Bicycle Commuting: Design of a Device to Increase Female Ridership in Atlanta Using V2V Technology

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TABLE OF CONTENTS

DESIGN PROCESS

CONCLUSION

ABSTRACT

Statistics indicate that there is a significant discrepancy between the amount of males and the amount of females who choose to commute by bicycle to work. Of all bicycle-commuting trips to work within Atlanta, 78% of all trips are made by men and 22% are made by women. This is on par with the national statistic of men outnumbering female bicycle commuters 3 to 1. Previous studies have shown that female cyclists are more sensitive to dangers than male cyclists. This project looks into the underlying concerns of female cyclists and seeks to allay fear in riding in the city. The result is Bicyclist Awareness System (BAS), a system of components designed, utilizing vehicle-to vehicle technology (V2V), to create a relationship between drivers and nearby cyclists.

WHAT IS THE BICYCLIST AWARENESS SYSTEM?

Bicycle commuting to work has grown significantly as an alternate mode of transportation to motor-vehicles and public transportation. For example, in the city of Atlanta, bicycle commuting alone has increased over 180% in the last 10 years. However, driver awareness and learning to "share the road" is an obstacle that both bicyclists and drivers still face today.

Vehicle-to vehicle technology (V2V) is a new wireless communication technology between cars within a vicinity of each other. With vehicle-to-vehicle technology, cars have the ability to track the speed and location of other nearby cars. The development and future implementation of this technology will help decrease and prevent traffic accidents.

Bicyclist Awareness System (BAS) is a system of components designed to help create a relationship between motor-vehicle drivers and bicyclists. BAS implements V2V technology into bicycles and cars with real-time updates to help drivers locate a bicyclist within a vicinity. With BAS, drivers are able to quickly identify nearby cyclists and react accordingly.

HOW THE SYSTEM WORKS

A device on the bicycle (the transceiver) sends out a signal to all vehicles within a 150-foot radius with the bicyclist's location. The signal is received by the vehicles and translates the bicyclist's location in reference to the vehicle to the driver.

Vehicle With V2V

Driver

Vehicle Without V2V
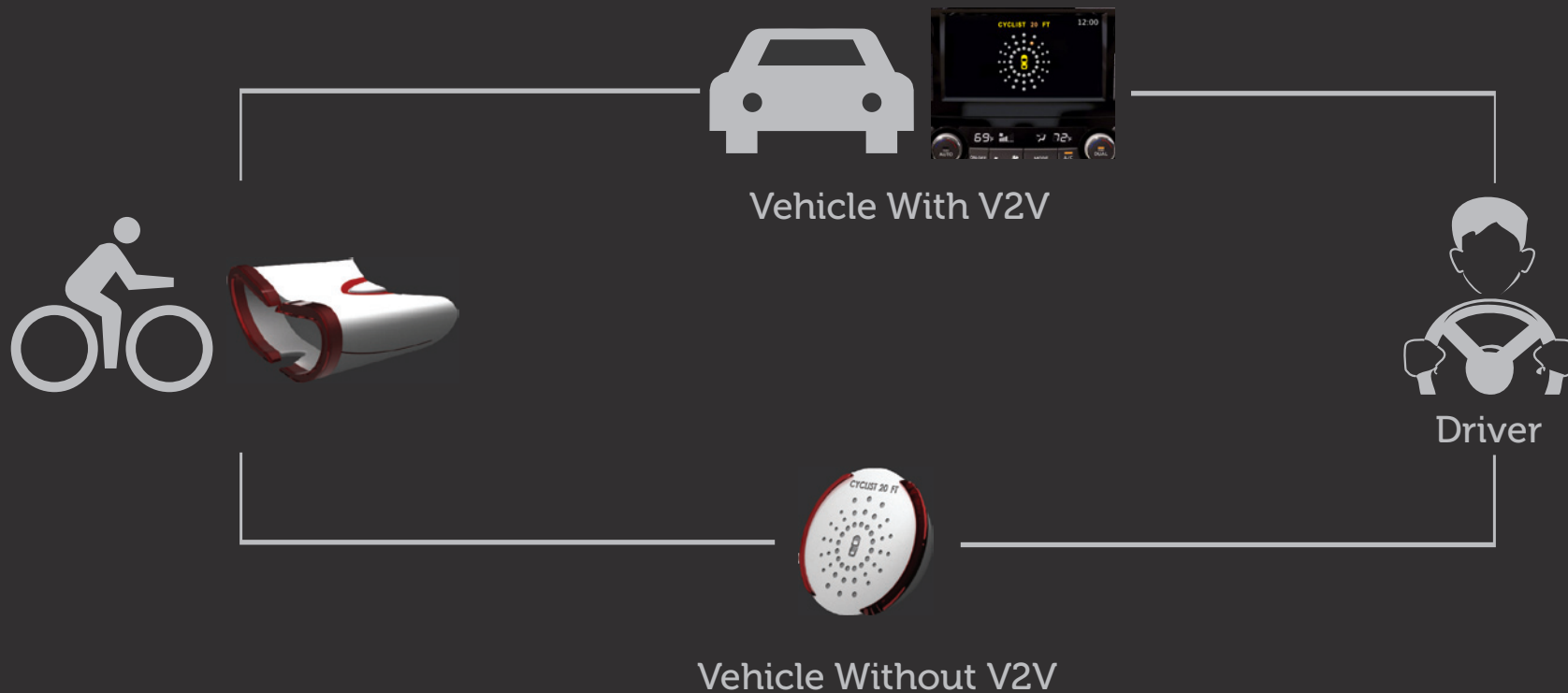
SYSTEM COMPONENTS

The BAS system is comprised of three components: a transceiver located on the bicycle, a interface for cars with V2V, and an attachable receiver that may be mounted inside cars without V2V.
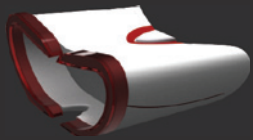
THE TRANSCEIVER

The transceiver, located on the bicycle, sends out a signal to receivers located inside of a vehicle.

THE INTERFACE

All cars in the future will have built-in V2V technology.[1] These cars will also have a built-in receiver to locate bicyclists. This interface,which helps drivers locate nearby bicyclists, would be implemented into infotainment systems within new cars.

THE ATTACHABLE RECEIVER

Cars of today, without V2V technology, will be retrofitted with an attachable receiver that also helps drivers locate nearby bicyclists. This retrofitted device is to be mounted on to a car's windshield for proper viewing and usage. This component was designed to help bridge the technology gap between cars with V2V and those without it.

[1] "V2V and me: Driving the smart cars of the future." Consumer Reports. < http://news.consumerreports.org/cars/2012/02/v2v-and-me-driving-the-smart-cars-of-the-future.html>

THE TECHNOLOGY

The transceiver is a passive device which is mounted onto the back (either the seat stay or pannier) of the bicycle. After being attached, the cyclist can turn the transceiver on with a simple push of a button.

After the transceiver is turned on, all vehicles equipped with V2V technology and located within a 150-foot vicinity of the bicycle will receive signals sent out by the transceiver. Because the transceiver is a passive device, the cyclist does not need to do anything other than focus on riding to their destination.

Once arrived at the bicyclist's destination, the bicyclist can turn off the transceiver.

"Vehicle-to-Vehicle (V2V) Communications for Safety is the wireless exchange of data among vehicles traveling in the same vicinity which offers opportunities for significant safety improvements."

-Research and Innovative Technology Associatiion, U.S. DOT

"The devices used for this technology can be small, about the size of a cigarette pack. Older cars could be easily retrofitted with V2V devices."

