ISSUES OF CONTROL WITH OLDER DRIVERS AND FUTURE AUTOMATED DRIVING SYSTEMS

by Marcus Sebastián Pérez Cervantes

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A thesis submitted for the degree of Master of Design in Interaction Design

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Jodi Forlizzi, Advisor

Acknowledgments

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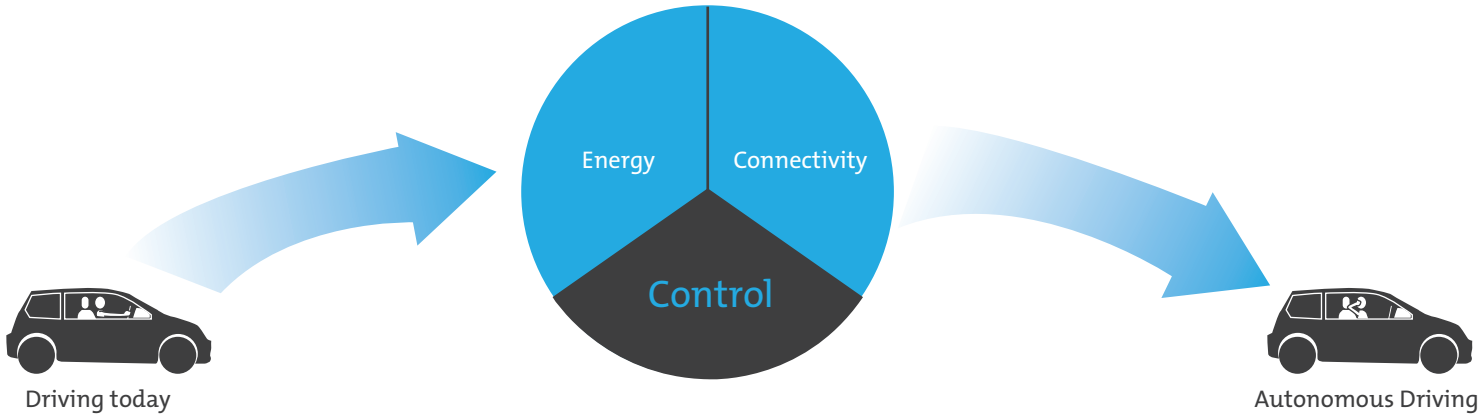
Abstract

It is inevitable that as a person ages they will encounter different physical and cognitive impairments as well as dynamic social issues. We started this project under the assumption that autonomous driving would greatly benefit the fastest growing population in developed countries, the elderly. However, the larger question at hand was how are older drivers going to interact with future automated driving systems? It was through the qualitative research we conducted that we were able to uncover the answer to this question; older drivers are not willing to give up "control" to autonomous cars. As interaction designers, we need to define what type of interactions need to occur in these future automated driving systems, so older drivers still feel independent and in control when driving.

Lawrence D. Burns, former Vice president of Research and Development at General Motors and author of Reinventing the Automobile Personal Urban Mobility for the 21st Century talks about two driving factors that will shape the future of the automobile. These factors are energy and connectivity (Burns et al., 2010). We would add a third one, which is control. If we address these three factors we might be able to bridge the gap between how we drive today and how we will drive in the future and thus create more cohesive future automated driving systems.

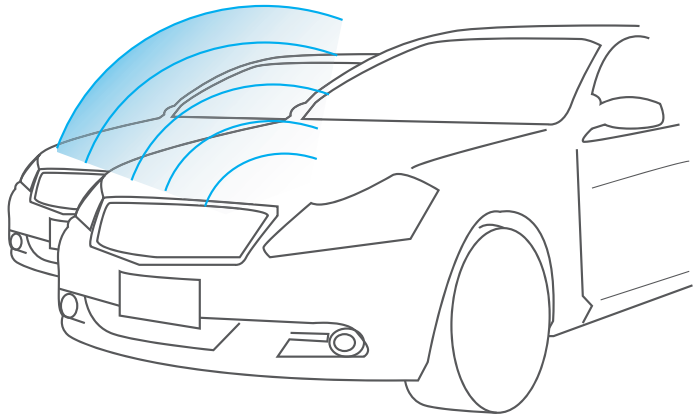


State-Of-The Art

Older drivers drive in vehicles and driving environments today that are very different from those in the past and will continue to undergo more dramatic changes in the near future (Vercruyssen, 1998). Sensing and actuating systems are already in place to address these challenges. Advances in GPS, sophisticated sensors, and navigation databases will allow intelligent vehicles to operate on the same roads we have today. However, as with many robotic developments, intelligent transportation systems (ITS) desperately need product design visions to have a positive impact on society.

Due to the aging baby boomer population, increased provisions for assisted living are very much needed for everyone in later life. The development of assistive technologies should be based on the health care and needs of seniors, with particular emphasis on adapting to changes within the individual, the individual's environment, and the person-environment interaction (Vercruyssen, 1998).

For example, driver training consists of enhancing the current training and assessment systems to evaluate drivers' skills and conditions to be in the road. This is of extreme importance as modification of driving behaviour may be the single, largest untapped potential for improving the safety of older drivers (Vercruyssen, 1998). Also, vehicle enhancements such as in-vehicle driver assistance currently available or in final testing include systems for (autonomous/automatic) cruise control, (for lane keeping, longitudinally and laterally), collision warning/evidence, feed-forward (advanced) sensors and displays, parking aids, and satellite navigation and communication. However, much research is needed to understand and design driver-vehicle interactions to ensure that the technology reduces, and not increases the physical and mental demands of the older drivers. Also it has to accommodate the subtle differences of individual drivers. At the same time, roadway environment improvements need to be implemented (Vercruyssen, 1998).



Electricity And Connectivity

In his book Reinventing the Automobile Personal Urban Mobility for the 21st Century Lawrence D. Burns presents four ideas around the areas of energy and connectivity that will define the future of the automobile. They are 1) Transforming the DNA of vehicles, 2) Mobility Internet, 3) Integrating electric cars with electric grids and 4) Providing real-time control capabilities for urban mobility and energy systems (Burns et al., 2010).

1) Transforming the DNA of vehicles: The DNA of today's cars and trucks depends on petroleum for energy [...] the new automotive DNA is based on electric-drive and wireless communication (Burns et al., 2010).

2) Mobility Internet: This is a logical development from its predecessors – the computer Internet, the cell-phone Internet, and the "Internet of things" enabled by electronic tags and sensors. It will enable vehicles to collect, process, and share enormous amounts of data so that traffic can be managed and travel times can be reduced and made more predictable (Burns et al., 2010).

3) Integrating electric cars with electric grids: To integrate electric drive-vehicles with smart electric grids that use clean, renewable energy sources — particularly solar, wind, hydro, and geothermal — together with dynamic electricity pricing (Burns et al., 2010).

4) Providing real-time control capabilities for urban mobility and energy systems: To provide real-time control capabilities for urban mobility and energy systems. This is accomplished by establishing dynamically priced markets not only for electricity, but also for road space, parking space, and in some contexts shared-use vehicles. The wireless connectivity and on board intelligence of the automobiles that we propose enables them to respond appropriately to the price signals within these markets. This provides an effective way to balance supply and demand, relieve road and parking space congestion, and increase the utilization rates of available vehicles (Burns et al., 2010).

Towards A Vision of Autonomous Driving

According to Industrial design studio Mike and Maaike (Core Jr., 2009), research revealed that self-driving cars, once a fantasy requiring an entirely new infrastructure, are now technologically possible, even inevitable. As mentioned above robotic products to assist in autonomous driving are already available. Advances in GPS, sophisticated sensors, and navigation databases will allow driverless vehicles to operate on the same roads we have today. Here is a list of a few examples:

• **Google Cars Drive Themselves, in traffic:** Google's modified Toyota Prius uses an array of sensors to navigate public roads without a human driver. Other components, not shown, include a GPS receiver and an inertial motion sensor (Markoff, 2010).

• **Semi-Autonomous Virtual Valet Parking:** This work describes a method and user interaction for low cost, short-range parking without a driver in the car. This will enable ingress/egress without the doors being blocked by neighboring cars (Suppé et al., 2010).

• **BMW 328 Mi:** BMW is building the ultimate "nanny" machine — a car that will safely guide itself to a stop and notify the authorities if the driver suffers a heart attack, stroke or other medical emergency and can no longer drive (Mack, 2009).

• **Volvo Thinks Locusts Can Make Us Safer Drivers:** Volvo is determined to build an injury-proof car by 2020. The goal is to incorporate the African locust's "sensory-input routing methodologies" in a car, making it smart enough to avoid hitting people. "If we could trace how the locust is able to avoid each other, maybe we could program our cars not to hit pedestrians," says Jonas Ekmark, Volvo's director of preventative safety (Squatriglia, 2008).

Google's modified Toyota Prius uses an array of sensors to navigate public roads without a human driver.
Photograph by Ramin Rahimian

Human-Centered Design Process

In order to attain a truly human-centered design approach the project was divided into three fundamental phases, 1) **Exploratory Research**, 2) **Generative Research** and 3) **Evaluative Research (IRB, 2010)**.

After doing a literature review of the current research that exists regarding the subject of automated driving systems and intelligent systems to aid the elderly, we set out to do our own qualitative research. In doing so, we were hoping to find out more about these people's lives and whether or not they would be receptive to new technologies, specifically automated driving systems.

The exploratory research phase consisted of ethnographic research and contextual inquiries. We conducted several contextual interviews with the elderly about driving. However, these interviews were not only limited to conversations, as we had the opportunity to ride in the car with some of these individuals and to observe how they currently interacted with their vehicle (IRB, 2010).

The generative research phase consisted of a participatory design session. In this 90-minute session participants discussed some driving issues that were uncover in the first phase of the project. Furthermore, the participants were asked to design their ideal car dashboard given specific use case scenarios (IRB, 2010).

Finally, the evaluative research phase consisted of two concept validation sessions and an experience prototyping session. For the concept validation sessions we employed a method called 'speed-dating' that allowed us to validate several design concepts addressing different user needs. These sessions were critical. Based on the results from these sessions we were able to focus on our final concept. As we developed it, we held an experience prototyping session with some participants to test out the interactions and functionality of the concept we chose to develop (IRB, 2010).

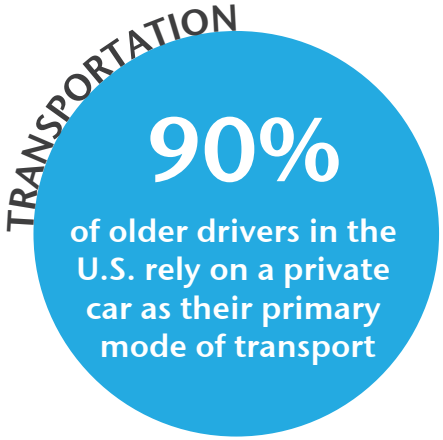
Why Focus On Older Drivers?

We decided to focus on the elder population for a number of reasons. In 2008, the National Highway Traffic Safety Administration (NHTSA) stated that 15% of all licensed drivers were over 65 years old, a percentage that will only continue to increase due to the aging population in the United States. By the year 2020, the NHTSA estimates that 20% of the population will be 65 and older (Hardy, 2008).

Driving plays an important role in older drivers' mobility, as 90% of older drivers rely on a private car as their primary mode of transport. This is due to the fact that most people, especially older adults, live in suburbs, exurbs, and rural areas where transportation strongly depends on the automobile (Fisk, et al. 2009).

Transportation is a means of conveyance. It is the key to continued independence of older adults and essential for engagement in community, social, and everyday activities. Having access to adequate transportation enables individuals to access needed healthcare and community resources, perform activities and engage in social activities (Fisk et al., 2009).

At the same time, road safety still is a fundamental issue that needs to be addressed. In 2008, the Federal Highway Administration (FHWA) stated that approximately 50% of all traffic crashes and 50% of injury crashes occur at intersections and 27% of intersection fatalities involved people 65 years of age or older in the United States. This is caused by the



physical and cognitive limitations that affect older drivers.

People are living longer today for several reasons including advances in medical science, technology, healthcare, nutrition, and sanitation. An important consequence of this progress is that those aged 60 or older are the fastest growing age group in the world (Feddersen, 2009). Furthermore, John Thackara, director of Doors of Perception, says:

"Imagine a world where every second European adult is over fifty years old. And where two-thirds of disposable consumer income is held by this age-group. By 2020 this will be a reality. There will be huge demand for services that enable older people to live independently in their own communities as they age." (Thackara, 2000)

Although this larger older population is in better heath than before, they experience changes in sensory, cognitive, and physical health, mobility and dexterity. For interaction designers this raises many questions about the ways that we think about human-environment interaction (Feddersen, 2009).

"They tell me that my senses are slowing down. I do not see it"

- Frank Marshall, 80 years old

Physical And Cognitive Aspects That Affect The Elderly

In a recent article published by BusinessWeek, older drivers ranked far lower than other drivers for incidents of dangerous aggressive driving behavior, but they tend to make more driving errors than other drivers in congested areas and where quick comprehension of signs is required. Drivers 85 and older are eleven times more likely to die in a crash than drivers age 40 to 49. Part of this is due to the increased frailty of very old drivers, but per mileage traveled, the likelihood of a being in an accident is significantly higher for older drivers (Halvorson, 2006). These are some of the reasons why the elderly are more prone to car crashes:

- Slower reaction time
- Vision problems
- Depth perception changes (another car seems farther or closer than it really is)
- Hearing problems
- Decreased ability to focus
- Feelings of nervousness and anxiety
- Medical problems

In particular slower reaction time, vision problems and depth perception changes, hearing problems, decreased ability to focus, and medical problems merit more discussion (Halvorson, 2006).

1) Slower reaction time: Though it can vary greatly depending on the person, and there seems to be some conflicting research, reaction time is estimated by some researchers at 0.2 to 0.3 second slower for drivers 65 and older, with an accompanying drop in motor skills that can further exaggerate the delay (Halvorson, 2006).

2) Vision problems: Most aspects of vision typically deteriorate with age. Static acuity - the ability for the eyes to focus on a stationary object - is measured on drivers' tests. Dynamic acuity, the ability for the eyes to stay focused on moving objects, decreases greatly with age, and it's not tested in drivers' vision tests. Even if an older driver might have perfect 20/20 static vision, that person's dynamic vision is probably much worse than that of a younger driver with 20/20 vision (Halvorson, 2006).

