ENHANCED SIGNALING SYSTEM DESIGN FOR 125CC MOTORCYCLES

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ENHANCED SIGNALING SYSTEM DESIGN FOR 125CC MOTORCYCLES

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DEDICATION

I dedicate my thesis work to my professors, classmates and all other friends in the last two years. A special gratitude to my loving parents, Saijun Wang and Chang'an Hou. They pushed me forward to this certain point where I can't reach on my own, as a loving son and a devoted industrial designer.

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LIST OF SYMBOLS AND ABBREVIATIONS

NHTSA   National Highway and Transportation Safety Association

NLOS   None-Line-Of-Sight

VR   Virtual Reality

HMD   Head Mounted Display

SUMMARY

In the recent years, the sales and popularity of small-displacement motorcycles has been increasing. With cities becoming larger and commuting with cars longer and tougher, more and more people are choosing smaller motorcycles for commuting and everyday drive because it's easier to use and lower in cost. However, as the total number of registered motorcycle drivers rises, the fatality rate per 100 million vehicle miles traveled has been increasing since year 2013. A great amount of accidents involved with motorcycles were involved with not being able to communicate with other traffic participants or misunderstanding the motorcycle driver's intention when the right of way is involved. This study gained insight in-to this problem by providing an enhanced signaling system for the motorcycle, specifically the 125cc motorcycle users to better communicate with other vehicles or people and state the right of way on the road. In this study, visual signal (lighting system different from current turning and stop signals) and auditory (notification sound different from current motorcycle horn and indicating sound) is used to test the usability of the design. Since it is illegal and unsafe to put this proto-type into road test, volunteers were invited to test the system in VR scene with realistic environment and motorcycle model equipped with the new signaling system. The test involves two conditions: 1. T-intersections when motorcycle is making a right turn and yielding the right of way to a pedestrian who wants to cross the road; 2. A 4-way stop intersection when the motorcycle is making a left turn while yielding the right of way to another vehicle that is going straight into the same direction from the right. Two different pieces of information, "please, you go first" and "Excuse me, I go first" will be delivered by different combination

of lighting and sound signals. The volunteers were asked to response to the signal given by the motorcycle and its driver from those two scenes by either going forward across the road (as the pedestrian) or hit the gas pedal (as the car driver). The response time of the volunteer between noticing the signal and the decision is timed, along with the decision either stop or go forward, is used to calculate the usability of the new enhanced signaling system. The study's findings prove that this new system will to some extent enhance the communication between the motorcycle driver and other traffic participants. With further development, this enhanced signaling system should be able to promote road safety, reduce accidents involve motorcycles and provide everyone with a safer and harmonious commuting environment.

CHAPTER 1.　　INTRODUCTION

Since the year 2011, major motorcycle manufactures like Honda, BMW, BRP Spyder and Ducati, etc., have been building more and more motorcycles (MMIC, 2016) than before in Canada. Statistics show that people in the United States are choosing to use a motorcycle as a daily commute method (Teoh, 2017). Among all different type of motorcycles, the number of street legal motorcycle up to 250 cc and off-road motorcycles with 1501 cc or higher has increased since 2007(MMIC, 2016). However, with the number of motorcycles registered and people riding a motorcycle increasing, the total accidents (both injury and casualty) also increased. Currently, most (32%) of accidents were happened on non-highway major roads, 34% of all accidents happened in intersections (NHTSA, 2018). With more and more motorcycles on the road, the safety of both the driver and all other traffic participants become an urgent concern.

1.1　Small displacement motorcycles

In this study, we will be using small displacement motorcycles as the example to test the possibility of the enhanced communication method.

1.1.1　*Motorcycle classification and small displacement motorcycles*

Study shows that the sales of scooter has been rising since 2008. In the year 2016, 59,951 units were sold in Canada, which is 23.2% more than 2011. Also, as the total registered number of commercial vehicles dropped from 3767, 1998 to 1147, 2015, the number of motorcycles registered rises from 334 to 709, which is also higher than the increase rate of light duty vehicles. The percent in retail motorcycle sales of the category

"street" and "dual purpose" motorcycles kept growing since 2012 to 2016, while the other types decreased (MMIC, 2016). The same thing happened in United States as well, younger people are getting their smaller scooters than their parents (Andrew Bornhop, 2013). The total registered motorcycle in the US 2017 is 8392682 units, which is more than twice the registered motorcycle in 2002(Teoh, 2017). According to the HLDI classification of motorcycles, all motorcycles were categorized into 10 different types (Chopper, Standard, Cruiser, Touring, Sport Touring, Unclad Sport, Sport, Super Sport, Dual Purpose and Scooter) based on size, license requirements and displacement. Among all those categories, the "Scooter" and "Dual Purpose" has the top 2 highest increase rate from 2002 to 2017 (171.58% and 264.2%).(Teoh, 2017).
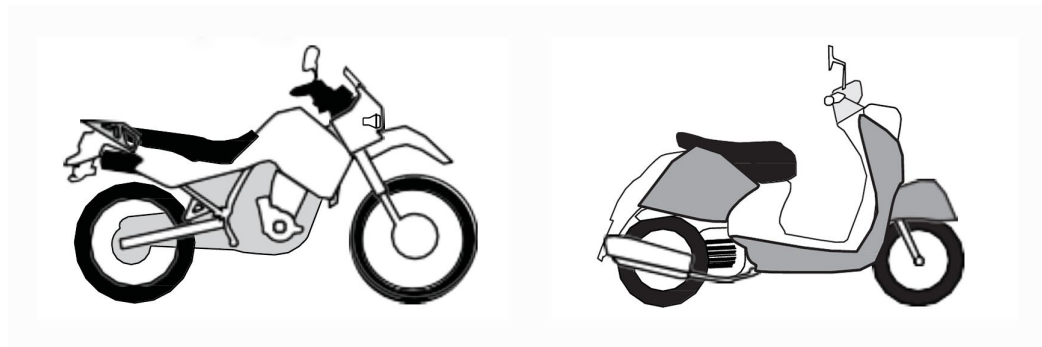
Figure 1-1 - Dual Purpose(left) and Scooter(right) motorcycle

Based on the data from those two countries, we can see that small-displacement motorcycle is becoming more and more popular recently.

1.1.2   City development and future trend for motorcycles.

There are many reasons that may cause the growth in the number of people who trades their cars for smaller motorcycles.

The first reason is the cost. Based on the classification of motorcycle by HLDI, the displacement of normal motorcycles will only be around 250-400cc. Compared with a medium-sized sedan or hatchback (typically 1500cc), the fuel consumption of a motorcycle is typically one fourth of a small passenger car (Teoh, 2017).

The second reason is the convenience of using a motorcycle when parking, travelling in traffic and storage. Motorcycles are significantly smaller than a normal passenger car, which means less parking space is needed to store the vehicle. When in a traffic congestion, a motorcycle can travel through the traffic when a car can't.

The third reason might be the development of modern cities. In the recent years, the development of modern city witnessed a trend that more and more people are leaving the city center and moving to the suburb. The city center means higher rent, cost, tax and transportation. Despite the fact that there might be more opportunity in the modern city, more and more people are leaving the city. The motorcycle certainly acted as a getaway vehicle for them when they want to quickly escape from their office and return to their home few miles away from the city center (Kramer & Pfaffenbach, 2011).

Presumably, in the future there will be more burden on city transportation, the small displacement motorcycles will be able to play a more important role in the future.

1.1.3   *Small displacement motorcycles and accidents*

National Highway Traffic Safety Administration (NHTSA)'s report shows that the fatality rate of accidents involving motorcycles in 2016 increased by 4.39/ 100 million vehicle miles traveled than 2011. As a matter of fact, motorcyclists accounted for 14

percent of all traffic fatalities and 17 percent of all occupant (driver and passenger) fatalities (NHTSA, 2018).

There are mainly three possible causes of motorcycle accidents,

i.   The environment, especially the intersection;

ii.   The accessories with which the users need to operate the motorcycle.

iii.   Other traffic participants, including pedestrians, cars and motorcycles.

Based on the report from NHTSA's report, more than half of the accidents involving motorcycles happened in cities (57%), most accidents happened in clear weather (97%), more than half of the accidents happened in daylight and a great amount of accidents happened in intersections (NHTSA, 2018). The report also stressed that motorcycles were more frequently involved in fatal collisions when having conflicts with other participants' right of way (NHTSA, 2018).

The motorcycle user needs specialized outfit to operate the motorcycle. The jacket and helmet will limit head movement and facial expressions (McKnight & McKnight, 1995). The requirement of using both hands to operate the vehicle means the user can't signal with waving hands. In other words, the accessories can affect the performance and safety of motorcycles.

