	207	2.010	0.837
Hazard Present	420	1.642	0.613
Total	627		

CHAPTER 5: CONCLUSIONS AND SCOPE FOR FURTHER WORK

This study captured 627 individual response times to various hazards including passenger vehicles and two-wheelers. The resulting data appears meaningful and indicates there is no substantial difference in a driver's ability to recognize a two-wheeled motorist compared to a passenger vehicle in a low fidelity simulator. These results are specific to urban environments in which street lighting is available. Logically, the more artificial lighting that is available to a driver enhances their ability to correctly recognize and respond to a hazard. Street lighting enables drivers to use some of the environmental cues available during daylight driving. In some cases the driver may discern the silhouette of a two-wheeler and rider to help with recognition. The same results may not hold true at rural intersections where the vehicle's headlights will be the only cue to identify a hazard.

The results of the data suggest that the conspicuity issues for two-wheelers in daytime conditions are not the same as nighttime conditions. The contrast created from a headlight against a dark environment, allows the two-wheeler to be identified just as quickly as a passenger vehicle. Therefore, the same treatments proposed for two-wheelers in daytime conditions may not be as beneficial or even needed during nighttime driving. As discussed in prior research (Donne, 1990), the results from this study suggest that adding additional lights to two-wheelers may not improve conspicuity under nighttime conditions. Further research is needed to fully vet this theory and should consider treatments to the rider as well, such as retro-reflective clothing.

Concluding there was no significant difference in the response time for passenger vehicles compared to two-wheelers under nighttime conditions, proposes the possibility that some crashes may be falsely labeled “looked-but-failed-to-see” errors. Rather it is a way for the driver at fault to rationalize their actions as to why the incident occurred. In other words, a driver who actually saw a two-wheeler prior to impact but failed to correctly judge the arrival time, may convince themselves otherwise after the collision is over. The other possibility is a driver simply did not look in the correct direction for a hazard, and reports afterwards that they did so but did not see any hazard approaching.

When contemplating the different conflict points motorists can encounter a two-wheeled vehicle and under the various environmental conditions, it is likely this study is an ideal scenario for recognizing a hazard quickly. Adding a more challenging environment with less street lighting or multiple oncoming vehicles would make recognizing a two-wheeler more difficult, thus extending the response time. It may be possible that a single headlight two-wheeler could align perfectly with one light on a trailing passenger car and cause a motorist to unintentionally turn in front of the two-wheeler.

Looking further into the data, the results suggests that as a hazard becomes more complex and is no longer emitting light, recognition time is extended. Passenger vehicles and two-wheelers had a general response time around 1.5 to 1.6 seconds. Comparing this to a scooter with no headlight and pedestrians, 1.8 to 2.0 seconds respectively, it can be concluded that these hazard are harder to detect and discern. At intersections without street lighting, these hazards may not be identified until they fall into the throw beam of a vehicle's headlights or could be virtually undetectable.

When the response time to two-wheelers from this study is compared to the response time of similar studies conducted in the daytime, it appears more time is necessary for drivers to identify a two-wheeler at night compared to daytime. Smither and Torrez in 2010 found a mean response time of approximately one second for a motorcycle alone on a roadway with its low beam activated. A very similar scenario in this study under nighttime conditions shows a mean response time closer to 1.5 seconds, suggesting an increase of approximately one half second to identify a two-wheeler at night compared to daytime.

Another interesting result of the study was the lengthened response time when no hazard was present, greater than 2 seconds on average. It seems reasonable that a driver will gaze longer at a roadway when deciding a turn is safe to make, to ensure their path is clear, but when a hazard is present the driver will recognize it more quickly. In real world driving, a person that identifies and correctly responds to a hazard during a turn maneuver must then wait and reassess the intersection once the hazard has passed. In this study, only the initial recognition is captured. It is possible a driver could make a decision to complete the turn more quickly once the first hazard has cleared the intended path.

Of course, there are limitations to a study involving a low fidelity simulator. First, the participants were not engaged in a driving task. Therefore, more focus and attention could be directed toward identifying each hazard. Secondly, the participants could generally anticipate where the hazard was going to appear prior to each video, although the distractor videos with pedestrians helped to keep the participants sharp. It was only obvious with one participant that the person was treating the study more like a gap acceptance experiment rather than a recognition experiment because the person had an unusually high number of “go” responses when passenger vehicle hazards were clearly visible.

The participants involved in this study were comprised of adults with at least five years driving experience. Therefore, care should be taken when applying the results to young or elderly drivers. Future studies could specifically evaluate inexperienced and older driver populations. Further, future studies should also include hazards appearing at different distances from the intersection and instruct the participant to both identify the hazard and then choose to complete the turn in front of it. Additionally, using a mix of urban and rural intersections would help confirm or contradict the results of this study.

Overall the study addressed the original questions sufficiently. Differing results were found at night compared to daylight studies. Also, the issues regarding conspicuity are somewhat lessened for two-wheelers at night compared to daytime driving.

REFERENCES

1. Ayres, T. J. (1996). Psychophysical Validation of Photographic Representations. *ASME - SERA 6*, 29-34.

2. Crundall, D., Humphrey, K., & Clarke, D. (2008). Perception and Appraisal of Approaching Motorcycles at Junctions. *Transportation Research Part F*, 159-167.

3. Donne, G. L. (1990). Research into Motorcycle Conspicuity and its Implementation. *International Congress and Exposition.* Detroit, MI: SAE International.

4. Haferkemper, N., Sprute, J. H., Schiller, C., & Khanh, T. Q. (2010). *The Effect of LED Daytimer Running Lights on Motorcycle Conspicuity and Detection Distance Estimation - Latest Test Results.* Darmstadt, Germany: SAE International.

5. Hancock, P. A., Wulf, G., Thom, D., & Fassnacht, P. (1990). Driver Workload during Differing Driving Maneuvers. *Accident Analysis and Prevention 22*, 281-290.

6. Hills, B. L. (1980). Vision, Visibility and Perception in Driving. *Perception, 9*, 183-216.

7. Hurt, Jr., H. H., & DuPont, C. J. (1977). Human Facotrs in Motorcycle Accidents. *International Automtive Engineering Congress and Exposition.* Detroit.

8. Klein, E., & Stephens, G. (1992). *Visibility Study - Methodologies and Reconstruction.* Costa Mesa, California: SAE Technical Paper 921575.

9. McCormack, P. D., & Wright, N. M. (1964). The Positive Skew Observed in Reaction Time Distribution. *Canadian Journal of Psychology, 18*, 43-51.

10. Minitab Inc. (2013). Minitab 17 version 17.1.0.

11. National Highway Traffic Safety Administration. (2012). *Traffic Safety Facts - Motorcycles.* Washington, DC: NHTSA's National Center for Statistics and Analysis.

12. Olson, P. L., Dewar, R., & Farber, E. (2010). *Forensic Aspects of Driver Perception and Response, Third Edition.* Tucson, Arizona: Lawyers and Judges Publishing Company.

13. Olson, P. L., Halstead-Nussloch, R., & Sivak, M. (1981). The Effect of Improvements in Motorcyce/Motorcyclist Conspicuity on Driver Behavior. *Human Factors: The Journal of Human Factors and Ergonomics Society, 23*, 237-248.