Furthermore, older drivers are also much more susceptible to glare, such that is encountered when exiting tunnels or seeing oncoming headlights, and they also have reduced contrast sensitivity, which can make low light conditions problematic even if their vision is sharp (Halvorson, 2006).

According to Thomas Seder from General Motors, Human Machine Interface, these are the safest approaches when designing a visual system:

- Design using monochrome colors and color as redundant information channel (this is particularly true for the elderly).
- Use desaturated colors for filling broad fields and saturated colors for small fields (fonts, lines).
- Readability increases with word shape variety, mix upper and lower case but avoid all caps.
- Always use familiar typefaces.

3) Hearing problems: Hearing sensitivity deteriorates over time. Some drivers may experience very little hearing loss over time, but keep in mind that the brain's ability to distinguish one sound over another (for example, to hear an approaching siren over music playing on the radio) might still deteriorate (Halvorson, 2006).

4) Decreased ability to focus: Older drivers are generally more susceptible to fatigue than younger drivers. Research has shown, however, that older drivers are better at gauging their state of fatigue than younger drivers (Halvorson, 2006).

5) Medical problems: There is an array of medical conditions that affect elderly drivers. Memory and perception aspects of vision, such as Arthritic conditions, mild cognitive impairment, and diabetes are not taken in to account during vision tests. Arthritic Conditions Compound the Vision Problems. It reduces the person's range of motion, rate of movement, strength, and fine motor skill (Seder, 2008). Moreover, the Mayo Foundation estimates that ~ 20% of people over 65 years old suffer from Mild Cognitive Impairment (MCI) which is a mental state prior to dementia. MCI is characterized by loss of a range of cognitive abilities such as declarative/spatial memory (medial temporal lobe system) higher-order/executive functions (prefrontal cortex). Also, an increasing number of diabetics are reporting vision problems (even with glasses on) (Seder, 2008).

Furthermore, due to arthritis, stiff joints, reduced muscle mass, or other health problems, older drivers have slower reactions such as turning their head quickly enough to scan side streets or backing up.

" I like a car that is reliable as I am getting too old to be breaking down in the middle of nowhere."

- Patrick McNulty, 65 years old

Social Aspects That Affect The Elderly

However, physical and mental changes are not the only characteristics to take into consideration. Social changes such as social isolation, lack of mobility and loss of independence are other factors that have a large influence as to why people don't want to give up driving (Fisk et al.,2009). Research shows that loneliness and isolation are some of the reasons that cause depression among the elderly. Of Americans ages 65 and older, two million suffer from full-blown depression and another five million suffer from a less severe form of the illness (Segal, 2007).

"Aging baby boomers still see themselves as active, vital people," said Jaron Rothkop, senior engineer for advanced product development at Lear Corp. "The trick is to design vehicles that have enablers for this population, but that don't look like cars for the aged. They still want a sporty look, even if they are more concerned about safety and how easy a car is to use" (Ehrenman, 2003).

Without a question, the baby boomer generations are leading the changes in the rights of older people to lead independent lives as full participants in all aspects of contemporary culture. On the practical level, this includes changes in attitudes and policies on ageing, accessibility, safety, health care, employment, living arrangements, community planning, maintenance of independence and life quality (Feddersen, 2009).

"Do you know how to change a tire? I do, it is important"

- John Fave , 71 years old

Exploratory Research

Prior to the qualitative research that we conducted with several older drivers, our hypothesis was that most of these people would want to have an automated car in their homes.

For this initial research we completed ten contextual interviews and four car ride alongs with six males and four females (age 65 -85). All of the participants lived in the city of Pittsburgh, Pennsylvania, United States (IRB, 2010).

The first group of individuals we interviewed lived in one of northern suburbs of Pittsburgh. We interviewed three people, a couple and the wife's younger brother. The interview was held at the brother's house located in a neighborhood where there were no sidewalks at all. This suburb resembles any other typical suburb in the United States. In fact, the participants complained that before it used to be more quite and calm because the children of the neighbour families were younger and didn't drive. Today, one of the participants says: "you need to be careful when you drive around here because these children tend to drive recklessly".

As the conversation went on, we found out very interesting things about them as well as their perspective on driving. Many of the answers and topics we talked about were reflected in the other participants we interviewed. As a general comment, all the participants that we interviewed still have a very active lifestyle and they are very tech savvy. Thus, having a car in their lives plays a fundamental role in accomplishing the many tasks they do throughout the day.

Community Involvement

The participants were all very involved within the Pittsburgh community. Some took classes at local universities; others worked for charities and others still worked in family businesses.

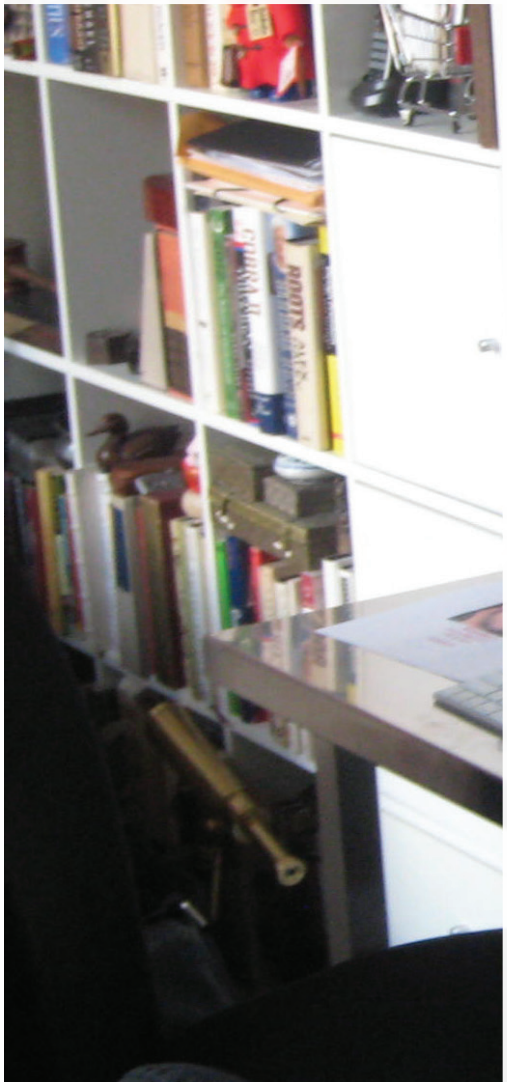
For example, Mrs. Evans aged 85 years old told us about what her daily routine was like. In the mornings, she woke up to read the newspapers and eat breakfast. She then looked to see what she had planned for the day in her calendar (she kept a general calendar in the dining room area with different colored post-notes to differentiate the multiple activities for each day). She attended gym classes, meetings, and volunteered regularly to deliver food to the underprivileged. She didn't really like to go out during night time because her vision is no longer as good as it used to be, but she enjoyed going to the symphony once a month.

Another participant who lives in downtown Pittsburgh also talked about his very busy lifestyle. Usually in the mornings he woke up to care for his dog. He ate breakfast and read the printed versions of the New York Times and other local newspapers. He went online to check his email and read other newspapers. Then, he prepared to go to the classes he is taking at Carnegie Mellon, through an institution called the Osher Lifelong Learning Institue (Osher). Many elderly in Pittsburgh are part of this Institute. After his classes at Osher, he went to the University of Pittsburgh where he was involved in the production of a film. He said that he usually doesn't eat out because his wife is a vegan and there are not many places in Pittsburgh that are vegan friendly.

A third participant described himself, "as busy as I ever was when I was working". A normal day for this participant consisted of going for a walk in the mornings and then prepared to go to the Family History Center where he volunteered. Other days, he volunteered to teach a class at a local Community College. He usually drove himself to these different places, especially because he had just purchased a new car. However, he said that sometimes he takes the bus to go downtown because of the worry of finding a parking space.

> " As busy as I ever was when I was working."
>
> - Andrew Muir, 75 years old

Technology Savvy



One of the main reasons as to why these individuals are so connected within their community is because of how technology savvy they are. All the participants that we interviewed had a laptop, smart phone, tablet, or desktop computer in their homes. And from all these devices, most participants enjoyed using the ones with a touch screen interface rather than the ones with physical buttons, because a touch screen interface is more legible and it is easier to use.

Also, all the participants had a GPS in their cars. Nonetheless, not all of them liked using their GPS as they found it unreliable at times, especially when navigating to parts of town they have never been to. It was interesting to hear the stories they had to share, as they would blame themselves for not knowing how to use the GPS whenever it was probably a GPS issue.

After talking to a couple that lived in the southern part of Pittsburgh, I realized that another main reason that these people are willing to be more technology savvy is so that they can relate to their grandchildren. This couple owns a Playstation, Nintendo Wii and a Game Boy. The main reason that they got these game consoles was so when their grandchildren would come

over to the house they will not be bored. They said that they enjoyed playing the Nintendo Wii mostly because it required more physical mobility and served as a form of exercise.

Furthermore, many of the couples that we interviewed owned a mobile phone or a smart phone that used to belong to their grandchildren or children. This is because younger generations tend to change their mobile phones more often than the elderly do, mainly because they like to have more functionality and application in their phones. On the other hand, the main types of activities that the elderly carry out using their mobile phones are calling people and occasionally sending a text message. However, most of them do not like to send text messages because it is time consuming and the keypads are usually too small for them to use.

Two of the people that we interviewed also had a Twitter and Facebook account. In fact, one of them said that the best way to stay in touch with their children and grandchildren was through these online social networks.

"My car is high-tech just like me. I feel like Johnny Jetson in this car"

- William Gattis, 65 years old

Self-Sufficiency

Another important aspect that determines a person's independency is how self-sufficient they can be. The best example of self-sufficiency came from one of the participants we interviewed, who not only lives by herself but she also is self-employed. She was a tax return agent that had been doing taxes for a set of clients in Pittsburgh. She worked from her apartment, which she divided into her home and office. When asked if anyone could use the tax return software she used, she replied that ones needs to have previous knowledge of income tax procedures.

Other examples of self-sufficiency include a conversation between two participants, where one of them explained to the other the importance of knowing how to change a car tire. He said that it is one of the fundamental things that a person needs to know. Furthermore, another participant told us about the importance of being able to fix his car. He told us about his old pick up truck and how he used to fix it every time that it would break down. He said that he didn't need to take to the local mechanic or car dealership because he knew how to fix it and he had all the necessary tools to fix it in his garage. However, when he sold his old truck he said that he no longer was able to fix it because new cars always change the location of the parts and require new tools to fix them. He said that fixing something as simple as the door lock was difficult because everything changed. He was required to take his car to a local mechanic to get it fixed. While he described this experience to us, we perceived his frustration and helplessness. There are things that require a special technician to fix them but there are other things that anyone should be able to do.

Cautious Drivers

The majority of the individuals we interviewed pride themselves in doing things on their own, but that doesn't mean that they do not take precautions when it comes to driving. Most of the participants were cautious drivers. They had a tendency to drive with someone else in the car and around familiar areas. Most of the participants that we interviewed said that they no longer liked to drive during bad weather or nighttime because their physical and cognitive abilities have diminished.

Most of the participants said that drivers today have to be more alert. They said that drivers today drive too fast and recklessly. One participant said, that if he could do anything in the world, he would go to Scotland and clone himself and then have his clones drive the other cars in the road. He said that if he knew how the other drivers in the road drove it would be much easier for him to avoid getting into accidents and would make him feel safer.

Also, most of the participants have not been in a serious accident in the last ten years. Some of them told us about accidents they had when they were younger, but except for one participant who almost lost his life, everyone else was never involved in a serious accident. However, accidents arise in the context of changing lanes, leaving a parking spot and running over stop signs. The reason these accidents happened were because older drivers do not have the same reflexes and mobility they used to have in their neck and back. In fact, one of the participants used a pillow to sit higher and have better visibility.

Another important factor that makes drivers feel safe is having a large size car. One of the couples we interviewed had a 1996 Buick car model; they really liked it because it was spacious. They really enjoyed driving this car on the highway and felt protected when they would get stuck between large cargo trucks.