-Nady Boules, Director of Electronics and Controls, GM

With the potential to vastly improve road safety, standards for the technology are being developed. Some future standards and applications include:

Emergency brake light warning
Forward collision warning
Intersection movement assist
Blind spot and lane change warning
Do not pass warning
Control loss warning
Vehicle stabilization activation

HOW THE SYSTEM WORKS

CYCLIST 20 FT   CYCLIST 9 FT   CYCLIST 6 FT   CYCLIST 7 FT
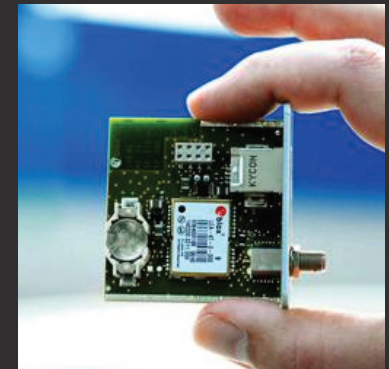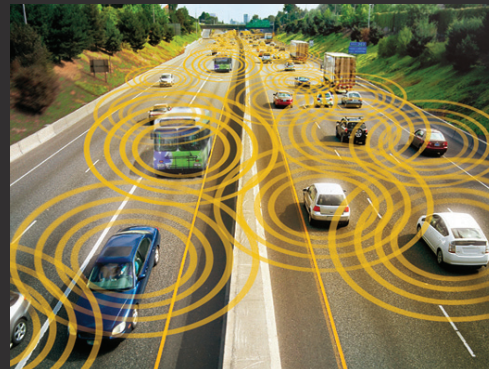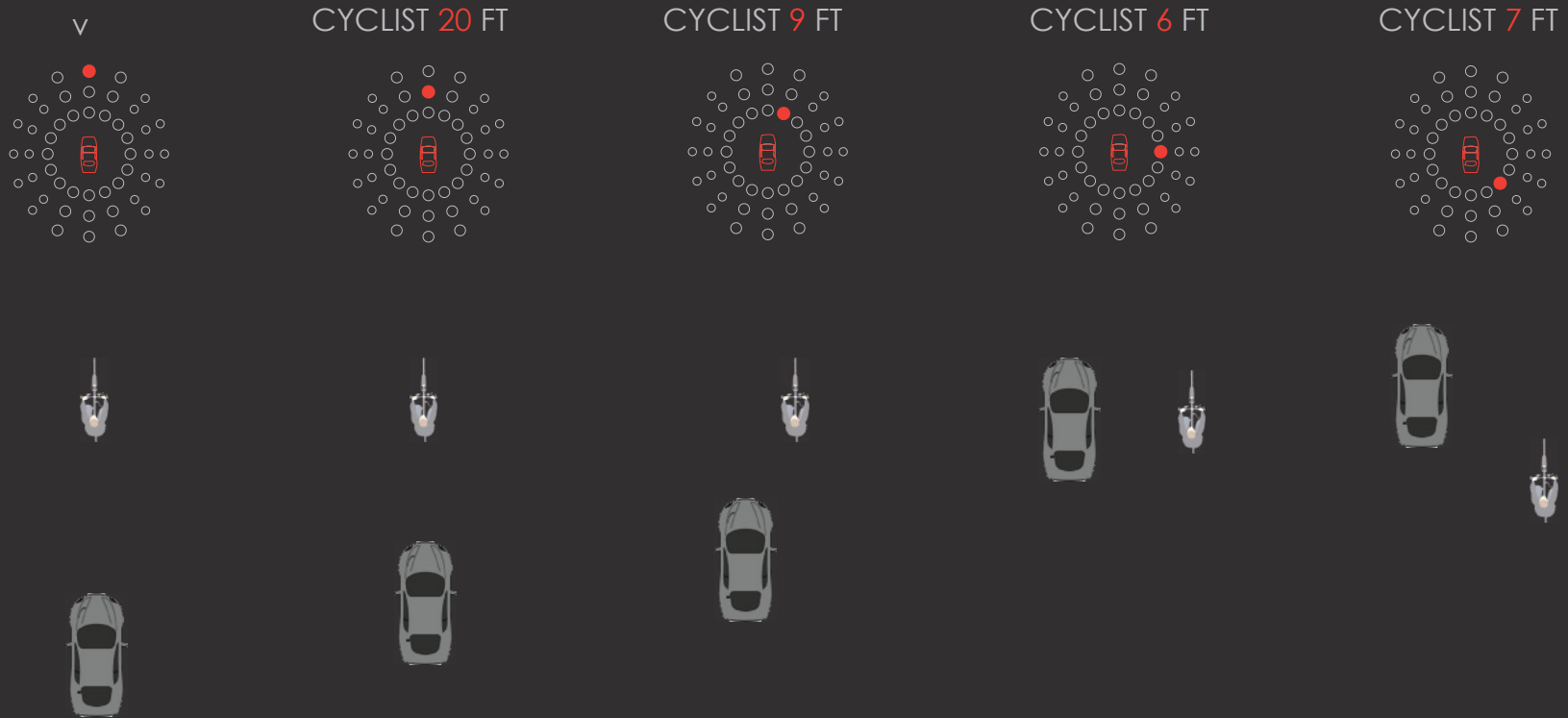
The above interface is located within the car. Both the interface and the attachable receiver use the same real-time graphics to indicate to the car driver where the cyclist is in reference to the driver's car. The moving red dot represents the bicyclist. The center of the interface, the car, represents the driver.
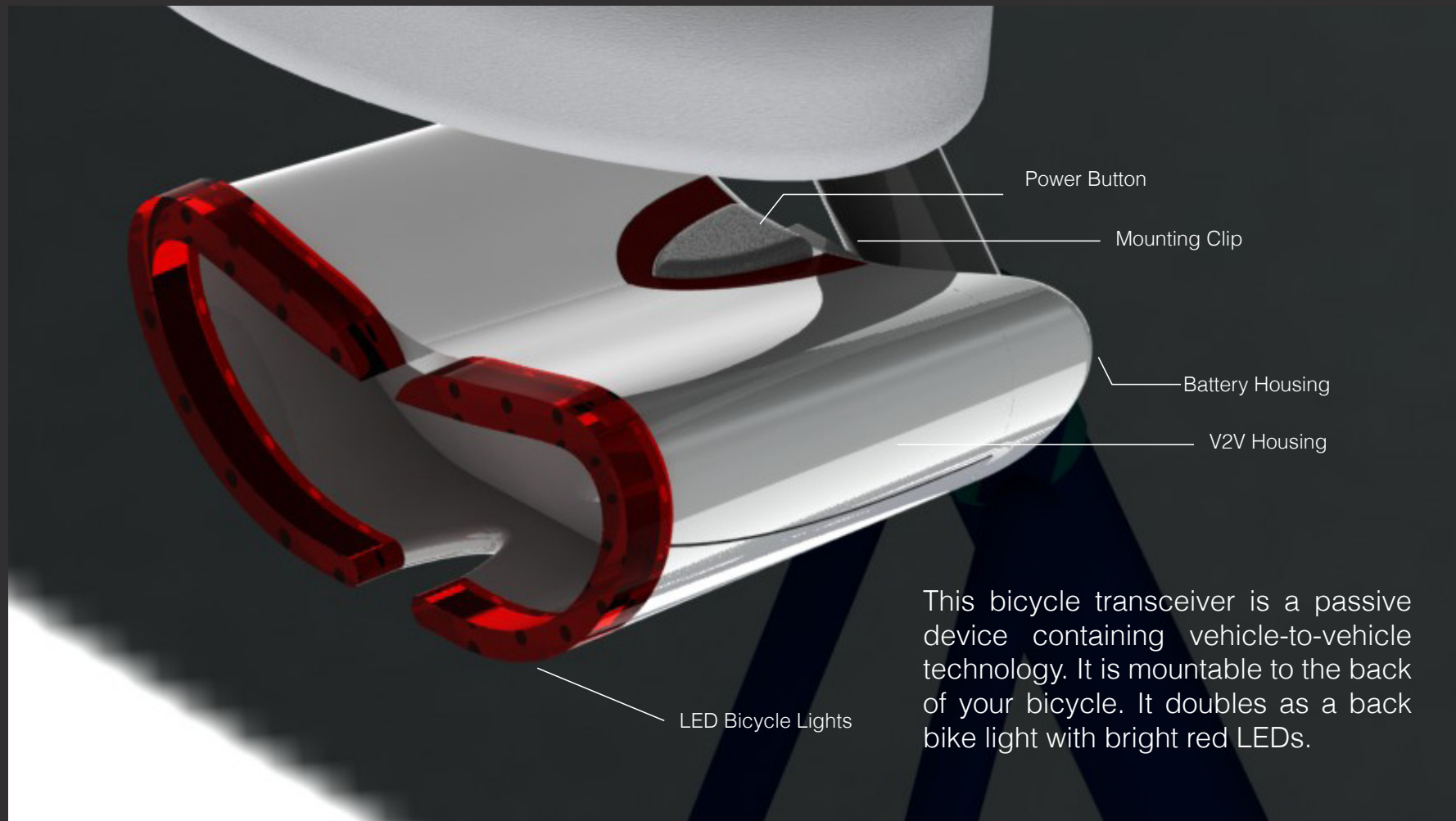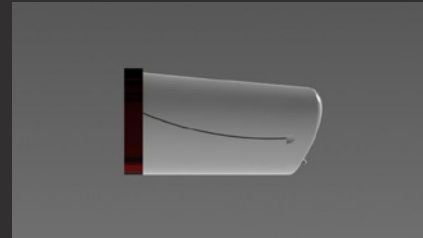
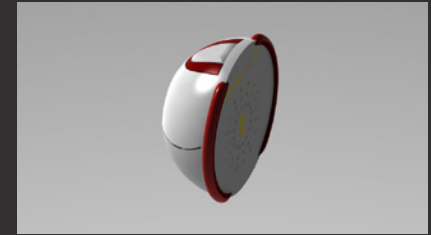Retrofit Receiver for
V2V Aftermarker

Built-in V2V Detection

Both the retrofit and built-in receivers use V2V technology. The built-in detection is displayed through V2V car infotainment systems. To decrease the technology gap between cars with V2V and cars without it, the retrofit receiver is available for cars without built-in V2V.