14. Pai, C. W. (2011). Motorcycle Right-of-way Accidents - A literature Review. *Accident Analysis and Prevention 43,* 971-982.

15. Pai, C.-W., Hwang, K., & Saleh, W. (2009). A Mixed-logit Analysis of Motorists' Right-of-way Violation in Motorcycle Accidents at Priority T-junctions. *Accident Analysis and Prevention 41 (3)*, 565-573.

16. Rogé, J., Douissembekov, E., & Vienne, F. (2012). Low Conspicuity of Motorcycles for Car Drivers: Dominat Role of Bottom-Up Control of Visual Attention or Deficit of Top-Down Control? *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *54*(1), 14-25.

17. Shadeed, M. S., Gkritza, K., & Marshall, D. (2012). *Motorcycle Conspicuity - What Factors Have the Greatest Impact.* Midwest Transportation Consortium, Ames, IA: Iowa State University - Center for Transportation Research and Education.

18. Smither, J. A.-A., & Torrez, L. I. (2010). Motorcycle Conspicuity: Effects of Age and Daytime Running Lights. *Human Factors: The Jounral of Human Factors and Ergonoics Society, 52*(3), 355-369.

19. Sprague, J., Shibata, P., & Auflick, J. (2014). Analysis of Nighttime Vehicular Collisions and the Application of Human Factors: An Integrated Approach. *SAE Technical Paper 2014-01-0442*.

APPENDIX A: INFORMED CONSENT DOCUMENT

INFORMED CONSENT DOCUMENT

Thesis Topic: Assessment of Nighttime Driving Visibility

Lead Investigator: Heath Spivey **Advisor:** Dr. Srinivas Pulugurtha

Contact Information: hspivey1@uncc.edu sspulurtha@uncc.edu

The following consent document outlines the research study in which you are being asked to participate.

WHAT IS THE PURPOSE OF THE STUDY?

This study is evaluating a motorist's visibility during nighttime driving. The study is needed to satisfy master's thesis requirements at the University of North Carolina at Charlotte. You are eligible to participate if you:

1. are between the ages of 18 and 70 years old;
2. hold a current valid driver's license in the United States;
3. have normal or corrected-to-normal vision;
4. have transportation to: 9401-D Southern Pine Blvd., Charlotte, NC (Pine Brooke Business Park) or UNCC EPIC building depending on study site;
5. speak english;
6. are not under the influence of any controlled substance or alcohol during participation.

HOW LONG WILL MY PARTICIPATION LAST?

The study will require approximately 20 minutes of your time.

WHAT WILL I BE ASKED TO DO?

If you agree to participate, you will be asked to watch a series of videos from a driver's perspective, of a vehicle at an intersection. Each video will last approximately five seconds. During each video you will be asked to determine whether a maneuver (e.g. a left turn) is safe to make given the current traffic conditions. If you determine the maneuver can be made safely, you will push a green button which indicates your decision. If you detect a hazard (e.g. oncoming vehicle or object) that would impede your ability to make the turn safely, you will press a red button to indicate your decision not to complete the maneuver. You will then be asked to identify out loud the detected hazard.

Prior to watching the videos you will be asked to complete a questionnaire which inquires about your driving experience and accident history. Questions about your gender and date of birth will also be asked, but will NOT include any personally identifying information such as your name, income level, or social security number.

AUDIO AND VIDEO RECORDING

During the study a video camera will record your response to each video scenario. This is needed to determine the elapsed time between the start of each video and your decision to complete the maneuver or the time needed to identify a hazard. The camera will not capture your face, but will capture your response in both pressing the appropriate button and audibly identifying any hazards. The audio and video captured will be kept indefinitely on a secure server for analysis.

VOLUNTARY PARICIPATION

Your participation in this study is completely voluntary. It is your choice whether to participate or not. If you choose to participate you may elect to stop participation at any point during the study.

WILL I BE PAID FOR PARTICIPATING?

At the end of your participation you will receive $15 cash.

BENEFITS

There will be no direct benefit to you for participating; however your participation may help nighttime driving become safer and prevent vehicle accidents.

CONFIDENTIALITY

Your participation will not be shared with anyone outside the lead investigator. No personal information will be collected during your involvement and you may choose not to answer any questions you do not feel comfortable answering. The information that is collected during your participation will be kept private. Your questionnaire and video footage will never be shared or produced publicly.

The ENGINEERING DATA collected and recorded in this study such as your performance and decisions will be analyzed along with every other participant. This data will be produced in summary as part of a thesis report. The data may also be released publicly or submitted to a professional society in the form of a report or journal article.

QUESTIONS?

I encourage you to ask questions. If you have questions now or at any point, please feel free to ask. You may contact the lead investigator, Heath Spivey at 704-609-2314 or hspivey1@uncc.edu. You may contact the advising professor, Dr. Srinivas Pulugurtha at sspulugurtha@uncc.edu or 704-687-1233. You may also contact the Office of Research Compliance at UNCC – 704-687-1871 or uncc-irb@uncc.edu.
This Informed Consent Document is not a contract. It is simply a written explanation of what will occur should you decide to participate. You are not waving any legal rights by

signing this document. Your signature indicates that this study has been fully explained to you, that you understand and agree to your involvement, and that all your questions have been answered.

Participant's Signature: ____

Date: ____________________

Statement by the researcher/person taking consent

I have discussed the about information with the potential participant, and to the best of my ability made sure that the participant understands their involvement. I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been forced into giving consent, and the consent has been given freely and voluntarily.
Signature of Person who Obtained Consent: ____

Date of Consent: _____________________

APPENDIX B: PRE-STUDY QUESTIONNAIRE

Pre-Study Questionnaire

Participant No. _______________ Date: _______________

Instructions

To begin this study it is important to collect information about your driving experience and accident history. As previous stated, there are no questions which are intended to obtain personally identifying information and your answer to all questions will be kept private. Please read each question carefully. If a question is unclear, please ask for clarification before answering.

Part I: Background Information

1) Please select the age group in which you currently belong:
   - ☐ 18-24
   - ☐ 25-30
   - ☐ 31-40
   - ☐ 41-50
   - ☐ 51-60
   - ☐ 61-70
   - ☐ 71+
2) Gender?
   - ☐ Male
   - ☐ Female
3) Have you ever participated in a study evaluating day or nighttime driving?
   - ☐ Yes
   - ☐ No
4) Are you currently under the influence of a controlled substance, alcohol, or any medication that would prevent you from operating a motor vehicle right now?
   - ☐ Yes
   - ☐ No
5) Do you possess a current valid U.S. driver's license?
   - ☐ Yes
   - ☐ No *(If no, please stop and return Questionnaire to investigator)*
6) In which state do you hold a driver's license? _______________

7) Do you hold any endorsements on your license? (For example: motorcycle, commercial driver's license)

☐ Yes - *Please describe:* ______________________________

☐ No

8) Do you have a close friend or family member who holds a commercial driver's license?

☐ Yes

☐ No

9) Do you have a close friend or family member who holds a motorcycle endorsement?