Making Plans

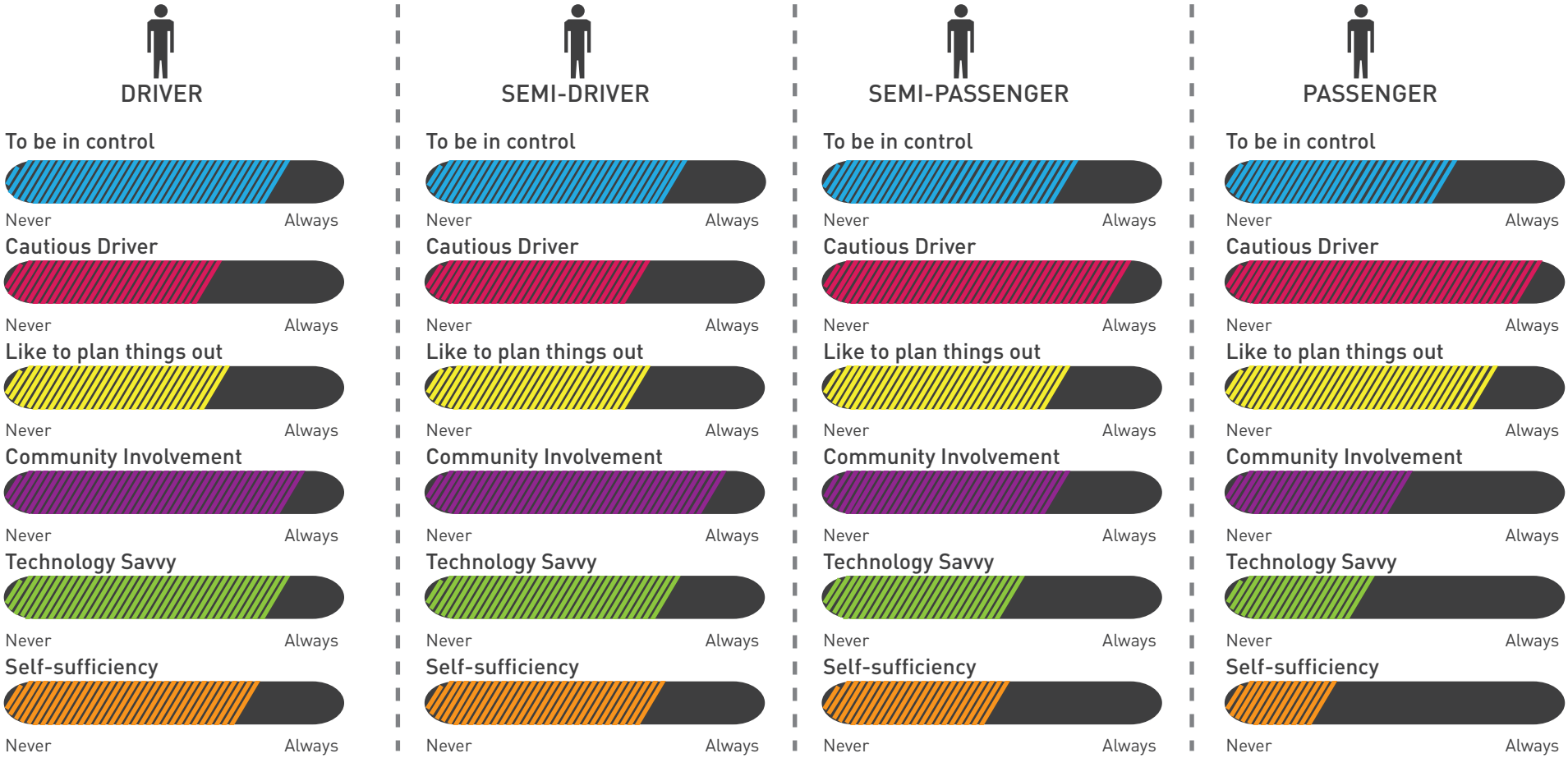
A couple of the participants we interviewed told us that they enjoyed taking car trips to visit their friends and family, or simply to get away. One of these participants drove every year from Pittsburgh to Phoenix, Arizona for a minerals convention that was held in November. He said that a couple of years ago he took a trip with his family from Pittsburgh to Anchorage, Alaska. Whenever he takes on a trip of this size, he spends most of the year preparing for it.

However, on a daily basis, activities were tracked using paper calendars. Most of the calendars were located in the kitchen and living room areas. Also the more technology savvy participants kept a digital calendar in their smart phones and computers. One of the participants had post-it-notes on her kitchen cabinets to keep track of the different activities she had for the day.

When it comes to planning a car trip whether out of town or within Pittsburgh most people liked using Google Maps. Some participants liked the fact that they could look up different ways of getting to places, and getting an overall picture of their current location in relation to their destination. However, it was interesting to find that most participants printed out directions even though they had a GPS in their car. One of the participants told us the story of when his wife went to Phoenix by herself and he had to print out various maps of the different places she was going to visit, as she was not familiar with the area. He said that this turned out to be very helpful for her as she was able to go to all the places on her itinerary and she didn't have to stop to ask for help.

Driving Profiles

After reviewing all the interview data, we created four different profiles that would represent the different individuals that we interviewed and their driving characteristics. We have labeled these profiles as 1) Driver, 2) Semi-Driver, 3) Semi-Passenger, and 4) Passenger.



Driver

The individuals that fall into this category are very active members within their community. They are involved in university classes, family businesses, play for a local music band, and help out in charities, among other things. They are also very technology savvy. Most of these participants have a least two computers and have the latest gadgets. Also, most of the cars that they drive are either new or had been upgraded in several ways. One of the participants incorporated mobile phones into every single car that the family owns. He says that in case of an emergency you can always be in touch.

Furthermore, these participants value being self-sufficient and being in control. They like the fact that other people look up to them for advice. For example, one participant said she always has a hard time turning on the TV at home because her husband has too many controls for the different TV sets. To this her husband responded very proudly and said that it is not as complicated as she makes it sound. However, he helps her turn the TV on every time she wants to watch it. Also this participant told us about how he had set up all the phones in the house (including their mobile phones) to be connected. It does not come as a surprise that this person likes to compare himself to Johnny Jetson as he has all the latest gadgets.

Semi-Driver

The individuals that fall in this category are very similar to the previous category, however they are not as active in the community and they are less technology savvy. They do value self-sufficiency and being in control a lot more, especially when it comes to driving. One of the participants told us about how his wife thought he should not be driving because he is losing his eyesight and hearing. However, he said that is not the case and that he just pretends he can't listen and feels a hundred percent aware of his surroundings. These individuals are very cautious drivers as well. In fact, when we were driving together, this participant decided not to turn on the radio so he could be more aware of his surroundings, even though we were driving around his neighborhood. Also, every time there was a caution sign in the street he would point it out and tell us how the last time he was driving around this area he saw someone not respecting the sign.

Semi-Passenger

These individuals are somewhat active in the community. One of the participants that best fits this profile is a woman aged 85 years old that lives with her oldest son. She was not as active in her community as she used to be, but whenever she could she delivered food to underprivileged individuals. Also, she said that every time her and her friends go out to eat lunch, she was the designated driver to pick them up. She was not as technology savvy as some of the other participants, however she still owned a mobile phone, laptop and GPS. Lately, she had been having problems with her GPS so she decided to lend it to one of her sons, because she didn't know how to fix it. In the meantime, she used Google Maps to get around town.

Passenger

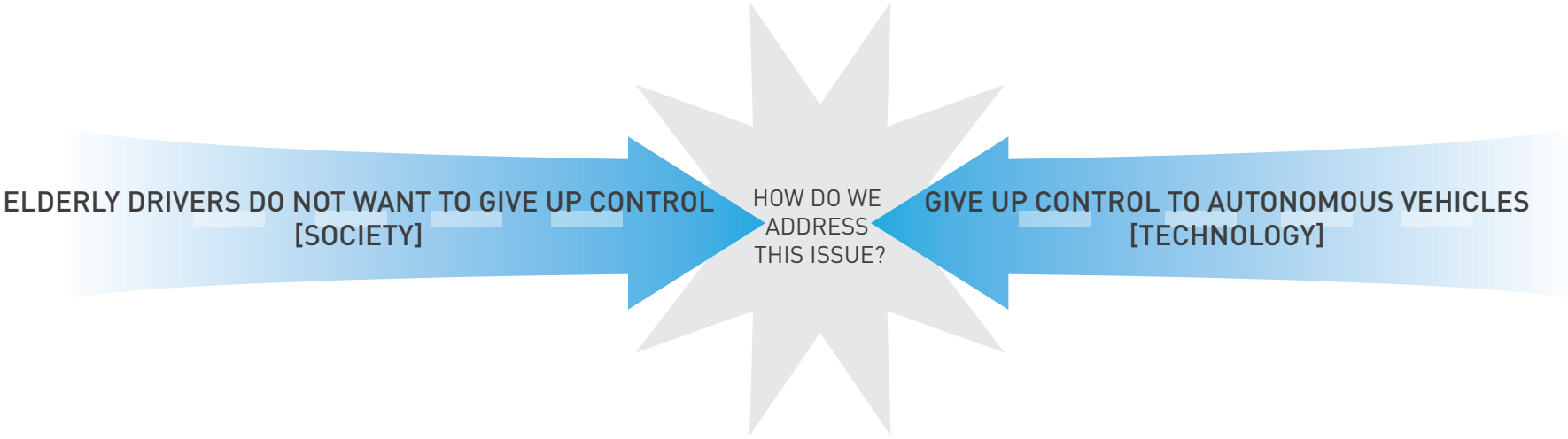
This last set of individuals is the least active, staying home and only driving when necessary. However, these individuals tend to be planners, planning trips ahead of time in comparison to the other participants. One of the planners kept a calendar in her kitchen with all the activities she and her husband have to do for the day. Also, she printed out all the directions she needed for that day. Furthermore, these individuals seem to resent the fact that they are ageing. As one participant explained, "I do not like to wear my glasses because then people will think that I am old and I can't see". She had cataracts surgery fifteen years ago, but she doesn't like talking about it because every time she mentions it people think that she is old. Nonetheless, the individuals in this category like to be in control of their lives. This older woman, even though she resented her age, she lived by herself and is self-employed.

The Importance Of ‘Being In Control’

The main insight we gathered from this exploratory research phase was the notion of drivers 'being in control'. As one participant stated, "I am ten percent better pilot than passenger". He was referring to how he likes to be in control when he drives. All the participants had similar feelings, not only about driving, but also about their lives in general. These individuals measure their independence by how much control they have over their lives.

When participants were asked about how would they feel if they didn't have a car, all of them gave me a negative response. Most of them argued that not having a car was synonymous with having no freedom. They see being dependent on someone else or something else is a burden. One of the participants told us that she could not imagine her daughter or son driving her around places, because it would be a burden for them and she will not have complete control of what she wants to do. Another participant told us about the time when he had a flat tire and he didn't want to call his son for help. He said that because he knew how to fix it himself, he didn't need his son's help. From this, we understood that if he were to accept his son's help then he would be giving up his independence of doing things himself.

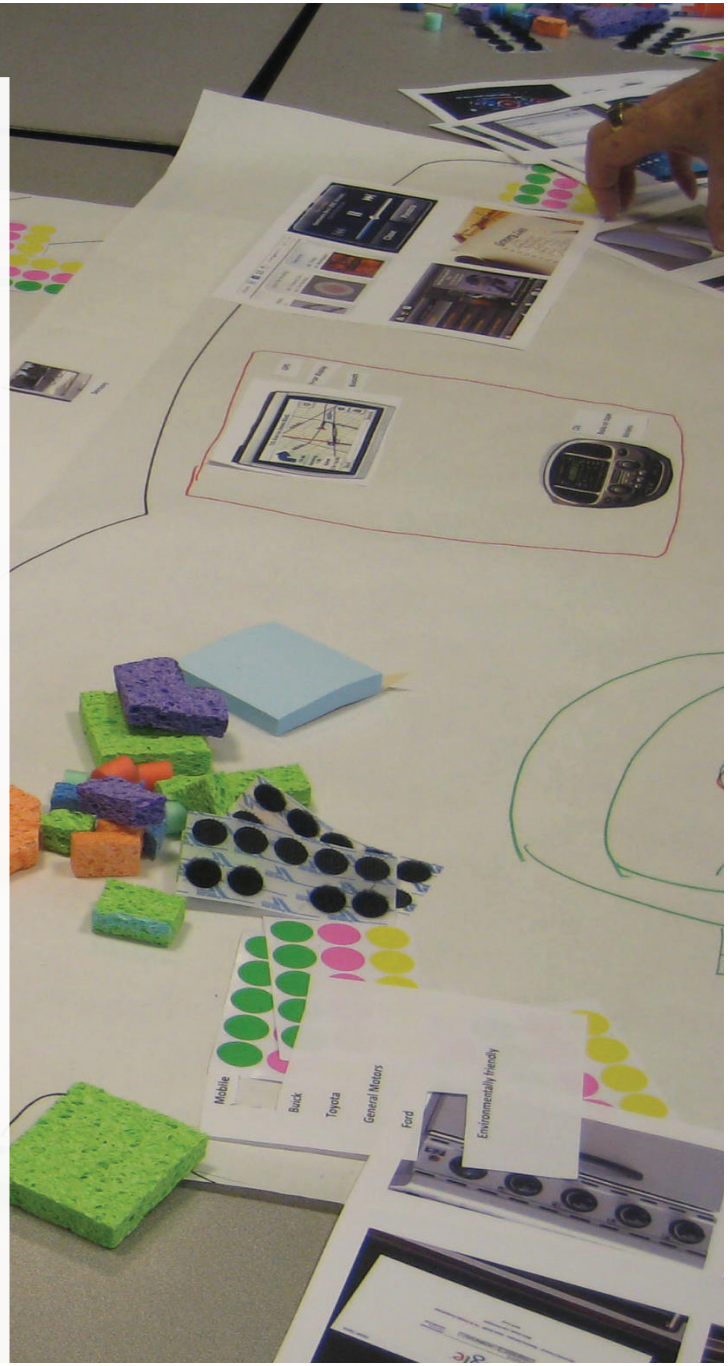
When we drove with one of the participants, he described his dashboard as if he was describing the environmental controls of a sophisticated machine. The reason we got this impression, was not because we didn't know what he was describing, but instead because of the level of detail he was using to describe it. He was trying to prove that he is not old and that he has full control of the car when he drives. What we found interesting throughout this description was the fact that new technologies that were incorporated into the car were well received. The reason they were well received was because it still allowed the driver to feel in control of the driving experience and not otherwise.



Generative Research

Participatory Design Session

Based on these findings, we set out to further uncover this notion of 'being in control' and what it really meant in the context of driving. In order to do this, we organized a participatory design session with six participants (at least one participant from each profile mentioned above). The session lasted about 90 minutes and was held in the School of Design at Carnegie Mellon. It was divided into two activities. The first activity consisted of a short focus group discussing a variety of driving experiences. The second activity consisted of creating an ideal car dashboard (in groups of two). To help them create these prototypes, a scenario was assigned to each group. At the end, participants had to act out each scenario using the car dashboards as their main props (IRB, 2010).



Activity One – Driving Experience

The participatory design session started with a small focus group in which participants were asked to describe what their best and worse driving experience were. Each participant was asked to prepare beforehand and to think about what made these good and bad. Some of the questions the participants were asked to consider when brainstorming their best and worse driving experience included:

- Where were you going?
- Who were you traveling with?
- What made you feel in control?
- What made it comfortable?
- What made it uncomfortable?
- How did technology play a role in this experience?

These were the main insights gained from this activity:

1) Most participants feel in control when they can anticipate what other drivers will do.
2) When participants have complete control of the car they feel comfortable driving.
3) Most participants said that they would not trust an autonomous car because they do not know if the car is aware of the different situations surrounding them.
4) Most participants said that they have to constantly adjust to new situations, and being able to do this easily means that they are in complete control of the car.

"I feel comfortable when I have complete control of the car"

- Emma Lee, 73 years old

Activity Two – Acting it out using props!

