# Study of in-vehicle technology for increasing motorcycle conspicuity

By

Benjamin Scott Campbell

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By

Benjamin Scott Campbell

Approved:

Lesley Strawderman
(Major Professor)

Stanley F. Bullington
(Committee Member/Graduate Coordinator)

Teena M. Garrison
(Committee Member)

Jason M. Keith
Dean
Bagley College of Engineering

Name: Benjamin Scott Campbell

Date of Degree: May 6, 2016

Institution: Mississippi State University

Major Field: Industrial Engineering

Major Professor: Lesley Strawderman

Title of Study: Study of in-vehicle technology for increasing motorcycle conspicuity

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Candidate for Degree of Master of Science

This study was conducted to determine whether adding in-vehicle technology to vehicles resulted in increased driver awareness of motorcycles. The specific technology tested consisted of a warning light which illuminated on the vehicle's instrument panel when the vehicle was near a motorcycle. The effect of motorcycle color on driver awareness was also explored. Participants were recruited to drive a high-fidelity driving simulator in a city environment. Eye-tracker data was collected and used to determine how much attention drivers paid to the motorcycles in the simulation. Results showed that the in-vehicle technology significantly increased driver awareness of motorcycles, but the color of the motorcycles had no impact on driver awareness.

Key words: vehicle technology, conspicuity, motorcycle safety

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# CHAPTER I

# INTRODUCTION

The fatality rate of motorcyclists is alarmingly high considering that in 2013, motorcycles made up only 3 percent of the vehicles on the road, but accounted for 14 percent of all traffic fatalities. The 4,668 motorcyclists killed in motor vehicle crashes and estimated 88,000 injured are evidence of how dangerous motorcycling can be (NHTSA, 2015). Motorcyclists are at particular risk of crashing with other vehicles. Data shows there were 2,182 two-vehicle fatal crashes involving a motorcycle and another type of vehicle, and in 42 percent of those crashes, the other vehicle was turning left while the motorcycle was going straight, passing, or overtaking other vehicles (NHTSA, 2015).

The low conspicuity of motorcycles is a likely reason for the high number of crashes. Some of these crashes can be attributed to the low sensory conspicuity of motorcycles. For example, motorcycles are small and difficult for drivers to see; the small size also makes it difficult for drivers to judge a motorcycle's speed. Other crashes may be attributed to low cognitive conspicuity. Some drivers do not pay as much attention to motorcycles because the driver is not expecting to see motorcycles on the road. While research has identified ways to increase sensory conspicuity for motorcycles, further research on ways to increase cognitive conspicuity is needed. This research looks at increasing cognitive conspicuity by using an in-dash warning system to alert drivers of nearby motorcycles.

# CHAPTER II

# LITERATURE REVIEW

Research shows that when a crash between a car and motorcycle occurs, the car driver is more often responsible for the crash than the motorcycle rider (Wulf, Hancock, & Rahimi, 1989). In many of these crashes, drivers claimed they "looked but failed to see"(LBFS) the rider (Langham, Hole, Edwards, & O'Neil, 2002). One possible reason for LBFS crashes between automobiles and motorcycles is the low conspicuity of motorcycles (Roge, Douissembekov, & Vienne, 2012). Conspicuity refers to how easily something, a motorcycle in this case, is recognized or noticed. Something with a high conspicuity level is easily recognized, while something with a low conspicuity level is not easily recognized. There are two main types of conspicuity: sensory and cognitive. Sensory conspicuity refers to the physical qualities of an object that can be compared using external references, and cognitive conspicuity is contingent upon the characteristics of the observer and relies critically on the salience of the target (Hancock, Wulf, Thom, & Fassnacht, 1990). The following sections present prior research on factors affecting the sensory and cognitive conspicuity levels for motorcycles.

## 2.1 Sensory Conspicuity

Sensory conspicuity deals with the physical properties of an object compared to that object's surroundings (Green, 2015). An object with a high level of sensory conspicuity has physical properties which are strikingly different than that object's surroundings. A large amount of research has been performed to see which physical properties can increase the sensory conspicuity of motorcycles.

The colors of both the motorcycle and the gear worn by a motorcyclist are important factors in increasing sensory conspicuity. Studies have shown that bright fluorescent colors are best at increasing the sensory conspicuity of motorcycles (e.g., Dahlstedt, 1986; Donne & Fulton, 1985; Fulton et al., 1980; Olson et al., 1979a, 1979b, 1981; Stroud & Kirkby, 1976; Stroud et al., 1980; Williams & Hoffmann, 1977).

Another factor which plays a role in increasing the sensory conspicuity of motorcycles is whether or not the motorcycle's headlight is turned on. Research shows that running lights during the day increase the sensory conspicuity of motorcycles (e.g., Dahlstedt, 1986; Fulton et al., 1980; Janoff, 1973; Janoff & Cassel, 1971).

A third physical property of motorcycles which affects sensory conspicuity is the size of the motorcycle. Hole et. al. showed that the larger a motorcycle is, the quicker other drivers' reaction time to the motorcycle will be; this suggests that larger motorcycles have a higher level of sensory conspicuity than smaller motorcycles (Hole et al., 1996).

The facts that most motorcycles sold in the US have automatic-on headlights to meet state laws (Motorcycle Safety Foundation, 2015) and almost all motorcycle equipment companies sell a line of high visibility helmets and jackets, show the commitment of the government and companies to increasing sensory conspicuity.

### 2.2 Cognitive Conspicuity

Our senses take in a larger amount of information than our brain can process, therefore our brains must decide which information is most relevant and focus on that in order to prevent an information overload (Grissinger, 2009). Cognitive conspicuity deals with the perceived relevance of information; items which our brains consider relevant have a high level of cognitive conspicuity. Even if a motorcycle has a high level of sensory conspicuity, it might not be seen by other drivers if those drivers do not consider motorcycles on the road as relevant information. A possible reason the brain may not consider motorcycles relevant is because drivers are not expecting to see motorcycles; the drivers are not purposely pushing the motorcycles out of their minds. In 2013, motorcycles made up only 3 percent of registered vehicles on the road (NHTSA, 2015). The relatively few number of motorcycles on the road compared to other vehicles supports the idea that drivers do not expect to see motorcycles. This literature review will present what little research has been performed on increasing cognitive conspicuity for motorcycles before presenting related research for increasing cognitive conspicuity for other vulnerable road users (VRUs) and road conditions.

Research shows that automobile drivers who also have a motorcycle license detect motorcycles more quickly than drivers without a motorcycle license. Drivers with a motorcycle license are more conscious of motorcycles in their environment; in other words, they have a higher cognitive conspicuity when it comes to motorcycles (Magazzù, Comelli, & Marinoni, 2006). A likely explanation for this is that people with a motorcycle license are likely more interested in motorcycles than people without a motorcycle licenses, thus, when they see a motorcycle their brains consider it relevant information. Increasing the cognitive conspicuity by making all drivers aware of motorcycles in their environment is likely to decrease the number of automobile-motorcycle crashes.

Some organizations and government groups hope to increase the cognitive conspicuity of motorcycles by launching public campaigns to bring awareness of this issue to drivers. Bumper stickers and signs reading “Watch for Motorcycles” are part of a campaign sponsored by the Motorcycle Awareness Campaign (MAC); the mission statement of MAC is “To promote awareness and safety of motorcyclists on roadways” (Motorcycle Awareness Campaign, 2016). There are many other campaigns with similar mission statements across the country, a couple of examples are the Texas Department of Transportation’s “Share the Road: Look Twice for Motorcycles” campaign (Texas Department of Transportation, 2016), and the North Carolina “Look Twice, Save a Life” campaign (Banks, 2011).

Another way of increasing the cognitive conspicuity of all drivers is to put a system in vehicles which detects motorcycles and lights up a symbol in the shape of a motorcycle on the instrument panel to warn the driver of the motorcycle’s presence. The idea is that the warning will remind the driver that it is important to look for motorcycles, so the driver will consider the motorcycle as relevant information when filtering which information to analyze. Many new vehicles are already equipped with technology such as vehicle-to-vehicle (V2V) communications, vehicle-to-infrastructure (V2I) communications, GPS, cameras and radar to increase drivers’ cognitive conspicuity of other automobiles, pedestrians, and road conditions.