☐ Yes

☐ No

10) Do you have any restrictions on your license? (For example: corrective lenses)

☐ Yes - *Please describe:* ______________________________

☐ No

11) If you require corrective lenses to drive at night, do you have them with you today?

☐ Yes

☐ No *(If no, please stop and return Questionnaire to investigator)*

☐ Not applicable

Part II: Driving Experience

12) Approximately how long have you had a driver's license?

☐ 0-5 years
☐ 5-10 years
☐ 10-15 years
☐ 15-20 years
☐ 20-25 years
☐ 25+ years

13) Approximately how many miles do you drive per week?
- ☐ 0-25 miles
- ☐ 25-50 miles
- ☐ 50-100 miles
- ☐ 100-200 miles
- ☐ 200+ miles

14) Of the miles you drive per week, approximately what percentage of these miles is driven at night?
- ☐ 0-10%
- ☐ 10-20%
- ☐ 20-30%
- ☐ 30-40%
- ☐ 40-50%
- ☐ 50% or more

15) How many automobile accidents have you been involved in when you were the driver? (regardless of fault)
- ☐ 0
- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5 or more

16) How many automobile accidents have you been involved in <u>at night</u> when you were the driver?
- ☐ 0
- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5 or more

17) Have you ever been involved in an accident with a commercial vehicle? (Examples: tractor-trailer, box truck, city bus, concrete truck, etc.)
- ☐ Yes
- ☐ No

18) Have you ever been involved in an accident with a two-wheeled vehicle? (Examples: motorcycle, scooter, or bicycle)
- ☐ Yes
- ☐ No

19) Have you ever been involved in an accident with a pedestrian?
- ☐ Yes

☐ No

20) Have you ever been involved in an accident while in an active construction zone?

☐ Yes
☐ No

21) Which type of vehicle best describes the type you have the most experience driving?

☐ Four door sedan
☐ Pickup truck
☐ Two door car / Sports car
☐ SUV
☐ Van
☐ Motorcycle
☐ Other: ___________________

22) Do you think nighttime driving is any more dangerous than daytime driving?

☐ Yes
☐ No

23) As a driver, do you believe you are more or less attentive while driving at night compared to daylight driving?

☐ I am more attentive while driving at night
☐ I am more attentive while driving during the day
☐ There is no difference in my attention level during the day or night

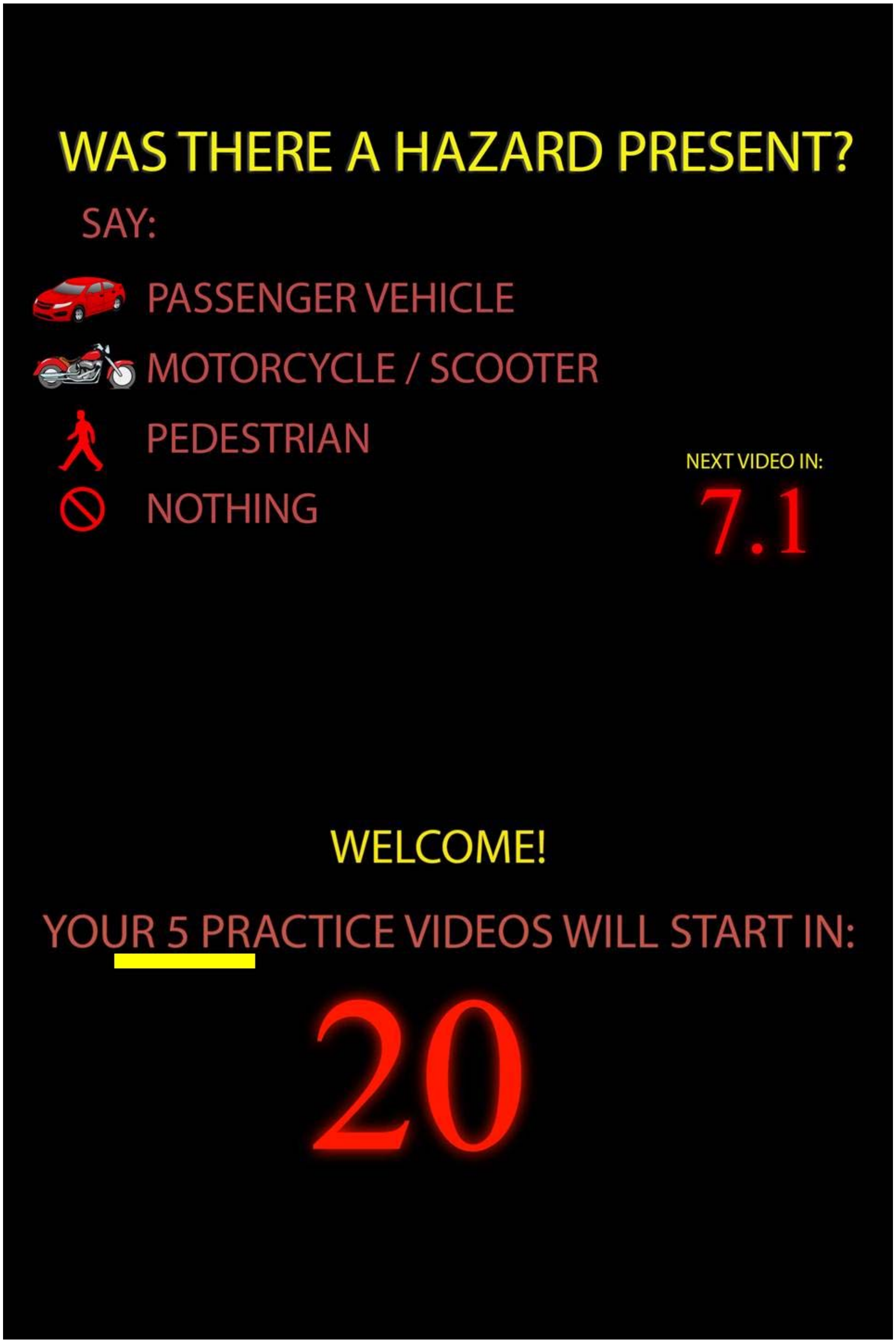
24) Have you fully understood all the questions on this Questionnaire?

☐ Yes
☐ No

Please return the Questionnaire to the investigator. Thank you.

APPENDIX C: INTRODUCTION PRESENTATION


All CLEAR?
GRIFFITH
ALL CLEAR
00.000
HAZARD DETECTED?
GRIFFITH
HAZARD
02.836


WAS THERE A HAZARD PRESENT?
SAY:
PASSENGER VEHICLE
MOTORCYCLE / SCOOTER
PEDESTRIAN
NOTHING
NEXT VIDEO IN:
7.1
WELCOME!
YOUR 5 PRACTICE VIDEOS WILL START IN:
20


PRACTICE SESSION COMPLETE!
YOUR RECORDED SESSION WILL START IN:
20

APPENDIX D: RECRUITMENT FLYER

UNC CHARLOTTE

VOLUNTEERS NEEDED

Research Topic: Assessment of Nighttime Driving Visibility

Every Participant will receive $15 CASH!!!