Figure 1-2 – A motorcycle user and his specialized outfit

1.2 Accidents related to communication

1.2.1 Right-of-way conflicts and accidents.

Misunderstanding or miscommunicating, especially between motorcycle user and other vehicles, can also lead to some certain scenario when traffic accidents tend to happen. Based on the research done in prior arts, there are three different possible conditions when a motorcycle is having a right-of-way conflict:

i.   Yielding right of way to other traffic participants;

ii.   Given the right of way from the other traffic participants;

iii.   Having mis-communication or mis-understanding of each other.
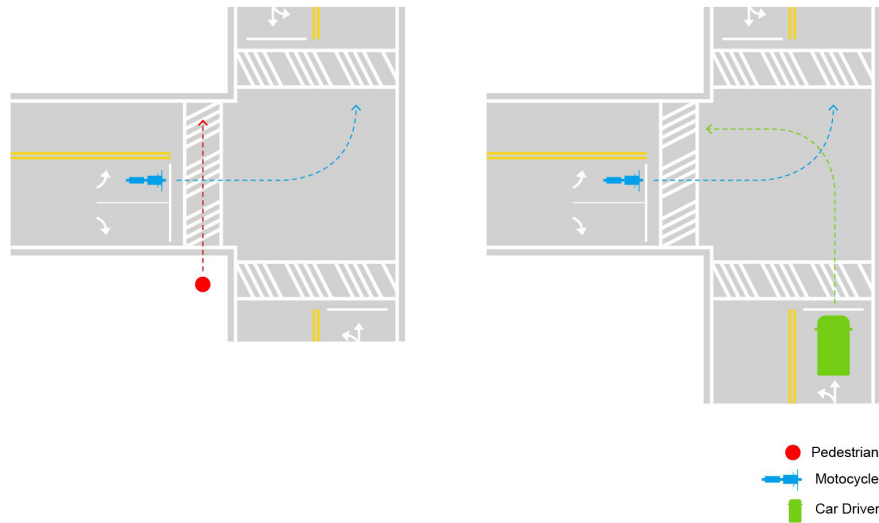
Figure 1-3 – Motorcycle drivers having right-of-way conflicts with others

In the three different scenarios, the motorcycle user is having a right-of-way conflict with at least one other traffic participant. This will lead to potential hesitation of action (i.e. press the brake or terminate the turning) or total misunderstanding or intentions. All of these will lead to potential accidents(Tang, 2003). Therefore, the communication between motorcycle users and other traffic participants in intersections when there is a potential right-of-way conflict.

1.2.2   *Signal system and communication methods.*

In this study, we will be trying to provide a solution to the problem when motorcycle drivers are having a communicating difficulty. According to prior studies, those accidents were most likely to happen when the vehicle is making turns or some traffic participants are in the non-line-of-sight (NLOS) zones (Hisaka & Kamijo, 2012).

In other words, accidents will mostly happen when the communication is difficult to deliver or will be easily obstructed by infrastructures. To solve the problem, we must develop a new approach to enhance the communication methods for the motorcycle users. There are mainly two places that have been considered to install those communication methods:

i.   On the traffic lights (Hisaka & Kamijo, 2012);

ii.   On the vehicle (motorcycles and cars) (Muzammel, Yusoff, Malik, Saad, & Meriaudeau, 2017; Rossger, Hagen, Krzywinski, & Schlag, 2012).

All those three previously mentioned possible solutions are trying to use different signals (visual and acoustic) to deliver certain messages to other traffic participants to avoid misunderstanding or miscommunicating. In a real-life scenario, the message that the motorcycle users mostly want to deliver would be some simple statements such as "you go first", "I go first", "I'm here" and "Thank you". The information carried by those expressions was similar to what was normally delivered by traffic and signal lights (stop lights, turning lights and front flash lights). All those methods were designed to declare right of way therefore help all traffic participants know where each other is and where they are going.

Mounting the sensors to the vehicle and traffic lights could be a possible approach to reduce the chance of accidents (Hisaka & Kamijo, 2012). In this study, multiple sensors were installed around the vehicle and the traffic lights to create a vehicle-to-infrastructure cooperative system. This system will help all vehicle entering the intersection cooperate with each other to avoid collisions or other accidents. However,

this approach does not include the condition when the vehicles (motorcycles or cars) are having a right-of-way conflict with pedestrians, which is also a great concern.

In the study conducted by Kuo-Hao, Li-Chen and Yueh-Hua, the turning signaling lights were used to boast the effect of stop lamp (Tang, Tsai, & Lee, 2006). Participants were asked to react to the scene demonstrated on a screen where the driving simulator is displayed, their responses recorded. This is a practical approach to test the usability of the new stop lamp design since the user will be provided with a real-to-life environment with which they can get a general understanding about the design. However, this study only tested the usability of the system when other vehicle is following the motorcycle and the motorcycle is decelerating. To test more possibility of real-life scenario, we must consider the possibility when the motorcycle is coming from both sides of other vehicles and the other driver can't see the rear brake light.

In the study conduct by Rossger, etc., the different configurations of motorcycle front lights were took into consideration to test is other traffic participants can notice the existence of the motorcycle (Rossger et al., 2012). In this study, front lights from the main body of the motorcycle, lights next to the handles ("T-configuration light") and the helmet light were taken into consideration. This study only discussed using different light configurations to indicate the existence of the motorcycle. To help motorcycle users communicate with other traffic participants, we need to try more configuration and combinations of light to deliver more information.

1.3 Signal and media

Based on prior arts, visual and auditory signals are two typical types of media that could be used to deliver the information of the motorcycle user.

1.3.1 Visual signals and lights

In real-life scenarios, other traffic participants, especially car drivers, are relying on visual cues from the motorcycles to identify their existence (Rossger et al., 2012). The visual signals, or in other words signal lights, can be used as an enhancement on the visual prominence of small motorcycles. When the body of a motorcycle and its user is reflective, the self-illuminated signal lights can be noticed faster and further therefore to avoid potential accidents caused by ignoring the existence of the motorcycle (Rossger et al., 2012).

On the other hand, coded light signals such as headlamp, rear lamp, turning indicator and brake lamp can be used to indicate the purpose of the driver. In the United States, different states have their own regulations about motorcycle turning signal lamps. But most of them share the same or similar requirements:

i. They must be high enough above the ground. In the state of Virginia, the height is more than 20 inch above the ground (Agency 30. Department of State Police, 2018).

ii. They must be apart from each other to be better seen from distance. In the state of California, front or real turning signals must be at least 23cm (or 9 inch) apart from each other (CA ADC, 2008).

iii.   They must maintain certain illuminance so that they could be seen easily(Department of Motor Vehicles, 2015).

In the study conducted by Tang etc., the modified stop lamp used specifically coded turning signals to help other traffic participants understand the intention to stop of motorcycle users(Tang et al., 2006). In this study both the pattern of flash and position of the turning light are coded to help deliver the intention to stop, the reaction time to the brake signal is significantly reduced (by 200ms on average). This study shows that it is possible to use visual signals to work as the media to deliver the motorcycle user's intention.

However, it is not approved by NHTSA to modify the headlamps, rear lamps, turning signal, brake light or danger lights on a scooter and do a road test. We will try to modify and apply additional signal lights to deliver the information required for communication.

The US 6864787 shows a patent of a frontal car brake design. This design uses a front horizontal stripe light to represent the brake of cars (Veah, 2005).
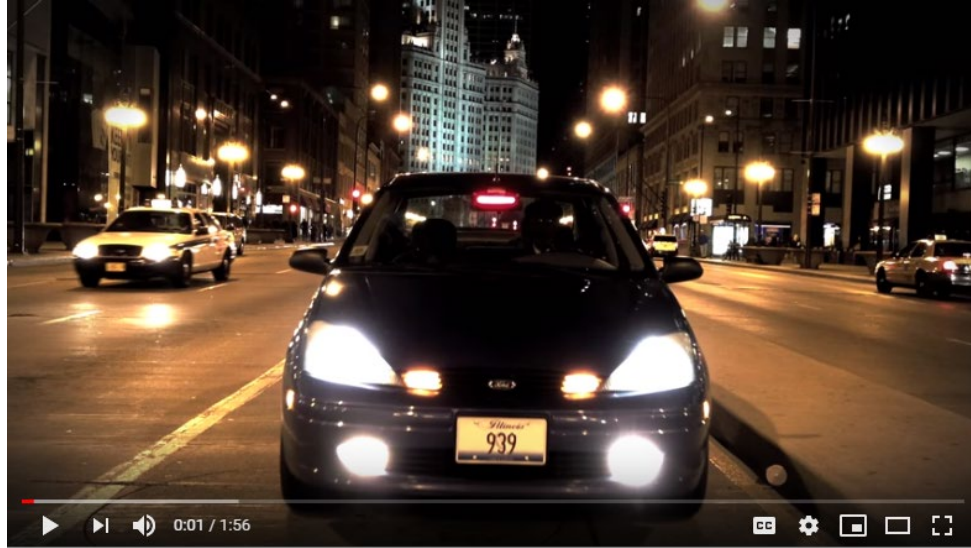
Figure 1-4 – Frontal brake light design for passenger cars

As shown in above, the frontal brake light can easily remind other people (especially driver) of an actual brake which normally will be installed in the back of a car. However, things were totally different when it comes to a motorcycle. This could be a reference about where and how to install those signaling lights in future experiments.

1.3.2   Auditory signals and sounds

Auditory signals, or sound signals, is using different sounds to deliver certain information. However, the sound intensity will decrease greatly when the distance between the viewer and the motorcycle increases. Therefore, the effectiveness of the auditory signals could be affected by the distance between the viewer and the motorcycle. All perceptions of sound, pitch, duration, loudness, timbre, sonic texture and spatial location can be used to carry certain information along or combined.

The effectiveness of sound, or in other words, the sound intensity, measures how easy we can hear the sound and therefore receive the information carried by it. Based on fluid mechanics principles, the intensity of sound (I) is decreasing as the distance (r) to the sound source is increasing (Emerson, Kim, Naghshineh, Myers, & Asme, 2013). Therefore, auditory signals' ability to deliver message is greatly decided by the distance between the motorcycle and the viewer as equation below shows.

$$I_2 = \left(\frac{r_1}{r_2}\right)^2 I_1 \tag{1}$$

Unlike visual signals, auditory signals could be detected from forward moving, backward moving, starts from a stop and alignment to passing traffic vehicles (Emerson et al., 2013). This means the sound signal could cover more areas and directions than light signals. However, the performance of auditory signals is not obvious compared with visual signals. In the study conducted by Emerson etc., the modified sounds meant for enhancing the detecting distance of normal hearing and hearing ability affected persons. Based on that prior research, coded auditory information can only increase the performance of detecting vehicle by 0.04%~18.4% (front detection) and 0.07%~29.4% (backward detection), which is not logistically obvious. This might be caused by the fact that the sound signal cannot carry as much information as visual signals. In further testing, we will be focusing more on visual cues and use auditory signals as a backup.