TRANSCEIVER FEATURES

Power Button

Mounting Clip

Battery Housing

V2V Housing

LED Bicycle Lights

This bicycle transceiver is a passive device containing vehicle-to-vehicle technology. It is mountable to the back of your bicycle. It doubles as a back bike light with bright red LEDs.

RECEIVER FEATURES
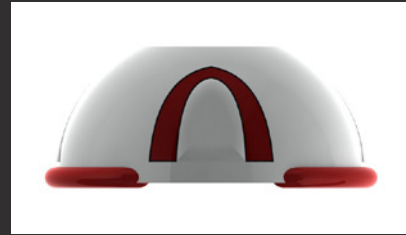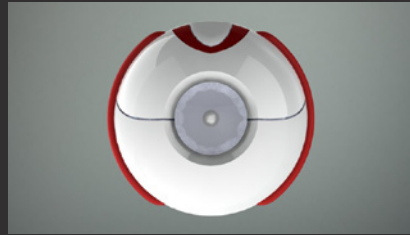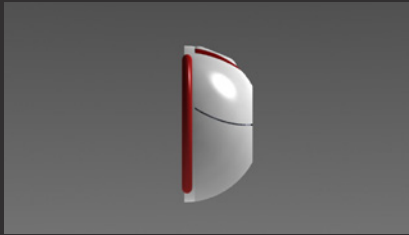
This retrofit receiver is a solar-powered device with an LED interface that updates in real-time. With a recharge-able ML2032 cell battery, it takes about 2 hours to charge from exhaust in daylight and can last up to several months depending on usage. It has a low watt rate (<2.5 watts) and is mountable to your windshield so you can just "stick it and forget it".

Power Button

Solar Cell Backing

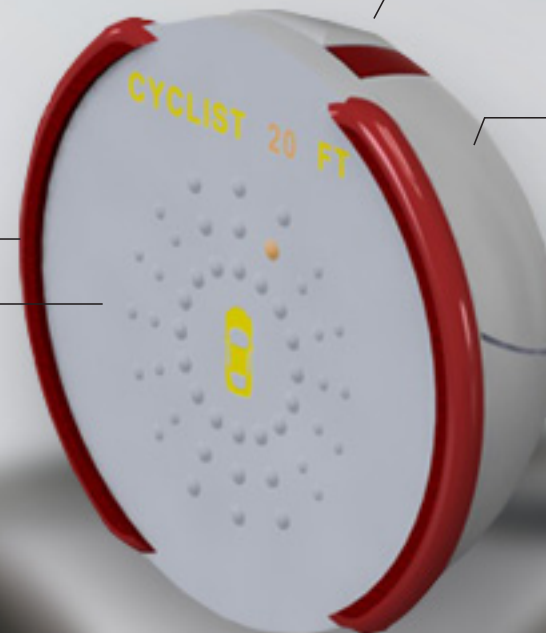CYCLIST 20 FT

Rubber Grips

Windshield Suction Attachment

LED Real-time Display
(Updates as the distance between the vehicle and cyclist changes)

DESIGN PROCESS

MOTIVATION

Statistics show bicycling has been growing as a mode of transportation in the last decade. Specifically in the city of Atlanta, bicycling to work grew 180% in the last 10 years – bicycling now making up 0.8% of all commutes in the city. However, looking at the demographic break-down across the nation, men outnumber on average women about 3 to 1 in bicycle commutes.

UNITED STATES SHARE OF BIKE COMMUTES

0.53%
OF 137 MILLION US WORKERS

CITY OF ATLANTA SHARE OF BIKE COMMUTES

0.88%
OF ~188,000 US WORKERS

CITY OF ATLANTA SHARE OF BIKE COMMUTES

74%
MEN

26%
WOMEN

CITY OF ATLANTA SHARE OF BIKE COMMUTES

78%
MEN

22%
WOMEN
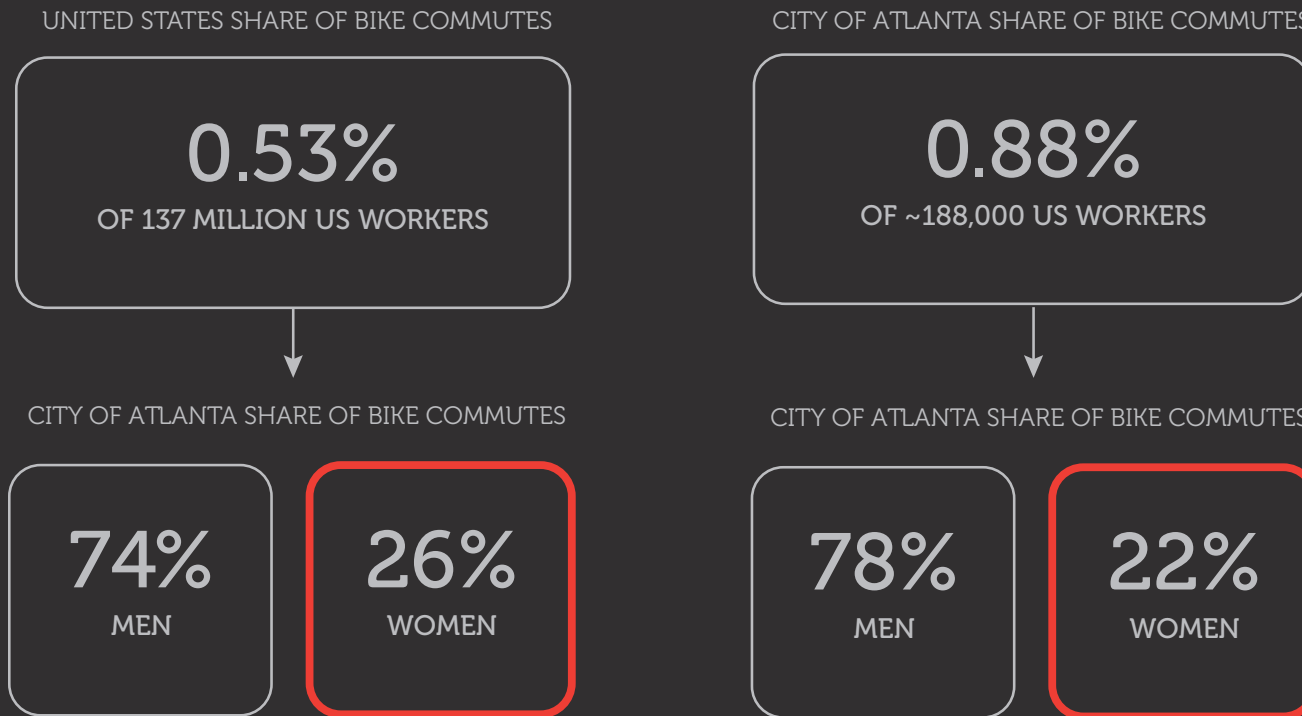
Prior research has also shown a gender misalignment in the decision making of whether to commute by bicycle or not. An article written by Welke et al. in 2004 explored women's cycling barriers in several countries such as Canada, Mozambique, the Netherlands, and China. The article stated that, within the City of Ottawa, 50% fewer women cycled to work or school than men (0.7% vs. 1.6%). In Continental Europe, women make up between 10-23% of bicycle commuters. A significant amount of Ottawan women (65%) were more likely than men to agree that that traffic safety was a major barrier to choosing to cycle.

Understanding why women are making less trips than men can help gain insight on how to increase the number of trips made to work, lowering barriers of entry for women riders, and or improving the ride experience.

SURVEY FINDINGS

A 13-question online survey was deployed to better understand bicycling habits, needs, and wants, by the working population in Atlanta. The survey focused on modes of transportation to work, distance from home to work, workplace accommodations for bicyclists, and people's concerns with cycling to work.