Studies have looked at different ways of using such technology for increasing a driver’s cognitive conspicuity about certain objects. XingXing He et al. studied the effectiveness of a system which uses radar and cameras to detect pedestrians and vehicles, and warns the driver if any of the pedestrians or vehicles are in a specified danger region (He, Ding, Wang, Liu, & Wang, 2014). Other research has gone a step further and studied the use of GPS and sensors to track the movement of other vehicles and pedestrians, and issue a warning to the driver if a collision is likely to occur (e.g., Ibanez-Guzman, Lefevre, Mokkadem, & Rodhaim, 2010; Peng, Wu, Huang, & He, 2013). Yet another study looked at the use of ultrasonic sensors for detecting and warning drivers of potholes (Madli, Hebbar, Pattar, & Golla, 2015).

Similar systems are also being developed for raising drivers' awareness of road conditions. Rajale et al. are developing a system which will use wireless communications between vehicles and road signs to provide drivers with information about the road on a screen inside the vehicle (Rajale, Khachne, & Oak, 2014). Another system was created by Jenkins et al. which relays work zone information, such as speed and whether or not workers are present, to drivers as audible messages (Jenkins & Shield, 2014).

All of the above systems show that using sensors and wireless communication to detect and warn drivers of hazards will effectively increase drivers' cognitive conspicuity about an object. Similar technology can be used to detect motorcycles, and alert drivers of the motorcycles' presence by illuminating a symbol of a motorcycle on the driver's instrument panel, as shown in Figure 2.1. The driver will then know to look for the motorcycle, which will decrease the chance of a crash.


Figure 2.1 Instrument panel with motorcycle warning

# CHAPTER III

# METHODS

## 3.1 Experimental Design

A 2x2 repeated measures design was used to evaluate the effect of the color of motorcycles (within-subjects: 2 levels) and the effect of an in-vehicle warning system (between-subjects: 2 levels) on increasing the conspicuity of motorcycles. Members of the general public in and around Mississippi State University were recruited to drive through a simulated city area in a high-fidelity driving simulator. All participants were subjected to both levels of motorcycle color (black and yellow), while half the participants had the in-vehicle warning system (Figure 2.1) and half did not.

The study took place in the driving simulator lab at the Center for Advanced Vehicular Systems (CAVS) at Mississippi State University. The simulator is a full-sized Nissan Maxima body mounted on a hexapod motion base with six degrees of freedom, which simulates the physics of a real-car drive. The simulator is based on a mid-sized sedan with an automatic transmission, and it has all the original components needed for safe and comfortable operation. The controls used by participants include the steering wheel, accelerator pedal, brake pedal, and gear shift. The visual environment is provided by three large projector screens in front of the vehicle (providing approximately 180 degrees of visual angle), one projector screen to the rear of the vehicle (visible from the rear view mirror), and two small LCD screens mounted in place of the side mirrors. These screens provide an immersive visual environment for the driving scenario.

There is also a video-based eye-tracking system (faceLAB) mounted on the dash board of the simulator. The eye tracker uses an infrared (IR) light source mounted between two cameras, which allows for the precise tracking of the eye via the relationship between the pupil and the reflection of the IR light on the cornea. The faceLAB system has a precision within approximately 0.5 degrees (°) of visual angle (~1° at the periphery), and a sampling rate of 60Hz. However, the eye tracker data is linked to a video software with a sampling rate of 30Hz; so the functional sampling rate for this experiment is 30Hz. The current configuration of the faceLAB system effectively captures participants' looks and glances at objects located anywhere on the forward center screen of the simulator.

## 3.2 Variables

The independent variables were color of the motorcycle and in-vehicle warning system. The dependent variables were time it took for the participant to notice the motorcycle, number of glances at the motorcycle, the mean duration of glances, and the total duration of time the participant looked at the motorcycle. A maximum, minimum, average, and standard deviation were calculated for each variable. All of the dependent variables were measured using faceLAB.

Specifics of how the variables were measured are as follows:

*Time to notice the motorcycle-* The motorcycle is programmed to enter the simulated environment when the participant reaches a certain location in the environment (the motorcycle is visible to the participant when it appears). An analyst used faceLAB data overlaid onto a video of the drive, and recorded the time at which the participant first looked at the motorcycle (Appendix D). The difference between a participant's first look at the motorcycle and the time the motorcycle entered the environment is the time to notice the motorcycle.

*Number of glances at the motorcycle*- An analyst looked at eye-tracker data from faceLAB overlaid onto a video of the drive and recorded the number of times the participant glanced at the motorcycle. A glance began when a participant first looked at the motorcycle, and ended when the participant stopped looking at the motorcycle.

*Duration of time looked at the motorcycle*- This is the total amount of time a participant spent looking at the motorcycle. It was calculated by summing the duration of each glance at the motorcycle.

*Mean duration of glances*- This is the average length of glance for each participant. It was calculated by dividing a participant's total duration of time spent looking at a motorcycle by the number of times they glanced at that motorcycle.

Optimizing all of the dependent variables is important for increasing the safety of motorcyclists, however reducing the time it takes a driver to notice a motorcycle is of particular importance. Reducing the time it takes automobile drivers to notice a motorcycle allows drivers more time to react to that motorcycle and other environmental factors.

### 3.3 Participants

A total of 50 participants were recruited from the general public in and around Mississippi State University to be a part of the study. To be a part of the study participants were required to have a valid driving license, good vision and hearing, and no history of epilepsy or simulator/motion sickness; these factors were measured via self-report by the participants in a screening process. There were 33 male and 17 female participants in the study with a mean age of 21.51 (SD=2.62); participants had an average of 5.78 (SD=2.36) years driving experience.

### 3.4 Protocol

Word-of-mouth and posted flyers were used to inform the population of this study. People interested in participating were first required to complete an online screening process, then a researcher scheduled a time for the participant to go to CAVS and complete the study. The first thing participants were required to do upon arrival was to read, sign, and date an informed consent form, agreeing to the terms of the experiment. Participants then completed a demographics survey (Appendix A), a driving behavior questionnaire (DBQ) (Appendix B), and a baseline motion/simulator sickness questionnaire (MS/SSQ) (Appendix C). Next, the participant was introduced to the driving simulator and given an overview of the simulation system, the simulator vehicle, and the eye-tracking system.

The experiment consisted of two drives, a familiarization drive and the drive in which data were collected. The familiarization drive lasted five minutes, in which the participant was instructed to drive freely through a city environment in order to become comfortable with how the simulator works.

After completing the familiarization drive, the participant was required to fill out another MS/SSQ. If the participant showed no signs of motion sickness, they got back into the vehicle and the eye-tracker was calibrated and initiated. Once the eye-tracker was successfully set up, the participant started the data collection drive.

The data collection drive took place in a city environment consisting of a total of 12 intersections; two of the intersections on the corners of the map were the intersections of interest to the study. The participants were exposed to a yellow motorcycle at one of these intersections and a black motorcycle at another intersection. It is important to note that the motorcycles had the right-of-way at these intersections. Data was collected at the intersections with a motorcycle present.

A map of the environment is shown in Figure 3.1; the blue lines represent streets, the red arrows represent the route the participant will drive, the yellow arrow represents the route of the yellow motorcycle and the black arrow represents the route of the black motorcycle. The green dots represent possible starting points for the participants; the starting point changes to achieve a counter balance of which intersections the participants are exposed to first. A close-up diagram of the corner intersections is shown in Figure 3.2. As the participants approached these intersections, they were given verbal instructions to turn left.

