

GPS Rerouting

Making Something Better Using Human Factors

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Introduction

Using a GPS device while driving has provided many advantages in the how drivers can find new routes to unfamiliar destinations. However, the process can be problematic and even dangerous from a human factors perspective. In this specific study, we focused on the problem of rerouting by entering a new address into a GPS device while driving, but also discovered that rerouting also carries the connotation of driving through the wrong streets due to GPS misguidance. We studied these scenarios from user studies, interviews, and a competitive analysis that directed us to a redesign to address such problems.

Task Analysis

Please refer to Item 1 in the Appendix for the full data of our user task studies. To replicate the issue of entering a new address on a GPS device, our task analysis study required 2 participants to each drive to one destination using a provided GPS device. They were unexpectedly prompted to enter a new destination in the middle of the task. We analyzed their methods tackling the situation to observe their decisions and errors. The major problem we discovered during in-vehicle navigation is the high attention cost of drivers.

Human Factors Problems. Multiple human factors issues emerged during our findings. A decision making issue was *optimism bias*; a driver from one interview believed that he was at less of a risk in experiencing a negative event compared to others, judging himself as a skillful driver having quick reflexes. He felt confident to operate a GPS device while driving, which is actually illegal and extremely risky. Naturalistic decision making issues include the presence of *unstable conditions*; that is, the whole process from driving on the road to parking on the side of road, which requires a series of potentially risky operations. *Cues were displayed simultaneously* as

well--when the driver was told that he needed to enter a new address, he had to attend to the road, cars passing by, parking space availability, etc. Interviewees mentioned difficulty of needing to pay attention to the road while operating the GPS. There was *high risk* involved for sudden reductions in speed and pulling the car over. Drivers from both the interviews and think aloud studies encountered this issue of entering new addresses while driving. Since *multiple people were involved* in the user study test, the driver kept on telling observers what he was thinking. The drivers' decision making might have been influenced by having passengers present.

A time-sharing and perception-related problem was of *divided attention*: When the drivers in the think aloud decided to pull over, they simultaneously had to drive, think aloud, turn on signals, look for open parking, and press the brake pedal. There was also the issue of working memory limitations when the drivers allocated their working memory for the aforementioned tasks. By following knowledge from their working memories, they had to follow driving directions based on familiar visual cues.

There was an impediment to the mental bottom-up processing since drivers' attention were focused on the environment. Sometimes they had to change lanes, and other times they had to look for a safe and available place to pull over. The driving task requires drivers to be very focused.

User Study

In our user studies, we performed 2 think alouds and conducted 5 interviews with different users. We only recruited users who had the experience of operating a GPS device while driving. Please refer to the Item 3 in the Appendix for the detailed profiles for each user.

Think Aloud Study

User Persona. The user persona has experience with driving and operating a GPS device and use the GPS device to provide the correct route guidance to reach an unfamiliar destination.

Methods & Task. The observer(s) first told our participant that we were analyzing the GPS device and not the performance of the user himself. We explained that in think aloud testing, the participant was required to comment their actions, intentions, and thoughts at all times, and that the observer(s) would provide little assistance if any at all; in addition, we would be doing a video/audio recording during the task. For our full step-by-step instructions, please refer to Item 2 in the Appendix.

Think Aloud Results. From our think aloud studies, we generally found the inefficiencies and problems that the drivers encountered include needing to spend extra time and energy to safely re-enter a new destination route into their GPS devices. Because the driver did not know where they were when they needed to reroute, he was required to adapt to their environment and determine the new set of directions as quickly as possible. In addition, the driver had to add on the extra task of straying away from their current route to pull over to an available spot, just to safely remove the GPS device out of the windshield mount and enter in the new destination, and then returning to the main road afterwards.

Potential problems that we discovered from the think-aloud include the constraint of the setting we were in. We only used one car and GPS device that was mounted to a windshield in both user studies. These factors are unrepresentative of a real scenario because users will usually drive their own cars and have their own preferences for GPS devices and positioning. The user study was always done in Pittsburgh, and so we could only sample users who drove in this neighborhood, which was not particularly dangerous or challenging. If the study had been conducted in another area, we would have obtained different results. We remedied this by

conducting interviews with users who drive using a GPS in areas other than in Pittsburgh. Passengers (i.e. the experimenters) could also influence driver decisions, since the driver was well aware that he was performing a task and being observed.