The survey garnered over 160 responses (44% female and 56% male). The average respondent's age was 27 years of age with a standard deviation of 9 years. Interestingly, while 46% of survey takers felt that biking is unsafe, 70% felt that biking specifically in Atlanta is unsafe.

88% Own a bike.

46% Feel biking is unsafe.

70% Feel biking in Atlanta is unsafe.

SURVEY FINDINGS

Repondents were asked to rate themselves and their experience as a cyclist on a Lickert scale. 1 being "I am unable to bike" and 5 being "I'm an expert."

Both males that biked to work and males that traveled with another mode of transportation rated themselves higher than women did.

Of all the survey respondents, only 1 respondent answered that they did not know how to ride a bicycle.

Self-Reported Rating of Expertise

1 - Unable to Bike   5 - Expert

|	Bikes to Work	Other
Male	4.52	3.97
Female	4.16	3.28

SURVEY FINDINGS

The survey also contained a free-response section in which respondents were allowed to list all of their concerns with bicycling to work.

I wrote out all the issues and concerns both women and men had with cycling to work. On the right, the top image depicts all the concerns people had with cycling to work (disregarding their primary mode of transportation).

The center image shows the issues women and men that did not cycle to work had. As you as see, the male pool shrinks significantly more than the female pool from the first picture. This showed that despite issues, most men cycled regardless.
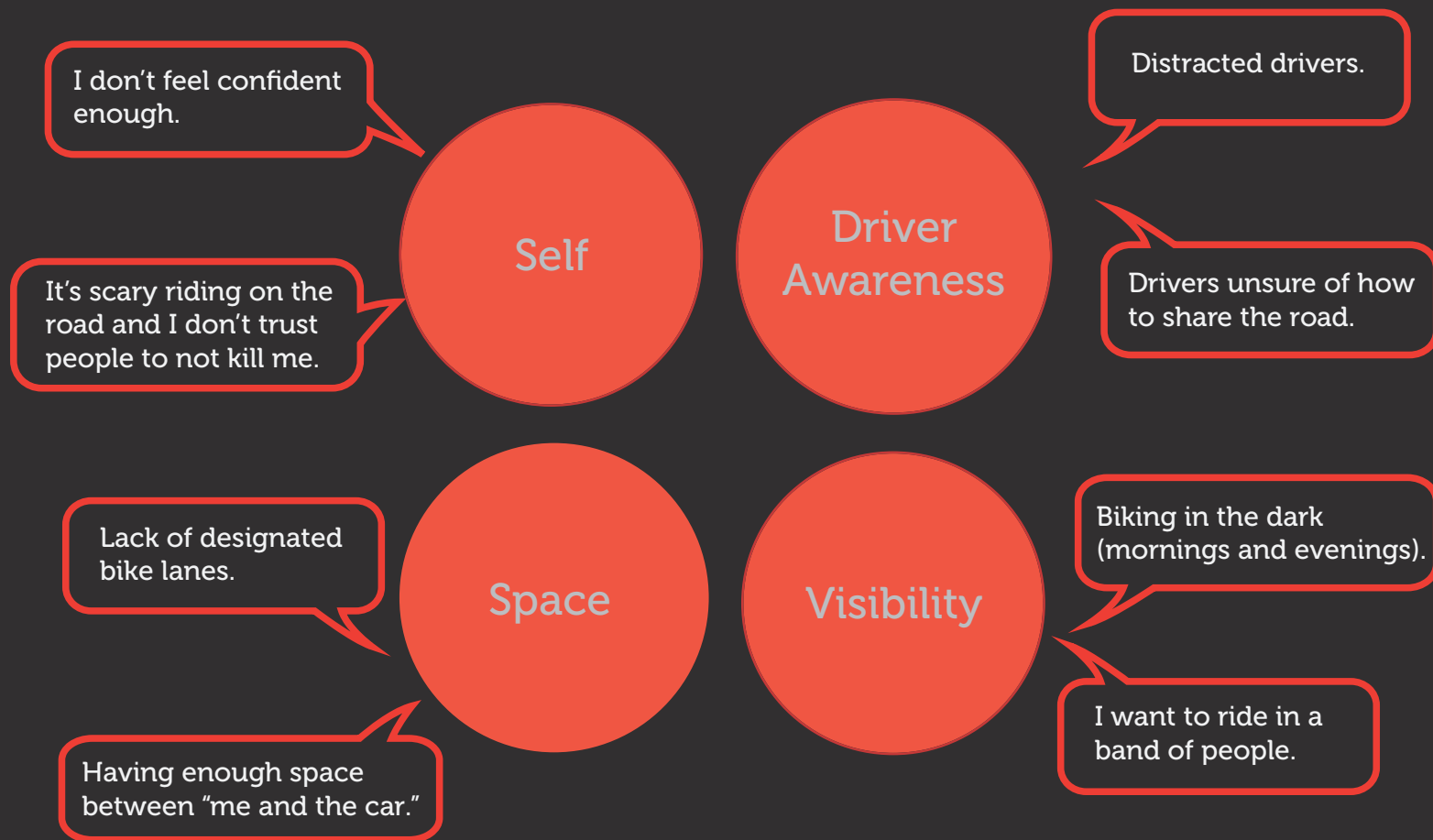
The last image shows an affinity map put together with the issues worded verbatim. Here, I grouped similar reasons into categories (i.e. infrastructure, driver awareness, visibility, etc).

By grouping the issues and drawing relationships and then regrouping again, I was able to gain insight on the issues women specifically had with bicycling to work.
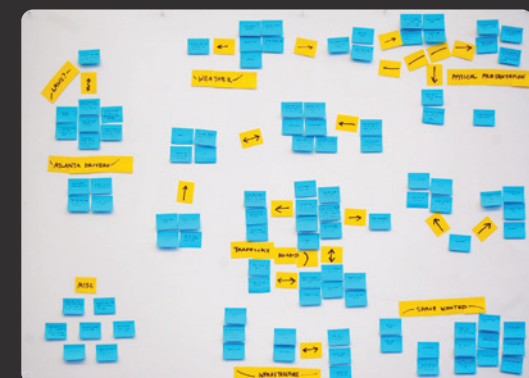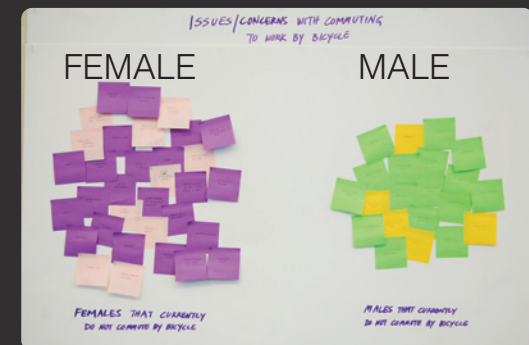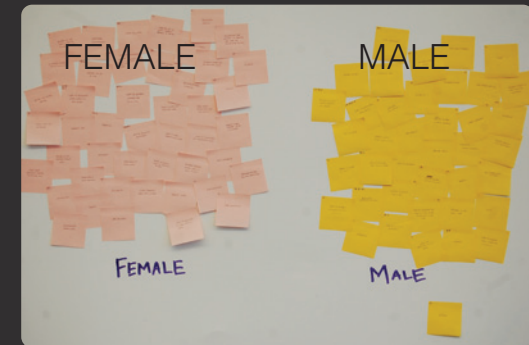
SURVEY FINDINGS

Within the affinity map, I noticed that the women respondents often used the word "safety" in their issues description. From there, I pulled all the reasons that used the word "safety" and regrouped them into additional categories. Below are the safety issues women were most concerned with.

I don't feel confident enough.

Distracted drivers.

Self

Driver Awareness

It's scary riding on the road and I don't trust people to not kill me.

Drivers unsure of how to share the road.

Lack of designated bike lanes.

Biking in the dark (mornings and evenings).

Space

Visibility

Having enough space between "me and the car."

I want to ride in a band of people.

INTERVIEWS

Eight women were interviewed and followed up with throughout the duration of the project. The 8 women's ages range from 22-50 years of age. They all worked inside the Atlanta perimeter. The sampling of women included both frequent and infrequent cyclists. The frequent cyclists would ride to work as often as 5 days a week. Infrequent cyclists would ride as less as once a month.

The interviews of female riders were used to further delve into what steps or thought processes were involved when deciding whether to ride. The interview format was comprised of a series of semi-structural questions for the subjects to answer. The interviews were audio taped for documentation and transcription.