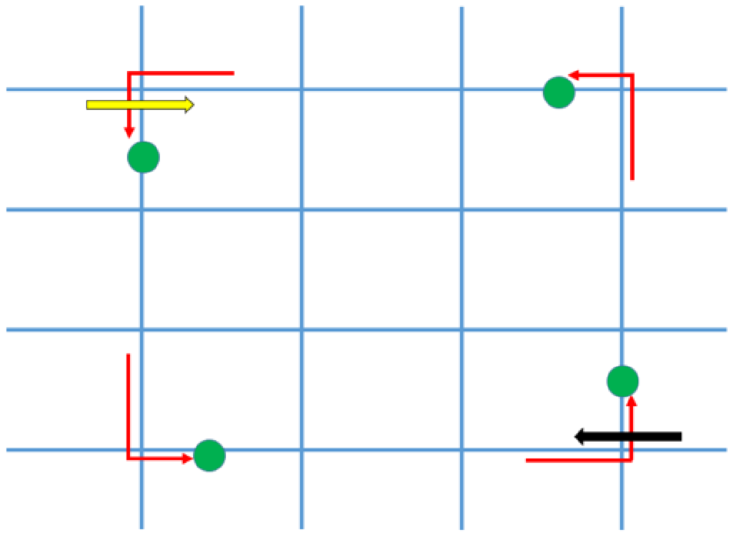

Figure 3.1 Map of simulated city

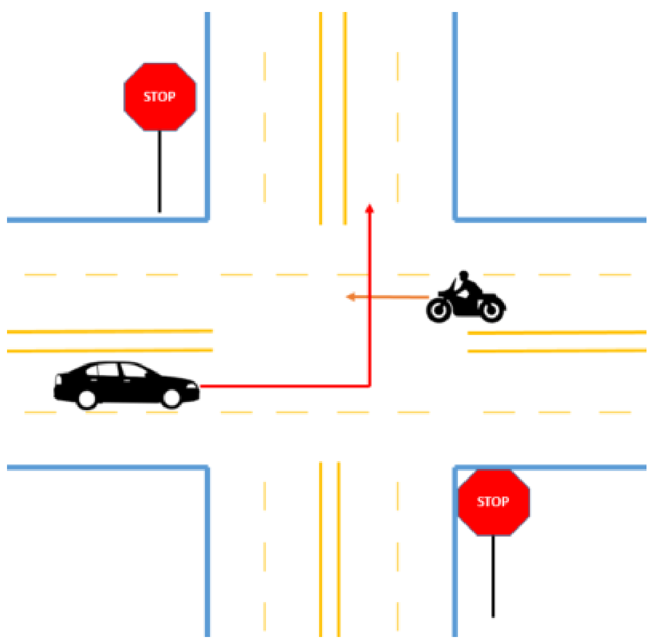


Figure 3.2 Data collection intersection

The drive ended after the participant passed through all four corner intersections. After the drive, the participant completed another MS/SSQ which was compared to the previous MS/SSQ to determine if the participant was showing signs of simulator sickness. The participant was then compensated for their time, informed of the true purpose of the study and allowed to leave.

# CHAPTER IV

## DATA PREPARATION/ANALYSIS

A total of 50 people participated in the study, and valid data was collected from 41 of those 50 participants. Valid data was not collected from the other 9 participants because we were unable to calibrate the eye tracker, or the participants were unable to complete the experiment due to motion sickness. For each participant, the data extracted from the eye tracker videos was the time to notice both the black and yellow motorcycles, the number of glances at both the black and yellow motorcycles, the total duration of time looked at both the black and yellow motorcycles, and mean duration of glances for both the black and yellow motorcycles. This data was extracted from the eye tracker videos, inputted into Microsoft Excel, and then imported into IBM SPSS Statistics 22 for analysis. Box plots created for each independent variable revealed there were no significant outliers which needed to be removed. The significance of color (a within-subjects IV) and in-vehicle technology (between-subjects IV) on the dependent variables was analyzed using the data above.

In order to test the significance of demographic data on the dependent variables, an average value was calculated for each participant's time to notice, number of glances, duration, and mean duration of glances. This data was checked for outliers and normality, and then analyzed using ANOVAs or Kruskal-Wallis tests.

## 4.1 Time to Notice

The descriptive statistics for *time to notice* based on color are shown in Table 4.1.

Table 4.1 Descriptive Statistics: Time to Notice by Color

| | n | $\bar{x}$ | s | Min | Max |
|---|---|---|---|---|---|
| **Overall** | 82 | 0.257 | 0.336 | 0.000 | 1.835 |
| **Color** | | | | | |
| Yellow | 41 | 0.287 | 0.371 | 0.000 | 1.835 |
| Black | 41 | 0.227 | 0.299 | 0.000 | 1.001 |

This data did not follow a normal distribution, so the significance of color on *time to notice* was analyzed using the non-parametric Friedman test. It was expected that participants would notice the yellow motorcycle more quickly than the black motorcycle, however results showed there was no significant difference between the two groups ($\chi^2$ (1, n=41)=0.862, p=0.353).

Table 4.2 shows the descriptive statistics for participant's *time to notice* both the black and yellow motorcycles based on the presence of the warning light.

Table 4.2 Descriptive Statistics: Time to Notice by Warning Light

| | | n | $\bar{x}$ | s | Min | Max |
|---|---|---|---|---|---|---|
| Black Motorcycle | **Overall** | 41 | 0.227 | 0.299 | 0.000 | 1.001 |
| | **Warning Light** | | | | | |
| | Yes | 19 | 0.119 | 0.205 | 0.000 | 0.700 |
| | No | 22 | 0.320 | 0.338 | 0.000 | 1.001 |
| Yellow Motorcycle | **Overall** | 41 | 0.287 | 0.371 | 0.000 | 1.835 |
| | **Warning Light** | | | | | |
| | Yes | 19 | 0.296 | 0.310 | 0.000 | 0.901 |
| | No | 22 | 0.279 | 0.424 | 0.000 | 1.835 |

Non-parametric Kruskal-Wallis tests were used to analyze the effects of in-vehicle technology on *time to notice*. The analysis revealed that participants with the warning light present noticed the black motorcycle more quickly than participants without the warning light ($\chi^2$ (1, n=41)=3.926, p=0.048). However, the presence of the warning light made no significant difference in the time it took participants to notice the yellow motorcycle ($\chi^2$ (1, n=41)=0.329, p=0.566).

The descriptive statistics for *average time to notice* based on demographic variables are shown in Table 4.3.

Table 4.3 Descriptive Statistics: Time to Notice by Demographics

| | n | $\bar{x}$ | s | Min | Max |
|---|---|---|---|---|---|
| **Overall** | 41 | 0.257 | 0.269 | 0.000 | 1.352 |
| **Gender** | | | | | |
| Male | 29 | 0.260 | 0.298 | 0.000 | 1.352 |
| Female | 12 | 0.249 | 0.191 | 0.000 | 0.532 |
| **Order** | | | | | |
| Yellow 1st | 19 | 0.209 | 0.182 | 0.000 | 0.534 |
| Black 1st | 22 | 0.298 | 0.325 | 0.000 | 1.352 |
| **Technology Level** | | | | | |
| Low | 5 | 0.200 | 0.249 | 0.000 | 0.634 |
| Medium | 28 | 0.259 | 0.289 | 0.000 | 1.352 |
| High | 8 | 0.286 | 0.232 | 0.000 | 0.534 |
| **Education Level** | | | | | |
| High school grad or GED | 2 | 0.242 | 0.342 | 0.000 | 0.484 |
| Some college or a 2-year degree | 30 | 0.276 | 0.285 | 0.000 | 1.352 |
| 4-year college degree | 4 | 0.334 | 0.264 | 0.000 | 0.617 |
| More than a 4-year degree | 5 | 0.090 | 0.095 | 0.000 | 0.217 |
| **Time Spent Driving per Day** | | | | | |
| 30 minutes or less | 15 | 0.200 | 0.226 | 0.000 | 0.617 |
| 30 minutes to 1 hour | 20 | 0.329 | 0.306 | 0.000 | 1.352 |
| 1-2 hours | 5 | 0.190 | 0.201 | 0.000 | 0.534 |
| >2 hours | 1 | 0.000 | - | - | - |
| **Frequency of Driving for Extended Periods** | | | | | |
| < Once week | 19 | 0.236 | 0.205 | 0.000 | 0.634 |
| Once a week or more | 22 | 0.275 | 0.318 | 0.000 | 1.352 |
| **Age** | | | | | |
| 16-20 | 15 | 0.362 | 0.332 | 0.000 | 1.352 |
| 21-25 | 22 | 0.206 | 0.209 | 0.000 | 0.634 |
| 26+ | 4 | 0.143 | 0.234 | 0.000 | 0.489 |
| **Years Driving** | | | | | |
| 0-4 | 15 | 0.359 | 0.332 | 0.000 | 1.352 |
| 5-10 | 20 | 0.200 | 0.214 | 0.000 | 0.634 |
| >10 | 4 | 0.143 | 0.234 | 0.000 | 0.489 |
| **Average DBQ Score** | | | | | |
| 0.000-0.999 | 27 | 0.239 | 0.297 | 0.000 | 1.352 |
| 1.000+ | 14 | 0.291 | 0.212 | 0.000 | 0.634 |
| **% of Driving in an Urban Environment** | | | | | |
| < 50% | 23 | 0.205 | 0.163 | 0.000 | 0.501 |
| 50% or more | 18 | 0.324 | 0.357 | 0.000 | 1.352 |

Kruskal-Wallis tests were used to analyze this data because it did not follow a normal distribution. As Table 4.4 shows, there was no significant reaction between any of these variables and *average time to notice.*

Table 4.4 Significance Values: Average Time to Notice

| | N | Df | $\chi^2$ | Sig. |
|---|---|---|---|---|
| Gender | 41 | 1 | 0.164 | 0.685 |
| Order | 41 | 1 | 0.402 | 0.526 |
| Technology Level | 41 | 2 | 0.538 | 0.764 |
| Education Level | 41 | 3 | 2.841 | 0.417 |
| Time spent driving per day | 41 | 3 | 4.256 | 0.235 |
| Frequency of driving for extended periods | 41 | 1 | 0.001 | 0.979 |
| Age Category | 41 | 2 | 3.057 | 0.217 |
| Years Driving Experience | 39 | 2 | 2.990 | 0.224 |
| Avg. DBQ Score | 41 | 1 | 1.426 | 0.232 |
| % of Driving in an Urban Environment | 41 | 1 | 0.699 | 0.403 |

## 4.2 Duration

The descriptive statistics for *duration* based on color are shown in Table 4.5.