Based on prior art research, the learning process of an auditory signal is always related to the time pattern feature of sound. In this case, how the sound signal is repeated will affect the learning cost of users (Kang, Agus, & Pressnitzer, 2017). In this case, the

usability of actual sound design in this study should be evaluated by "How hard it is to learn the signal" and "How hard it is to remember the signal". Limited by the scale of the study, we will only be discussing the first question in this study.

1.3.3 *Immersive user experience design*

It is not approved by NHTSA to test new signals and sounds that have not been approved on real vehicles. To better conduct the user experience testing, a realistic immersive environment could be very helpful. Based on prior art research, there are mainly three different categories of immersive environment that can be used in this case.

    i.   Large screen and a drive simulator (Tang et al., 2006);

    ii.   Large surrounding screen system (CAVE);

    iii.   Head Mounted Display (HMD) virtual reality system (Mallaro, Rahimian, O'Neal, Plumert, & Kearney, 2017);

In the study conducted by Tang etc., the volunteers were asked to response to the signal coming from the vehicle ahead of them by pressing the pedals on the driving simulator. This approach is very useful to avoid the danger in real road testing. However, this setting can only work when the subject vehicle is in front of the tester. In a real intersection scenario, users might meet motorcycles coming from all directions.

The CAVE system is a CAVE-like environment consists of multiple big screen surrounding the tester. Four high resolution projectors will be casting high quality image to the three screens on the front, left and right and the floor under the tester. A stereo sound system is also included in the setting to ensure a spatialized traffic sound environment. Unlike the Large Screen and a drive simulator system, CAVE system can create a realistic scene around the user rather than just in front of the user.

A Head Mounted Display (HMD) system is a virtual reality system that requires the user to wear an immersive helmet with which the position and orientation of the eye (viewing point) can be tracked. With the HMD system, the vision from left and right eye will be divided and rendered separately to create an immersive environment of both visual and sound. Since the feedback is directly sent into the high-resolution display and stereo headset inside the helmet, HMD system can maintain a shorter lag and higher performance compared with other methods (Mallaro et al., 2017). Mallaro etc., used an HTC Vive system as demonstration. By comparing the CAVE and HMD virtual reality system, we can clearly see that the HMD system is slightly better than a CAVE system when the users make decisions quicker and more precise.

CHAPTER 2.   EXPERIMENT 1

Based on the literature findings, the focus of this project will be trying new methods of communication using different media to deliver messages from scooter users to the other participants. The signal will be triggered by the scooter driver before approaching an intersection or walkway. The intended message will be displayed using visual and auditory signals for the other traffic participant (pedestrian or driver) to apprehend. The focus of the experiment design would be:

i.   What kind of visual signal will be ideal for this scenario (color, pattern and position);

ii. How can auditory cues affect the performance of visual signals;

The entire experiment consists of two parts, the online questionnaire and the on-site virtual reality user testing. The purpose of the online questionnaire is to get more participants and to narrow the selection of visual/auditory signal designs in order to remove unnecessary settings. The best designs in the first section will be presented in the VR scene in the Experiment 2 on-site test to get deeper results.

2.1   Design

The online questionnaire consists of three parts:

i.   Basic information;

ii.   Visual Signals;

iii. Auditory Signals.

In section I, the gender, age range, annual income, frequency of motorcycle usage and frequency of four-wheel vehicle usage is asked. The main target user of this study is

the general population that could encounter a motorcycle in his daily life. The prior knowledge of driving will be evaluated since this could potentially affect the understanding of new signal patterns. All questions in this section are multi choices, participants could not enter a specific number to the question.

In section II, the pattern, color and where to fit the lights to the vehicle will be chosen from multiple choices. Users were presented with GIF animated pictures and were allowed to preview the combination of their choice. As is shown in Figure 2-1, if the user selected the "Simple Flashing Light" pattern in question 6 "Which one best represents 'you (the questionnaire taker) go first'.". In question 7 "What color can best represent the meaning mentioned above?", all four animations related to four color choices will have a motorcycle flashing blue, red, green and yellow lights in "simple flashing light" pattern. If the choice in question 7 is "Red", all four animations related to four position selections will have a motorcycle flashing red "simple flashing light" pattern lights at "Full lights", "Top only", "Top and side", "Two sides only", "Up sides only" and "Down sides only" locations in question 9 "Where should the lights be?".

What color can best represent the meaning mentioned above? *

○ Blue

○ Red

○ Green

○ Yellow

Figure 2-1 - Question 7 Color of Light

Users can go back, undo, redo and preview their selections to get their most desired pattern of visual light signal.

In section III, the pitch, loudness, sonic texture and pattern of the auditory signal will be chosen from multiple choices. We know that compared with visual signals, auditory alone will not guarantee obvious enhancement when used by motorcycle users to signaling other traffic participants (Emerson et al., 2013). 10 different pre-selected samples generated by different instrument, synthesizer or vehicle were presented along with the animation of a motorcycle image. As is shown in Figure 2-2, the image of motorcycle is static in order to eliminate the bias created by visual signals.

Figure 2-2 - Auditory Signal Sample 2

The questionnaire is powered by 3rd party forms service Google Form. When the interactive questionnaire is finished, a unique, shortened and not pre-filled link is generated to redirect volunteers to the questionnaire. The link is distributed to volunteers on social media including but not limited to Wechat, Facebook, Instagram and GroupMe. All participants are voluntary and anonymous.

The results from online questionnaire is collected and analyzed to get the most accepted design for both the lighting signal (4 combinations) and the sound signal (top 3 sound clips). Those designs were converted to interactive model and used in on-site VR testing.

2.2 Materials and media

To make the questionnaire more interactive and realistic to the user, the questionnaire design is specially designed.

Based on prior art research, the most popular model of small displacement motorcycle is a scooter (Andrew Bornhop, 2013; MMIC, 2016; Teoh, 2017). Scooters also have the most obvious correlation between the total user registered and number of accidents per million miles travelled per user (NHTSA, 2018). We chose scooter as the model of this study and we will be talking about new signaling method design for scooters.

To better illustrate the effect of potential visual and auditory signal selection, a realistic scooter CAD model is helpful and necessary. Based on the best sold models provided by major manufactures and online review websites, we selected 10 best sold scooter models and removed those "characteristics" features and merged the styles into a new model (as is shown in Figure 2-3).

Figure 2-3 – De-stylized Scooter and Driver Model

This scooter design is a typical 125cc displacement scooter with up-right sitting position, up-right bar, flat deck, flat seat and circular head lamp. This scooter is also sharing some common features with some electrical scooters popular in other countries.

The additional lights were designed to be put near the edges of the frontal part of the scooter and the top. The additional system is isolated from the original signal system (brake, headlight, high beam, turning signal and danger indicator) in order to avoid violation of rules or regulation (Federal Highway Administration, 2012). Studies also shown that modifying turning signal could affect the detection of brake signal (Tang, 2003; Tang et al., 2006). Based on those reasons mentioned above, the up-left, up-right, down-left, down-right, top and central positions were assigned as potential new light locations as shown Figure 2-4.
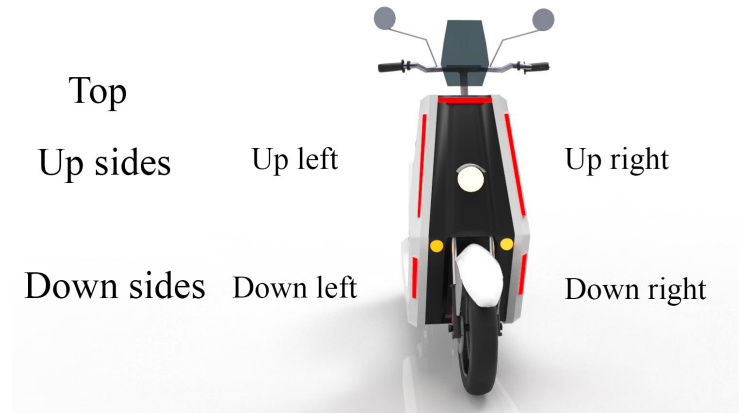
Figure 2-4 – Potential light locations

The four colors tested in Experiment 1, red, green, yellow and blue are the most common lights on the road. More detailed explanation of how the location, color and pattern of flashing (or not) is classified and coded in next session Experimental variables.

The pattern of flash is inspired by the current vehicles' turning signal design and some emergency vehicle signal design. As is shown in Figure 2-5, the name of the configurations are "both sides", "top and sides", "top only", "down sides", "up sides" and

"full light". Those design were partly inspired by Rossger's study in 2012. (Rossger et al., 2012)
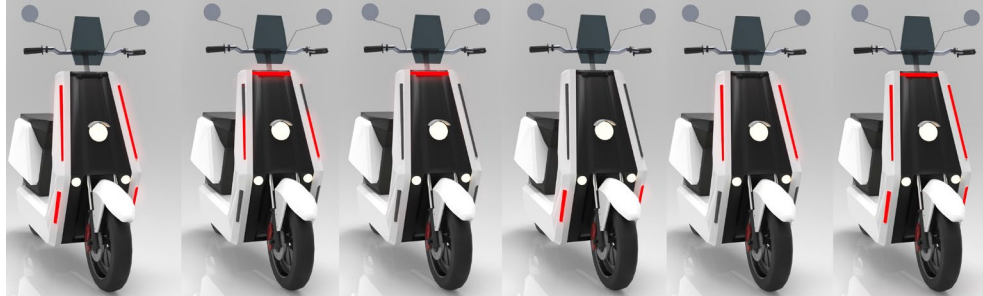
Figure 2-5 – Different configurations of lights

Based on prior arts, the feature of sounds does not play a significant role in the determination of vehicle's intentions. In this study we did not generate new synthesis sound clips to try to improve the communication between the motorcycle and other traffic participants. Instead, we will be discussing the mutual influence between light signals and sound signals. The description of 10 samples of sound were listed as below.