What I found from the women was similar to the findings of my survey. The women wanted space (3-6 ft of space between them and motor vehicles) and for cars to see them. For the infrequent cyclists, most wanted more confidence in themselves to ride with cars.
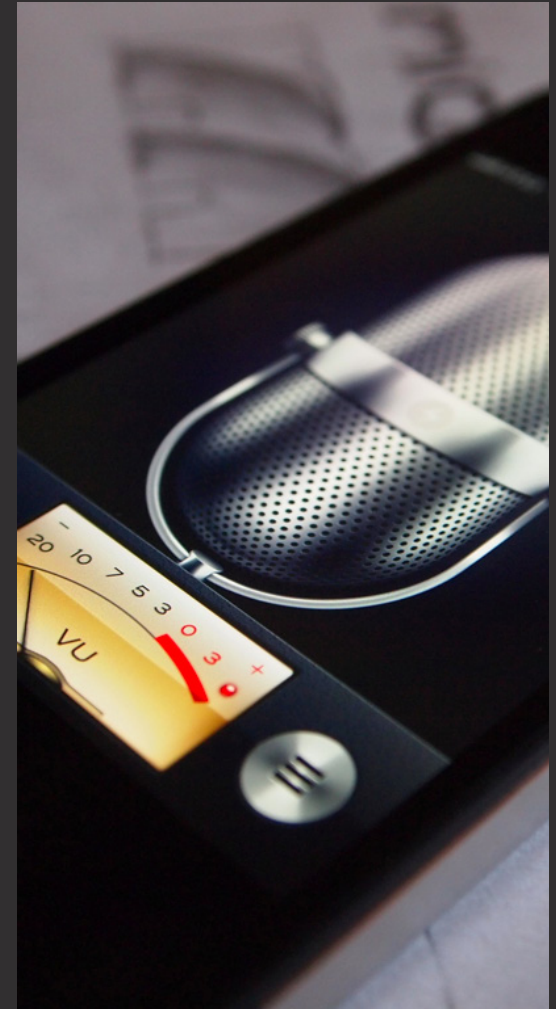
INTERVIEWS

The following are a few quotes taken from the interview transcriptions:

SPACE:

"Getting buzzed by a car is the scariest thing in the world."

"Atlanta is terrible in terms of bike lanes. And I often feel like I have to take my lane in order to be safe, which obviously makes other drivers mad, but I'd rather make them mad, than be dead."

VISIBILITY

"Being tall actually helps. Because I can like stand up on the pedals and like make myself bigger. Kind of like an animal would do if it felt threatened."

"I don't feel like they would see me unless I am wearing something like glowy neon."

SELF-CONFIDENCE

"I don't trust myself and other people to, you know, not kill me."

DESIGN OBJECTIVES

The following design objectives were developed to help design a product to get women back on the road.

1) Increase feelings of safety while commuting by bicycle

2) Create driver awareness of the cyclist in order to create more physical space when a vehicle is passing a bike.

3) Increase the perception of increased space on the rider's behalf. If the rider perceives him or herself to be receiving enough space from passing cars, he or she is less likely to have emotions of fear and lower confidence.

DESIGN DEVELOPMENT

The first series of form development included concepts that were products that either would force physical space (example: spikes on a bike) or increase visibility (glowing helmets).

However, when I following up with the women, they seemed to be lukewarm to the concepts. The women, while wanting more space and visibility, admitted that they wanted to be "bigger" without physically making their bicycle bigger.

In addition, they didn't want any type of physical intrusion on the road. And several agreed that while light-up apparel seemed pretty novel, they themselves would not "get caught dead" wearing it riding to work.

As one girl put it, "design me an invisible force shield so that cars will go around me."

So I went back to the drawing board.
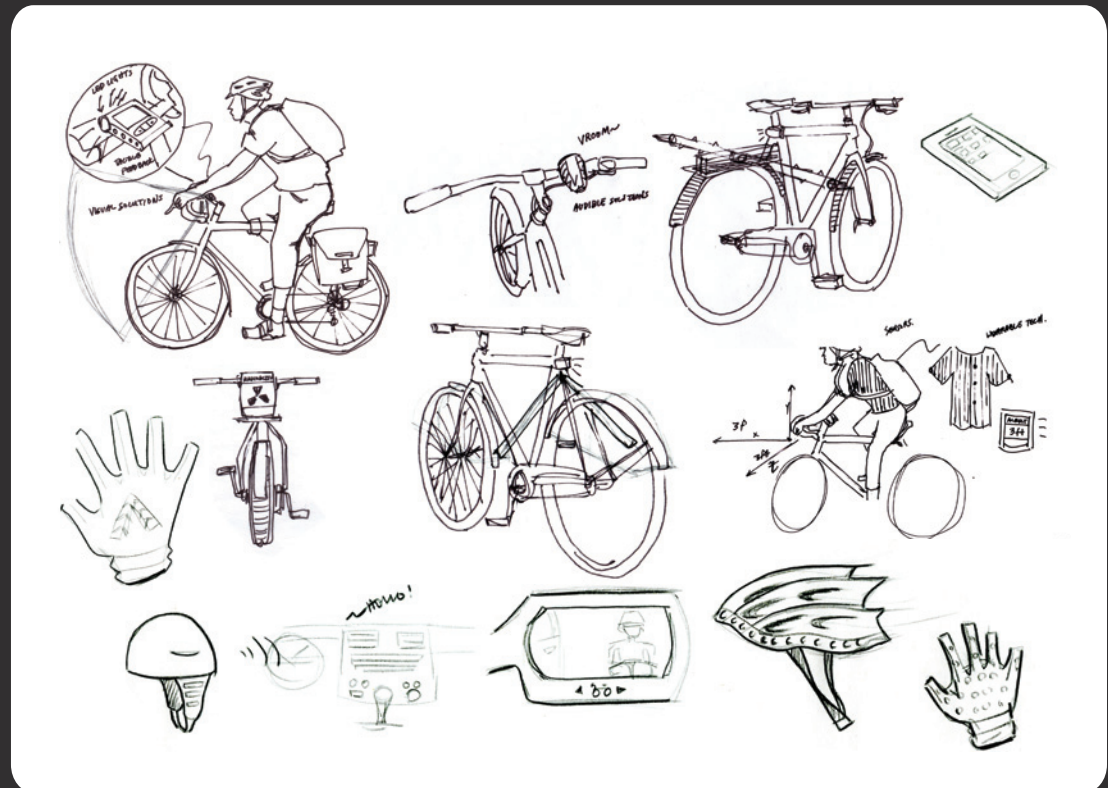
In order to utilize vehicle-to-vehicle technology, the second series of concept development comprised of concepts that were 1) large enough to house V2V technology and 2) something more than just the V2V technology. In order to not reduce additional space on the bicycle, the product double as something such as a bicycle light or bicycle computer.
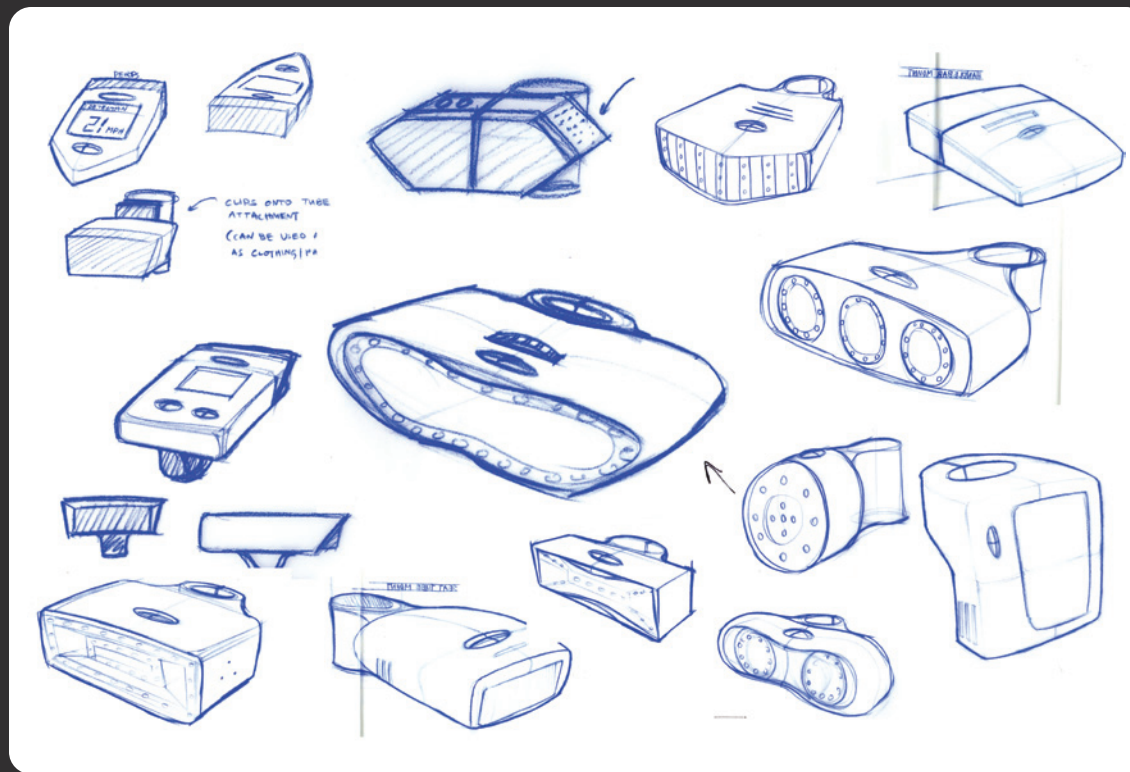
DESIGN DEVELOPMENT:
Transceiver

Next, I developed a series of study models, varying in shapes and sizes. I used playing cards and batteries to simulate the area needed for V2V (the technology being about the size of a standard cigarette pack).