The second activity required the participants to build their own car dashboards in groups of two. To help them develop these prototypes, one scenario was assigned per group. Each scenario was divided into three parts, so it was easier for the participants to act them out. Also, each scenario was presented with a constraint that they had to take into account when acting it out. These were the three scenarios that were assigned to each group:

Scenario One – A trip to the grocery store.
Constraint: bad weather (raining)
Using your dashboard what would you do when...
Part 1: you plan your trip to the grocery store.
Part 2: you cannot find a parking space in the parking lot of the grocery store because it is full.
Part 3: you load groceries to your car.

Scenario Two – Going to class at the University.
Constraint: heavy traffic
Using your dashboard what will you do when...
Part 1: you realize that the main highway is closed.
Part 2: you see that the alternate route is completely packed with cars.
Part 3: you need to contact someone to let them know that you are going to be late.

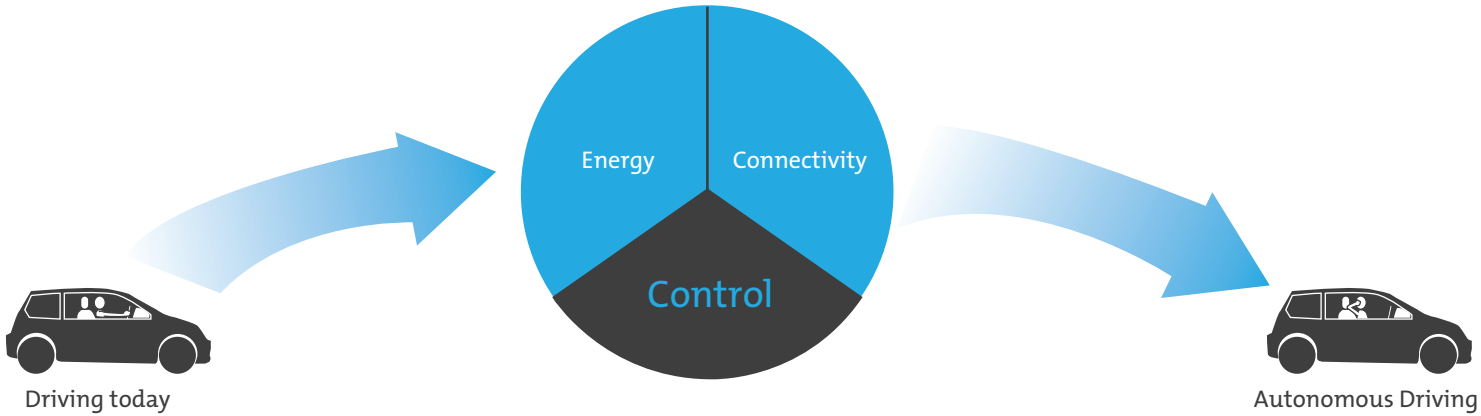
Scenario Three – Going to your friends' new house located in a new area of town
Constraint: Your car breaks down on the way there.
Using your dashboard what will you do when...
Part 1: your car breaks down and you need assistance.
Part 2: you need to let them know you are going to be late.
Part 3: you need to find an alternate way to get to your friends' house.

These were the main insights gained from this activity:

1) Based on scenario one, the participants proposed having a feature in their advanced GPS to find a parking spot at their final destination.
2) Based on scenario one, the participants said that the driver should always have access to the condition of the car.
3) Based on scenario two, the participants proposed connecting the driver's mobile phone to the main car dashboard. The car dashboard would import the driver's mobile phone information and display it.
4) Based on scenario two, the participants said that the GPS should give the driver different routes to take based on the current situation the driver is in.
5) Based on scenario three, the participants proposed having the main controls for the car navigation on the steering wheel.
6) Based on scenario three, the participants suggested creating a "control center" which would be located in the center of the car. This "control center" would contain information about the in-car system and act as an entertainment center.
7) Some of the participants suggested including a head-mounted display in the windshield, which would give them general information about their environment.

Energy, Connectivity And Control

Despite, recent advances in health care, science and other technological fields that allow the elderly to live longer and better, their quality of life is heavily dependent on being able to live independently. It is inevitable that as a person ages they will encounter different physical and cognitive impairments as well as dynamic social issues. Nonetheless, this does not mean that they are willing to give up their independence and ability to choose for themselves. Thus, we would add a third factor to the ones already established by Lawrence D. Burns (energy and connectivity), which is control. If we address these three factors we might be able to bridge the gap between how we drive today and how we will drive in the future and thus create more cohesive future automated driving systems.



Evaluative Research

Scenarios Development

Once the focus of the project was revisited and reestablished we moved on to concept generation. In order to create relevant and valuable concepts, we developed a set of scenarios based on the user needs and daily routines we gathered from the first two research phases. Each set of scenarios was composed of a current scenario and a visionary scenario (IRB, 2010). These were the scenarios developed:

Scenario One – A trip to the grocery store

Background Information:
Michael Fave (70 years old) and Louise Streja (67 years old) are a married couple from Columbus, Ohio, United States. They have been living in Pittsburgh, Pennsylvania, United States since 1997. They currently live in a suburb north of Pittsburgh. He retired from Quaker Oats five years ago. She retired from an insurance company as sales person. They usually drive together to the grocery store and some times to their class at the University of Pittsburgh. They drive a grey RX Hybrid Lexus 2010.

Current scenario:
Louise realizes that the second gallon of milk is almost empty and that they need to go buy more at the grocery store. She decides to check and see if there any other things she should buy as well. She makes a list of everything she needs to get at the local grocery store and asks Michael to take her. Even though it is raining outside and that Michael is watching the football game, Steelers vs. Ravens, he agrees to go. They decide to go to the closest supermarket because it is raining and they don't like to drive in the rain. Michael and Louise get in the car and as soon as they get in Louise turns on the GPS. She tries to see which is the closest supermarket they could go to and sees that Giant Eagle is. However, Michael said that he read in the newspaper that there was some type of road construction going on around that area. So Louise tries to look up the next closest supermarket, which is Right by Nature. Michael disagrees and says he doesn't like going there because it is in the strip district, which is downtown and it is always hard to find a parking space. Louise suggests that because of the football game there might not be as many people out. Louise

convinces Michael to go to Right by Nature. Michael says that if they go there he won't listen to the GPS because he says that it always takes them through some sketchy areas of town. Once they arrive to Right by Nature, as Michael predicted it, there is no parking space available. They go around a couple of times to see if there is any available parking spots, until they finally find one four blocks from the supermarket. On the way to the grocery store, they make a quick stop in a furniture store, because Louise sees a table she really likes. Michael follows Louise to the furniture store. Inside the store Michael and Louise wonder if they should or shouldn't purchase the table because they are not sure if it will fit inside their car. They finally decide not to do it and continue walking to the grocery store. On the way out of the grocery store, they find themselves stranded because it started to rain harder. They wait for a couple of minutes, hoping the rain will cease and it does. However, on the way back they forget where they parked and accidentally turn one block ahead. As they approach their car, it opens automatically so they can put the grocery bags inside. When Michael starts backing out he has some problems turning around to see how close he is to the car behind him. After a couple of manoeuvres he manages to get out but he has to break suddenly because there is a fast car approaching from the right. He lets the car go and then proceeds to drive back home.

These are the issues with the current scenario:

1) Louise has to go through all the things she needs to buy and make a list.
2) Michael has to leave in the middle of his football game.
3) They are both worried about the weather.
4) Unaware of current road constructions.
5) They are not able to over write the GPS and select a safer route.
6) Unaware if there is available parking spots at their destination.
7) They do not purchase the table because they are unaware of how much space there is inside their car.
8) They forgot where they parked their car.
9) Michael doesn't have full vision when backing out from the parking spot.
10) Michael doesn't anticipate the fast car approaching from the right.

Visionary Scenario:
Louise realizes that the second gallon of milk is almost empty and that they need to go buy more at the grocery store. Louise grabs her car keys and scans every item in the kitchen to upload the grocery list in the car. She asks Michael to accompany her to the grocery store. Even though it is raining outside and that Michael is watching the football game, Steelers vs. Ravens, he agrees to go. Michael agrees to go as he can keep watching the game in the car. When Michael gets in the car he swipes his car key to start the engine of the car. Michael gets a weather update and a car status update. When Louise swipes her car keys, the system knows she is going to the supermarket because it is able to retrieve the grocery list. Based on the current weather, traffic and city updates (road constructions) she is presented with a list of the closest supermarkets. She can filter this list based on parking spots availability, whether or not she can use her coupons, safest route, or quickest route. Based on all the information entered, the best option is Right by Nature. On the way to the supermarket Michael puts the football game on the main screen (the windshield), so they can watch it. Once they get close to the supermarket area, the game is interrupted and prompts Michael to select where does he want to park. There are three available parking spots only two blocks away from the grocery store and they are available for three hours. Michael selects the second option. The car drops them off in front of the grocery store and then it goes park itself at the designated parking spot that Michael selected. Louise notices a table she really likes inside the furniture shop next to Right by Nature and decides to take a look. In the store Michael and Louise wonder if they should or shouldn't purchase the table because they are not sure if it will fit inside their car. Michael pulls out his car key and scans the bar code on the side of the table and gets information about whether or not the piece of furniture will fit their car. Fortunately, it does and so they send the car a notification that they will be buying a table and it needs to readjust itself. Now the car knows it needs to create space for a table (with specific dimensions) and grocery bags. Meanwhile Michael and Louise tell the storekeeper they will come back to pick up the table. On the way out of the grocery store, Michael sends a notification to the car so they can be

picked up. Michael goes to get the table; meanwhile Louise starts to load the grocery bags to the car. Once Michael puts the table in the car, he helps Louise with the rest of the grocery bags. After loading the car they leave. The car notifies Louise if she wants to save this store in her bookmarks to find out information about future deals.

These are the function requirements that need to be met:

1) Louise should be able to scan grocery items to create a shopping list.
2) There needs to be an 'entertainment center' in the car so Michael can watch the game.
3) Weather update and car status – how does the latter affect the former?
4) Being able to select the best route based on current context.
5) Filter information based on available parking spots, coupons/deals, safety and fastest route.
6) Notification about approaching final destination and available parking spots (based on time, cost and safety).
7) Car should be able to park itself.
8) Michael and Louise should be able to check the dimensions of table and figure out whether or not it will fit in their car.
9) If a piece of furniture is scanned because it is going to potentially be purchased, then the car should be able to re-arrange itself to make room for the new piece of furniture.
10) Michael can send a request to car to get picked up (think about security...what if they loose key?)
11) Louise should be able to bookmark new places.

Scenario Two – New area of town

Background Information:
Joel Campbell (71 years old) and Erin Wittkamp (68 years old) are a married couple from Columbus, Ohio, United States. They have been living in Pittsburgh, Pennsylvania, United States since 1980. They live in one of the neighbourhoods, close to the University of Pittsburgh. He is CFO of his family business, run by his older son. She works as a part-time volunteer at UPMC (University of Pittsburgh Medical Center). She usually drives to the casino on Fridays and he likes to drive to his son business on Mondays and Wednesdays. She drives a 2005 Buick LeSabre and he drives a 2009 Toyota Corolla.

Current Scenario:
Joel and Erin get invited to spend Saturday afternoon at their son's new house. Sam (their son) just moved to a neighbourhood in the southern suburbs of Pittsburgh. Before they leave their house, Erin prints out the directions to his son's new house she found using Google Maps. She doesn't like going to unknown places without printing out directions. She says that she doesn't really trust the GPS and is always useful to have a back-up plan. Once Joel starts the car engine he pulls out the GPS and hands it to Erin so she can enter their son's address. She does after struggling a few moments with the GPS because it was auto-filling the address information, which was not the correct one. Finally, they manage to get on their way. As soon as they approach the main highway, traffic starts to slow down because there has been a car accident. However, Joel can't see what happened and he is not sure how long they will be stuck in traffic. After waiting for half an hour, Joel tells Erin to call Sam to let him know they are going to be late. Erin tells Sam that they are going to be half an hour late due to some incident on the main highway. Joel tries to find an alternate route to take but he is unsuccessful. He tries different destination points but the GPS wants to re-route him to a completely different area of town. As the traffic starts to move slowly, Joel sees an exit he thinks will cut them some time. The GPS keeps telling them that they got out in the wrong exit and that they should re-route. Joel decides to ignore the GPS instructions. The detour Joel tried to take turned out to take a lot longer due to some roadblocks. After a

couple of miles, both Joel and the GPS are once again on the same page. However, at this point Joel realizes that he should fill up his tank of gas because he is running low. Joel tells Erin to be in the look out for the next gas station as they are not familiar with this area. Erin spots one out that happens to be in the other side of the highway, fortunately there is U-turn coming up that they can take. Again the GPS tells them that they need to re-route and Joel gets very frustrated. After filling up with gas, they are back on track and head to their son's house. As they approach their son's house, the GPS takes them through some back roads and around a mall's parking lot, which makes no sense to them. Finally they get on their son's street and with 45 minutes of delay they arrive to his house.

These are the problems with the current scenario:

1) Erin has to print out the directions from Google Maps because they do not entirely trust their GPS.
2) They are not aware of the car accident on the highway and they are stranded for some time.
3) The people waiting for them at their final destination are not aware of Joel and Erin's delay caused by the car accident on the highway.
4) The GPS does not offer alternate routes when they are caught in the traffic jam.
5) They can't anticipate the roadblocks along their way.
6) They are unfamiliar with the new area and have no indication of where certain things are located (e.g. gas station).

Visionary Scenario:
Joel and Erin get invited to spend Saturday afternoon at their son's new house. Sam (their son) just moved to a neighbourhood in the southern suburbs of Pittsburgh. Erin looks up her son's home address using Google and sends it to the GPS in their car. Once Joel swipes his car key to start the car, he sees there are two notifications, one is regarding the trip information that Erin sent and the other one about the car status. Joel sees that their car battery is fully charged. Joel selects the "safest routes" option to get to his son's house. Joel is presented with three different routes to take as the main route is closed due to a traffic incident, which has caused traffic jam in the highway. Joel selects the second route. On the way to their son's house, Joel is able to control the speed of the car. Erin sees a convenient store where she wants to stop, because she remembers her son asked her to

buy some condiments for this afternoon's barbecue. Joel decides to over write the system and indicate they want to go to that convenient store by pointing in the windshield. The car recognizes Joel's hand gesture and re-configures it's route to include this unexpected stop. It turns out that they don't have the condiments she is looking for on stock. When they get back to the car, Erin enters the condiments she is looking for and the car suggests different convenient stores located on their way to her son's house. She browses through the different convenient stores and select the one that has best prices and won't delay their trip. The car sends a notification to Sam's smart phone letting him know that they will be five minutes, because Joel and Erin need to make an unexpected stop. Before Joel and Erin arrive, Sam gets a notification in his smart phone from the car to let him know that they will be arriving soon.