Table 4.5 Descriptive Statistics: Duration by Color

| | n | $\bar{x}$ | s | Min | Max |
|---|---|---|---|---|---|
| **Overall** | 82 | 4.242 | 0.738 | 1.969 | 5.572 |
| **Color** | | | | | |
| Yellow | 41 | 4.270 | 0.752 | 1.969 | 5.439 |
| Black | 41 | 4.213 | 0.723 | 3.069 | 5.572 |

This data was normally distributed, so a paired samples t-test was used to analyze whether or not color had an effect on *duration.* It was expected that participants would have higher durations when looking at the yellow motorcycle compared to the black motorcycle, however results showed no significant difference in the two groups (t(1,41) = 0.412, p = 0.682).

Table 4.6 shows the descriptive statistics for participants' duration of time looking at both the black and yellow motorcycles based on the presence of the warning light.

Table 4.6 Descriptive Statistics: Duration by Warning Light

| | | n | $\bar{x}$ | s | Min | Max |
|---|---|---|---|---|---|---|
| Black Motorcycle | **Overall** | 41 | 4.213 | 0.723 | 3.069 | 5.572 |
| | **Warning Light** | | | | | |
| | Yes | 19 | 4.090 | 0.599 | 3.069 | 5.272 |
| | No | 22 | 4.319 | 0.814 | 3.103 | 5.572 |
| Yellow Motorcycle | **Overall** | 41 | 4.270 | 0.752 | 1.969 | 5.439 |
| | **Warning Light** | | | | | |
| | Yes | 19 | 4.311 | 0.660 | 2.803 | 5.239 |
| | No | 22 | 4.235 | 0.838 | 1.969 | 5.439 |

ANOVAs were used to analyze the effects of in-vehicle technology on *duration*. It was expected that participants with the in-vehicle technology present would have a higher *duration* for both the black and yellow motorcycles. However, results showed the in-vehicle technology made no significant difference for *duration* on the black motorcycle (F(1, n=41)=1.027, p=0.317) or *duration* on the yellow motorcycle (F(1, n=41)=0.103, p=0.751).

The descriptive statistics for *average duration* based on demographic variables are shown in Table 4.7.

Table 4.7 Descriptive Statistics: Average Duration by Demographics

| | n | $\bar{x}$ | s | Min | Max |
|---|---|---|---|---|---|
| **Overall** | 41 | 4.242 | 0.591 | 2.886 | 5.205 |
| **Gender** | | | | | |
| Male | 29 | 4.261 | 0.604 | 2.886 | 5.205 |
| Female | 12 | 4.195 | 0.581 | 3.036 | 5.139 |
| **Order** | | | | | |
| Yellow 1st | 19 | 4.244 | 0.575 | 3.036 | 5.139 |
| Black 1st | 22 | 4.240 | 0.617 | 2.886 | 5.205 |
| **Technology Level** | | | | | |
| Low | 5 | 4.174 | 0.589 | 3.470 | 4.804 |
| Medium | 28 | 4.262 | 0.617 | 2.886 | 5.205 |
| High | 8 | 4.210 | 0.591 | 2.886 | 5.205 |
| **Education Level** | | | | | |
| High school grad or GED | 2 | 3.946 | 0.389 | 3.671 | 4.221 |
| Some college or a 2-year degree | 30 | 4.188 | 0.643 | 2.886 | 5.205 |
| 4-year college degree | 4 | 4.459 | 0.366 | 4.088 | 4.871 |
| More than a 4-year degree | 5 | 4.505 | 0.393 | 4.122 | 5.055 |
| **Time Spent Driving per Day** | | | | | |
| 30 minutes or less | 15 | 4.241 | 0.682 | 2.886 | 5.205 |
| 30 minutes to 1 hour | 20 | 4.231 | 0.562 | 3.036 | 5.139 |
| 1-2 hours | 5 | 4.124 | 0.421 | 3.786 | 4.805 |
| >2 hours | 1 | - | - | 5.055 | 5.05 |
| **Frequency of Driving for Extended Periods** | | | | | |
| < Once week | 19 | 4.085 | 0.647 | 2.886 | 5.039 |
| Once a week or more | 22 | 4.377 | 0.514 | 3.653 | 5.205 |
| **Age** | | | | | |
| 16-20 | 15 | 4.155 | 0.570 | 3.036 | 5.155 |
| 21-25 | 22 | 4.265 | 0.623 | 2.886 | 5.205 |
| 26+ | 4 | 4.437 | 0.577 | 3.800 | 5.055 |
| **Years Driving** | | | | | |
| 0-4 | 15 | 4.005 | 0.589 | 2.886 | 5.155 |
| 5-10 | 20 | 4.344 | 0.565 | 3.270 | 5.205 |
| >10 | 4 | 4.437 | 0.577 | 3.800 | 5.055 |
| **Average DBQ Score** | | | | | |
| 0.000-0.999 | 27 | 4.235 | 0.584 | 2.886 | 5.205 |
| 1.000+ | 14 | 4.254 | 0.625 | 3.270 | 5.155 |
| **% of Driving in an Urban Environment** | | | | | |
| < 50% | 23 | 4.150 | 0.585 | 2.886 | 5.139 |
| 50% or more | 18 | 4.359 | 0.593 | 3.270 | 5.205 |

This data was normally distributed, so ANOVAs were used to test for significance. As Table 4.8 shows, there was no significant reaction between any of these variables and *average duration.*

Table 4.8 Significance Values: Average Duration

| | N | Df | F | Sig. |
|---|---|---|---|---|
| Gender | 41 | 1 | 0.105 | 0.747 |
| Order | 41 | 1 | 0.001 | 0.982 |
| Technology Level | 41 | 2 | 0.058 | 0.943 |
| Education Level | 41 | 3 | 0.745 | 0.532 |
| Time spent driving per day | 41 | 3 | 0.685 | 0.568 |
| Frequency of driving for extended periods | 41 | 1 | 2.602 | 0.115 |
| Age Category | 41 | 2 | 0.384 | 0.683 |
| Years Driving Experience | 39 | 2 | 1.799 | 0.180 |
| Avg. DBQ Score | 41 | 1 | 0.010 | 0.922 |
| % of Driving in an Urban Environment | 41 | 1 | 1.273 | 0.266 |

## 4.3 Mean Duration of Glances

The descriptive statistics for *mean duration of glances* based on color are shown in Table 4.9.

Table 4.9 Descriptive Statistics: Mean Duration of Glances by Color

| | n | $\bar{x}$ | s | Min | Max |
|---|---|---|---|---|---|
| **Overall** | 82 | 2.453 | 1.450 | 0.701 | 5.439 |
| **Color** | | | | | |
| Yellow | 41 | 2.687 | 1.549 | 0.701 | 5.439 |
| Black | 41 | 2.219 | 1.322 | 0.734 | 5.372 |

This data did not follow a normal distribution, so the significance of color on *mean duration of glances* was analyzed using the non-parametric Friedman test. It was expected that the *mean duration of glances* would be higher when participants looked at the yellow motorcycle compared to the black motorcycle, however results showed there was no significant difference ($\chi^2(1, n=41)=0.610, p=0.435$).

Table 4.10 shows the descriptive statistics for participants' *mean duration of glances* for both the black and yellow motorcycles based on the presence of the warning light.