Table 1 – Sound Samples

Sound	Sound feature*			
	Texture	Pitch	Tone	Beat
1	Toy duck	Medium	Mild	Medium
2	Car horn	Medium	High	N/A
3	Tambourine	Low	Mild	Fast

4	Synthesizer	Low	Mild	Slow
5	Whistle	High	Mild	Slow
6	Trumpet	High	Mild	Fast
7	Bubble	High	High	Fast
8	Ring tone	High	Mild	Fast
9	Toy duck	High	Mild	Fast
10	Whistle	High	Mild	Fast

*Sound intensity is not considered as a valid variable

We selected 10 possible candidates of sound based on the research of Chevrolet Malibu car design and online racing games (Emerson et al., 2013; Forza Motorsport, 2018). In the section about auditory signals in the questionnaire, we set four choices ('I go first', 'You go first', 'Not clear' and 'I am here') and an open-ending response. Participants will be given chances to make choice if they think the sound has a lopsidedness to declare right of way (choice 'I go first' and 'You go first') or just neutral alarm or notification (choice 'I am here'). Apart from a simple 'Not clear' choice, participants were also allowed to write down their own understanding of the meaning.

2.3 Experimental variables

Two groups, six variables were tested in this experiment.

The first group of variables consists of three features of lighting signals, the color, the position on the motorcycle and the pattern of flashing or not. The second group consists of three features of auditory signals, the sonic texture, tone and pitch.

2.4   Participants

For the pre-testing focus group, six people participated in.

For the online questionnaire, 68 volunteers participated in this experiment. 25 of participants were male and 41 of participants were female. 30 of the participants ride motorcycles while 48 of the participants drive a car.

2.5   Results

We received 66 valid responses in 10 days, the valid rate is 97.06. In the first section of the online questionnaire: basic information. As is shown in Table 2 – Question 7, more than half (55.4%) of the responses do not ride a scooter. The detailed rate and response are shown on the table below.

Table 2 – Question 7

Do you ride a scooter / motorcycle?

■ Yes, everyday   ■ Yes, few times a week   ■ Yes, but not often   ■ No, I don't ride a scooter
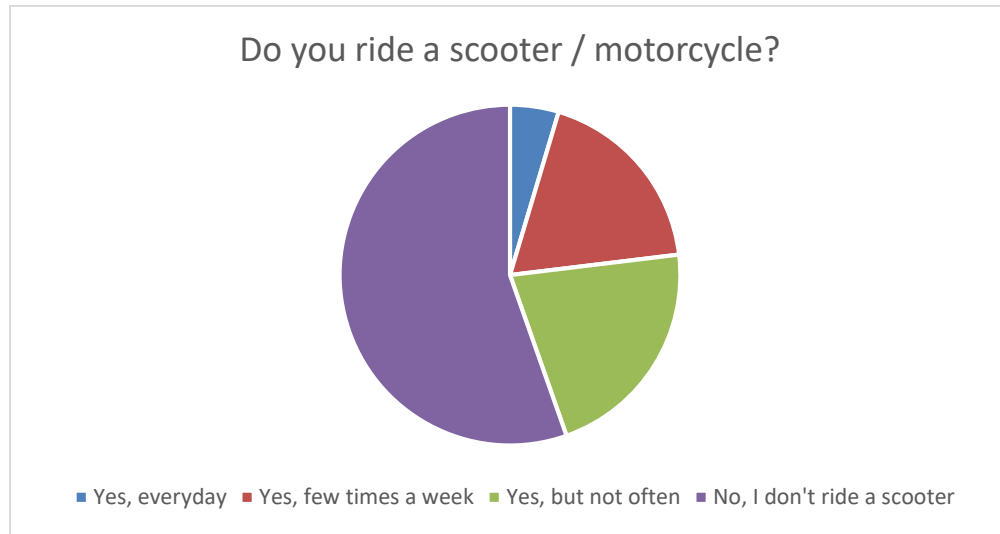
Compared with motorcycles, car/4-wheel vehicle have more users (60%). We were thinking that the experience of driving would potentially affect the performance of participants in the next study, however, in this design we were more concerning the pedestrian/driver part of the interaction. It is acceptable that most of the participants are not active motorcycle users. Therefore, we will not be considering the professional scooter users from the research.

Table 3 – Question 8
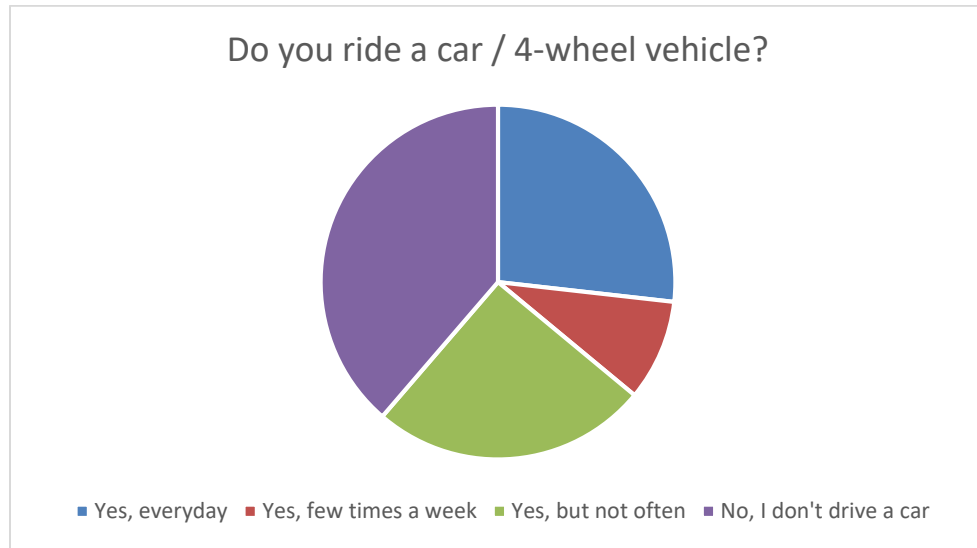
In the second section of the online questionnaire: Lighting Signals, the questionnaire has multiple choices relating to the position, pattern and color of the signaling light in two different conditions. Based on prior art research, we selected two common scenarios that will happen:

i.   The motorcycle is yielding the right of way to the pedestrian ("you (pedestrians) go first");

ii.   The motorcycle is requesting the right of way from the pedestrian ("I (scooter) go first").

Based on the design of the interactive questionnaire, each combination of lighting signal has 144 possible solutions (4 choices of color, 6 choices of location and 4 choices of pattern). It would require more than 288 responses to traverse all possible solutions.

To make the results for convincing, we would like to apply Pearson's Chi-Squared test to the results and to check if the data is reasonable. In other words, the choices are not

randomly selected. The equation of Pearson's Chi-Square is listed as below. For example, we would like to calculate the p-Value of color. Firstly, we assume all choice of color is random, therefore the possibility of each color is equal. Since the total choice of color is 4, pi=1/4=0.25, by calculating χ^2 in:

$$\chi^2 = \sum_{i=1}^{r} \frac{(n_i - np_i)^2}{np_i} \tag{2}$$

We can get the cumulative test statistic of this assumption.

Since the total possibility of color is 4, the degrees of freedom k=4-1=3. By checking the distribution table, we can get the precise p-Value of this assumption. p-Value evaluates the correlation between the variables and the decision participants were making. When p>0.1, the variable is most likely unreasonable, when p<0.001, the variable is most likely reasonable.

Table 4 – p-Value of all variables

Scenarios	Variables		
	Pattern	Color	Location
You go first	0.0003	**0.0000000813***	0.000000625
I go first	**0.2191****	0.001556	0.000000143

*Color is the most reasonable variable in this scenario.
**Pattern is probably not important in this scenario.

Based on the finding in Table 4 – p-Value of all variables, we can see that location is an important variable in both scenarios. For the "you go first" scene, color is the most

26

important variable while in "I go first" scene, the pattern of light does not show a high correlation to the decision participants made. In the process of selecting the best combination of signal, we will be considering more for colors and locations over patterns.

In this study, we assume it is the combination of "features" of the signals that can affect the usability of the signals. To find the best combination of pattern, color and location, we enumerated the total number N of each combination. Here, n is equal to the total number of responses, A_i means the total number of choices i in pattern, B_j means the total number of choice j in color and C_k means the total number of choice k in locations.

$$N = \frac{n^3}{A_i B_j C_k}$$

(3)

Based on this method, we can get the top combinations of the two scenes. In this case, the top 5 choices of combinations for the two scenes are listed:

Scene	Features			
	Flash Pattern	Color	Position	Count
"You go first"	Simple flash light	Green	Two sides only	5
	Accelerating flash light*	**Red**	**Full lights**	4
	Simple flash light	Green	Full lights	4

	Switch flash light	Green	Full lights	4
	Accelerating flash	Green	Full lights	3
"I go first"	**Accelerating flash light***	**Red**	**Full lights**	**8**
	Simple flash light	Red	Full lights	7
	Continues light	Red	Full lights	3
	Switching flash light	Red	Full lights	3
	Switching flash light	Red	Top and side	3

*The most selected combination in "I go first" and the second most selected combination in "You go first" is same (Accelerating flashing red full light).

In this case, the most preferred lighting combination of "I(motorcycle) go first" is "Accelerating flash light", this choice is identical to the second most preferred lighting combination of "You(pedestrian) go first". Based on the p-Value shown in Table 4 – p-Value of all variables, the color should be an obvious variable in this research, therefore the choice is not selected by random. To confirm the assumption that color is an obvious variable, we will be continue testing this variable in the next experiment.