Human factors problems that we discovered from the interviews include naturalistic decision making issues, perception issues (divided attention), limited working memory, time sharing, and bottom-up processing. For in-depth analysis, please refer to the above Human Factors Problems under the Task Analysis section.

Interviews

In the Appendix, see Item 4 for our interview questions outline and Item 5 for transcripts.

User Demographics. The users were diverse in demographics and experience, ranging from 22 to 50 years old (the majority being in their 20s), male and females, and varying driving and GPS usage experiences. In addition, these users were located in different cities, states, and countries.

Methods. We first planned our interview protocol by deciding which questions to ask that would aid us in our research. Each of us conducted 1-2 interviews each for a different user, totalling 5 interviews. We recruited users who had the experience of operating a GPS device while driving and asked about their past experiences, opinions, perceptions, and attitudes about driving and usage of GPS devices. From this, we could discover new design opportunities that our think alouds did not encompass. We mainly focused on the scenario that the user encounters a situation in which they are driving while re-entering a destination address on a GPS device.

During the interview, we introduced ourselves, explaining that we were trying to understand how people are using GPS devices while driving. We estimated the length of the interview (10-15 minutes) and then asked for detailed answers using background questions (age, etc), behavioral questions (walking through last relevant experiences), and subjective

feeling/opinion questions. When appropriate, we probed the interviewees with follow-up questions to solicit detailed answers that pertained to the topic of rerouting a GPS. We concluded the interview by asking the user if there was anything else they would like to add to the interview that we did not ask.

Interview Findings. The interviewees demonstrated some consistent preferences, generally favoring the use of a GPS app on a smartphone because of availability of live updates such as traffic information. Most pulled over to the side in order to re-enter a destination address into their GPS device; one specified that while on the highway, she had to find an exit to pull over in a local destination. One exception was an interviewee who unsafely operated his smartphone's GPS while driving. Drivers had to frequently spend additional time waiting for the route to recalculate before resuming the route they were on, making the convenience of GPS devices less than desirable.

Users asserted that verbal/voice operation provided a safer alternative to the problem of being distracted and poor visual attention while operating GPS devices. One proposed a redesign idea of requiring voice input to specify destination addresses. There were also other problems we discovered other than entering new destination addresses while driving. The route that the GPS provided was not always the most efficient or optimized and not always well understood, causing drivers to become misguided and lost. This is evidenced by several drivers from the interview, who mentioned that they sometimes noticed that there was a faster route than the one the GPS provided. Also, one driver from the interview reported GPS directions causing him to go around in circles, and another missed the road and had to wait for the GPS device to recalculate it.

Human factors problems that we discovered from the interviews include optimism bias, decision making bias, and attention problems. For in-depth analysis, please refer to the above Human Factors Problems under the Task Analysis section.

Competitive Analysis

To better understand the market and current products, we conducted a competitive analysis. We analyzed several popular GPS we had on hand now, including: a Garmin GPS device, a Toyota in-car navigation system and several smartphone apps by comparing 14 dimensions based on important human factors, and categorized them into 5 general human factor dimensions including visual and audio perception, cognition, control and training, plus an extra feature dimension. Refer to Item 6 in the Appendix for our comparative data; Item 7 for photographs of each device. Looking at the data and final visualization of our competitive table (Figures 6.1 and 6.2 in the Appendix), we came up with several opportunities besides voice input and audio control as we discovered in our interviews, which might greatly increase the user experience and quality of current products involving cognition, training, control and some potential gaps in perception. For example, we found that most GPS devices have constrained screen sizes, which makes it able to display only a limited amount of information and provides limited operations. Also, most of the GPS systems still require lots of attention from the driver by having them turn their head to look at some position in the car away from the road or require high precision of operations.

The human factors-focused competitive analysis complemented our task study and interviews, exposing redesign opportunities involving visual and audio perception, control and cognition/attention.

Redesign

Opportunities & Justifications. Based on the data collected, we have determined several opportunities for redesigning the GPS device to address the problem of rerouting. We also

discovered that rerouting was not only limited to users who were trying to enter a new destination address into the GPS, but also to those who found themselves travelling on the wrong route and need recalculation from GPS device. Both situations require a significant amount of attention and concentration. Drivers need to pay attention to the primary task of driving involving the road, instrumental panels, and other information sources such as road signs. In particular, most modern navigation systems do not carefully consider drivers' cognitive loads and attention states--delivering all information in the same way regardless of context.^[2] We come up with this new design to alleviate this problem by reducing their cognitive load.