Table 4.10 Descriptive Statistics: Mean Duration of Glances by Warning Light

| | | n | $\bar{x}$ | s | Min | Max |
|---|---|---|---|---|---|---|
| Black Motorcycle | **Overall** | 41 | 2.219 | 1.322 | 0.734 | 5.372 |
| | **Warning Light** | | | | | |
| | Yes | 19 | 2.071 | 1.163 | 0.767 | 5.138 |
| | No | 22 | 2.346 | 1.460 | 0.734 | 5.372 |
| Yellow Motorcycle | **Overall** | 41 | 2.687 | 1.549 | 0.701 | 5.439 |
| | **Warning Light** | | | | | |
| | Yes | 19 | 2.761 | 1.598 | 0.701 | 5.138 |
| | No | 22 | 2.623 | 1.541 | 0.747 | 5.439 |

Non-parametric Kruskal-Wallis tests were used to analyze the effects of in-vehicle technology on *mean duration of glances*. It was expected that participants with the in-vehicle technology present would have a higher *mean duration of glances* for both the black and yellow motorcycles. However, results showed the in-vehicle technology made no significant difference for *mean duration of glances* on the black motorcycle ($\chi^2(1, n=41)=0.186, p=0.667$) or *mean duration of glances* on the yellow motorcycle ($\chi^2(1, n=41)=0.068, p=0.794$).

The descriptive statistics for *average mean duration of glances* based on demographic variables are shown in Table 4.11.

Table 4.11 Descriptive Statistics: Average Mean Duration of Glances by Demographics

| | n | $\bar{x}$ | s | Min | Max |
|---|---|---|---|---|---|
| **Overall** | 41 | 2.453 | 1.121 | 0.973 | 5.139 |
| **Gender** | | | | | |
| Male | 29 | 2.566 | 1.073 | 0.973 | 4.655 |
| Female | 12 | 2.180 | 1.234 | 0.989 | 5.139 |
| **Order** | | | | | |
| Yellow 1st | 19 | 2.406 | 1.216 | 0.973 | 5.139 |
| Black 1st | 22 | 2.494 | 1.060 | 0.989 | 3.887 |
| **Technology Level** | | | | | |
| Low | 5 | 2.073 | 1.051 | 0.998 | 3.729 |
| Medium | 28 | 2.492 | 1.201 | 0.973 | 5.139 |
| High | 8 | 2.555 | 0.932 | 1.439 | 3.804 |
| **Education Level** | | | | | |
| High school grad or GED | 2 | 2.168 | 1.031 | 1.439 | 2.897 |
| Some college or a 2-year degree | 30 | 2.278 | 1.141 | 0.973 | 5.139 |
| 4-year college degree | 4 | 3.101 | 1.155 | 1.783 | 3.754 |
| More than a 4-year degree | 5 | 3.099 | 0.808 | 1.783 | 3.754 |
| **Time Spent Driving per Day** | | | | | |
| 30 minutes or less | 15 | 2.311 | 1.111 | 0.973 | 3.887 |
| 30 minutes to 1 hour | 20 | 2.539 | 1.187 | 0.989 | 5.139 |
| 1-2 hours | 5 | 2.274 | 0.994 | 1.510 | 3.695 |
| >2 hours | 1 | 3.754 | - | 3.754 | 3.754 |
| **Frequency of Driving for Extended Periods** | | | | | |
| < Once week | 19 | 1.963 | 0.941 | 0.973 | 3.804 |
| Once a week or more | 22 | 2.876 | 1.110 | 0.989 | 5.139 |
| **Age** | | | | | |
| 16-20 | 15 | 2.282 | 1.124 | 0.989 | 5.139 |
| 21-25 | 22 | 2.522 | 1.146 | 0.973 | 4.655 |
| 26+ | 4 | 2.714 | 1.188 | 1.592 | 3.754 |
| **Years Driving** | | | | | |
| 0-4 | 15 | 2.021 | 0.829 | 0.989 | 3.879 |
| 5-10 | 20 | 2.629 | 1.145 | 0.973 | 4.655 |
| >10 | 4 | 2.714 | 1.189 | 1.529 | 3.754 |
| **Average DBQ Score** | | | | | |
| 0.000-0.999 | 27 | 2.394 | 0.984 | 0.989 | 3.887 |
| 1.000+ | 14 | 2.567 | 1.383 | 0.973 | 5.139 |
| **% of Driving in an Urban Environment** | | | | | |
| < 50% | 23 | 2.224 | 1.083 | 0.989 | 5.139 |
| 50% or more | 18 | 2.745 | 1.130 | 0.973 | 4.655 |

Kruskal-Wallis tests were used to analyze this data because it did not follow a normal distribution. As Table 4.12 shows, the only significant reaction occurred between frequency of driving for extended periods and *average mean duration of glances.* Participants who drove extended periods (one hour or more) less than once a week had a lower average mean duration of glances than participants who drove extended periods at least once a week ($\chi^2(1, n=41)=6.699, p=0.010$).

Table 4.12 Significance Values: Average Mean Duration of Glances

| | N | Df | $\chi^2$ | Sig. |
|---|---|---|---|---|
| Gender | 41 | 1 | 1.589 | 0.207 |
| Order | 41 | 1 | 0.098 | 0.754 |
| Technology Level | 41 | 2 | 0.659 | 0.719 |
| Education Level | 41 | 3 | 4.782 | 0.188 |
| Time spent driving per day | 41 | 3 | 1.826 | 0.609 |
| Frequency of driving for extended periods | 41 | 1 | 6.699 | 0.010 |
| Age Category | 41 | 2 | 0.881 | 0.644 |
| Years Driving Experience | 39 | 2 | 2.989 | 0.224 |
| Avg. DBQ Score | 41 | 1 | 0.007 | 0.934 |
| % of Driving in an Urban Environment | 41 | 1 | 2.827 | 0.093 |

## 4.4 Number of Glances

The descriptive statistics for *number of glances* based on color are shown in Table 4.13.

Table 4.13 Descriptive Statistics: Number of Glances by Color

| | n | $\bar{x}$ | s | Min | Max |
|---|---|---|---|---|---|
| **Overall** | 82 | 2.232 | 0.998 | 1.000 | 5.000 |
| **Color** | | | | | |
| Yellow | 41 | 2.122 | 1.077 | 1.000 | 5.000 |
| Black | 41 | 2.341 | 0.911 | 1.000 | 5.000 |

This data did not follow a normal distribution, so the significance of color on *number of glances* was analyzed using the non-parametric Friedman test. It was expected that participants would glance at the yellow motorcycle more than the black, however results showed there was no significant difference the two groups ($\chi^2(1, n=41)=1.059$, $p=0.303$).

Table 4.14 shows the descriptive statistics for participants' *number of glances* at both the black and yellow motorcycles based on the presence of the warning light.

Table 4.14 Descriptive Statistics: Number of Glances by Warning Light

| | | n | $\bar{x}$ | s | Min | Max |
|---|---|---|---|---|---|---|
| Black Motorcycle | **Overall** | 41 | 2.341 | 0.911 | 1.000 | 5.000 |
| | **Warning Light** | | | | | |
| | Yes | 19 | 2.316 | .749 | 1.000 | 4.000 |
| | No | 22 | 2.364 | 1.049 | 1.000 | 5.000 |
| Yellow Motorcycle | **Overall** | 41 | 2.112 | 1.077 | 1.000 | 5.000 |
| | **Warning Light** | | | | | |
| | Yes | 19 | 2.105 | 1.049 | 1.000 | 4.000 |
| | No | 22 | 2.136 | 1.125 | 1.000 | 5.000 |

Non-parametric Kruskal-Wallis tests were used to analyze the effects of in-vehicle technology on *number of glances*. It was expected that participants with the in-vehicle technology present would have a higher *number of glances* for both the black and yellow motorcycles. However, results showed the in-vehicle technology made no significant difference for *number of glances* at the black motorcycle ($\chi^2(1, n=41)=0.013$, $p=0.910$) or *number of glances* at the yellow motorcycle ($\chi^2(1, n=41)=0.000$, $p=0.989$).

The descriptive statistics for average *number of glances* based on demographic independent variables are shown in Table 4.15.