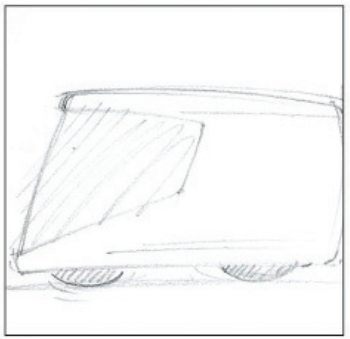
These are the function requirements that need to be met:

1) Being able to transfer information from Google Maps to the in-car GPS.
2) Once the car engine starts Joel is presented with the latest notifications and updates (weather and traffic updates, messages, car status, new addresses, etc.).
3) The car's GPS should give Joel and Erin a wide range of routes to choose from based on the information that is relevant to their trip.
4) Joel and Erin should be able to over write the in-car system at any time.
5) The car should recognize hand-gestures to select things.
6) Erin should be able to scan a specific item and get information about it. This includes finding the item in surrounding areas (based on cost and time).
7) The car should be able to communicate with smart phones to send information such as letting Sam know that Joel and Erin will be delayed.

Concept Generation – Round One

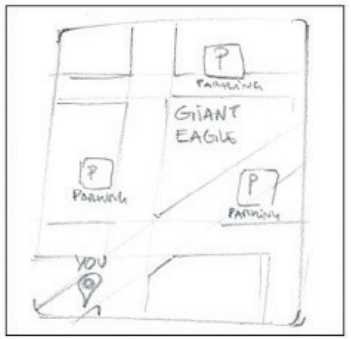
The sections led to concept developments that were evaluated using a rapid-evaluation technique know as speed-dating (Davidoff et al., 2000). These included:

1) Looking for a parking spot at destination



1) John and Emily are approaching the grocery store and wonder if there are any available parking spots.

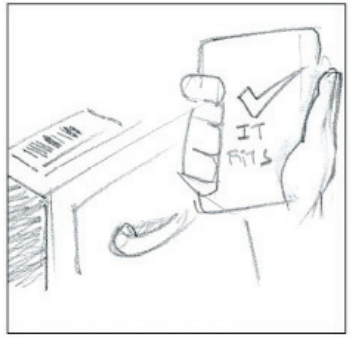
2) The car notices they are approaching their destination and sends a notification that they will be arriving soon and it asks them if they want to see what are the available parking spots.



3) John checks to see what are the available parking spots and selects one.

2) Buying a new piece of furniture:

1) When John and Emily go to IKEA they see a piece of furniture they would like to buy. However, they wonder if it will fit in their car.



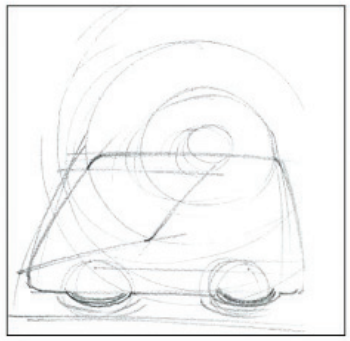
2) John pulls out his car key and scans the price tag on the furniture item to see if it will fit their car.

3) John and Emily go home with their new piece of furniture.

3) Making an unexpected stop during a trip :

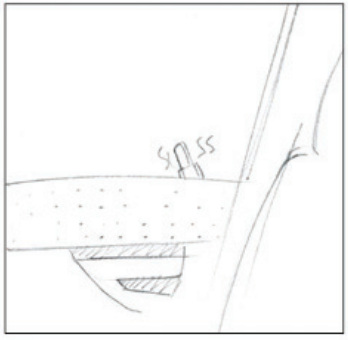
1) On the way to their daughter's cook out, Emily realizes she needs to make a quick stop to buy plastic cups. She promised her daughter she will bring them to the party. She spots a Rite Aid on the other side of the road where she might be able to get them.

2) Emily tells the car she needs to make a quick stop at the Rite Aid.

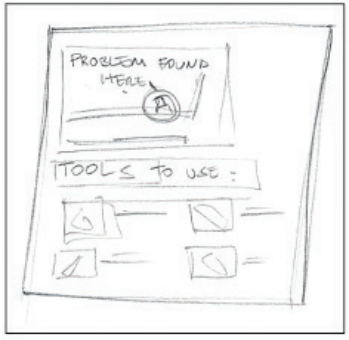


3) The car makes a quick scan of the area and re-routes itself towards the Rite Aid.

4) Being able to fix your car:



1) John gets back from his son's house and when he tries to unlock the car, Emily's lock gets jammed and it needs to get fixed.

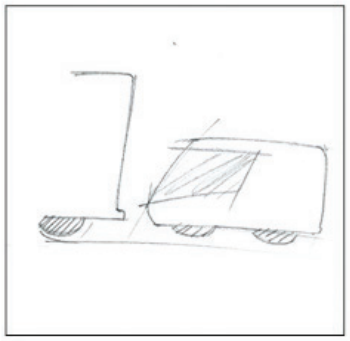


2) Since they just bought this car, John decides to check out the in-car fix-it-yourself system which gives him a step by step easy to fix tutorial.

3) Saving time and money, John successfully is able to fix the car lock.

5) Being stuck in a traffic jam:

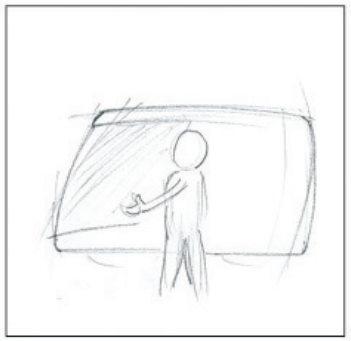
1) John and Emily are on the way to their daughter's cook out which is about thirty minutes away from their home.



2) On the way there, they get stuck in an unexpected traffic jam. John tells the car to send a notification to their daughter about their delay due to the traffic jam.

3) The car sends out the notification to their daughter which informs her that they are going to be a little late to the cook out.

6) Sending a reminder to the driver:

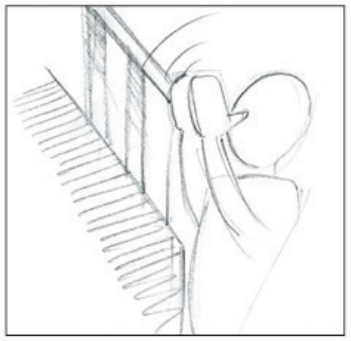


1) John is going to the hardware store to buy a piece he needs to finish putting together their new kitchen sink.

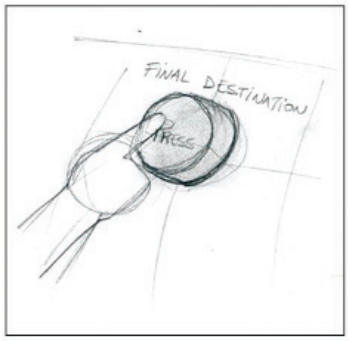
2) At home, Emily sees in the calendar that today they needed to go pick-up their granddaughter's birthday cake. She decides to send John a reminder.

3) When John starts the car engine he sees Emily's reminder about their granddaughter's birthday cake.

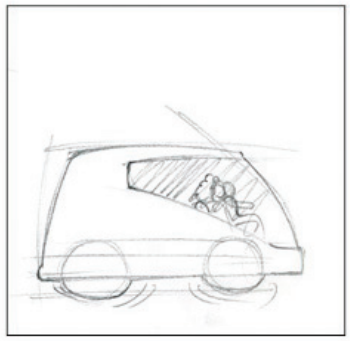
7) Reaching your destination in a rush:



1) John calls Emily and tells her to hurry up because they are going to be late to the symphony.



2) John and Emily get in the car in a hurry. John presses a button that will take them to their final destination.

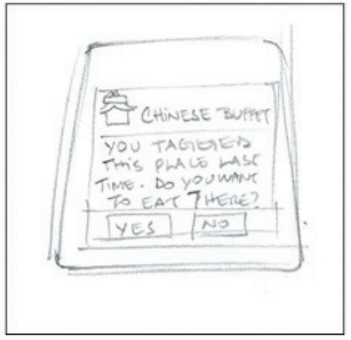


3) John and Emily are on their way to the symphony.

8) Book marking a new place for future reference :

1) On the way to their daughter's cook out, John and Emily pass a Chinese Restaurant they would like to try in the future. She bookmarks it in the car system for future reference.

2) On their next trip to the symphony, John and Emily want to get something to eat but they don't know what.

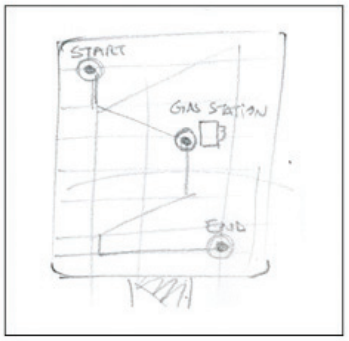


3) The car suggests the Chinese restaurant that not only they bookmarked recently, but it happens to be around their destination area. John and Emily accept to go after the symphony to get dinner.

9) Planning a car trip:

1) John and Emily want to go to the grocery store. John enters their destination.

2) The car knows it is running low on gas so it let's John know they should make a stop at a gas station. The car presents John with a number of gas stations located near their destination.



3) Once John has selected which gas station to go to, the car shows their final itinerary to the grocery store which includes a quick stop at the gas station.

Concept Validation – Round One

The speed-dating process was used to evaluate these concepts. Speed-dating is a method that aids designers and researchers in quickly identifying and understanding the critical aspects of the social environments that have huge impacts on the success of products, without requiring a huge investment in implementation. (Davidoff et al., 2000). An online survey containing the speed-boards was launched for ten days to capture high-level results regarding each concept. These were some of the reactions to this first round of concept generation:

1) Buying a new piece of furniture:
• "I measured the space and then determined what size the furniture should be and then looked for the pieces."
• "Had it delivered"
• "I didn't buy it. I had to borrow somebody's bigger vehicle... nuisance..."

2) Looking for a parking spot at destination:
• "I ride around until a space opens up or I find one open..."
• "I wait until I get in the parking lot and then look for a space. I have never not been able to find one. I think what you described above is compulsive behaviour.

3) Being able to fix your car:
• "Steering wheel locked up - had instructions available and used them successfully. However, if new car and chance of doing damage would expect repair to be covered under warranty."
• "I call AAA or ask a friend...get frustrated!"

4) Making an unexpected stop during a trip:
• "I live in a smallish city--don't need the car to tell me how to get from place A to place B. This seems a bit silly to me."
• " I stopped the car and programmed the location in the GPS and added it to the route, proceeded on."

5) Being stuck in a traffic jam:
• "I use my cell phone--that is what it is for."
• "Would just use cell phone. This not needed."

6) Sending a reminder to the driver:
• "Try to coordinate trips so as to accomplish both tasks."
• "No problem with cell phones available now. Before tried to contact at store with message to call home."

7) Reaching your destination in a rush:
• "Try to get there without any wasted turns or lost ways--but yet try to be cautious as to get there safely."
• "I programmed location in GPS and took shortest route."

8) Book marking a new place for future reference:
• "I made a mental note."
• "I usually figure it out before I get in the car. Originally, I might make a note in my notebook...then I put on my "restaurant list" and refer to it before we go out...Anyway, I might not want Chinese..."
• " I Look up what is near on Urban Spoon on the iPhone."

9) Planning a car trip:
• " I looked for the nearest, cheapest, gas station, filled up and then went grocery shopping."
• "If I am near home and the 'light goes on', I get gas... and I don't need a GPS except when traveling. This would be a good application for the traveler, though."

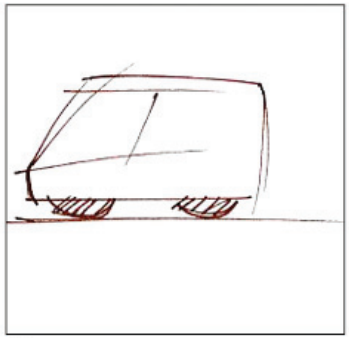
Based on these findings, we realized that some of these concepts were not truly capturing the issue of control with older drivers and future automated driving systems. Some of these concepts resemble many current smart phone applications and were not appropriate for the context of use. However, some of these concepts could be regarded as secondary features in the overall system. Thus, we kept exploring the issue at hand and developed more concepts.

"I usually figure it out before I get in the car. Originally, I might make a note in my notebook...then I put on my "restaurant list" and refer to it before we go out...Anyway, I might not want Chinese..."

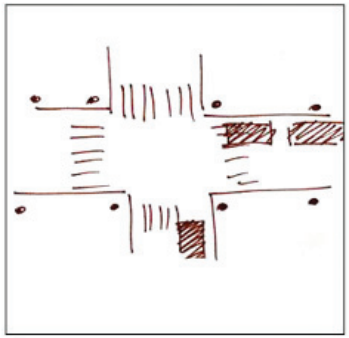
Concept Generation – Round Two

After revising the feedback collected from the first round of concept development, we set out to develop another round of concepts. The difference between these concepts and the first ones was that in this second round we focused more on the overall system. We explored how the context of driving might affect the drivers' actions the car infrastructure and make them feel empower. We looked at how the street infrastructures as well as should interact with each other to create a cohesive system that responds to the drivers' actions. These included:

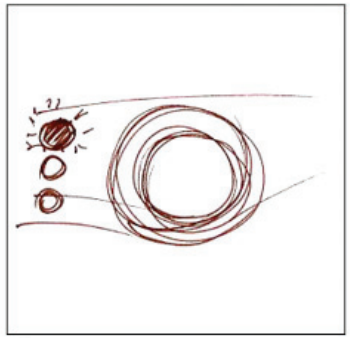
1) The in-car traffic light:



1) John and Emily have been out shopping for the day and they are on their way back home.