Audio. The first involves utilizing verbal/voice operation in place of visual and physical operation of GPS, a technique which many interviewees also mentioned or recommended. We plan to implement an audio feature directly into the GPS, so users can easily speak their desired function, mostly revolving around the input of a new destination address. Verbal/voice operation provided safer alternatives to the problem of being distracted and poor visual attention while operating GPS devices. In addition, 2 of the interviewees mentioned finding it easier and less diverting (due to a reduction in cognitive processing) to use audio input for GPS devices compared to manual touch screen taps. As the redesign sketch shows (Figure 8.1 in the Appendix), the driver can refer to the system as "GPS" as if it were a person, asking it to change the route, and then verbally speaking the new destination address. "GPS" provides audio feedback by reporting that it understands the driver's commands, and explains that it is now recalculating the route.

Visual. Another opportunity we identified is utilizing an augmented reality windshields heads-up display. The competitive analysis demonstrates that various GPS and maps all require relatively high level of attention and cognition. For a driver who is required to focus on the road in front of him, a small separate screen requires him to constantly need to switch his visual focus and mental attention back and forth. To reduce such distractions, a bigger screen could be applied

directly within the center of the drivers' vision. An augmented reality heads-up display that is implemented directly into the windshield eliminates the additional screen, and expands to have a "bigger" screen size for the driver. Furthermore, it reduces distractibility due to being directly in front of the driver.

In their paper, Narzt, Wolfgang, et al. report that "the augmented reality (AR) research community has been developing a manifold of ideas and concepts to improve the depiction of virtual objects in a real scene. In contrast, current AR applications require the use of unwieldy equipment which discourages their use."^[4] Integrating virtual display into the actual drivers' view is a field that research community is currently already pursuing. As the paper reports, "In order to essentially ease the perception of digital information and to naturally interact with the pervasive computing landscape, the required AR equipment has to be seamlessly integrated into the user's natural environment."

Current GPS devices isolate drivers from their primary driving task by the need of having them switch their visual focus back and forth: "Presenting information where users are already focusing their attention will reduce the effort required to shift attention from the physical space to the information space."^[1] More cognitive effort, attention, and time is necessary for a user to switch from looking outside at his environment to the screen of the GPS device, and then to make sense of the information displayed on the device. The user must compare the information with his observations of the environment. Additionally, when a user needs to re-enter a new destination, even more effort is required from the user to make sure he can find the suitable conditions to do so. It is not only unproductive but also dangerous for the driver to need to shift tasks and focuses between different spaces.

Sato, et al.^[3] point out that visual information is useful and can convey rich information to drivers because it is easy to understand and recognize in a short amount of time, with the

exception that most of the systems require drivers to move their eye away from the road to get such information. This is indeed the most serious disadvantage of current visual displays. However, it is not difficult to avoid such eye movements if we display the visual information in the windshield, which can considerably reduce drivers' attention or cognitive effort, both of which are precious resources while rerouting.

Trade-offs. Verbal/voice operation can be sometimes hard to recognize by an apparatus, especially in a car with high exposure to different noises in the environment, such as when passengers are talking or when open windows bring in outside noises. These factors could make voice recognition difficult, especially for voice input navigation when precision is required for recognizing addresses. Also, there are streets with names that are hard for voice recognition, for example, similar street names in different areas. Audio input is also not suited to those who have speaking impairments. Finally there are street names that have the potential to be mispronounced, or misconceived by foreign visitors, and the GPS would need to be internationalized to conform to those who cannot speak English well.

The majority of augmented reality windshields are currently still in development phase and extremely expensive to maintain and produce. GM and Daimler assert that augmented reality windshields are at least five years away from being available in mainstream consumer automobiles.^[5] The technology for windshields have still yet to be fully developed, and since it is not readily available, it will take some time to be tested and finalized for production. More feasible alternatives must be considered for more immediate solutions to the relevant concerns.