Table 4.15 Descriptive Statistics: Average Number of Glances by Demographics

| | n | $\bar{x}$ | s | Min | Max |
|---|---|---|---|---|---|
| **Overall** | 41 | 2.232 | 0.869 | 1.000 | 4.000 |
| **Gender** | | | | | |
| Male | 29 | 2.127 | 0.728 | 1.000 | 4.000 |
| Female | 12 | 2.500 | 0.879 | 1.000 | 4.000 |
| **Order** | | | | | |
| Yellow 1st | 19 | 2.368 | 0.847 | 1.000 | 4.000 |
| Black 1st | 22 | 2.114 | 0.723 | 1.500 | 4.000 |
| **Technology Level** | | | | | |
| Low | 5 | 2.400 | 0.742 | 1.500 | 3.500 |
| Medium | 28 | 2.268 | 0.855 | 1.000 | 4.000 |
| High | 8 | 2.000 | 0.535 | 1.500 | 3.000 |
| **Education Level** | | | | | |
| High school grad or GED | 2 | 2.500 | 0.707 | 2.000 | 3.000 |
| Some college or a 2-year degree | 30 | 2.350 | 0.822 | 1.000 | 4.000 |
| 4-year college degree | 4 | 1.625 | 0.479 | 1.000 | 2.000 |
| More than a 4-year degree | 5 | 1.900 | 0.548 | 1.500 | 2.500 |
| **Time Spent Driving per Day** | | | | | |
| 30 minutes or less | 15 | 2.300 | 0.819 | 1.500 | 4.000 |
| 30 minutes to 1 hour | 20 | 2.175 | 0.832 | 1.000 | 4.000 |
| 1-2 hours | 5 | 2.400 | 0.548 | 1.500 | 3.000 |
| >2 hours | 1 | 1.500 | - | 1.500 | 1.500 |
| **Frequency of Driving for Extended Periods** | | | | | |
| < Once week | 19 | 2.526 | 0.754 | 1.500 | 4.000 |
| Once a week or more | 22 | 1.977 | 0.732 | 1.000 | 4.000 |
| **Age** | | | | | |
| 16-20 | 15 | 2.367 | 0.855 | 1.000 | 4.000 |
| 21-25 | 22 | 2.182 | 0.780 | 1.000 | 4.000 |
| 26+ | 4 | 2.000 | 0.577 | 1.500 | 2.500 |
| **Years Driving** | | | | | |
| 0-4 | 15 | 2.466 | 0.767 | 1.500 | 4.000 |
| 5-10 | 20 | 2.150 | 0.813 | 1.000 | 4.000 |
| >10 | 4 | 2.000 | 0.577 | 1.500 | 2.500 |
| **Average DBQ Score** | | | | | |
| 0.000-0.999 | 27 | 2.241 | 0.739 | 1.500 | 4.000 |
| 1.000+ | 14 | 2.214 | 0.893 | 1.000 | 4.000 |
| **% of Driving in an Urban Environment** | | | | | |
| < 50% | 23 | 2.348 | 0.775 | 1.000 | 4.000 |
| 50% or more | 18 | 2.083 | 0.791 | 1.000 | 4.000 |

Kruskal-Wallis tests were used to analyze this data because it did not follow a normal distribution. As Table 4.16 shows, the only significant reaction occurred between frequency of driving for extended periods and *average number of glances.* Participants who drove extended periods (one hour or more) less than once a week had a higher average number of glances than participants who drove extended periods at least once a week ($\chi^2(1, n=41)=5.580, p=0.018$).

Table 4.16 Significance Values: Average Number of Glances

| | N | Df | $\chi^2$ | Sig. |
|---|---|---|---|---|
| Gender | 41 | 1 | 2.145 | 0.143 |
| Order | 41 | 1 | 1.286 | 0.257 |
| Technology Level | 41 | 2 | 0.941 | 0.625 |
| Education Level | 41 | 3 | 4.613 | 0.202 |
| Time spent driving per day | 41 | 3 | 2.117 | 0.548 |
| Frequency of driving for extended periods | 41 | 1 | 5.580 | 0.018 |
| Age Category | 41 | 2 | 0.731 | 0.694 |
| Years Driving Experience | 39 | 2 | 2.174 | 0.337 |
| Avg. DBQ Score | 41 | 1 | 0.016 | 0.898 |
| % of Driving in an Urban Environment | 41 | 1 | 1.490 | 0.222 |

# CHAPTER V

# DISCUSSION

Results of our experiment show that the presence of the in-vehicle technology significantly reduced the time it took participants to notice the black motorcycle, but had no effect on duration, mean duration, or number of glances. The results suggest that the technology will quickly draw a driver's attention to motorcycles which have a low level of sensory conspicuity; however, it does not keep the driver's attention focused on the motorcycle. It is likely that drivers do not keep their attention focused on motorcycles due to the fact that driving is a complex task and drivers must still pay attention to other traffic, road signs, and the task of operating the vehicle. Our finding is significant because it provides evidence that the in-vehicle visual alert is able to reduce a driver's time to notice a motorcycle, which effectively increases the amount of time available for the driver to react to the presence of that motorcycle, without distracting the driver from other environmental factors.

It is reasonable to believe an auditory warning combined with the visual warning would more effectively capture a driver's attention than the visual warning by itself. If we had added an auditory warning to the vehicle, the technology may have had a greater impact on time to notice, total duration of glances, mean duration of glances, and number of glances.

Our experiment showed there was no significant effect of motorcycle color on time to notice, duration, mean duration, or number of glances. This was surprising because it seems to contradict previous literature stating that the yellow motorcycle should have been more conspicuous than the black motorcycle (e.g., Dahlstedt, 1986; Donne & Fulton, 1985; Fulton et al., 1980; Olson et al., 1979a, 1979b, 1981; Stroud & Kirkby, 1976; Stroud et al., 1980; Williams & Hoffmann, 1977). However, the reason we may not have seen similar results could be that participants in our study were subjected to favorable driving conditions, and it is likely that the effect of color on conspicuity increases as favorable driving conditions decrease. The participants in our experiment were subjected to a low driver workload, and drove in a daytime environment with a low traffic density and clear weather conditions. If we had subjected participants to a higher driver workload by giving them a task to perform while driving or adding more traffic to the environment, perhaps we would have seen a more significant effect of color. We may have also seen a more significant effect of color if participants had driven in conditions of lower visibility, such as at night or in the rain.

Analysis of the demographic surveys revealed that participants who drove extended periods of time (one hour or more) less than once a week took a high number of short duration glances at the motorcycles. Participants who drove extended periods of time at least once a week took fewer glances at the motorcycles, but the duration of the glances was longer. A likely explanation for this is that long drives usually occur on highways and short drives usually occur in more complex city environments. Long highway drives allow drivers to get the information needed about an object by taking a lower number of long duration glances at the object. The complexity of city environments does not allow drivers to take long glances at anything, so in order to get the information needed about an object the driver must take a higher number of short duration glances. The participants who frequently drove extended periods of time are likely in the habit of taking longer glances at objects because that is what they are used to doing.

## 5.1 Limitations

This study was subject to the limitations which are present in all driving simulated studies. First, the simulation is a simplified version of reality, therefore many environmental factors which may affect how people drive are not able to be perfectly replicated in the simulation. Also, there is the concern that participants may alter their driving behavior because they know none of the dangers associated with driving in the real world are present in the simulator. These limitations were minimized by requiring all participants to go through a familiarization drive in the simulator and instructing the participants to drive as they normally would.

Another limitation was the fact that participants knew they were being observed, which may have caused some of them to be hyper-vigilant in the way they drove. Also, the participant sample was limited to college students, which is not representative of the population of drivers.

## 5.2 Conclusion and Future Work

In conclusion, it was found that in-vehicle technology significantly reduces the time it takes drivers to notice motorcycles which have a low level of sensory conspicuity. The technology we tested alerted drivers when they were near a motorcycle by illuminating a symbol of a motorcycle on the driver's instrument panel. Our results also showed that motorcycle color had no effect on driver awareness.

Future research could be conducted to see if adding an audible component with the visual warning will increase a driver's awareness of motorcycles. Also, training could be provided to participants, so they are knowledgeable on how the in-vehicle technology works.

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# APPENDIX A

# DEMOGRAPHIC SURVEY

Demographic Survey

Part 1. Participant Information

1. What is your age? ____________

2. What is your gender?

   [ ] Male

   [ ] Female

3. What is your level of education?

   [ ] 8th grade or less

   [ ] Some high school

   [ ] High school grad or GED

   [ ] Some college or 2-year degree

   [ ] 4-year college degree

   [ ] More than 4-year degree

4. Which of the following best describes your eye sight?

   [ ] 20/20

   [ ] 20/20 corrected with glasses

   [ ] 20/20 corrected with contact lenses

   [ ] Less than 20/20

5. Do you have any hearing problems?

   [ ] Yes

   [ ] No

6. Do you have a history of epilepsy?

   [ ] Yes [ ] No

7. Do you have a history of simulator-induced motion sickness?

[ ] Yes [ ] No

Part 2. Driving History

8. How old were you when you received your first driver's license? ____________

9. On average, how much do you drive on a given day?
   - [ ] 30 minutes or less
   - [ ] 30 minutes to one hour
   - [ ] One to two hours
   - [ ] More than two hours

10. How often do you drive for extended periods of time (one hour or more)? [ ] Daily
    - [ ] A few times a week
    - [ ] Once a week
    - [ ] Once a month
    - [ ] A few times a year
    - [ ] Once a year or less

11. Consider all driving that you do. What percentage of your driving is rural, urban, or interstate? Your answers must sum to 100%.