For the audio sample section, we already known that audio clips can display a sign of warning (Liedtke, 2009) and can help the other traffic participants to locate the vehicle (Emerson et al., 2013). Since the most people on the road might have the basic understanding that vehicle horns mean that the vehicle wants to warn others, we here

consider "I am here" as a similar choice to "You go first" than "I go first" to get a preference to audio signals better.

Based on this approach, the top two sounds of "You (pedestrian) go first" is sample 1 and sample 5, the top two sounds of "I (motorcycle) go first" is sample 2 and sample 8.

CHAPTER 3.   EXPERIMENT 2

In this experiment, the best combinations of lights and sounds signal were tested in virtual reality environment to confirm the usability of this enhanced new system.

3.1   Design

The on-site virtual reality test consists of three parts:

i.   Virtual reality scene orientation;

ii. Usability test A visual signals;

iii. Usability test B visual signals + auditory signals.

In the orientation part, all participants were introduced to HTC Vive Virtual Reality System and were given the basic tutorial about this test. In order to reduce the chance of motion sickness, a short demo of a $360°$ panorama video was presented to participants to check their capability with VR scene. Participants without prior VR experience will be companied with an additional coordinator to ensure safety during the task.

In the usability test A (visual signals), participants were asked to response to the visual signals from the scooter animation.

In the usability test B (visual signals + auditory signals), participants were asked to response to the visual signals combined with audio signals from the scooter animation. The combination of visual and auditory signals was listed in Table 5 – Variables and group.

Table 5 – Variables and group

Experiment		Variables			
		Pattern	Color	Location	Sound
Group 1	Signal 1	Simple flash	Green	Two sides	Mute
	Signal 2	Simple flash	Green	Two sides	Audio 1
	Signal 3	Simple flash	Green	Two sides	Audio 5
Group 2	Signal 1	Accelerate	Red	Full light	Mute
	Signal 2	Accelerate	Red	Full light	Audio 1
	Signal 3	Accelerate	Red	Full light	Audio 5
Group 3*	Signal 1	Simple flash	Red	Full light	Mute
	Signal 2	Simple flash	Red	Full light	Audio 2
	Signal 3	Simple flash	Red	Full light	Audio 8

*We preset group 3 as signals representing "I (scooter) go first" in this study.

3.2 Material and media

The material and media design consist of two parts:

i.   Virtual reality scene;

ii.   Interactive motorcycle/driver model.

3.2.1   *Virtual reality scene*

The virtual reality scene is captured in actual intersections and rendered in VR software.

We decided to use a realistic immersive environment to test subjects in order to get a more reliable result. To get this, we need to create an environment that is i. Familiar to the volunteers; ii. In actual size; iii. In high resolution and dynamic range. There are mainly three ways to get to these requirements: i. Capture a series of image 90 degree to each other and map them to an CAVE system(Morrongiello, Corbett, Milanovic, Pyne, & Vierich, 2015); ii. Build a realistic 3d model of the actual scene and render objects in the environment; iii. Capture a 360-degree panorama picture and map it as the spherical environment shading.

The first approach was tested with a set of prime-lens cameras in an intersection inside Georgia Institute of Technology near College of Design. We used a Sony ILCE-7RM2 camera and a Carl Zeiss 18/2.8 prime lens to capture a wide-angle picture. However, the distortion in the edge is too obvious that we cannot generate a seamless super-wide view.

Figure 3-1 – Screenshot from the super wide-angle view

The second approach was tested with Autodesk 3ds Max and pre-rendered in Keyshot 6.0. However, the 3ds Max interactive does not support HTC Vive plug-in, we did not continue with this approach.
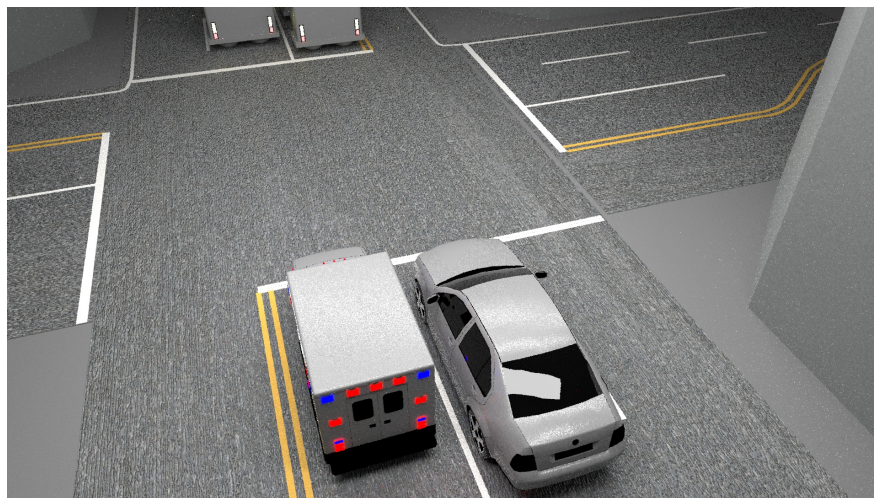
Figure 3-2 – Intersection simulator generated in 3ds Max

The second approach was tested with a Go Pro Fusion 360 camera. A seamless HDR file is captured by the dual 1-inch sensors fixed to the front and back of the camera.

Figure 3-3 – A seamless 360-degree panorama picture

The build-in 10-bit raw .png file provided information enough for an HDR import into VR software. However, the dynamic range problem can't provide enough tolerance for a sunny day scene. In this case, the scene used in this study should be a cloudy day.

3.2.2   Interactive motorcycle and driver model

To get more accurate results from usability test, a realistic and interactive motorcycle is required. Based on prior art research, the most concerned motorcycle model in this study is a small displacement scooter.

The template of scooter design is based on the top sales models of scooter in the past years. The styling parts of the scooter model (logos, unique decals, and unique features) were removed to eliminate potential bias of preference as shown in Figure 3-4 – Interactive Scooter model in V-Red software.
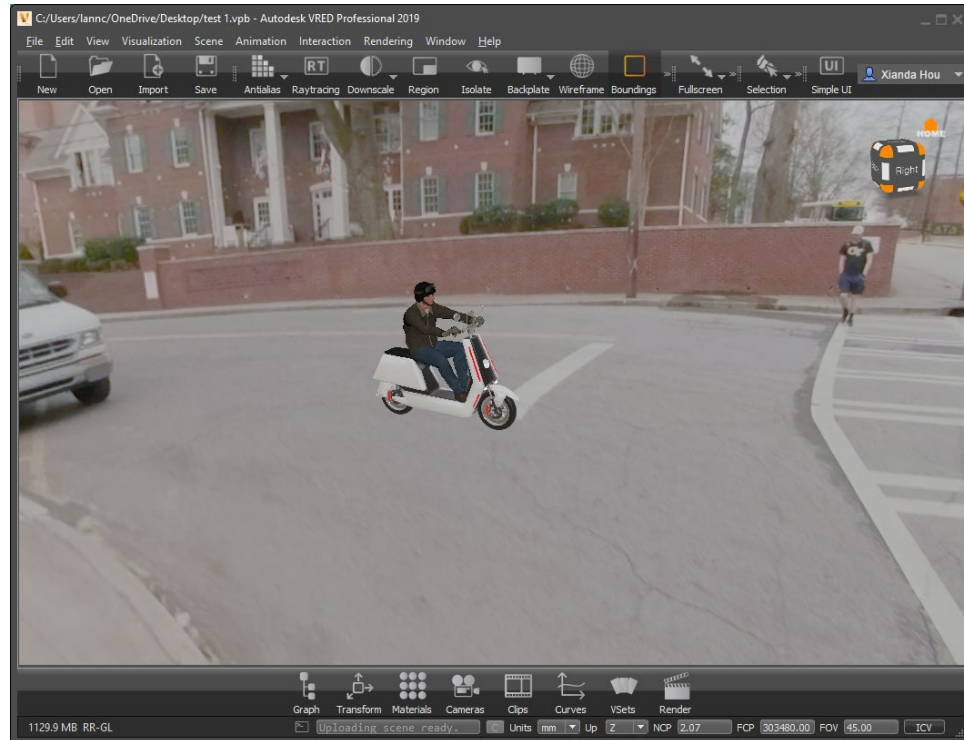
Figure 3-4 – Interactive Scooter model in V-Red software

The model was then rendered in Autodesk V-RED pro to be tested with participants. The driver of the scooter is also important part of the scene design. In this study, the figure of driver was created with Adobe Fuse then imported to Maximo to generate binding skeletons.

Figure 3-5 – The dome and spherical map

A dome was created in the software with the 360-degree panorama picture set as a spherical map. There is a minor difference between this setting and a "real" immersive interactive environment since the scene was created with a single still 360-degree panorama image not an actual environment. The movement limit to the use is a circular region in the center of the area with a radius of 1 meter(3.3feet).

The entire interaction was enabled with Steam VR service and HTC Vive Pro HMD system. We planted two trackers in the lab to track the orientation of the helmet and the controllers. Since there is a boundary in the VR scene, we marked the playing area on the actual ground in the lab to ensure the participants will not hit any object when the test is running.

Figure 3-6 – Playing area was marked with sticker notes

Contrary to the experiment design of Emerson etc., to make sure that the performance of pedestrian was actually linked to the method of signaling the participants were not asked to "write down" or "speak out" their thinking. Instead, the volunteers were assigned the objective to response to the different groups of signals and their performance will be recorded by a moderator.

3.3 Procedure

In the beginning of the experiment, all participants will be given a short orientation about the experiment setting and the VR testing system. They were told that they will be signaled by a scooter and then response accordingly by "step forward" or "wave and stop". After that, test takers were asked to perform their version of "step forward" and "wave and stop" to make sure the moderator can understand their response and intention. Then the moderator will help put the VR helmet on the participants and make sure they will not

suffer with VR motion sickness. During the signaling test, the time between the motorcycle signal and the tester's response were timed and recorded along with the decision they made. After each signal, the users were given a post usability survey to evaluate the performance of the signal as shown in Appendix 2. POST STUDY SYSTEM USABILITY QUESTIONNAIRE.