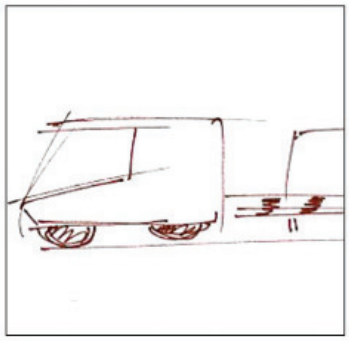


2) As they approach their destination, the streets measure the traffic load on them to control the overall traffic flow.

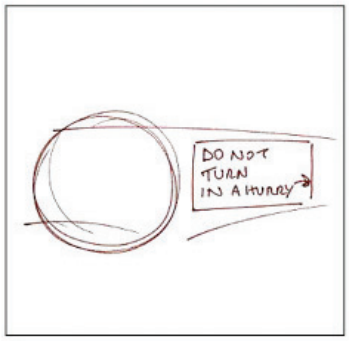


3) They happen to be in the street that has less traffic and their "in-car" traffic light turns from green to red as they approach the intersection.

2) Other cars warning:



1) John and Emily are on the way to their daughter's cook out which is about thirty minutes away from their home.

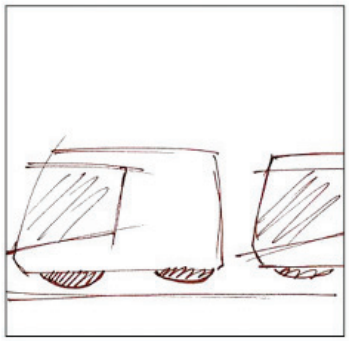


2) As they drive in the highway they get a notification in their dashboard informing them that there is a car to their right approaching in a hurry.

3) As soon as the car passes them the notification disappears and John can change lanes.

3) Following the leader:

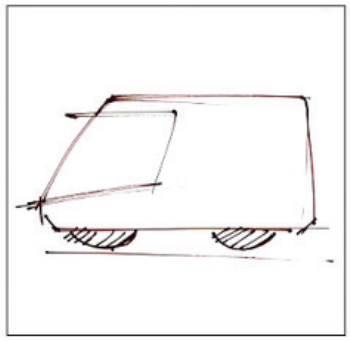
1) John and Emily are invited to their friends' summer house but they don't know how to get there because it is out in the woods.



2) Instead of going by themselves, they decide to follow their friends. Their cars sync together.

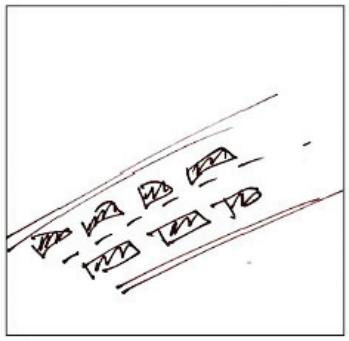
3) John and Emily don't have to worry about the driving as their car automatically follows their friend's car and thus they can get some sleep.

4) Priority tag:



1) John and Emily are on the way to the symphony.

2) As they approach the highway, their "priority tag" sync with the the highway system which assigns them a lane to follow.



3) John and Emily get in that lane and follow it until they reach their exit.

Concept Validation – Round Two

The speed-dating process was used to evaluate these concepts. An online survey containing the speed-boards was launched for ten days to capture high-level results regarding each concept. These included:

1) The in-car traffic light:
• "When I encounter this situation, I check the rear view mirror for vehicles which may rear-end me if I should stop for the traffic light. If no danger of being hit from behind I usually stop for the red light."
• "Entering high speed expressways or busy roads when there is poor visibility to oncoming traffic due to obstructions, snow, fog or rain. Situation required me to go much slower which made it more difficult to safely merge into the traffic flow. Could eliminate the need for Stop Signs in many places."

2) Other cars warning:
• "I just wait until they pass and then change lanes, would be nice to have a sign to remind of the situation."
• "Changing lanes to the right OR left and last moment decisions to make turns or take an exit. I added convex mirrors to my side view mirrors."

3) Following the leader:
• "I would never sleep while driving under NO circumstances. When following, I become extra alert for fear of rear-ending the leading vehicle."
• "I have followed and been followed many times which can be especially difficult in heavy traffic. Made a note of license plate, color and make of car I'm following. I had the car following me turn on their bright headlights during daylight hours. Designated a passenger when possible to keep track of other car."

4) Priority tag:
• "I would like a little guidance but would rely on reality of the roads."
• "GPS does essentially this I think."

The reactions to these concepts were far more positive than the ones from the previous round. Participants related to the situation presented at hand and understood the relevance of the system. Based on these concepts and some from last round we started the final concept development of the system.

"Changing lanes to the right OR left and last moment decisions to make turns or take an exit. I added convex mirrors to my side view mirrors."

Final Concept Development

Final Visionary Scenario

Based on the feedback from the concept validation rounds, we analyzed the different responses gathered and moved on to create a final visionary scenario. The visionary scenario that we developed, highlights the different touch points in which the driver interacts with the in-car system as well as other infrastructure systems from the moment the driver enters the car until he arrives to his final destination.

Final Visionary Scenario – A trip to the new concert hall

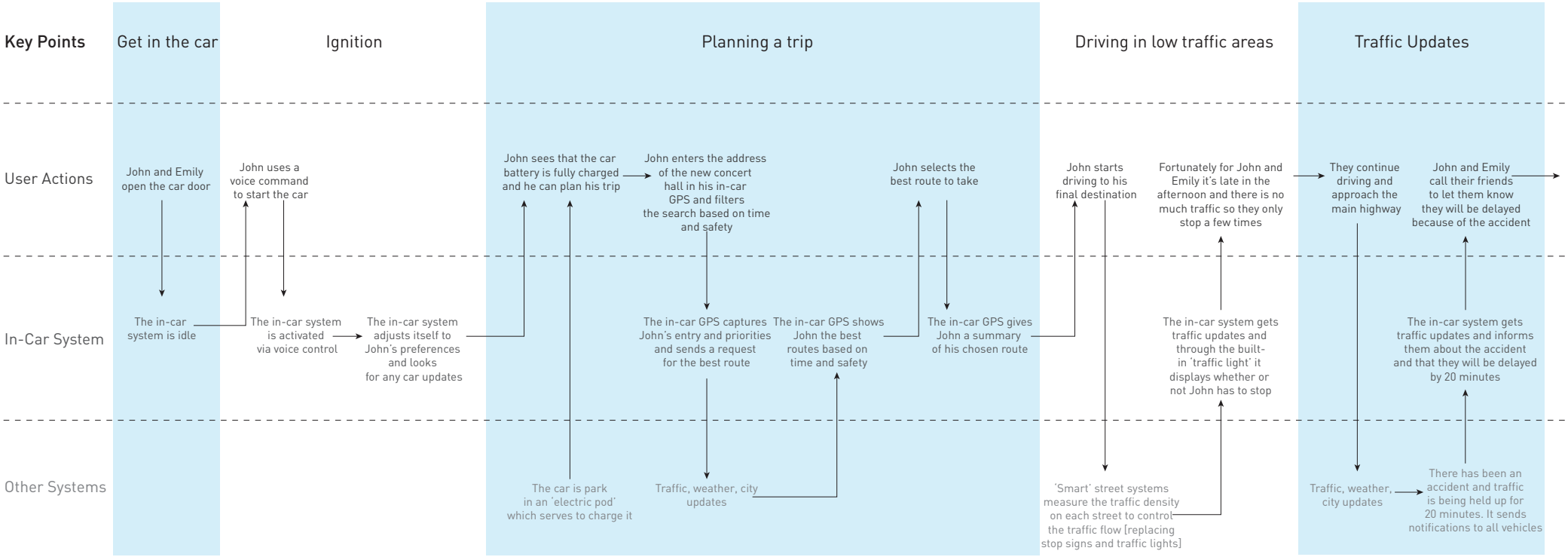
Background Information:
Joel Campbell (71 years old) and Emily Wittkamp (68 years old). They are a married couple from Columbus, Ohio, United States. They have been living in Pittsburgh, Pennsylvania, United States since 1980. They live in one of the neighborhoods south of the city. He is CFO of his family business, run by his older son. She works as a part-time volunteer at UPMC (University of Pittsburgh Medical Center). She usually drives to the casino on Fridays and he likes to drive to his son business on Mondays and Wednesdays.

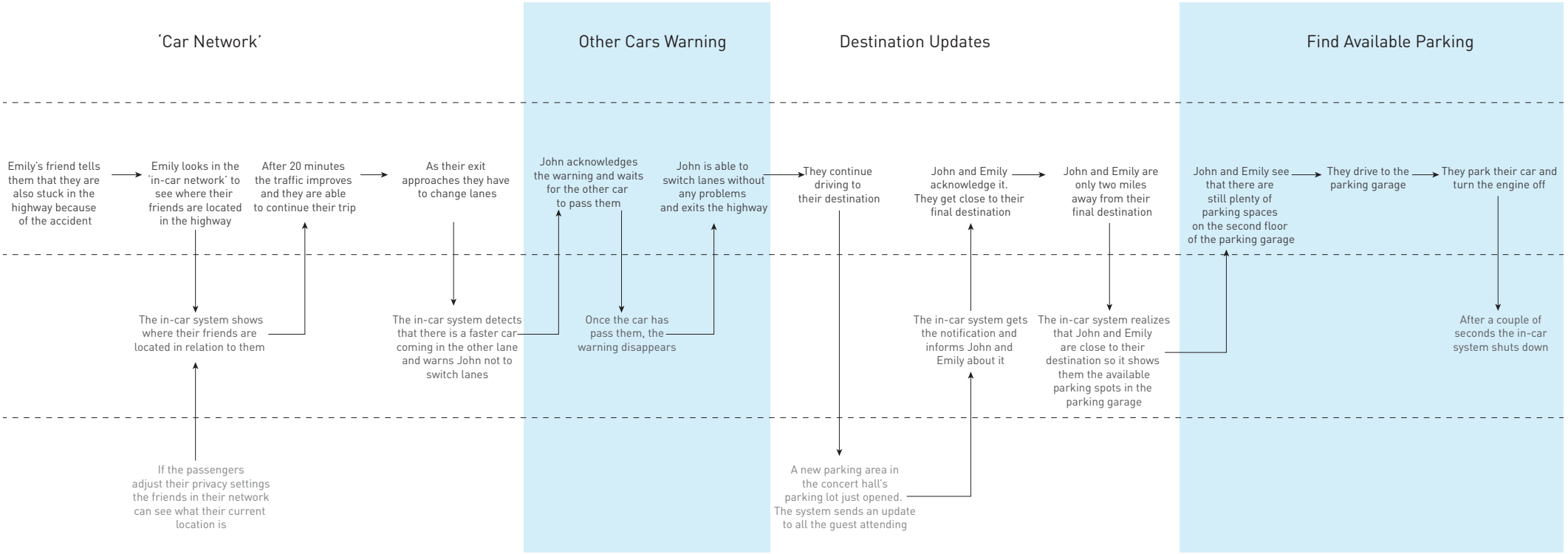
Visionary Scenario:
John and Emily have been invited to the symphony in the new concert hall located 20 minutes north of the city in a new area of town. As they prepare to leave, John checks their car status and notices that the car battery is fully charged as it has been charging in the "electric pod" all day. John enters the address of the new concert hall in his in-car GPS and filters the search based on time and safety. The in-car GPS presents John with the best routes to take and he selects one. John starts driving to his final destination. The 'Smart' street systems measure the traffic density on each street to control the traffic flow [replacing stop signs and traffic lights]. The in-car system gets traffic updates and through the built-in 'traffic light' it displays whether or not John has to stop. Fortunately for John and Emily it's late in the afternoon and there is no much traffic so they only stop a few times. When they enter the highway they get a notification about a recent accident, which has caused traffic jam that will delay them for 20 minutes. Emily calls their friends to let them know they will be delayed because of the accident. Emily's friend tells them that they

are also stuck in the highway because of the same reason. Emily looks in the 'in-car network' to see where their friends are located in relation to them in the highway. After 20 minutes, the traffic improves and they are able to continue their trip. As their exit approaches they have to change lanes. The in-car system detects that there is a fast car approaching from the right and warns John not to switch lanes and let the other car pass them. John acknowledges the warning and waits for the other car to pass them. Once the car has passed them, the warning disappears and John can switch lanes. As they continue driving to their destination they receive an update from the new concert hall. A new parking area in the concert hall's parking lot has just opened. John and Emily acknowledge the notification and continue driving. The in-car system realizes that John and Emily are close to their destination so it shows them the available parking spots in the concert hall's parking garage. John and Emily see that there are still plenty of parking spaces near the parking garage elevators on the second floor. They drive to the parking garage and find a good parking spot near the elevators. They park their car and turn the engine off.

Experience Journey

Based on the visionary scenario that we developed, we created an experience journey to help us revise the flow of the drivers' actions between each touch point as well as how different aspects of the overall system connected to each other.