While many of the women tended to favor the smallest model, it was unable to contain the technology, power source, and circuit board for LED lighting.

These study models helped determine and better guage the height, width, and depth constraints for the product.

DESIGN DEVELOPMENT: Transceiver

The study models were then taken and attached to a bicycle to see what the device would look like as a back light on a bicycle. This also helped better grasp proportions and front profile shapes to better complement the bicycle.

USER GENERATED MODELS:
Retrofit Receiver

Using styrofoam, I created a collection of abstract shapes and asked subjects to build a receiver that would be located in a car. As instructed to the subjects, the receiver's purpose is to show the driver the location of nearby cyclists.

When given the pieces, 4 out of 8 of the women picked up the square piece and insisted that the device would be flat and easily mountable on the windshield.

The explanation for the top and bottom images to the right were developed by two different women that said that their device was inspired by a compass. The top model would show the bicyclist being north, south, east or west.
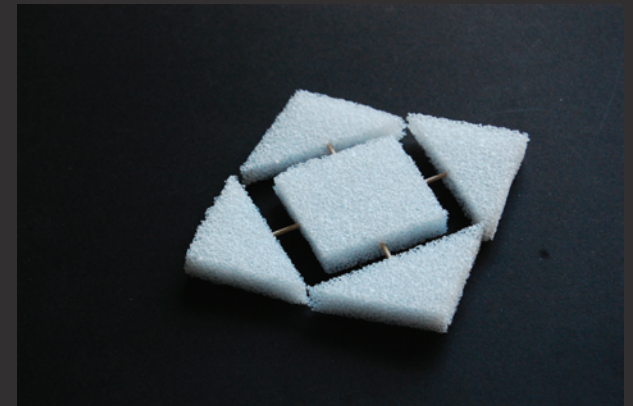
FORM REFINEMENT

I then took the study models and developed a generic profile for each orthographic view (top, side, front). Over 50 iterations of each orthographic for both the transceiver and retrofit receiver were drawn.

Following the iteration process, I presented the iterations to several people and selected the ones that tended to draw people in more. Using those, I geometrically refined each of the orthographic views. Seen below is one version, the front view, in which each unit is based off of the width of the LED casing.
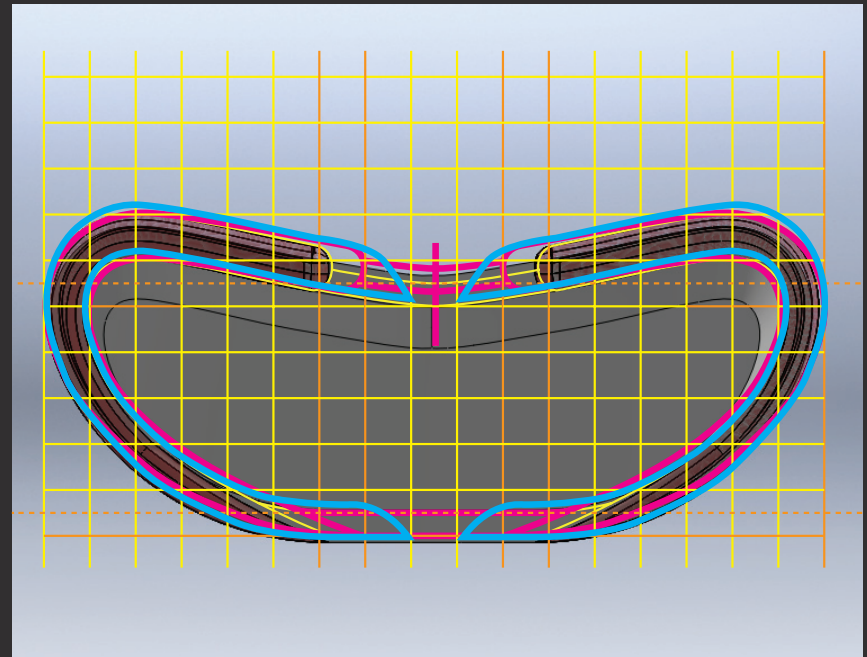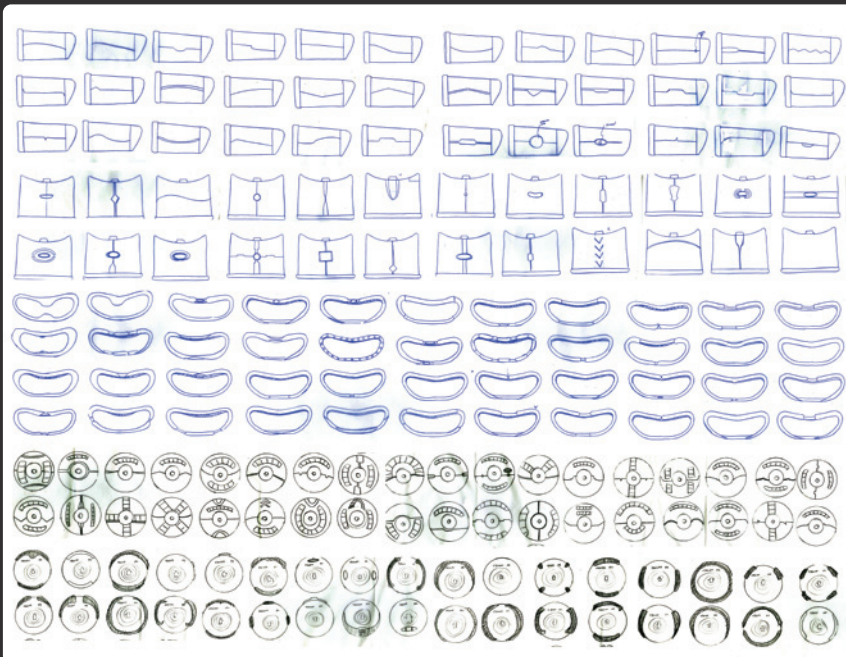
INTERFACE DEVELOPMENT

The purpose for developing an interface was to find a way to quickly convey information from the bicyclist to the driver. Because driving requires attention to the road, it's important to inform the driver concisely. We took a few cues for inspiration by looking at threat condition maps (theatcons) located in the bottom left corner of several first-person shooter games.


Threatcons give the game player relevant information on moving targets within the player's environment. Because the game player is focused on stayed alive and not getting hit, the threatcon's purpose to to convey all the necessary information on nearby targets in a glance.

Similarly, because cars and bicycles are both moving targets, the environment and subjects in a specific vicinity are changing at any given point in time. Because of this, the interface needs to be able to convey the necessary information about nearby cyclists in a glance. After all, the driver's eyes should first and foremost be on the road.