3.4   Participants

A total of 16 participants took part in the experiment. However, there was one participant who experienced motion sickness, his response was deleted from the record. In the end, there were 15 valid participants, the valid rate is 93.75%.

CHAPTER 4.   RESULTS

The results of both experiments shown the consistency of choice making when people are responding to signals from a scooter. Since there is no baseline in the second experiment, all groups will be comparing with each other to get results.

Since there is response time and the accurate rate in this study, the performance of the signaling system will be evaluated by correct response number per minute M as shown in the equation below:

$$M = \frac{n^{'}}{\sum_{n=1}^{i} t} * 60 \tag{4}$$

Here the n' means the total number of correct responses, the t_i means the time cost of each cost. When the total number of correct responses is divided by total number used and multiplied by 60 seconds, we can get the correct response number in every minute M. The higher the value of M is, the better performance this signal is.

By calculation all M values of each signal, we get the result.

Table 6 – Performance of signals

	Number	Accurate Rate	M value
Group 1	1	78.57%	9.267

	2	71.43%	7.969
	3	71.43%	6.142
Group 2*	1	28.57%	7.623**
	2	14.29%	9.113**
	3	21.43%	9.985**
Group 3	1	71.43%	8.70
	2	85.71%	12.61
	3	78.57%	7.64

*Group was default as "You (pedestrian) go first.
**M value was calculated after correction.

The Group 2 was set as "You (pedestrian) go first" as default, since the survey in experiment 1 pointed out that this signal could present both meanings at the same time. For this we assume the chance of each meaning is equal, both "You go first" and "I go first" has a 50% of chance. However, the accuracy of test 2-1, 2-2 and 2-3 was all smaller than 50%. This means the original assumption was proven false, the second group of signals should mean "I(scooter) go first".

Comparing results from test 1-1 with 1-2 and 1-3 or compare test 3-1 with 3-2 and 3-3, we can get that with some audio cues played along with the visual signal, users will make decisions faster than when only visual signals were played but the accuracy will

decrease. Some volunteers complained that the audio simply made them confused about the meaning the scooter is trying to deliver.

Comparing results from test 2-1 and 3-1 we can learn that the pattern of flashing does not affect the accuracy of understanding but will slightly affect the decision-making speed of users (by 1.03 decisions per minute).

From the result of test 3-2 we can learn that an extremely unfriendly alarming sound signal can affect the decision-making speed.

CHAPTER 5.   DISCUSSION

Overall, this study provides a possible approach to test new signaling systems on actual road vehicles without building actual prototypes and having road tests.

For the industry, this means that a lot of fund could be saved when testing new designs of motorcycles. Using interactive questionnaire and VR to commence usability test can maintain a high fidelity while greatly reduce cost of testing. This process can also reduce the testing time circle, meaning the manufacturer can develop new prototypes faster than before.

For road safety, this study shows that it is possible to use a more enhanced method of signaling to deliver more information on the road when different people met. Communication is the key to reduce accidents related to right of way.

Enough proof has shown that the popularity of small displacement motorcycles, or in the future, other types of small passenger vehicles, will be essential part of modern transportation system. This signal design and its method of usability testing provided possible approach to test, enhance and strengthen all those designs.

5.1   Experiment design and usability test

According to the experiment 1 and 2, this configuration of light might only be applied to motorcycles so far.

As shown in Table 7 – Color You go first, most of people selected "Green" as the indicating color for the meaning "You go first" (the motorcycle gives the right of way to pedestrian. This is totally the opposite of the same case on passenger vehicles.

Table 7 – Color You go first
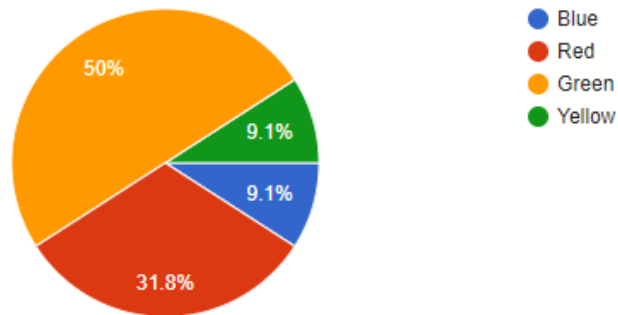
This could probably be caused by the size and the relative location of the vehicle to the user. In this study we learned that the pattern and location of the light do has an affect on the performance of signals, we can safely make an assumption that the size of the light could affect the effect of the signal itself.

Also, the participants might not be very consistent about their preference of light signal. In experiment 1 the most selected visual signal in the case "I go first" is Accelerated Red Flash Full Light, which is identical to the second most selected signal in the case "You go first". In experiment 2, the group 2 has an accuracy rate of 71.43%, 85.71% and 78.57%, which is at the same level of group 3. This means the red light has a significant more

possibility to mean "I (scooter) go first". This could probably be caused by the different setting of the two experiments: the first experiment does not provide the volunteers with a realistic environment as the second do. The users might be expecting something more than what is described in the questionnaire and the actual experiment settings.

The participant number of this study is also an aspect that could be improved in further developments. For example, the most selected visual signal method in the case "I go first" is identical to the second most selected visual signal method in the case "You go first". As a matter of fact, the total count of that selection is only 4 and was equal to the count of "Simple flash green light" and "Switching flash green light". If we have more participants, the total count of those selections will be different.

In the experiment design of part I, we did not consult designers from the industry but started building the design on our own. This resulted in the possibility of different combinations ended up with the total number of 144. This required an extra step of calculation the correlation of each indicator to the results. If we managed to seek reference from prior designers from industry, we might be able to simplify the experiment process.

In this study, we were not able to determine the relationship between different features of auditory signals (texture, pitch and tone) and the performance of the signal method. Based on experiment 2, we can only confirm that a suitable auditory cue can slightly improve the performance of the signaling method and a not suitable auditory cue can make users confused.

5.2 Future works

In further studies, there are some potential directions can follow:

i.   The relationship between the color and pattern;

ii.   How does color affect the judgement of users;

iii.   Auditory signals.

In this study we gained enough proof that the color and pattern of signals can affect the performance of pedestrians. However, it is not clear if the decision of color can actually affect the decision of pattern as well. In future works, we can bring more models of different types of vehicle and test the preference of users. This study can reveal the relationship between two different aspects of the same problem and their mutual affect to each other.

Color played an important role in this study when the users shown an obvious preference of color when trying to display different meanings. However, the color psychology behind it has never be officially discussed and tested. In future study we can try to generate a dictionary of different "color code" and better conclude the meaning of different colors in specific scenarios. This study can reveal the relationship between color and user decisions.

We learned from this study and prior art that auditory signals can not delivery solid and precise information as visual signals do. We confirmed that auditory signals can affect the decision making of users combined with visual signals. But we never considered the case that people might be able to learn the meaning of some specific auditory signal. In future study we should include this part where the easy-to-learn of auditory signal is tested. This would provide support when sound design is required for future vehicles.

APPENDIX A. ONLINE QUESTIONNAIRE

Enhanced signaling system for scooters

Hi! beloved test taker.
This is part of a Georgia Tech research study about scooter and road safety, your response is totally voluntary.
This is the part one study of a two part research, in this section you will be asked 11 different questions about yourself and your experience with seeing scooters around your neighborhood.
You response will be recorded anonymously and will not be disclosed to any third party.
By continuing finish the questionnaire, you are accepting the condition listed above.
Thank you for your time, the total time required to finish the questionnaire is around 7 mins.

*Required

[If you are located in a European Union (EU) country, you are not permitted to participate in this study due to the General Protection Data Regulation (GDPR)]

1. What's your gender?
Mark only one oval.

- ◯ Female
- ◯ Male
- ◯ Prefer not to say
- ◯ Other: _____

2. What is your age range?
Mark only one oval.

- ◯ 21-24 years old.
- ◯ 25-35 years old.
- ◯ 35-45 years old.
- ◯ 45-55 years old.

3. How is your annual income?
Mark only one oval.

- ◯ less than 10k $
- ◯ 10K $-15K$
- ◯ 15K $-25K $
- ◯ 25K $-35K $
- ◯ 35K $-45K $
- ◯ More than 45K $

4. Do you ride a scooter/motorcycle?

Mark only one oval.

- ( ) Yes, Everyday
- ( ) Yes, few times a week
- ( ) Yes, but not often.
- ( ) No I don't ride a scooter

5. Do you drive a car/4-wheel vehicle?

Mark only one oval.

- ( ) Yes, Everyday
- ( ) Yes, few times a week
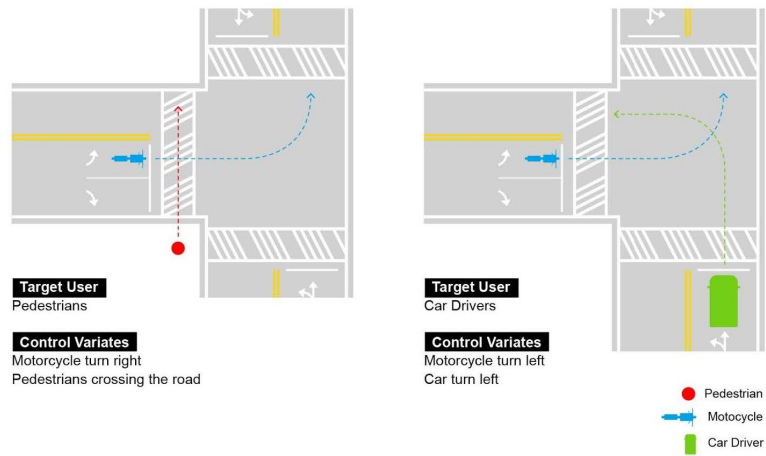- ( ) Yes, but not often
- ( ) No I don't drive a car

Lighting signal. (You go first)

Imaging you and the scooter both arrive at the stop sign at the same time, the scooter is yielding the right of the way and wants you to go first, then...