'Car Network'
Other Cars Warning
Destination Updates
Find Available Parking
Emily's friend tells them that they are also stuck in the highway because of the accident
Emily looks in the 'in-car network' to see where their friends are located in the highway
After 20 minutes the traffic improves and they are able to continue their trip
As their exit approaches they have to change lanes
John acknowledges the warning and waits for the other car to pass them
John is able to switch lanes without any problems and exits the highway
They continue driving to their destination
John and Emily acknowledge it. They get close to their final destination
John and Emily are only two miles away from their final destination
John and Emily see that there are still plenty of parking spaces on the second floor of the parking garage
They drive to the parking garage
They park their car and turn the engine off
The in-car system shows where their friends are located in relation to them
The in-car system detects that there is a faster car coming in the other lane and warns John not to switch lanes
Once the car has pass them, the warning disappears
The in-car system gets the notification and informs John and Emily about it
The in-car system realizes that John and Emily are close to their destination so it shows them the available parking spots in the parking garage
After a couple of seconds the in-car system shuts down
If the passengers adjust their privacy settings the friends in their network can see what their current location is
A new parking area in the concert hall's parking lot just opened. The system sends an update to all the guest attending

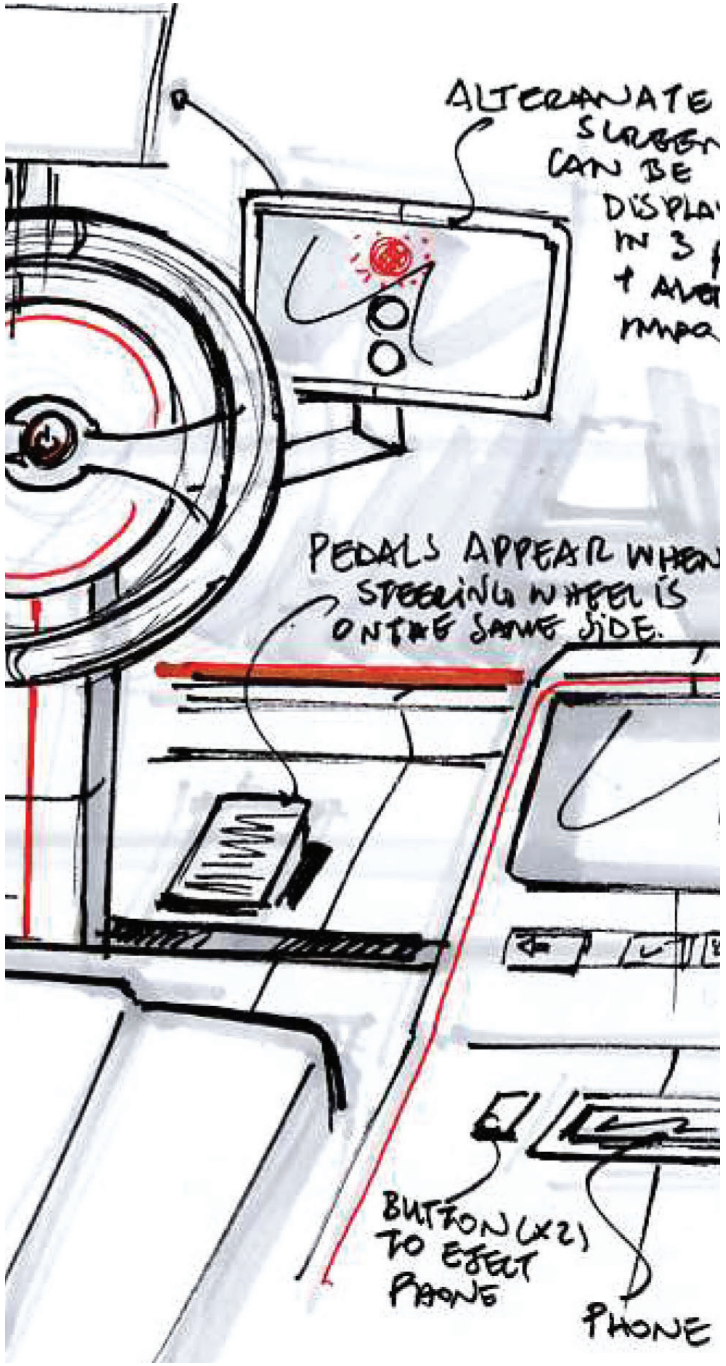
Final Concept Overview

From the experience journey we generated multiple two-dimensional sketches of what the interior of this future car could possibly look like. Some already established car concepts such as the General Motors Hy-Wire concept car inspired us to develop the final interior of the car. Even though the focus of this project was not on re-designing the physical aspect of the car, I had to have a general understanding of the environment in which the interactions between the driver and the in-car system would take place.

We focused on the front area of the car because that is currently where the controls are located. The following are the three different platforms we developed:

1) **The steering wheel**
2) **The main console**
3) **The windshield**

All the platforms will be controlled by touch screen. All the participants interviewed during the research phase expressed their preference of touch screen interfaces over physical ones. They said that touch screen interfaces are larger, which makes them more legible and easier to use. Especially, when it comes to pressing buttons.



Steering Wheel Concept

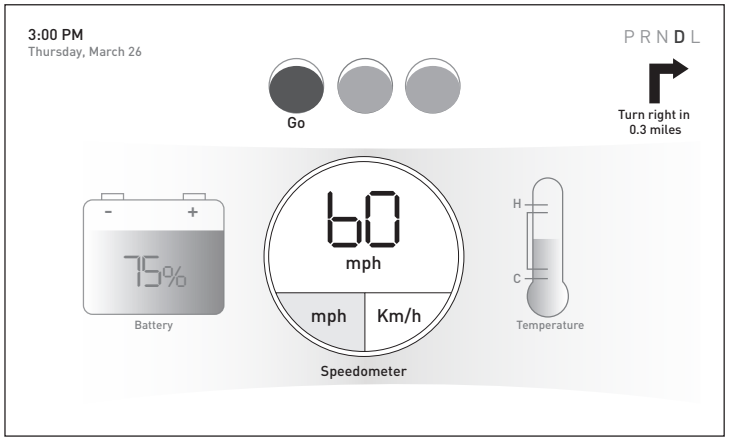
The steering wheel was chosen as one of the three points of interaction based on the car ride alongs we conducted in the first phase of this project. Many of the drivers we drove sat in the car with tended to either place their GPS monitor on the left side of their steering wheel or keep it in their hands and look at it every so often when driving. This inspired us to place a screen on the steering wheel. This should not be an issue, because ideally the drivers should be able to adjust the height and distance of the steering wheel according to their preference. Thus, creating a safe reading distance. In what concerns the information contained in this screen, it is the most relevant to the driver. The driver has access to the following information:

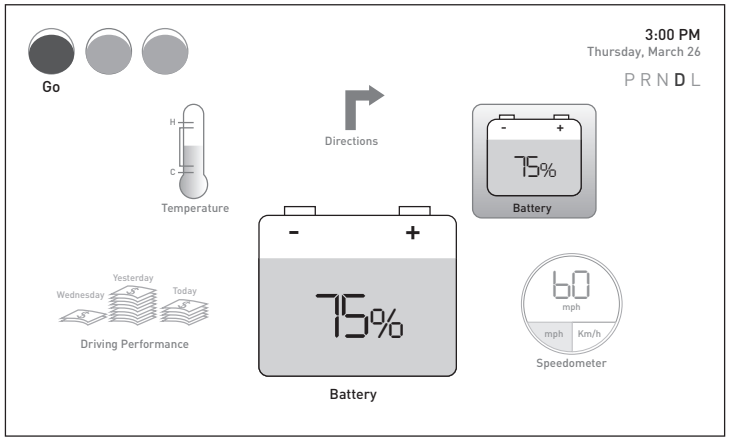
1) Speedometer
2) Car battery level
3) Alert systems such as driving alerts, traffic alerts and car status alerts (if something breaks down).
4) Immediate directions for the current trip.

The interface is displayed in carousel view so the driver can quickly browse through the different options and still be able to see as much information as possible.

Other secondary information includes:

1) When the driver has to stop, which is represented by a traffic light icon at the top left of the interface. In addition, the perimeter of the screen lights up in red to indicate when the driver has to stop and an overlay of a stop sign appears on the screen. Warning signs are also displayed and the perimeter of the screen lights up in yellow.
2) Automatic transmission (Park, Reverse, Neutral, Drive, Low)





These are high-fidelity wire frames of the steering wheel. We explored multiple way of how the information should be displayed on the screen.

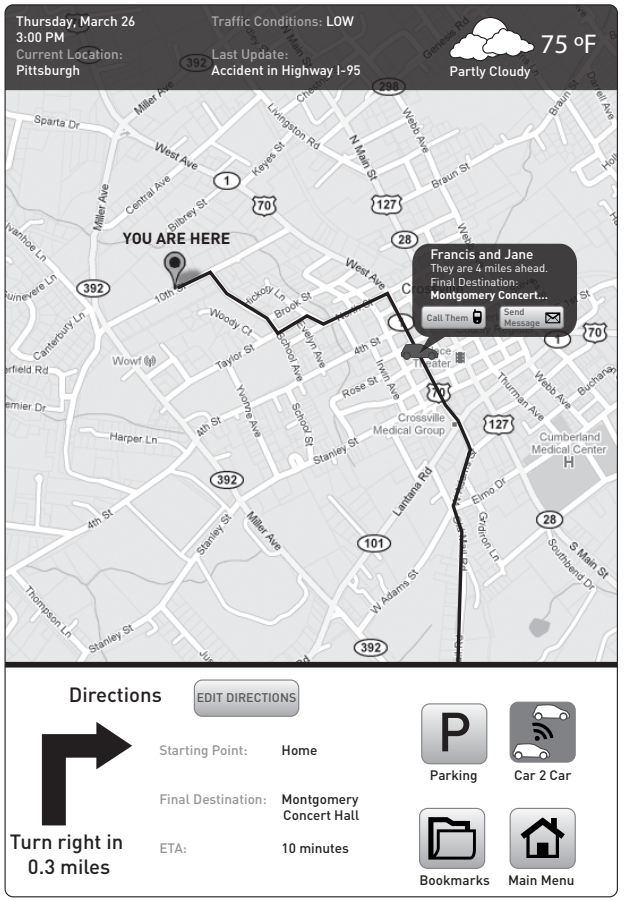
Main Console Concept

The main console was chosen as one of the three points of interaction based on the current location of the main controls in car dashboards. Usually, car dashboards have all the main controls in the center of the car so both the driver and passenger can interact with them. The main console idea merges two ideas proposed by participants during the participatory design session. The first idea is a "control center" that would contain all the information about the in-car system and act as an entertainment center. The second idea is connecting the driver's mobile phone to the main car dashboard. The car dashboard would import the driver's mobile phone information and display it. Thus, the main console will combine both ideas and act as the primary control center for the in-car system. The driver can access different information from the main console such as:

1) Advanced GPS – All the information regarding the current trip. From the moment the driver plans a trip by selecting the best route to take based on time and safety to what are the available parking spots at his destination. The driver can also book mark places for future reference.
2) Contacts – The contacts are imported from the driver's mobile phone.
3) Entertainment – The driver and passenger have the option of watching TV or doing work when they are in long trip and the car is in cruise control.
4) Alert systems such as driving alerts, traffic alerts and car status alerts (if something brakes down).

Other secondary information includes:

1) When the driver has to stop the perimeter of the screen lights up in red to indicate when the driver has to stop and an overlay of a stop sign appears on the screen. Warning signs are also displayed and the perimeter of the screen lights up in yellow.



An example of a high-fidelity wire frame of the main console.

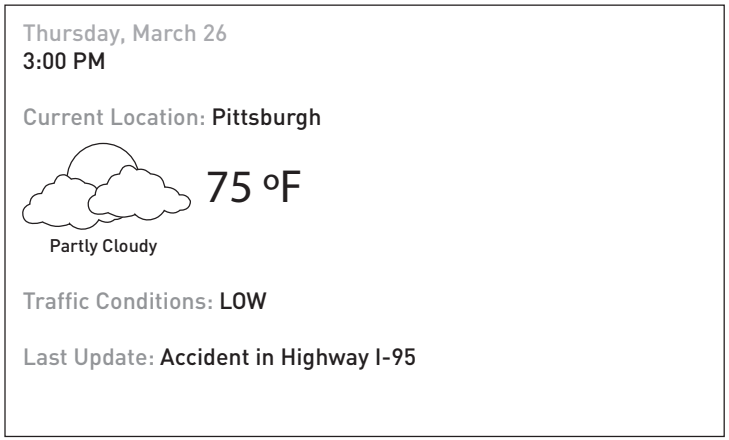
Windshield Concept

The windshield was chosen as one of the three points of interaction because some of the participants expressed the idea of including a head-mounted display in the windshield, which would give them general information about their environment. The driver only has to glance at the windshield to get information about real-time traffic and weather updates. Thus, I have decided to include the following information in the windshield display:

1) Time and date information
2) Traffic and weather updates

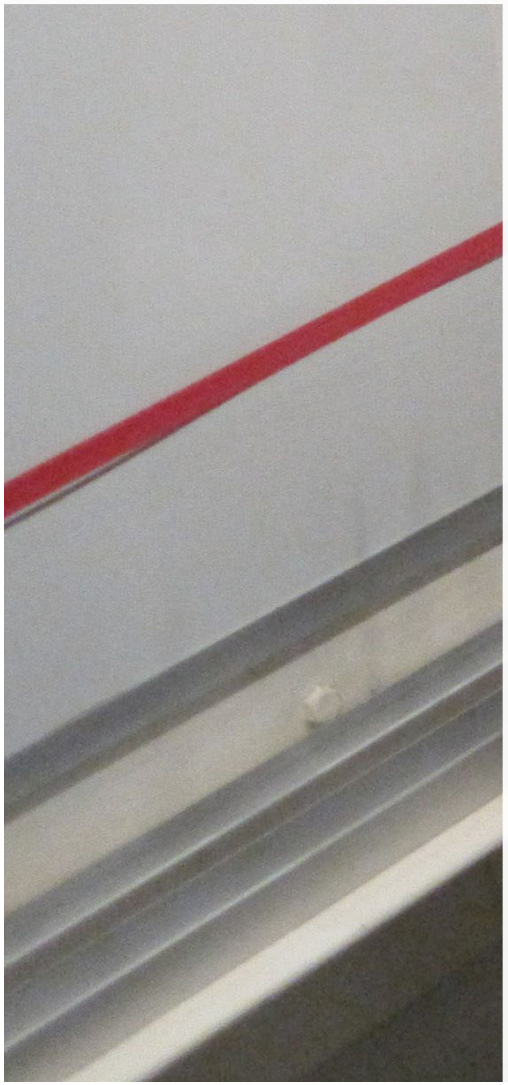
Other secondary information includes:

1) When the driver has to stop the perimeter of the windshield lights up in red to indicate when the driver has to stop and when a warning is issued then the perimeter lights up in yellow.



An example of a high-fidelity wire frame of the windshield.

Experience Prototyping



Once we developed the final concept we decided to conduct an experience prototyping sessions to evaluate the interactions between the driver and the three points of interaction as well as the information displayed in them. We made three-dimensional models to re-create the interior of what this futuristic car would look like. We made a steering wheel with a stand and a main console frame. To mock-up the windshield we used a classroom white board and we used colour tape to indicate when the driver has to stop or that a warning has been issued (IRB, 2010).

In order to get valuable results, we conducted the sessions with two participants at a time. In each session we made the participants read the experience journey we created and then told them to act out the different aspects of the journey. They acted out these aspects of the system:

1) Interacting with the in-car system when the driver is approaching an intersection and has to stop.
2) Interacting with the in-car system when the driver is cautioned not to make a turn or switch lanes because there is a fast car approaching.