Rural (country roads, highways) ______

Urban (city streets) ______

Interstate ______

TOTAL _100%_

12. For your primary vehicle, what is the level of technology?

[ ] High (ex: touch screen dash system, bluetooth capability, safe driving alarms)

[ ] Medium (ex: cruise control, 6-CD changer, steering wheel controls)

[ ] Low (ex: no cruise control, no steering wheel controls, single CD/tape player, no extra safety alarms)

# APPENDIX B

# DRIVING BEHAVIOR QUESTIONNAIRE

Driving Behavior Questionnaire

For each type of item listed below, circle the number that corresponds to how often you engage in that type of behavior.

| Driving Behavior | Never | Hardly Ever | Occasionally | Quite Often | Frequently | Nearly All the Time |
|---|---|---|---|---|---|---|
| 1. Check your speedometer and discover that you are unknowingly travelling faster than the legal limit. | 0 | 1 | 2 | 3 | 4 | 5 |
| 2. Become impatient with a slow driver in the outer lane and overtake on the insider. | 0 | 1 | 2 | 3 | 4 | 5 |
| 3. Drive especially close or 'flash' the car in front as a signal for that driver to go faster or get out of your way. | 0 | 1 | 2 | 3 | 4 | 5 |
| 4. Stuck behind a slow-moving vehicle on a two-lane highway, you are driven by frustration to try to overtake in risky circumstances. | 0 | 1 | 2 | 3 | 4 | 5 |
| 5. Take a chance and cross on lights that have turned red. | 0 | 1 | 2 | 3 | 4 | 5 |
| 6. Angered by another driver's behavior, you give chase with the intention of giving him/her a piece of your mind. | 0 | 1 | 2 | 3 | 4 | 5 |
| 7. Deliberately disregard the speed limits late at night or very early in the morning. | 0 | 1 | 2 | 3 | 4 | 5 |
| 8. Forget when your road tax/insurance expires and discover that you are driving illegally. | 0 | 1 | 2 | 3 | 4 | 5 |
| 9. Drive back from a party, restaurant, or pub, even though you realize that you may be over the legal blood-alcohol limit. | 0 | 1 | 2 | 3 | 4 | 5 |
| 10. Have an aversion to a particular class of road user, and indicate your hostility by whatever means you can. | 0 | 1 | 2 | 3 | 4 | 5 |
| 11. Lost in thought or distracted, you fail to notice someone waiting at a marked crossing, or a crossing light that has just turned red. | 0 | 1 | 2 | 3 | 4 | 5 |
| 12. Park on a double-yellow line and risk a fine. | 0 | 1 | 2 | 3 | 4 | 5 |
| 13. Overtake a slow-moving vehicle on the inside lane or hard shoulder of a motorway. | 0 | 1 | 2 | 3 | 4 | 5 |
| 14. Cut the corner on a left-hand turn and have to swerve violently to avoid an oncoming vehicle. | 0 | 1 | 2 | 3 | 4 | 5 |
| 15. Fail to yield when a bus is signaling its intention to pull out. | 0 | 1 | 2 | 3 | 4 | 5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 16. Ignore 'yield' signs, and narrowly avoid colliding with traffic having right of way. | 0 | 1 | 2 | 3 | 4 | 5 |
| 17. Deliberately drive the wrong way down a deserted one-way street. | 0 | 1 | 2 | 3 | 4 | 5 |
| 18. Disregard red lights when driving late at night along empty roads. | 0 | 1 | 2 | 3 | 4 | 5 |
| 19. Get involved in unofficial 'races' with other drivers. | 0 | 1 | 2 | 3 | 4 | 5 |
| 20. 'Race' oncoming vehicles for a one-car gap on a narrow or obstructed road. | 0 | 1 | 2 | 3 | 4 | 5 |

# APPENDIX C

# MOTION/SIMULATOR SICKNESS QUESTIONNAIRE

MSQ/SSQ Survey

Pre-exposure/Post-exposure Simulator and Motion Sickness Questionnaire

Please circle the appropriate items below according to your CURRENT feelings with respect to the symptoms listed.

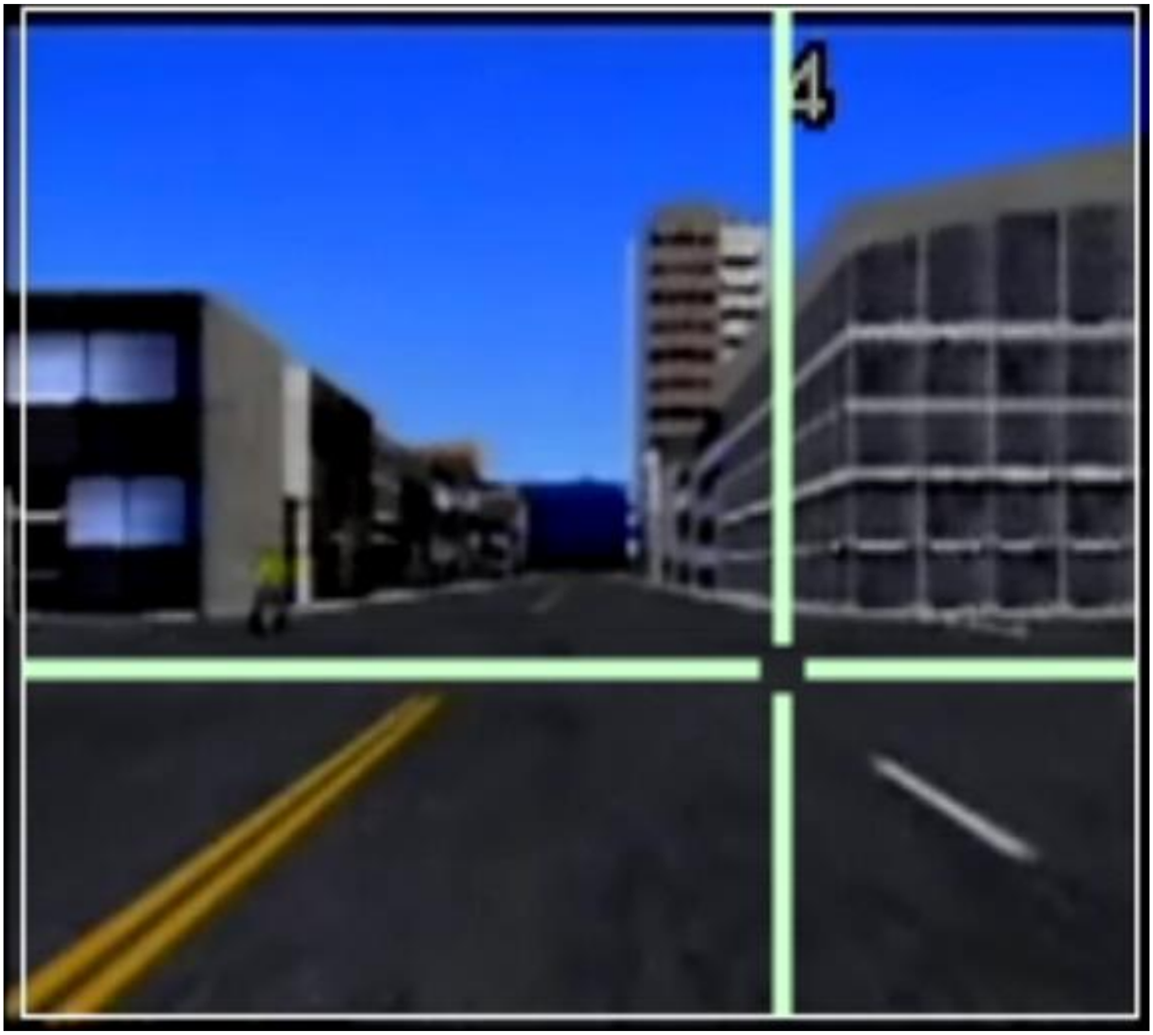
You will be asked to answer this questionnaire again after each scenario.