Visual (lighting) signals

SCENARIO ONE
Junction without traffic lights

Target User
Pedestrians

Control Variates
Motorcycle turn right
Pedestrians crossing the road

Target User
Car Drivers

Control Variates
Motorcycle turn left
Car turn left

- ● Pedestrian
- ← Motocycle
- ■ Car Driver

6. **Which one best represents "you(the questionnaire taker) go first". The scooter is giving the right of the way to you? ***

Mark only one oval.

◯ Accelerating flash

◯ Continues light

◯ Switching flashing light

◯ Simple flashing light

7. What color can best represent the meaning mentioned above? *

Mark only one oval.

Blue   *Skip to question 8.*

Red   *Skip to question 9.*

Green   *Skip to question 10.*

Yellow   *Skip to question 11.*

Skip to question 12.

Blue lights 1

8. **Where should the lights be?**
Mark only one oval.

◯ Full lights

◯ Top only

◯ Top and side

◯ Two sides only

◯ Up sides only

◯ Down sides only

Red lights 1

9. **Where should the lights be?**
   Mark only one oval.

○ Full lights

○ Top only

○ Top and side

○ Two sides only
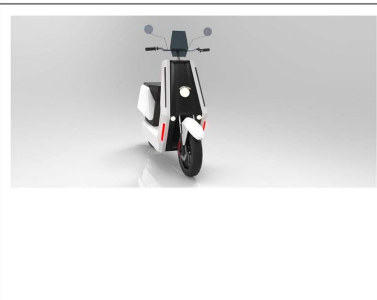
○ Up sides only

○ Down sides only

Skip to question 12.

Green lights 1

10. **Where should the lights be?**
Mark only one oval.

⬭ Full lights

⬭ Top only

⬭ Top and side
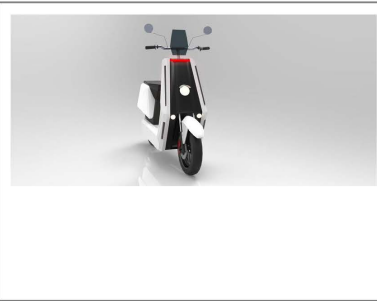

⬭ Two sides only

⬭ Up sides only

⬭ Down sides only

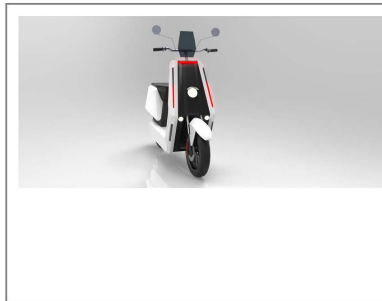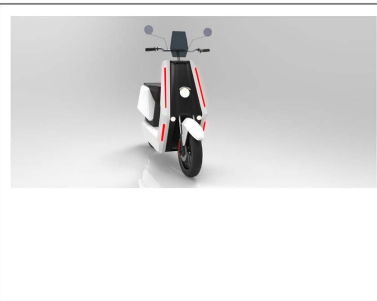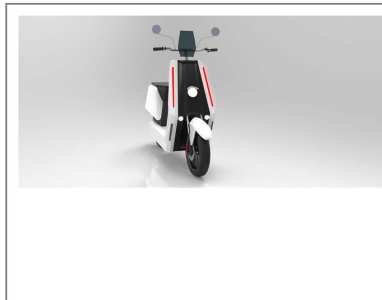*Skip to question 12.*

Yellow lights 1

11. Where should the lights be?

Mark only one oval.

◯ Full lights

◯ Top only

◯ Top and side

◯ Two sides only

◯ Up sides only

◯ Down sides only

Skip to question 12.

Lighting signal. (Scooter go first)

Imaging you and the scooter both arrive at the stop sign at the same time, the scooter is signaling you that he is requesting the right of way and...

Visual (lighting) signals

SCENARIO ONE
Junction without traffic lights

Target User
Pedestrians

Control Variates
Motorcycle turn right
Pedestrians crossing the road

Target User
Car Drivers

Control Variates
Motorcycle turn left
Car turn left

● Pedestrian
🔵 Motocycle
🟩 Car Driver

12. **Which one best represents "I(scooter) will go first". The scooter is requesting the right of the way from you? ***

Mark only one oval.

◯ Accelerating flash

◯ Continues light

◯ Switching flashing light

◯ Simple flashing light

13. **What color can best represent the meaning mentioned above? ***
Mark only one oval.

◯ Blue   *Skip to question 14.*   ◯ Red   *Skip to question 15.*

◯ Green   *Skip to question 16.*   ◯ Yellow   *Skip to question 17.*

Skip to question 18.

Blue lights 2

14. **Where should the lights be?**
Mark only one oval.

⬭ Full lights

⬭ Top only

⬭ Top and side

⬭ Two sides only

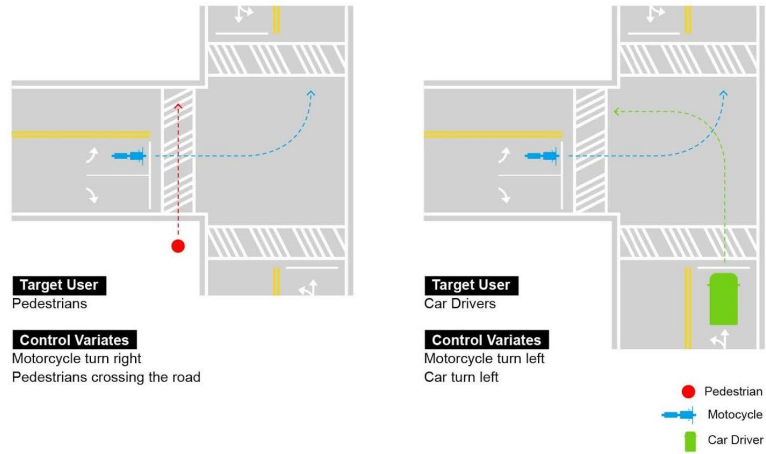⬭ Up sides only

⬭ Down sides only

Skip to question 18.

Red lights 2

15. Where should the lights be?

Mark only one oval.

○ Full lights

○ Top only
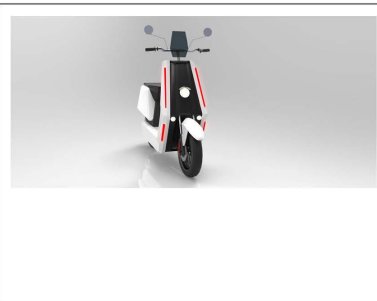
○ Top and side
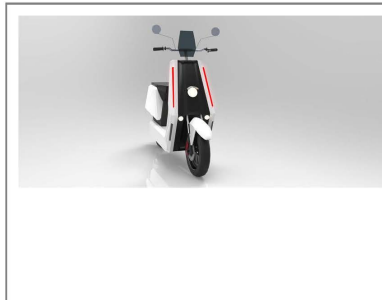
○ Two sides only
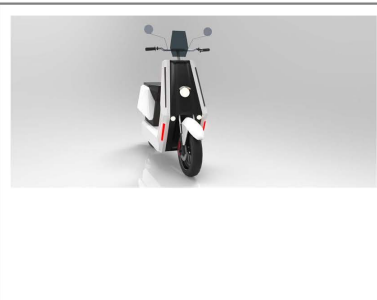
○ Up sides only

○ Down sides only

Skip to question 18.

Green lights 2

59

16. **Where should the lights be?**
Mark only one oval.

◯ Full lights

◯ Top only

◯ Top and side

◯ Two sides only

◯ Up sides only

◯ Down sides only

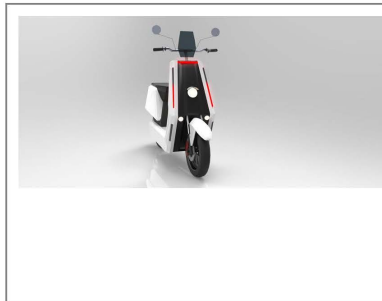*Skip to question 18.*

Yellow lights 2

17. Where should the lights be?

Mark only one oval.

⬭ Full lights

⬭ Top only

⬭ Top and side

⬭ Two sides only

⬭ Up sides only

⬭ Down sides only

Skip to question 18.

Sound (auditory) signals.

In further test, the sound signal will be displayed with or without the lighting signals mentioned above, please click the video, listen to the sound and make the selection of choice that you think best match the meaning.

Sample 1 (click video to play)

http://youtube.com/watch?v=mdN_P4-XR5s

18. **What message does this sound sample deliver to you? (1)**
Mark only one oval.

- ◯ You go first.
- ◯ I(scooter) go first.
- ◯ I(scooter) am here.
- ◯ Not clear
- ◯ Other: _____

Sample 2

http://youtube.com/watch?v=oucVi8JPm2k

19. **What message does this sound sample deliver to you? (2)**
Mark only one oval.

- ◯ You go first.
- ◯ I(scooter) go first.
- ◯ I(scooter) am here.
- ◯ Not clear
- ◯ Other: _____

Sample 3

62

20. **What message does this sound sample deliver to you? (3)**

   Mark only one oval.

   ⬭ You go first.

   ⬭ I(scooter) go first.

   ⬭ I(scooter) am here.

   ⬭ Not clear

   ⬭ Other: _____

Sample 4

21. **What message does this sound sample deliver to you? (4)**

   Mark only one oval.

   ⬭ You go first.

   ⬭ I(scooter) go first.