3) Interacting with the Advanced GPS to find a parking spot at their destination.

These were the main insights gained from this activity:

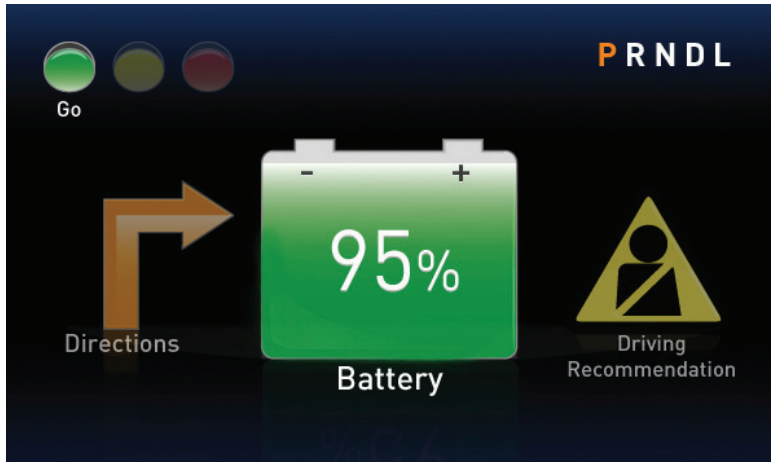
1) There should be other warnings apart from approaching an intersection and a fast car approaching. Other warnings could include entering and leaving a parking spot, road conditions, pedestrian crossing, speed limits, etc.
2) Think about the time or distance of when the car should alert the driver that he has to stop.
3) Incorporate sound feedback as an additional modality to alert the driver when he has to stop or when a warning has been issued.
4) The in-car system should know if you are a defensive or aggressive driver. If you are more defensive driver then you would be caution about more things than if you are an aggressive one.
5) The entertainment feature of the car should only be activated when the car is on autonomous drive.
6) The carousel view is appropriate for the steering wheel interface.

After concluding the experience prototype sessions, we continued to refine the final concepts and incorporate some of the suggestions made by the participants. However, due to time constraints some suggestions were labelled as next steps of this ongoing process.

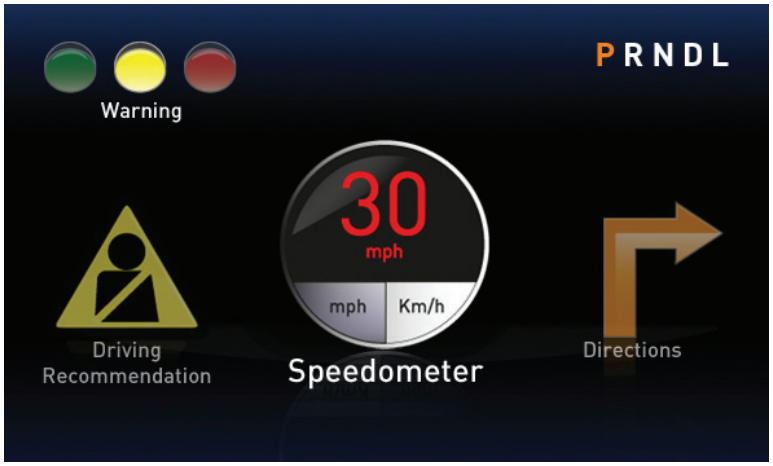
“The in-car system should know if you are a defensive or aggressive driver. If you are more defensive driver then you would be caution about more things than if you are an aggressive one.”

Final Design

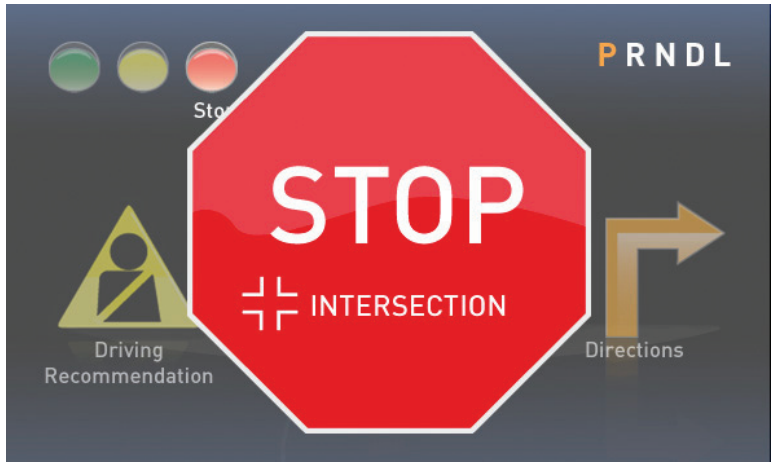
Final Steering Wheel Design



Car battery level



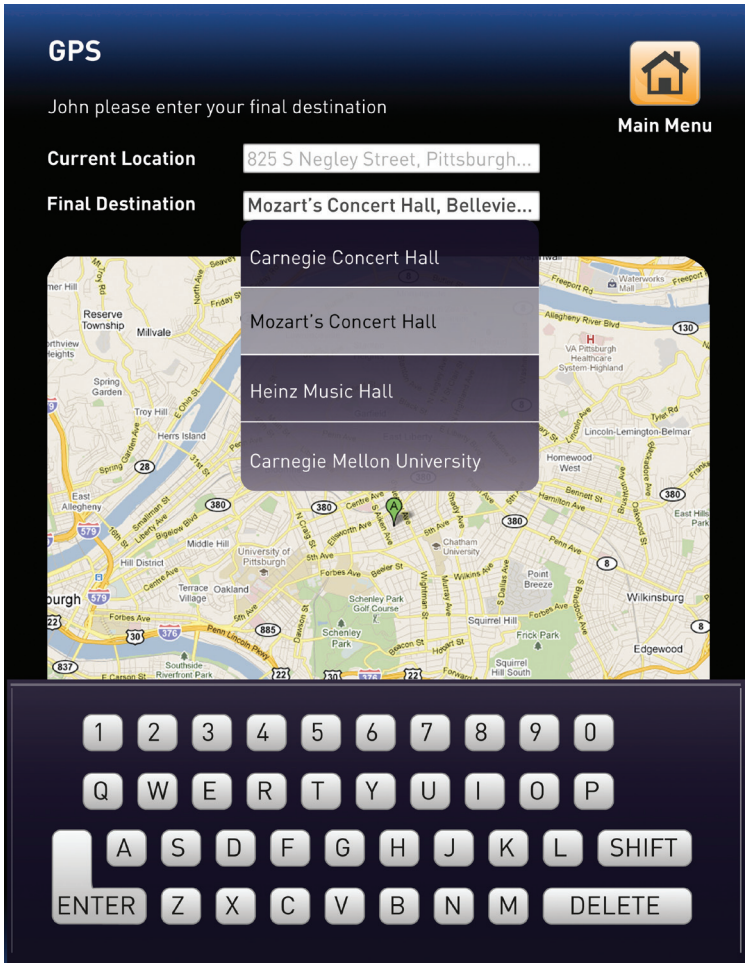
Speedometer



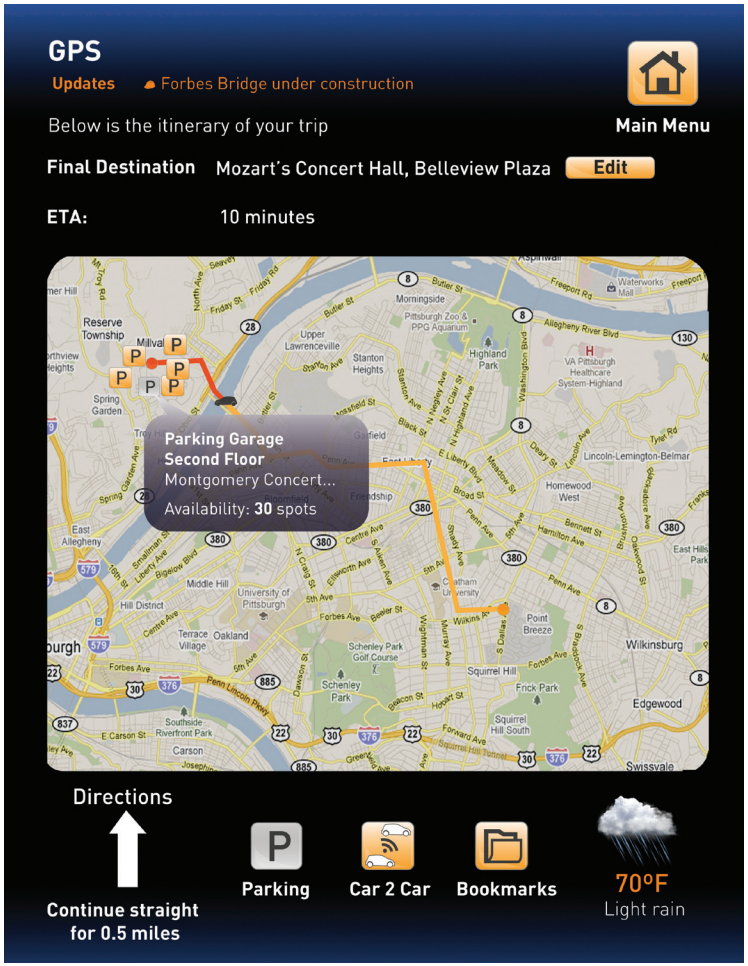
Stop signal alert

Warning signal alert

Final Main Console Design

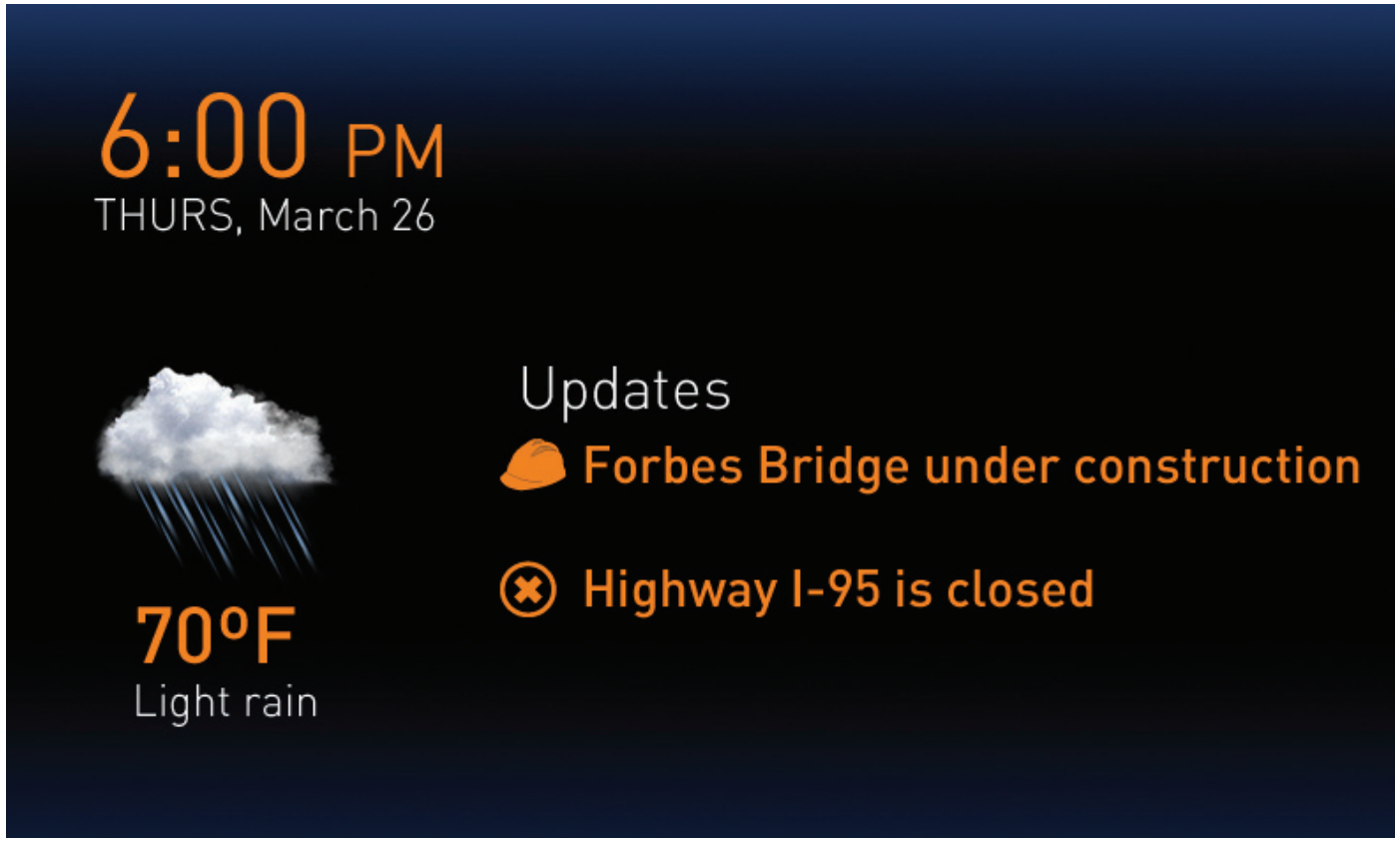


Entering final destination in GPS



Looking up available parking spots at final destination

Final Windshield Design



Traffic and weather updates displayed in windshield

Concluding Thoughts

The design process is an iterative process that has no real end, but needs to be stopped at some point mainly because of the time constraints in a project. And this project was not the exception. It was a nine month long project in which we went through the human-centered design process to uncover some of the nuances behind the topic of issues of control with older drivers and future automated driving systems.

Based on the nine months of work these are some of the conclusions we gathered and that we would suggest doing moving forward with this project:

1) What are the opportunities to transfer the knowledge gain in this project to the automotive industry?

2) Keep refining the User Interface of the three platforms we created. More research on how other features could be incorporated to make the driver feel more in control. Also, the legibility of the User Interface has to be revised. What are the appropriate fonts, size of icons and other features that need to be taken into account when the driver is interacting with them? Especially because the driver will be interacting with these interfaces at different distances.

3) Keep pushing some of the visionary interactions of this project as some of them seem to be constrained by the traditional in-car interactions. Look at other areas of the car the driver and passengers could interact with.

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