| | | | | |
|---|---|---|---|---|
| 1. General Discomfort | None | Slight | Moderate | Severe |
| 2. Fatigue | None | Slight | Moderate | Severe |
| 3. Boredom | None | Slight | Moderate | Severe |
| 4. Drowsiness | None | Slight | Moderate | Severe |
| 5. Headache | None | Slight | Moderate | Severe |
| 6. Eyestrain | None | Slight | Moderate | Severe |
| 7. Difficulty Focusing | None | Slight | Moderate | Severe |
| 8. Salivation Increase | None | Slight | Moderate | Severe |
| Salivation Decrease | None | Slight | Moderate | Severe |
| 9. Sweating | None | Slight | Moderate | Severe |
| 10. Nausea | None | Slight | Moderate | Severe |
| 11. Difficulty Concentrating | None | Slight | Moderate | Severe |
| 12. Mental Depression | None | Slight | Moderate | Severe |
| 13. “Fullness of the Head” | None | Slight | Moderate | Severe |
| 14. Blurred Vision | None | Slight | Moderate | Severe |
| 15. Dizziness (eyes open) | None | Slight | Moderate | Severe |
| Dizziness (eyes closed) | None | Slight | Moderate | Severe |
| 16. Vertigo | None | Slight | Moderate | Severe |

| | | | | |
|---|---|---|---|---|
| 17. Visual Flashbacks | None | Slight | Moderate | Severe |
| 18. Faintness | None | Slight | Moderate | Severe |
| 19. Aware of Breathing | None | Slight | Moderate | Severe |
| 20. Stomach Awareness | None | Slight | Moderate | Severe |
| 21. Loss of Appetite | None | Slight | Moderate | Severe |
| 22. Increased Appetite | None | Slight | Moderate | Severe |
| 23. Desire to Move Bowels | None | Slight | Moderate | Severe |
| 24. Confusion | None | Slight | Moderate | Severe |
| 25. Burping | None | Slight | Moderate | Severe |
| 26. Vomiting | None | Slight | Moderate | Severe |
| 27. Other (please describe) | None | Slight | Moderate | Severe |

# APPENDIX D

# EYE-TRACKER OVERLAY


4

APPENDIX E

RAW DATA

| Participant ID | Motorcycle ID | Color | Warning Light | TTN | Duration | Glances |
|---|---|---|---|---|---|---|
| 1 | 1 | Yellow | Yes | | | |
| 1 | 2 | Black | Yes | | | |
| 2 | 3 | Yellow | no | 0.534 | 3.503 | 1 |
| 2 | 4 | Black | no | 0.467 | 3.803 | 3 |
| 4 | 7 | Black | no | 0.634 | 3.737 | 3 |
| 4 | 8 | Yellow | no | 0.634 | 4.07 | 2 |
| 5 | 9 | Yellow | Yes | 0.634 | 2.803 | 4 |
| 5 | 10 | Black | Yes | 0.434 | 3.737 | 3 |
| 6 | 11 | Yellow | no | 0.400 | 5.439 | 1 |
| 6 | 12 | Black | no | 0.467 | 4.838 | 1 |
| 7 | 13 | Black | Yes | 0.000 | 5.272 | 2 |
| 7 | 14 | Yellow | Yes | 0.000 | 5.138 | 1 |
| 8 | 15 | Black | no | 1.001 | 3.237 | 4 |
| 8 | 16 | Yellow | no | 0.000 | 4.672 | 4 |
| 10 | 19 | Yellow | no | 0.000 | 5.072 | 1 |
| 10 | 20 | Black | no | 0.000 | 4.805 | 2 |
| 11 | 21 | Black | Yes | 0.000 | 4.004 | 2 |
| 11 | 22 | Yellow | Yes | 0.000 | 3.704 | 3 |
| 12 | 23 | Black | no | 0.868 | 3.903 | 2 |
| 12 | 24 | Yellow | no | 1.835 | 3.57 | 1 |
| 13 | 25 | Yellow | Yes | 0.267 | 4.371 | 3 |
| 13 | 26 | Black | Yes | 0.000 | 3.47 | 2 |
| 14 | 27 | Yellow | no | 0.200 | 4.171 | 3 |
| 14 | 28 | Black | no | 0.167 | 3.671 | 5 |
| 15 | 29 | Black | Yes | 0.300 | 3.137 | 3 |
| 15 | 30 | Yellow | Yes | 0.000 | 3.803 | 4 |
| 16 | 31 | Black | no | 0.267 | 3.937 | 2 |
| 16 | 32 | Yellow | no | 0.000 | 4.171 | 3 |
| 17 | 33 | Yellow | Yes | 0.534 | 4.271 | 1 |
| 17 | 34 | Black | Yes | 0.000 | 5.039 | 1 |
| 19 | 37 | Black | Yes | 0.000 | 4.437 | 2 |
| 19 | 38 | Yellow | Yes | 0.000 | 4.705 | 2 |
| 20 | 39 | Black | no | 0.901 | 4.438 | 2 |
| 20 | 40 | Yellow | no | 0.167 | 5.171 | 1 |
| 22 | 43 | Yellow | no | 0.000 | 3.471 | 4 |
| 22 | 44 | Black | no | 0.301 | 5.038 | 1 |
| 23 | 45 | Black | Yes | 0.000 | 3.971 | 2 |
| 23 | 46 | Yellow | Yes | 0.200 | 3.103 | 3 |
| 24 | 47 | Black | no | 0.700 | 3.103 | 2 |
| 24 | 48 | Yellow | no | 0.100 | 2.668 | 3 |
| 25 | 49 | Yellow | Yes | 0.000 | 5.239 | 2 |
| 25 | 50 | Black | Yes | 0.133 | 3.704 | 3 |
| 27 | 53 | Black | Yes | 0.234 | 3.904 | 2 |
| 27 | 54 | Yellow | Yes | 0.743 | 3.695 | 3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 28 | 55 | Black | no | 0.501 | 3.503 | 2 |
| 28 | 56 | Yellow | no | 0.401 | 4.672 | 2 |
| 29 | 57 | Yellow | Yes | 0.468 | 4.237 | 3 |
| 29 | 58 | Black | Yes | 0.000 | 4.038 | 2 |
| 31 | 61 | Black | Yes | 0.000 | 4.47 | 2 |
| 31 | 62 | Yellow | Yes | 0.334 | 5.138 | 1 |
| 32 | 63 | Black | no | 0.501 | 4.671 | 2 |
| 32 | 64 | Yellow | no | 0.000 | 4.572 | 1 |
| 33 | 65 | Yellow | Yes | 0.267 | 4.504 | 2 |
| 33 | 66 | Black | Yes | 0.000 | 3.069 | 4 |
| 34 | 67 | Yellow | no | 0.000 | 4.471 | 2 |
| 34 | 68 | Black | no | 0.000 | 5.271 | 2 |
| 35 | 69 | Black | Yes | 0.700 | 3.804 | 2 |
| 35 | 70 | Yellow | Yes | 0.534 | 4.638 | 1 |
| 36 | 71 | Black | no | 0.267 | 3.17 | 4 |
| 36 | 72 | Yellow | no | 0.700 | 4.171 | 2 |
| 37 | 73 | Yellow | Yes | 0.901 | 4.105 | 2 |
| 37 | 74 | Black | Yes | 0.000 | 4.171 | 3 |
| 38 | 75 | Yellow | no | 0.000 | 4.905 | 2 |
| 38 | 76 | Black | no | 0.000 | 3.339 | 3 |
| 39 | 77 | Black | Yes | 0.000 | 5.138 | 1 |
| 39 | 78 | Yellow | Yes | 0.000 | 4.939 | 2 |
| 40 | 79 | Black | no | 0.000 | 5.205 | 1 |
| 40 | 80 | Yellow | no | 0.000 | 5.105 | 2 |
| 41 | 81 | Yellow | Yes | 0.734 | 4.572 | 1 |
| 41 | 82 | Black | Yes | 0.033 | 4.204 | 3 |
| 42 | 83 | Yellow | no | 0.600 | 3.737 | 5 |
| 42 | 84 | Black | no | 0.000 | 5.572 | 3 |
| 44 | 87 | Black | no | 0.000 | 5.104 | 2 |
| 44 | 88 | Yellow | no | 0.000 | 4.504 | 2 |
| 45 | 89 | Yellow | Yes | 0.000 | 4.471 | 1 |
| 45 | 90 | Black | Yes | 0.000 | 3.97 | 3 |
| 46 | 91 | Yellow | no | 0.000 | 4.905 | 1 |
| 46 | 92 | Black | no | 0.000 | 5.205 | 2 |
| 47 | 93 | Black | Yes | 0.434 | 4.171 | 2 |
| 47 | 94 | Yellow | Yes | 0.000 | 4.471 | 1 |
| 48 | 95 | Black | no | 0.000 | 5.372 | 1 |
| 48 | 96 | Yellow | no | 0.166 | 4.172 | 2 |
| 50 | 99 | Yellow | no | 0.401 | 1.969 | 2 |
| 50 | 100 | Black | no | 0.000 | 4.103 | 3 |