INTERFACE DEVELOPMENT

I then created and printed several different basic interfaces to be used in locating bicyclists. The tick marks would indicate a cyclist's position in relation to the driver (the center of the graphic). When I presented these to the women and other male subjects, the ones that tended to be favored were ones that could give a more accurate location of a cyclist. The graphics with more tick marks would also be more helpful for drivers in a real-time scenario of tracking nearby cyclists.
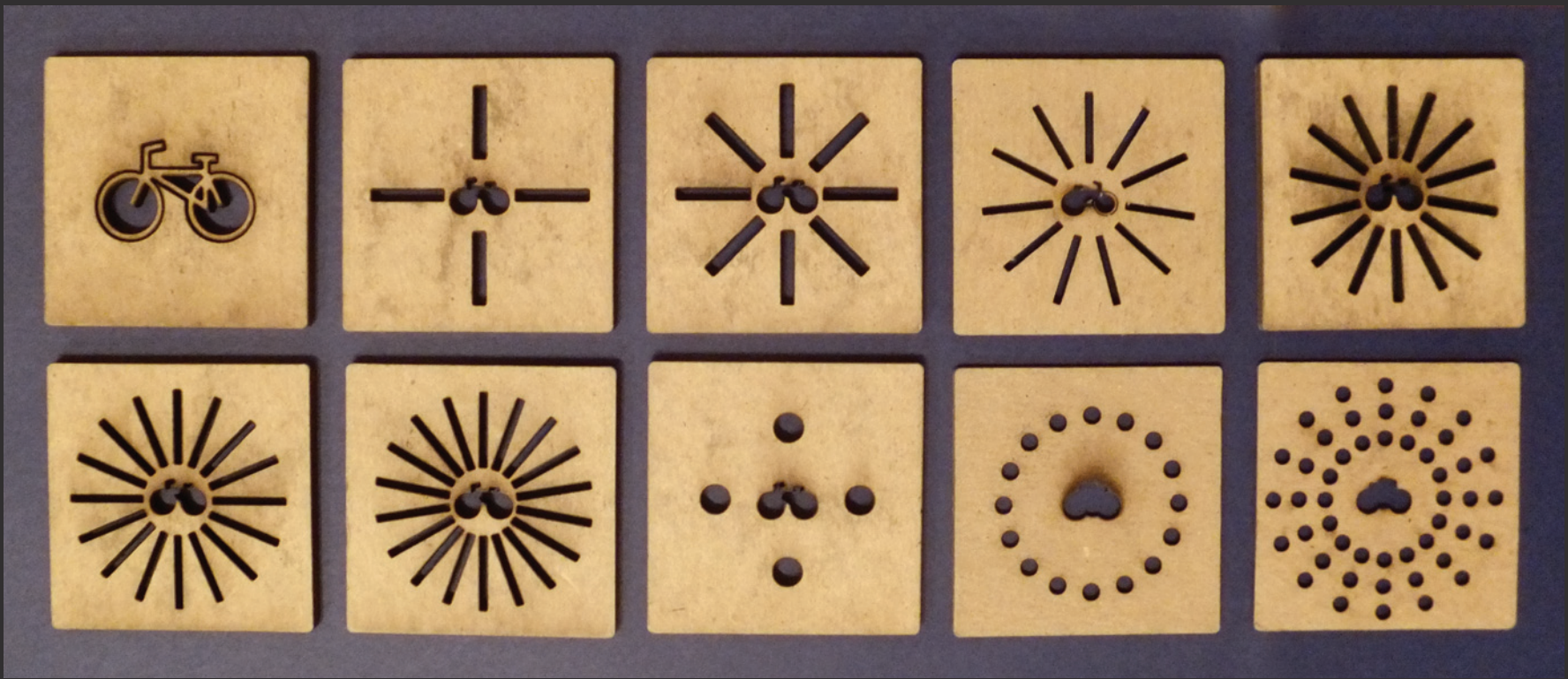
INTERFACE DEVELOPMENT
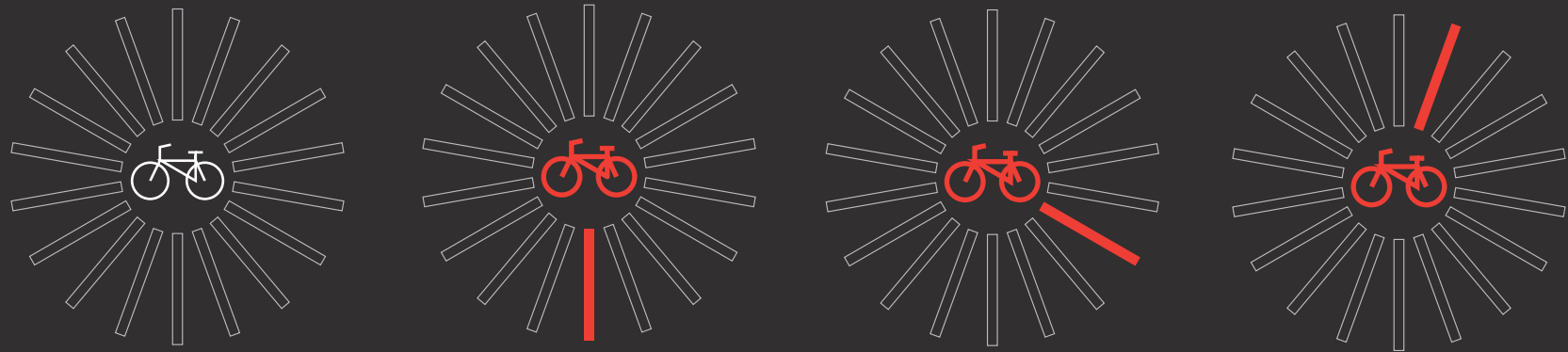
From one of the interfaces that received positive feedback , a quicktime mockup video of how it would relay messages was generated. This was important as the previous mockup was static and subjects could not see how it would work.

When the video was shown to the subjects, we realized several things. First, it was unclear to whether the tickmarks were referring to the cyclist or the driver as the center symbol was a bike. The center was supposed to represent the driver, but because the symbol was a bike, subjects were unclear to whether the moving tick mark was them... or the driver.

Second, this model could not convey how close the cyclist was to the car. Was it 60 feet within proximity? Or 7 feet? And was there only one cyclist present? Or three?

INTERFACE DEVELOPMENT

Using the subjects' suggestions and the findings from the last followup, I refined the interface to consist of three concentric circles of points around the car. The concentric circles represent zones within a vicinity of the car. The outer zones being less imperative for attention while the closer zones showing the driver that the bicyclist was very near.

This design also allowed us to convey whether several or one bicyclist was in the vicinity of the vehicle. And it also conveyed more information about the cyclist's location in reference to the driver in a quick glance.

INTERFACE DEVELOPMENT
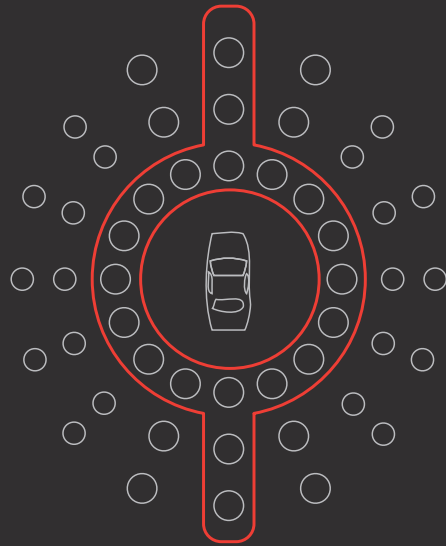
Because a vehicle passing a cyclist tends to be more life-threatening to the cyclist than when the vehicle is in any other position, the interface zones were refined to illustrate priority and urgency.

The top image to the right highlights the areas a cyclist may be present when a vehicle is passing the cyclist within a distance of one lane.
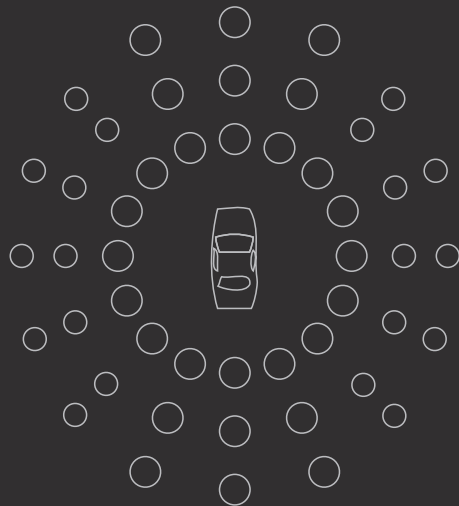
The outer circles to the side tend to be less urgent as cars two lanes over tend to pose less danger to cars riding in the same lane as the cyclist.

DETERMINING DEVICE VICINITY

When interviewed, most women gave a range of 20-40 ft for the desired range in which they would like to appear within the tracking vicinity.

Stopping distance = thinking distance + braking distance

The Stopping Distance Chart was used to help determine device vicinity and safety zones within the receiver's range. According to the chart below, if a car is closing in on a cyclist at 20 miles an hour, the driver's thinking distance is 44 ft. If the device's vicinity is a 40 feet, by the time the driver reacts, he or she will have theoretically passed the cyclist already.