Another aspect that we could take into consideration in the future is a contextually optimized display. In Lee, Forlizzi et al.'s paper, the MOVE system significantly reduces driver's cognitive load by presenting information that uses an appropriate amount of drivers' attention.^[2] Our augmented reality heads-up display behaves similarly by presenting street labels in text form

that only inform the driver what the next street to turn is. They are also translucent so that the driver can still perceive the environment around them. The previous and current street names are also displayed but heavily dimmed in case a driver wants to quickly refer to them to understand where they are located in the instructions process. Guided path arrows are placed directly over streets to show drivers where they should prospectively drive to; they are translucent for similar reasons. The windshield is minimal in design, only containing these digital design elements in the screen so as to not confuse the driver from the much more important task of discriminating cues in their environment.

Sketches. Please refer to Figure 8.1 in the Appendix.

Conclusion

From our study, GPS rerouting problem can be effectively solved by our redesign. First, the augmented reality windshield display with audio input control is a good choice of navigation for drivers even in the need of rerouting. Windshield heads-up displays, unlike traditional navigation systems, do not require drivers to move their eyes away from the road to get the navigation information--which can be quite distracting and dangerous; rather, drivers save most of their attention and cognitive effort on the road condition. This is very vital and helpful for one of the rerouting scenario in which drivers drive on the wrong way waiting for the navigation to recalculate, being more nervous and confused than normal.

Furthermore, the audio control maintain drivers' overall control of the vehicle by freeing drivers' hand from moving away from the steering wheel to manually operate the GPS devices which makes it much safer than before in another rerouting scenario in which drivers need to

change the destination half way. With audio control, the drivers does not need to find a place to pull over to change the destination nor to even try changing it during driving.

References

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Appendix

1. Task Analysis

1.1: *People*

- A person with the ability to drive (by having a driver's license) an automobile
- He/she must have sufficient knowledge and experience to operate a GPS device

1.2: *User Demographics*

- 23 year old male and 27 year old female; both experienced drivers who use GPS devices often

1.3: *Equipment and supplies provided*

- Automobile for driving: Toyota Camry Solara
- GPS device or GPS-enabled smartphone: Garmin GPS device, nüvi 40LM (Figure 1)
- Windshield mount for the GPS device

1.4: *Environment or Setting*

- Total route distance is under 5 miles.
- Start point (Point A) from which the driver departs with his/her automobile.
- The driver's intended destination or end point (Point B) using a GPS device.
- A new end point following a stimulus event that causes a change in destinations (Point C).
- The driver has insufficient procedural knowledge (sequence of actions to follow route) or working memory (following driving directions based on familiar visual cues) to get to B or C.

- The route that the driver is on only include streets that are registered by the GPS device.
- To enable GPS functionality, the area containing the driving route(s) must be able to be detected by the GPS/GPS-enabled device's satellite system or receiver.
- The visibility of the environment is clear enough to see road cues and operate the GPS.

1.5: Actions required in sequence needed to operate the device

We assume that the user knows how to start-up a car. We document the time when the user is driving but prompted to input a new destination address into his/her GPS device. This task analysis is most relevant to a driver's experience, safety, and usability pertaining to our area of focus.

1. Turn on your right turn signal.
2. Look for a safe opening and change to the driving lanes to the next right lane over.
3. Repeat above steps until reaching the rightmost lane.
4. Pull over to the side of the road and park in a legal parking area.
5. Park the car or turn off the car.
 - a. Shift the car into Park (P) transmission operating mode (automatic).
 - b. Shift the car into Neutral (N) transmission operating mode (manual).
6. Set the parking brake in place.
7. Turn on hazard warning lights/flashers.
8. Enter a new destination address on the GPS.
 - a. Press “Return” (left arrow icon) button to return to the menu.
 - b. Press the “Stop” button to exit the current route.
 - c. Press the “Where To?” (magnifying glass image) button, “Address” button, and follow the on-screen location categories (country, city, postal code, etc) to input the address.

- d. Press the correct address selection, then press “Go!” to start route calculation.
- 9. Start up car again.
- 10. Turn on left turn signal; return to the road through the rightmost driving lane during safe opening.