YOU ARE ELIGIBLE IF YOU:

1. Are between the age of 18 and 70;
2. Hold a current valid driver's license in the United States;
3. Have normal or corrected-to-normal vision;
4. Speak English;
5. Are not under the influence of a controlled substance or alcohol during participation.
6. Have transportation to:
   9401-D Southern Pine Blvd. Charlotte, NC (Pine Brook Business Park) or UNCC EPIC

About the study:

A master's student at UNC Charlotte and engineer at DELTA [v] Forensic Engineering, Inc., Heath Spivey is conducting a study on nighttime driving visibility. Heath is in need of volunteers to watch a series of videos from a driver's perspective. During each video, participants will be asked to determine if a normal driving maneuver (e.g. a left turn) is safe to make given the current traffic conditions. Participants will also be asked to identify hazards which may prevent them from making a maneuver safely. Participation will last approximately 20 minutes.

Participants will also be asked to complete a brief questionnaire regarding your driving experience and accident history.

DELTA [V]

Please contact Heath Spivey at 704-609-2314 to schedule an appointment.

APPENDIX E: RAW VIDEO RESPONSE DATA SEPARATED BY PARTICIPANT

Age Key	
Group	Range
1	18-24
2	25-30
3	31-40
4	41-50
5	51-60
6	61-70
7	71+

Hazard Type	
Group	Hazard
1	Nothing
2	Passenger Car
3	Motorcycle
4	Scooter
5	Scooter No headlight
6	Pedestrian

Response Time	Response Time (Log10 Transformed)	Gender	Age Range	Hazard Present?	Hazard Type	Button Response	Intersection
2.503	0.398	F	5	N	1	G	GS
1.568	0.195	F	5	Y	2	R	GS
1.668	0.222	F	5	Y	3	R	GS
2.402	0.381	F	5	Y	2	R	BD
2.669	0.426	F	5	N	1	G	GS
3.136	0.496	F	5	Y	6	R	GS
2.002	0.301	F	5	Y	3	R	GS
2.569	0.410	F	5	N	1	G	BD
2.302	0.362	F	5	Y	2	R	GS
1.835	0.264	F	5	Y	4	R	GS
2.369	0.375	F	5	N	1	G	GS
2.903	0.463	F	5	N	1	G	BD
2.069	0.316	F	5	Y	5	R	GS
1.768	0.247	F	5	Y	2	R	GS
2.069	0.316	F	5	Y	6	R	GS
2.135	0.329	F	5	Y	4	R	GS
2.402	0.381	F	5	N	1	G	GS
2.069	0.316	F	5	Y	6	R	GS
2.436	0.387	F	5	Y	2	R	BD
2.636	0.421	F	5	N	1	G	BD
1.768	0.247	F	5	Y	3	R	GS
1.635	0.214	F	4	N	1	G	GS
1.401	0.146	F	4	Y	2	R	GS
1.268	0.103	F	4	Y	3	R	GS
2.169	0.336	F	4	Y	2	R	BD
1.869	0.272	F	4	N	1	G	GS
1.869	0.272	F	4	Y	6	R	GS

2.035	0.309	F	4	Y	3	R	GS
2.603	0.415	F	4	N	1	G	BD
1.702	0.231	F	4	Y	2	R	GS
1.368	0.136	F	4	Y	4	R	GS
2.135	0.329	F	4	N	1	G	GS
1.835	0.264	F	4	N	1	G	BD
1.635	0.214	F	4	Y	5	R	GS
1.435	0.157	F	4	Y	2	R	GS
1.802	0.256	F	4	Y	6	R	GS
1.168	0.067	F	4	Y	4	R	GS
3.871	0.588	F	4	N	1	G	GS
1.535	0.186	F	4	Y	6	R	GS
1.835	0.264	F	4	Y	2	R	BD
2.302	0.362	F	4	N	1	G	BD
1.468	0.167	F	4	Y	3	R	GS
2.202	0.343	F	2	N	1	G	GS
2.97	0.473	F	2	Y	2	G	GS
1.568	0.195	F	2	Y	3	R	GS
1.168	0.067	F	2	Y	2	R	BD
2.236	0.349	F	2	N	1	G	GS
5.172	0.714	F	2	Y	6	R	GS
2.302	0.362	F	2	Y	3	R	GS
2.302	0.362	F	2	N	1	G	BD
2.035	0.309	F	2	Y	2	R	GS
1.902	0.279	F	2	Y	4	R	GS
2.936	0.468	F	2	N	1	G	GS
1.969	0.294	F	2	N	1	G	BD
1.602	0.205	F	2	Y	5	R	GS
1.869	0.272	F	2	Y	2	R	GS
2.836	0.453	F	2	Y	6	G	GS
1.835	0.264	F	2	Y	4	R	GS
2.269	0.356	F	2	N	1	G	GS
1.702	0.231	F	2	Y	6	R	GS
2.469	0.393	F	2	Y	2	R	BD
2.603	0.415	F	2	N	1	G	BD
1.468	0.167	F	2	Y	3	R	GS
2.135	0.329	F	5	N	1	G	GS
1.034	0.015	F	5	Y	2	R	GS
1.235	0.092	F	5	Y	3	R	GS
1.168	0.067	F	5	Y	2	R	BD
2.035	0.309	F	5	N	1	G	GS
1.134	0.055	F	5	Y	6	R	GS

2.035	0.309	F	5	Y	3	R	GS
1.869	0.272	F	5	N	1	G	BD
1.268	0.103	F	5	Y	2	R	GS
1.502	0.177	F	5	Y	4	R	GS
2.035	0.309	F	5	N	1	G	GS
1.668	0.222	F	5	N	1	G	BD
1.735	0.239	F	5	Y	5	R	GS
1.034	0.015	F	5	Y	2	R	GS
1.635	0.214	F	5	Y	6	R	GS
1.268	0.103	F	5	Y	4	R	GS
1.502	0.177	F	5	N	1	G	GS
0.767	-0.115	F	5	Y	6	R	GS
1.335	0.125	F	5	Y	2	R	BD
1.869	0.272	F	5	N	1	G	BD
1.235	0.092	F	5	Y	3	R	GS
1.835	0.264	F	4	N	1	G	GS
1.368	0.136	F	4	Y	2	R	GS
1.368	0.136	F	4	Y	3	R	GS
1.502	0.177	F	4	Y	2	R	BD
2.269	0.356	F	4	N	1	G	GS
2.97	0.473	F	4	Y	6	R	GS
3.136	0.496	F	4	Y	3	R	GS
1.635	0.214	F	4	Y	2	R	GS
2.202	0.343	F	4	Y	4	R	GS
3.337	0.523	F	4	N	1	G	GS
4.705	0.673	F	4	N	1	G	BD
2.236	0.349	F	4	Y	5	R	GS
1.301	0.114	F	4	Y	2	R	GS
2.202	0.343	F	4	Y	6	R	GS
2.035	0.309	F	4	Y	4	R	GS
3.036	0.482	F	4	N	1	G	GS
1.401	0.146	F	4	Y	6	R	GS
1.401	0.146	F	4	Y	2	R	BD
3.537	0.549	F	4	N	1	G	BD
1.768	0.247	F	4	Y	3	R	GS
1.635	0.214	F	2	N	1	G	GS
1.034	0.015	F	2	Y	2	R	GS
1.101	0.042	F	2	Y	3	R	GS
1.001	0.000	F	2	Y	2	R	BD
1.034	0.015	F	2	N	1	G	GS
3.837	0.584	F	2	Y	6	R	GS
2.336	0.368	F	2	Y	3	R	GS