Because of this, 40 ft of range is not sufficient enough. To leave enough time and distance for the driver to think, react, and adapt, we are proposing a range of 150 feet for the receiver to pick up cyclists' locations.

Stopping/Braking Distances [2]

Closing Speed (MPH)	Thinking Distance (FT)
10	22
15	33
20	44
25	55
30	66
35	77

150-ft Radius
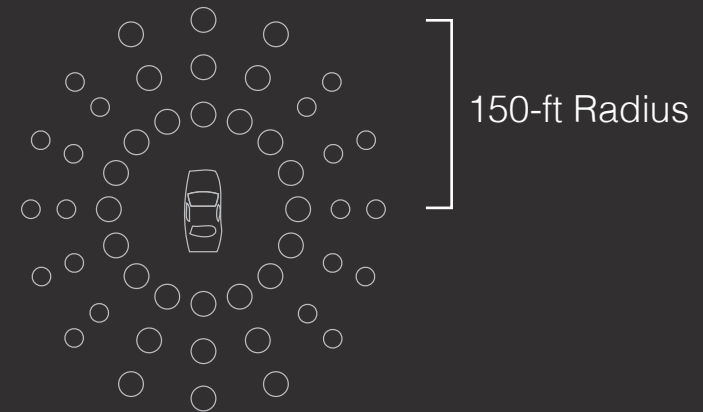
[2] "Braking/Stopping Distances Chart." CSG Network < http://www.csgnetwork.com/stopdistinfo.html>

WHY PASSIVE, NOT ACTIVE?

In determining the what information should be exchanged between the bicyclist and driver, I asked the bicyclists if they wanted a passive or an active device. A passive device is one where the user and turn on the device and no commands are necessary for incoming or out-going messages. An active device would be one where the user would key in commands or prompt for information or updates.

When asked whether they wanted to receive information or feedback from the vehicles, most of the women were against it. Below are some of the quotes taken from follow up interviews.

"I'm already giving 100% of my attention to staying alive on the road. The last thing I want is something that I need to periodically check on."

"I would like the thing to beep at me when it gives my location to every new car so that I know whatever car coming up next to me does actually know where I'm at."

"I think it's better not to notify cyclists– just let them be on guard. I think one-sided informa-tion, for drivers only, might be safer."

"If it's blinking or beeping at me, I would get annoyed and just not use it."

PROTOTYPE MODELS

3D printing was used to produce a physical prototype. The physical model was presented to the wome and the majority of them were, for the most part, pleased with the outcome. However, the one major gripe they had about the transceiver was the size. With a width of 6 inches and a depth of 4.5 inches, the object was about the size of standard binoculars.
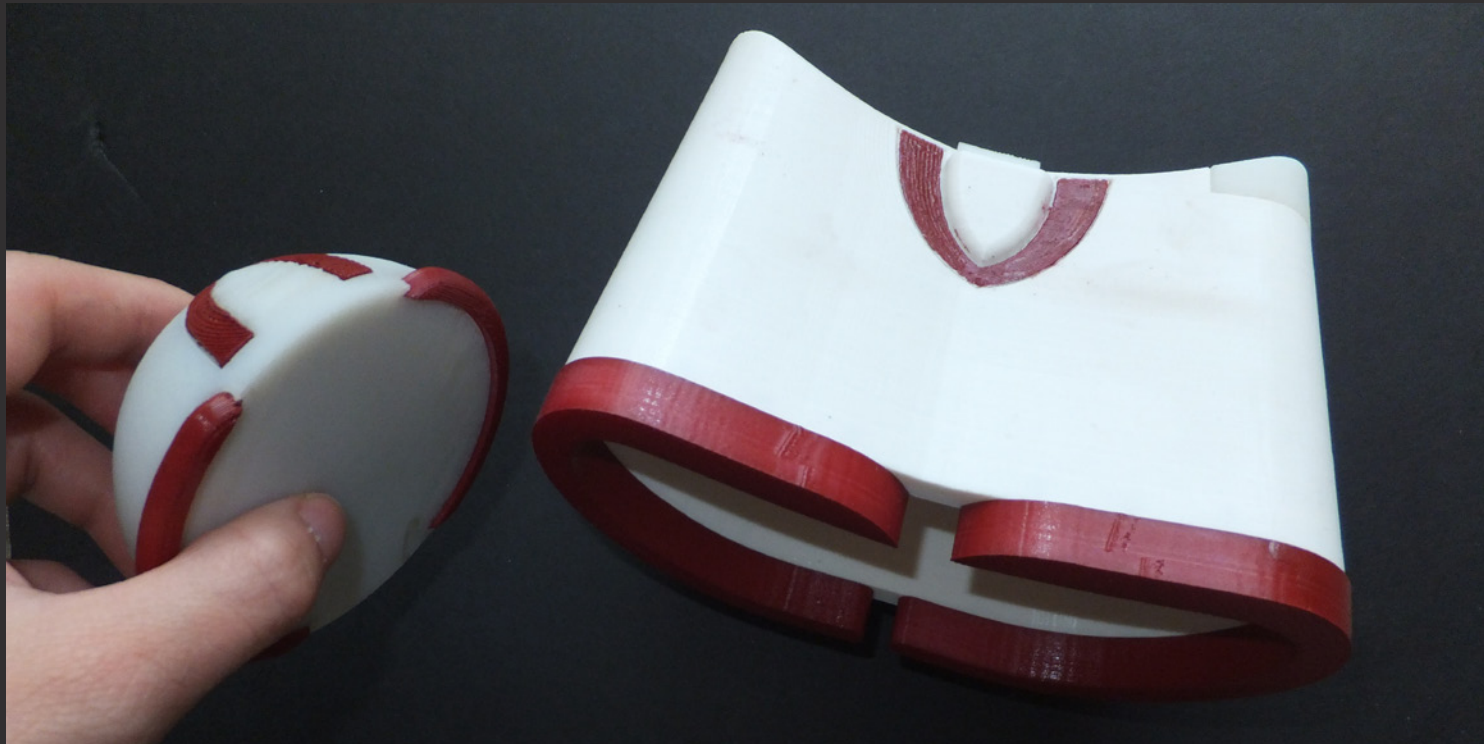
MARKETING AND DISTRIBUTION

Because BAS is a device with the intentions of locating cyclists, selling the retrofit receiver on the market by itself presents little to no motivation for most drivers. Why would a driver deliberately purchase a device that is cyclist-centered?

To combat this issue, BAS would be sold as a package and marketed towards cyclists. The package would include both the transceiver for the bike and two retrofit receivers. The purchaser of BAS may distribute the system components to his or her accord. For example, if a cyclister were to purchase BAS, he or she may decide to either keep the retrofit receiver for him or herself or pass the receiver along to a friend or family.

This distribution process not only fills the technology gap without the driver being mandated to purchase one, but it also adds to the story. Having a good friend or a love one gift a retrofit receiver shares the message of cycling safety. And drivers may have a deeper reason to be aware of cyclists when someone they are close to is a cyclist.

MARKETING AND DISTRIBUTION

STEP 1   Bicyclist purchases system.

STEP 2   Bicyclist gives away receivers to friends and family.

CONCLUSION

DISCUSSION

This study only covers a conceptual level of the Bicycle Awareness System. The results of the project were based off of the subjects' perceptions and understandings of the technology and the system. Actual testing and being able to trial the device through traffic would help the system develop further.

In determining the vicinity of the device, there is room for improvement. Without testing, it is difficult to determine how drivers might react to the receiver's alert. With testing, we may find that 150 ft may not be the optimal amount of distance to alert the driver. There may also be the possibility of needing a greater range of tracking on roads with higher speeds.

There is also the issue of the size of the transceiver. Currently at it's size (6 inches in width and 4.5 inches in depth), the transceiver is large and heavy. If the technology can improve and the size and weight of the transceiver could cut down, the product itself would be more marketable.

NEXT STEPS

While the concept of BAS is developed, there is still room for evolution and growth for this product. Many challenges were encountered during this project's process and not all of the questions have been answered. For instance, it is difficult to assess the effectiveness of the product.

As stated in the Discussion (page 39), there are still issues with BAS that can be refined. For instance, without testing and simulation, it is difficult to analyze how both bicyclists and drivers will react with the device. In addition, it is difficult to have the subjects rate their utility and the effectiveness of the product. The next steps of the project include the following:

- Testing and simulation
- Size reduction and refinement
- Refined prototyping and models
- Determining the actual effects on women's frequency to ride to work

Once the above have been performed, then the concept can undergo futher evaluation.

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