   ⬭ I(scooter) am here.

   ⬭ Not clear

   ⬭ Other: _____

Sample 5

http://youtube.com/watch?v=Xpi2GsuMqSM

22. What message does this sound sample deliver to you? (5)

Mark only one oval.

◯ You go first.

◯ I(scooter) go first.

◯ I(scooter) am here.

◯ Not clear

◯ Other: _____

Sample 6

http://youtube.com/watch?v=2edaO39NLlQ

23. What message does this sound sample deliver to you? (6)

Mark only one oval.

◯ You go first.

◯ I(scooter) go first.

◯ I(scooter) am here.

◯ Not clear

◯ Other: _____

Sample 7

24. **What message does this sound sample deliver to you? (7)**
Mark only one oval.

- ○ You go first.
- ○ I(scooter) go first.
- ○ I(scooter) am here.
- ○ Not clear
- ○ Other: _____

Sample 8

25. **What message does this sound sample deliver to you? (8)**
Mark only one oval.

- ○ You go first.
- ○ I(scooter) go first.
- ○ I(scooter) am here.
- ○ Not clear
- ○ Other: _____

Sample 9

26. **What message does this sound sample deliver to you? (9)**

   Mark only one oval.

   ◯ You go first.

   ◯ I(scooter) go first.

   ◯ I(scooter) am here.

   ◯ Not clear

   ◯ Other: _____

Sample 10

27. **What message does this sound sample deliver to you? (10)**

   Mark only one oval.

   ◯ You go first.

   ◯ I(scooter) go first.

   ◯ I(scooter) am here.

   ◯ Not clear

   ◯ Other: _____

28. **Do you have any suggestion about scooter signaling problems?**

   _____

   _____

   _____

   _____

   _____

[If you are located in a European Union (EU) country, you are not permitted to participate in this study due to the General Protection Data Regulation (GDPR)]

APPENDIX B. POST STUDY SYSTEM USABILITY QUESTIONNAIRE

The PSSUQ is provided to the subject after they have completed all normal condition scenarios. the PSSUQ requires that the user circle their response to each question based on a 7-point scale (where the lower the response, the higher the subject's usability satisfaction with their system). The subject can also clarify their answers by adding comments in the provided spaces. After the subject has completed filling out the questionnaire, it is good practice for the analyst to quickly go over the subject's answers in order to make sure the subject hasn't missed anything and that all comments are understood.

Participate ID:_____   **Site:_____**   **Date:____/____/____**

1.Overall, I am satisfied with how easy it is to use this signaling system.

STRONGLY AGREE   1   2   3   4   5   6   7   **STRONGLY DISAGREE**

COMMENTS:

2. It was easy to learn this signaling mode.

STRONGLY AGREE   1   2   3   4   5   6   7   **STRONGLY DISAGREE**

COMMENTS:

3. The signaling mode was effective in helping me complete the tasks.

STRONGLY AGREE 1 2 3 4 5 6 7 **STRONGLY DISAGREE**

COMMENTS:

4. I felt comfortable using this signaling mode.

STRONGLY AGREE 1 2 3 4 5 6 7 **STRONGLY DISAGREE**

COMMENTS:

5. The information provided with this signaling mode was clear.

STRONGLY AGREE 1 2 3 4 5 6 7 **STRONGLY DISAGREE**

COMMENTS:

6. The information provided for the signaling mode was easy to understand.

STRONGLY AGREE 1 2 3 4 5 6 7 **STRONGLY DISAGREE**

COMMENTS:

7. The signaling mode of this system was pleasant.

STRONGLY AGREE 1 2 3 4 5 6 7 **STRONGLY DISAGREE**

COMMENTS:

8. I like using this signaling mode.

STRONGLY AGREE 1 2 3 4 5 6 7 **STRONGLY DISAGREE**

COMMENTS:

9. Overall, I am satisfied with this signaling mode.

STRONGLY AGREE 1 2 3 4 5 6 7 **STRONGLY DISAGREE**

COMMENTS:

APPENDIX C. CONSENT FORM

Thank you for your interest of our project, this project is a research study about the signaling system of scooters. By participating this study, you are contributing your effort into making the community a safer place because riding a scooter will be safer and more comfortable. The next test is an on-site VR test, it will take approximately 10 minutes. There is a slight chance that you might feel motion sickness after some time in the VR scene. You can pause or abort the test at any time. Your participation is totally voluntary.

CONSENT DOCUMENT FOR ENROLLING ADULT PARTICIPANTS IN A RESEARCH STUDY

Georgia Institute of Technology

Georgia Institute of Technology

Project Title: Enhanced Signaling Method Design For Scooters

Investigators: *Principal Investigator (Roger Ball, Ph.D.)*

Co-Investigator (Xianda Hou)

Co-Investigator (Yuan Cao)

Protocol and Consent Title: *Consent form for On-Site VR Scene Test (Main 01/31/2019v1)*

You are being asked to be a volunteer in a research study.

Purpose:

- The purpose of this study is to evaluate whether our selected signaling method for scooters in the designated case scenes are effective, accurate and understandable. Since it is too dangerous to involve real life experiment on actual road, VR technology is introduced to help. We plan to recruit 15 participants into the VR test.

Exclusion/Inclusion Criteria:

- Participants who are 18 years old or younger, people with certain disability that not suggested to walk, drive or ride on the road on their own are excluded from the study.
- Male and female participants who age from 22-45, have 1 year of more driving/scooter riding experience are most welcomed to participate in this study.

Procedures:

- During the entire test period, only you and the test moderators will be in the test room, none of the experiment will be video-taped or audio recorded. However, the test moderators will write down some comments or thoughts your mentioned in the study.
- If you decide to be in this study, your part will involve an on-site test with VR scene in Arch West Building Room 150 body scan lab. In the visit, which will take about half hour (30 minutes), you will be given the basic training about using the VR helmet if you have no prior knowledge about VR experience. We will then fit you with the VR helmet and controllers, and you will walk on the virtual scene I and scene II for 5 minutes each.
- During the walk you are supposed to see a scooter with different signaling settings, you should response based on your own observation and understand. A research assistant will be with you to ensure that you do not fall. With your permission, we will screenshot the VR scene when you are experiencing the scene. After you finish the steps, we will ask you some questions about the usability of the scooter signaling system and the VR experience. Remember, you may stop at any time.

Risks or Discomforts:

- The following risks or discomforts may occur as a result of your participation in this study. Although we will carefully set the VR gadgets and scene, motion sickness still got a chance to occur. Please inform the researcher immediately if you feel dizzy, uncomfortable or unwilling to continue. It is also possible that you could fall, although research assistants will be at your side whenever you are inside the scene.
- Even if you feel all okay during the test but the total time you spent inside the VR scene is longer than 15 minutes, we will pause the experiment for your health.

Benefits:

- By participating this study, you are helping us identifying a better method for scooters to signaling other participants. This will greatly enhance the user experience and safety of all scooter users. Even if you are currently not a scooter user, with the help of this enhanced design, your interaction with a scooter and its driver will be easier and more friendly. Besides, the entire society will benefit greatly from this study since the overall road safety will be promoted.

Compensation to You:

- There is no compensation for participation."

Storing and Sharing your Information:

- *Your participation in this study is gratefully acknowledged. It is possible that your information/data will be enormously valuable for other research purposes. By signing below, you consent for your de-identified information/data to be stored by the researcher and to be shared with other researchers in future studies. If you agree to allow such future sharing and use, your identity will be completely separated from your information/data. Future researchers will not have a way to identify you. Any future research must be approved by an ethics committee before being undertaken."*

Use of Photographs, Audio, or Video Recordings:

- We may want to use some of the photographs, audio, or video recordings of you in public presentations related to the research. The attached MODEL RELEASE FORM outlines several possible uses and asks for your specific written consent to use these items in each way. We will not use any videotapes, photographs, recordings, or other identifiable information about you in any future presentation or publication without your consent."

Confidentiality:

- The following procedures will be followed to keep your personal information confidential in this study: Your privacy will be protected to the extent required by law. To protect your privacy, your records will be kept under a code number rather than by name. Your records will be kept in locked files and unless you give specific consent otherwise, only study staff will be allowed to look at them. Your name and any other fact that might point to you will not appear when results of this study are presented or published.

- You should be aware that the experiment is not being run from a 'secure' https server of the kind typically used to handle credit card transactions, so there is a small possibility that responses could be viewed by unauthorized third parties such as computer hackers. In general, the web page software will log as header lines the IP address of the machine you use to access this page, e.g.,102.403.506.807, but otherwise no other information will be stored unless you explicitly enter it.

Costs to You:

- There are no costs to you, other than your time, for being in this study."

Questions about the Study:

If you have any questions about the study, you may contact principal investigator

roger.ball@coa.gatech.edu

Questions about Your Rights as a Research Participant:

- Your participation in this study is voluntary. You do not have to be in this study if you don't want to be.
- You have the right to change your mind and leave the study at any time without giving any reason and without penalty.
- Any new information that may make you change your mind about being in this study will be given to you.
- You will be given a copy of this consent form to keep.
- You do not waive any of your legal rights by signing this consent form.

If you have any questions about your rights as a research participant, you may

contact

Ms. Melanie Clark, Georgia Institute of Technology

Office of Research Integrity Assurance, at (404) 894-6942.

If you sign below, it means that you have read (or have had read to you) the

information given in this consent form, and you would like to be a volunteer in

this study.

_____

Participant Name (printed)

_____   _____

Participant Signature   Date   Time

_____   _____

Signature of Person Obtaining Consent   Date

Consent to Store and Share your Information:

"I agree that my de-identified information/data may be stored and shared for future,

unspecified research.

SIGNATURE _____

I do not allow my de-identified information/data to be stored and shared for future,

unspecified research. These may only be used for this specific study.

SIGNATURE _____"

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