1.502	0.177	F	2	N	1	G	BD
1.268	0.103	F	2	Y	2	R	GS
1.335	0.125	F	2	Y	4	R	GS
1.435	0.157	F	2	N	1	G	GS
1.735	0.239	F	2	N	1	G	BD
1.735	0.239	F	2	Y	5	R	GS
1.268	0.103	F	2	Y	2	R	GS
2.836	0.453	F	2	Y	6	G	GS
1.301	0.114	F	2	Y	4	R	GS
1.502	0.177	F	2	N	1	G	GS
1.468	0.167	F	2	Y	6	R	GS
1.835	0.264	F	2	Y	2	R	BD
1.134	0.055	F	2	N	1	G	BD
1.068	0.029	F	2	Y	3	R	GS
1.768	0.247	M	2	N	1	G	GS
1.735	0.239	M	2	Y	2	G	GS
2.035	0.309	M	2	Y	3	R	GS
1.702	0.231	M	2	Y	2	G	BD
2.135	0.329	M	2	N	1	G	GS
2.369	0.375	M	2	Y	6	R	GS
2.503	0.398	M	2	Y	3	G	GS
4.438	0.647	M	2	N	1	G	BD
1.935	0.287	M	2	Y	2	G	GS
1.935	0.287	M	2	Y	4	R	GS
3.437	0.536	M	2	N	1	R	GS
3.904	0.592	M	2	N	1	R	BD
2.803	0.448	M	2	Y	5	R	GS
2.169	0.336	M	2	Y	2	G	GS
3.103	0.492	M	2	Y	6	G	GS
3.036	0.482	M	2	Y	4	R	GS
2.769	0.442	M	2	N	1	R	GS
1.335	0.125	M	2	Y	6	R	GS
1.702	0.231	M	2	Y	2	R	BD
3.77	0.576	M	2	N	1	G	BD
1.735	0.239	M	2	Y	3	R	GS
4.071	0.610	M	2	N	1	G	GS
1.401	0.146	M	2	Y	2	R	GS
1.502	0.177	M	2	Y	3	R	GS
1.602	0.205	M	2	Y	2	R	BD
2.936	0.468	M	2	N	1	G	GS
3.036	0.482	M	2	Y	6	R	GS
1.902	0.279	M	2	Y	3	R	GS

3.27	0.515	M	2	N	1	G	BD
1.301	0.114	M	2	Y	2	R	GS
1.368	0.136	M	2	Y	4	R	GS
1.535	0.186	M	2	N	1	G	GS
2.669	0.426	M	2	N	1	G	BD
1.802	0.256	M	2	Y	5	R	GS
1.268	0.103	M	2	Y	2	R	GS
1.768	0.247	M	2	Y	6	R	GS
1.134	0.055	M	2	Y	4	R	GS
1.602	0.205	M	2	N	1	G	GS
1.168	0.067	M	2	Y	6	R	GS
1.301	0.114	M	2	Y	2	R	BD
1.435	0.157	M	2	N	1	G	BD
1.168	0.067	M	2	Y	3	R	GS
0.934	-0.030	M	5	N	1	G	GS
0.868	-0.061	M	5	Y	2	R	GS
0.934	-0.030	M	5	Y	3	R	GS
0.934	-0.030	M	5	Y	2	R	BD
0.367	-0.435	M	5	N	1	G	GS
0.434	-0.363	M	5	Y	6	G	GS
1.034	0.015	M	5	Y	3	R	GS
0.968	-0.014	M	5	N	1	R	BD
0.701	-0.154	M	5	Y	2	R	GS
0.934	-0.030	M	5	Y	4	R	GS
1.201	0.080	M	5	N	1	R	GS
0.901	-0.045	M	5	N	1	G	BD
0.934	-0.030	M	5	Y	5	R	GS
0.701	-0.154	M	5	Y	2	R	GS
1.034	0.015	M	5	Y	6	G	GS
1.001	0.000	M	5	Y	4	R	GS
0.868	-0.061	M	5	N	1	G	GS
1.134	0.055	M	5	Y	6	R	GS
1.001	0.000	M	5	Y	2	R	BD
0.868	-0.061	M	5	N	1	G	BD
0.934	-0.030	M	5	Y	3	R	GS
1.468	0.167	M	3	N	1	G	GS
0.801	-0.096	M	3	Y	2	R	GS
0.834	-0.079	M	3	Y	3	R	GS
0.834	-0.079	M	3	Y	2	R	BD
0.501	-0.300	M	3	N	1	G	GS
2.369	0.375	M	3	Y	6	G	GS
1.435	0.157	M	3	Y	3	R	GS

1.235	0.092	M	3	N	1	G	BD
0.701	-0.154	M	3	Y	2	R	GS
0.767	-0.115	M	3	Y	4	R	GS
0.901	-0.045	M	3	N	1	G	GS
1.001	0.000	M	3	N	1	G	BD
1.168	0.067	M	3	Y	5	R	GS
0.601	-0.221	M	3	Y	2	R	GS
1.602	0.205	M	3	Y	6	G	GS
0.701	-0.154	M	3	Y	4	R	GS
0.834	-0.079	M	3	N	1	G	GS
1.335	0.125	M	3	Y	6	R	GS
0.701	-0.154	M	3	Y	2	R	BD
1.068	0.029	M	3	N	1	G	BD
0.601	-0.221	M	3	Y	3	R	GS
0.734	-0.134	M	5	N	1	G	GS
0.801	-0.096	M	5	Y	2	G	GS
1.368	0.136	M	5	Y	3	R	GS
0.834	-0.079	M	5	Y	2	G	BD
0.901	-0.045	M	5	N	1	G	GS
1.168	0.067	M	5	Y	6	G	GS
2.369	0.375	M	5	Y	3	R	GS
1.535	0.186	M	5	N	1	G	BD
2.102	0.323	M	5	Y	2	R	GS
1.668	0.222	M	5	Y	4	R	GS
1.602	0.205	M	5	N	1	G	GS
1.869	0.272	M	5	N	1	G	BD
1.468	0.167	M	5	Y	5	R	GS
1.335	0.125	M	5	Y	2	R	GS
2.402	0.381	M	5	Y	6	R	GS
1.602	0.205	M	5	Y	4	R	GS
2.002	0.301	M	5	N	1	G	GS
1.101	0.042	M	5	Y	6	R	GS
2.035	0.309	M	5	Y	2	R	BD
2.236	0.349	M	5	N	1	G	BD
1.635	0.214	M	5	Y	3	R	GS
1.502	0.177	F	4	N	1	G	GS
1.468	0.167	F	4	Y	2	R	GS
1.468	0.167	F	4	Y	3	R	GS
2.769	0.442	F	4	Y	2	R	BD
1.869	0.272	F	4	N	1	G	GS
3.337	0.523	F	4	Y	6	R	GS
1.602	0.205	F	4	Y	3	G	GS

3.904	0.592	F	4	N	1	G	BD
2.903	0.463	F	4	Y	2	R	GS
2.069	0.316	F	4	Y	4	R	GS
3.203	0.506	F	4	N	1	G	GS
3.57	0.553	F	4	N	1	G	BD
2.97	0.473	F	4	Y	5	R	GS
1.235	0.092	F	4	Y	2	R	GS
2.936	0.468	F	4	Y	6	R	GS
1.735	0.239	F	4	Y	4	R	GS
2.436	0.387	F	4	N	1	G	GS
1.969	0.294	F	4	Y	6	R	GS
1.335	0.125	F	4	Y	2	R	BD
2.436	0.387	F	4	N	1	G	BD
1.335	0.125	F	4	Y	3	R	GS
1.235	0.092	M	2	N	1	G	GS
1.168	0.067	M	2	Y	2	R	GS
1.034	0.015	M	2	Y	3	R	GS
1.268	0.103	M	2	Y	2	R	BD
1.068	0.029	M	2	N	1	G	GS
0.868	-0.061	M	2	Y	6	G	GS
1.635	0.214	M	2	Y	3	R	GS
1.969	0.294	M	2	N	1	G	BD
1.101	0.042	M	2	Y	2	R	GS
1.568	0.195	M	2	Y	4	R	GS
1.301	0.114	M	2	N	1	G	GS
1.435	0.157	M	2	N	1	G	BD
1.401	0.146	M	2	Y	5	R	GS
1.101	0.042	M	2	Y	2	R	GS
2.269	0.356	M	2	Y	6	G	GS
1.368	0.136	M	2	Y	4	R	GS
1.468	0.167	M	2	N	1	G	GS
1.502	0.177	M	2	Y	6	R	GS
1.268	0.103	M	2	Y	2	R	BD
1.735	0.239	M	2	N	1	G	BD
1.235	0.092	M	2	Y	3	R	GS
2.369	0.375	F	5	N	1	G	GS
1.668	0.222	F	5	Y	2	R	GS
1.635	0.214	F	5	Y	3	R	GS
1.635	0.214	F	5	Y	2	R	BD
1.301	0.114	F	5	N	1	G	GS
2.87	0.458	F	5	Y	6	R	GS
2.769	0.442	F	5	Y	3	R	GS

1.268	0.103	F	5	N	1	G	BD
1.401	0.146	F	5	Y	2	R	GS
2.169	0.336	F	5	Y	4	R	GS
2.836	0.453	F	5	N	1	G	GS
3.103	0.492	F	5	N	1	G	BD
2.302	0.362	F	5	Y	5	R	GS
2.436	0.387	F	5	Y	2	R	GS
2.436	0.387	F	5	Y	6	R	GS
1.301	0.114	F	5	Y	4	R	GS
2.536	0.404	F	5	N	1	G	GS
2.002	0.301	F	5	Y	6	R	GS
1.969	0.294	F	5	Y	2	R	BD
1.802	0.256	F	5	N	1	G	BD
1.602	0.205	F	5	Y	3	R	GS
0.868	-0.061	F	3	N	1	G	GS
1.068	0.029	F	3	Y	2	R	GS
1.602	0.205	F	3	Y	3	R	GS
1.802	0.256	F	3	Y	2	R	BD
1.101	0.042	F	3	N	1	G	GS
2.002	0.301	F	3	Y	6	R	GS
1.702	0.231	F	3	Y	3	R	GS
1.368	0.136	F	3	N	1	G	BD
1.435	0.157	F	3	Y	2	R	GS
1.468	0.167	F	3	Y	4	R	GS
1.535	0.186	F	3	N	1	G	GS
1.635	0.214	F	3	N	1	G	BD
1.768	0.247	F	3	Y	5	R	GS
1.068	0.029	F	3	Y	2	R	GS
3.337	0.523	F	3	Y	6	G	GS
1.435	0.157	F	3	Y	4	R	GS
1.568	0.195	F	3	N	1	G	GS
1.935	0.287	F	3	Y	6	R	GS
1.034	0.015	F	3	Y	2	R	BD
1.969	0.294	F	3	N	1	G	BD
1.502	0.177	F	3	Y	3	R	GS
1.568	0.195	M	2	N	1	G	GS
1.001	0.000	M	2	Y	2	R	GS
0.934	-0.030	M	2	Y	3	R	GS
1.268	0.103	M	2	Y	2	R	BD
1.602	0.205	M	2	N	1	G	GS
1.201	0.080	M	2	Y	6	G	GS
1.768	0.247	M	2	Y	3	R	GS

1.935	0.287	M	2	N	1	G	BD
1.935	0.287	M	2	Y	2	R	GS
1.735	0.239	M	2	Y	4	R	GS
1.502	0.177	M	2	N	1	G	GS
1.435	0.157	M	2	N	1	G	BD
1.835	0.264	M	2	Y	5	R	GS
1.201	0.080	M	2	Y	2	R	GS
4.037	0.606	M	2	Y	6	G	GS
1.368	0.136	M	2	Y	4	R	GS
1.101	0.042	M	2	N	1	G	GS
1.401	0.146	M	2	Y	6	R	GS
1.602	0.205	M	2	Y	2	R	BD
1.068	0.029	M	2	N	1	G	BD
1.168	0.067	M	2	Y	3	R	GS
1.535	0.186	M	4	N	1	G	GS
0.868	-0.061	M	4	Y	2	R	GS
0.968	-0.014	M	4	Y	3	R	GS
1.568	0.195	M	4	Y	2	R	BD
1.401	0.146	M	4	N	1	G	GS
1.568	0.195	M	4	Y	6	R	GS
2.402	0.381	M	4	Y	3	R	GS
1.134	0.055	M	4	N	1	G	BD
1.268	0.103	M	4	Y	2	R	GS
0.968	-0.014	M	4	Y	4	R	GS
1.134	0.055	M	4	N	1	G	GS
1.401	0.146	M	4	N	1	G	BD
0.968	-0.014	M	4	Y	5	R	GS
0.834	-0.079	M	4	Y	2	R	GS
1.802	0.256	M	4	Y	6	G	GS
1.335	0.125	M	4	Y	4	R	GS
1.201	0.080	M	4	N	1	G	GS
0.801	-0.096	M	4	Y	6	R	GS
0.968	-0.014	M	4	Y	2	R	BD
0.667	-0.176	M	4	N	1	G	BD
0.834	-0.079	M	4	Y	3	R	GS
2.903	0.463	M	3	N	1	G	GS
1.935	0.287	M	3	Y	2	R	GS
1.568	0.195	M	3	Y	3	R	GS
2.035	0.309	M	3	Y	2	R	BD
4.271	0.631	M	3	N	1	G	GS
2.069	0.316	M	3	Y	6	R	GS
2.736	0.437	M	3	Y	3	R	GS

3.036	0.482	M	3	N	1	G	BD
2.736	0.437	M	3	Y	2	R	GS
2.269	0.356	M	3	Y	4	R	GS
2.903	0.463	M	3	N	1	G	GS
3.136	0.496	M	3	N	1	G	BD
2.336	0.368	M	3	Y	5	R	GS
2.069	0.316	M	3	Y	2	R	GS
3.036	0.482	M	3	Y	6	R	GS
1.535	0.186	M	3	Y	4	R	GS
3.17	0.501	M	3	N	1	G	GS
1.201	0.080	M	3	Y	6	R	GS
1.468	0.167	M	3	Y	2	R	BD
2.236	0.349	M	3	N	1	G	BD
1.368	0.136	M	3	Y	3	R	GS
1.902	0.279	M	3	N	1	G	GS
1.268	0.103	M	3	Y	2	R	GS
1.101	0.042	M	3	Y	3	R	GS
1.635	0.214	M	3	Y	2	R	BD
1.768	0.247	M	3	N	1	G	GS
1.201	0.080	M	3	Y	6	R	GS
1.201	0.080	M	3	Y	3	R	GS
1.902	0.279	M	3	N	1	G	BD
1.401	0.146	M	3	Y	2	R	GS
1.268	0.103	M	3	Y	4	R	GS
2.035	0.309	M	3	N	1	G	GS
2.035	0.309	M	3	N	1	G	BD
1.602	0.205	M	3	Y	5	R	GS
1.101	0.042	M	3	Y	2	R	GS
1.635	0.214	M	3	Y	6	R	GS
1.034	0.015	M	3	Y	4	R	GS
1.668	0.222	M	3	N	1	G	GS
1.335	0.125	M	3	Y	6	R	GS
1.134	0.055	M	3	Y	2	R	BD
1.935	0.287	M	3	N	1	G	BD
1.068	0.029	M	3	Y	3	R	GS
1.502	0.177	F	3	N	1	G	GS
2.002	0.301	F	3	Y	2	R	GS
1.468	0.167	F	3	Y	3	R	GS
1.635	0.214	F	3	Y	2	R	BD
2.669	0.426	F	3	N	1	G	GS
1.668	0.222	F	3	Y	6	R	GS
2.87	0.458	F	3	Y	3	R	GS

2.336	0.368	F	3	N	1	G	BD
2.669	0.426	F	3	Y	2	R	GS
2.135	0.329	F	3	Y	4	R	GS
2.936	0.468	F	3	N	1	G	GS
2.669	0.426	F	3	N	1	R	BD
1.668	0.222	F	3	Y	5	R	GS
2.035	0.309	F	3	Y	2	R	GS
2.236	0.349	F	3	Y	6	R	GS
1.802	0.256	F	3	Y	4	R	GS
3.437	0.536	F	3	N	1	G	GS
1.668	0.222	F	3	Y	6	R	GS
2.002	0.301	F	3	Y	2	R	BD
3.27	0.515	F	3	N	1	G	BD
2.102	0.323	F	3	Y	3	R	GS
1.568	0.195	F	5	N	1	G	GS
1.101	0.042	F	5	Y	2	R	GS
0.801	-0.096	F	5	Y	3	R	GS
1.001	0.000	F	5	Y	2	R	BD
0.934	-0.030	F	5	N	1	G	GS
1.869	0.272	F	5	Y	6	G	GS
1.768	0.247	F	5	Y	3	R	GS
1.401	0.146	F	5	N	1	G	BD
1.235	0.092	F	5	Y	2	R	GS
1.268	0.103	F	5	Y	4	R	GS
1.168	0.067	F	5	N	1	G	GS
1.201	0.080	F	5	N	1	G	BD
1.335	0.125	F	5	Y	5	R	GS
1.101	0.042	F	5	Y	2	R	GS
1.001	0.000	F	5	Y	6	R	GS
1.134	0.055	F	5	Y	4	R	GS
0.968	-0.014	F	5	N	1	G	GS
0.734	-0.134	F	5	Y	6	R	GS
1.201	0.080	F	5	Y	2	R	BD
1.101	0.042	F	5	N	1	G	BD
1.001	0.000	F	5	Y	3	R	GS
1.969	0.294	F	5	N	1	G	GS
1.502	0.177	F	5	Y	2	R	GS
1.068	0.029	F	5	Y	3	R	GS
1.535	0.186	F	5	Y	2	R	BD
1.735	0.239	F	5	N	1	G	GS
3.37	0.528	F	5	Y	6	G	GS
1.502	0.177	F	5	Y	3	R	GS

3.036	0.482	F	5	N	1	G	BD
1.001	0.000	F	5	Y	2	R	GS
1.869	0.272	F	5	Y	4	R	GS
2.236	0.349	F	5	N	1	G	GS
3.103	0.492	F	5	N	1	G	BD
1.468	0.167	F	5	Y	5	R	GS
1.134	0.055	F	5	Y	2	R	GS
1.702	0.231	F	5	Y	6	R	GS
1.435	0.157	F	5	Y	4	R	GS
2.769	0.442	F	5	N	1	G	GS
1.702	0.231	F	5	Y	6	R	GS
1.201	0.080	F	5	Y	2	R	BD
2.87	0.458	F	5	N	1	G	BD
1.168	0.067	F	5	Y	3	R	GS
3.136	0.496	F	5	N	1	G	GS
1.368	0.136	F	5	Y	2	R	GS
1.101	0.042	F	5	Y	3	R	GS
1.235	0.092	F	5	Y	2	R	BD
1.401	0.146	F	5	N	1	G	GS
1.568	0.195	F	5	Y	6	R	GS
1.401	0.146	F	5	Y	3	R	GS
1.969	0.294	F	5	N	1	G	BD
1.235	0.092	F	5	Y	2	R	GS
1.301	0.114	F	5	Y	4	R	GS
2.269	0.356	F	5	N	1	G	GS
1.802	0.256	F	5	N	1	G	BD
1.535	0.186	F	5	Y	5	R	GS
1.101	0.042	F	5	Y	2	R	GS
2.102	0.323	F	5	Y	6	R	GS
1.401	0.146	F	5	Y	4	R	GS
2.202	0.343	F	5	N	1	G	GS
1.168	0.067	F	5	Y	6	R	GS
1.568	0.195	F	5	Y	2	R	BD
3.403	0.532	F	5	N	1	G	BD
1.268	0.103	F	5	Y	3	R	GS
1.468	0.167	M	5	N	1	G	GS
1.168	0.067	M	5	Y	2	R	GS
1.235	0.092	M	5	Y	3	R	GS
1.034	0.015	M	5	Y	2	R	BD
1.635	0.214	M	5	N	1	G	GS
2.736	0.437	M	5	Y	6	R	GS
1.835	0.264	M	5	Y	3	R	GS

1.301	0.114	M	5	N	1	G	BD
1.201	0.080	M	5	Y	2	R	GS
1.168	0.067	M	5	Y	4	R	GS
1.268	0.103	M	5	N	1	G	GS
1.401	0.146	M	5	N	1	G	BD
1.335	0.125	M	5	Y	5	R	GS
1.068	0.029	M	5	Y	2	R	GS
1.702	0.231	M	5	Y	6	R	GS
1.101	0.042	M	5	Y	4	R	GS
1.668	0.222	M	5	N	1	G	GS
1.034	0.015	M	5	Y	6	R	GS
1.001	0.000	M	5	Y	2	R	BD
1.535	0.186	M	5	N	1	G	BD
0.934	-0.030	M	5	Y	3	R	GS
2.236	0.349	M	2	N	1	G	GS
1.401	0.146	M	2	Y	2	R	GS
1.535	0.186	M	2	Y	3	R	GS
2.102	0.323	M	2	Y	2	R	BD
1.969	0.294	M	2	N	1	G	GS
3.07	0.487	M	2	Y	6	R	GS
2.202	0.343	M	2	Y	3	R	GS
2.636	0.421	M	2	N	1	G	BD
2.436	0.387	M	2	Y	2	R	GS
1.902	0.279	M	2	Y	4	R	GS
1.802	0.256	M	2	N	1	G	GS
2.035	0.309	M	2	N	1	G	BD
2.169	0.336	M	2	Y	5	R	GS
2.736	0.437	M	2	Y	2	R	GS
1.869	0.272	M	2	Y	6	R	GS
1.869	0.272	M	2	Y	4	R	GS
1.401	0.146	M	2	N	1	G	GS
1.368	0.136	M	2	Y	6	R	GS
1.869	0.272	M	2	Y	2	R	BD
1.435	0.157	M	2	N	1	G	BD
1.301	0.114	M	2	Y	3	R	GS
1.034	0.015	M	1	N	1	G	GS
1.535	0.186	M	1	Y	2	R	GS
1.468	0.167	M	1	Y	3	R	GS
2.302	0.362	M	1	Y	2	R	BD
0.834	-0.079	M	1	N	1	G	GS
1.335	0.125	M	1	Y	6	R	GS
1.735	0.239	M	1	Y	3	R	GS

1.468	0.167	M	1	N	1	G	BD
1.568	0.195	M	1	Y	2	R	GS
1.335	0.125	M	1	Y	4	R	GS
1.368	0.136	M	1	N	1	G	GS
1.768	0.247	M	1	Y	5	R	GS
2.135	0.329	M	1	Y	2	R	GS
2.102	0.323	M	1	Y	6	R	GS
1.268	0.103	M	1	Y	4	R	GS
3.103	0.492	M	1	N	1	G	GS
1.768	0.247	M	1	Y	6	R	GS
1.568	0.195	M	1	Y	2	R	BD
2.236	0.349	M	1	N	1	G	BD
1.969	0.294	M	1	Y	3	R	GS
2.436	0.387	M	3	N	1	G	GS
1.068	0.029	M	3	Y	2	R	GS
1.301	0.114	M	3	Y	3	R	GS
1.502	0.177	M	3	Y	2	R	BD
1.902	0.279	M	3	N	1	G	GS
2.269	0.356	M	3	Y	6	R	GS
1.602	0.205	M	3	Y	3	R	GS
2.436	0.387	M	3	N	1	R	BD
2.536	0.404	M	3	Y	2	R	GS
1.902	0.279	M	3	Y	4	R	GS
1.768	0.247	M	3	N	1	G	GS
1.935	0.287	M	3	N	1	G	BD
1.635	0.214	M	3	Y	5	R	GS
1.368	0.136	M	3	Y	2	R	GS
1.668	0.222	M	3	Y	6	R	GS
1.502	0.177	M	3	Y	4	R	GS
2.302	0.362	M	3	N	1	G	GS
1.235	0.092	M	3	Y	6	R	GS
1.668	0.222	M	3	Y	2	R	BD
2.336	0.368	M	3	N	1	G	BD
1.134	0.055	M	3	Y	3	R	GS
4.571	0.660	M	4	N	1	G	GS
1.935	0.287	M	4	Y	2	R	GS
1.568	0.195	M	4	Y	3	R	GS
1.568	0.195	M	4	Y	2	R	BD
2.836	0.453	M	4	N	1	G	GS
3.57	0.553	M	4	Y	6	R	GS
2.336	0.368	M	4	Y	3	R	GS
1.735	0.239	M	4	Y	2	R	GS

1.368	0.136	M	4	Y	4	R	GS
2.436	0.387	M	4	N	1	G	GS
4.037	0.606	M	4	N	1	G	BD
1.635	0.214	M	4	Y	5	R	GS
1.735	0.239	M	4	Y	2	R	GS
2.636	0.421	M	4	Y	6	R	GS
1.768	0.247	M	4	Y	4	R	GS
2.436	0.387	M	4	N	1	G	GS
1.502	0.177	M	4	Y	6	R	GS
2.035	0.309	M	4	Y	2	R	BD
2.603	0.415	M	4	N	1	G	BD
1.435	0.157	M	4	Y	3	R	GS
1.368	0.136	M	4	N	1	G	GS
1.201	0.080	M	4	Y	2	R	GS
1.301	0.114	M	4	Y	3	R	GS
1.768	0.247	M	4	Y	2	R	BD
1.435	0.157	M	4	N	1	G	GS
2.069	0.316	M	4	Y	6	G	GS
2.069	0.316	M	4	Y	3	R	GS
1.301	0.114	M	4	N	1	G	BD
1.568	0.195	M	4	Y	2	R	GS
1.935	0.287	M	4	Y	4	R	GS
1.835	0.264	M	4	N	1	G	GS
1.335	0.125	M	4	N	1	G	BD
2.269	0.356	M	4	Y	5	R	GS
1.602	0.205	M	4	Y	2	R	GS
4.271	0.631	M	4	Y	6	R	GS
1.268	0.103	M	4	Y	4	R	GS
2.202	0.343	M	4	N	1	G	GS
1.401	0.146	M	4	Y	6	R	GS
1.668	0.222	M	4	Y	2	R	BD
1.969	0.294	M	4	N	1	G	BD
1.401	0.146	M	4	Y	3	R	GS
1.735	0.239	M	3	N	1	G	GS
1.401	0.146	M	3	Y	2	R	GS
1.301	0.114	M	3	Y	3	R	GS
1.602	0.205	M	3	Y	2	R	BD
1.435	0.157	M	3	N	1	G	GS
1.535	0.186	M	3	Y	6	R	GS
1.735	0.239	M	3	Y	3	R	GS
1.702	0.231	M	3	N	1	G	BD
1.335	0.125	M	3	Y	2	R	GS

1.468	0.167	M	3	Y	4	R	GS
1.502	0.177	M	3	N	1	G	GS
1.502	0.177	M	3	N	1	G	BD
2.002	0.301	M	3	Y	5	R	GS
1.268	0.103	M	3	Y	2	R	GS
1.768	0.247	M	3	Y	6	R	GS
1.535	0.186	M	3	Y	4	R	GS
1.602	0.205	M	3	N	1	G	GS
1.768	0.247	M	3	Y	6	R	GS
1.768	0.247	M	3	Y	2	R	BD
1.802	0.256	M	3	N	1	G	BD
1.335	0.125	M	3	Y	3	R	GS