2. Think Aloud Task Instructions

We read aloud the first step of the task instructions to the driver: “Follow our instructions as we tell you each step” and then prompted them appropriate with the following steps:

1. Using your GPS device, enter the destination to: 6343 Penn Ave, Pittsburgh, PA 15206
2. Follow the GPS’s live audio instructions.
3. You receive a phone call from a friend asking you to pick up something from another store.
You need to change your directions on the GPS device.
4. Enter the new destination to the GPS device: 877 Freeport Rd, Pittsburgh, PA 15238

3. Task Analysis Studies

3.1: User 1: EL

- **User subject profile**
 - Age: 23
 - Gender: Male
 - General experience with GPS devices: Frequent user, 2-3 years
- **Setting**
 - Test Date: Sunday, November 10, 2013
 - Time of Day: 10-11 am
 - Lighting: Good (Clear skies, sufficient sunlight)
 - Number of Passengers: 2
 - Traffic Conditions: Light traffic
- **Start Address**
 - 1252 S Negley Ave Pittsburgh, PA 15217
- **User 1 (EL) Task Analysis: Errors and Error Corrections**

Error Correction	Error	Occurrence in
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		Sequence
Turning right turn signal first.	Didn't turn on right turn signal, but instead, turned on hazard warning flashers while he was still driving on the road.	Step 1
Set the parking brake in place.	Having shifted the car into P transmission operating mode, the user didn't set the parking brake in place.	Step 6
Turn on left turn signal before returning to the road.	Didn't turn on left turn signal and went straight to the road again.	Step 10

- **User 1 (EL) Task Analysis: Decisions and choices required in sequence**

Choice	Decision	Occurrence in Sequence
In the middle of the street, user turned on hazard warning flashers instead of the right turn signal.	Whether to turn on the right turn signal, and when to turn it on.	Step 1
User was already on the only lane of a road containing two lanes moving in opposite directions.	Whether there is a safe opening to change lanes.	Steps 2 & 3
Parked in the nearest opening he could find at the side of the street.	Whether there is a legal parking area nearby - where to park car.	Step 4
Pressed brake pedal to park car. Did not pull the parking brake. Turned on hazard warning light.	What steps to follow to park my car. When/Whether I need to press the brake pedal, pull the parking brake, put the car in Park, and turn on hazard warning light.	Steps 5-7
Didn't turn on left turn signal and went straight to the road again.	How to start my car and return to the road.	Steps 9 & 10

3.2: User 2: JR

- **User subject profile**
 - Age: 27
 - Gender: Female
 - General experience with GPS devices: Occasional user, 4 years
- **Setting**
 - Test Date: Sunday, November 11, 2013
 - Time of Day: 2-3 pm
 - Lighting: Good (Clear skies, sufficient sunlight)
 - Number of Passengers: 1
 - Traffic Conditions: Light traffic
- **Start Address**
 - 150 Atwood Street, Pittsburgh, PA, 15213
- **User 2 (JR) Task Analysis: Errors and Error Corrections**

Error Correction	Error	Occurrence in Sequence
Park in a legal parking area that does not violate any street/driving laws.	Parked in an illegal area next to a fire hydrant (curb marked with a yellow line), noting that she was parking here for “only a minute”.	Step 4
Set the parking brake in place.	Having shifted the car into P transmission operating mode, the user didn’t set the parking brake in place.	Step 6
Turn on the hazard warning lights.	After parking the car, the user did not turn on her hazard warning lights.	Step 7
Turn on left turn signal before returning to the road.	Didn’t turn on left turn signal and went straight to the road again.	Step 10

- **User 2 (JR) Task Analysis: Decisions and choices required in sequence**

Choice	Decision	Occurrence in Sequence
Turned on hazard warning flashers instead of the right turn signal.	Whether to turn on the right turn signal, and when to turn it on.	Step 1

Checked mirrors and blind spot before changing into the next lane.	Whether there is a safe opening to change lanes.	Steps 2 & 3
Parked in a yellow-lined curb next to a fire hydrant.	Whether there is a legal parking area nearby - where to park car.	Step 4
Pressed brake pedal to park car. Did not set the parking brake or turn on hazard warning lights.	What steps to follow to park my car. When/Whether I need to press the brake pedal, pull the parking brake, put the car in Park, and turn on hazard warning light.	Steps 5-7
Didn't turn on left turn signal and went straight to the road again.	How to start my car and return to the road.	Steps 9 & 10

4. Interview Questions

The following is a general format we used for interviewing our participants. We did not necessarily use all of the questions; we adjusted our conversations based on the interviewees' responses.

Age (in years), Driving Locations, Driving Experience (in years): GPS Usage Frequency/Experience.

1. Do you use navigation while driving?
 - If they don't: Have you ever used navigation while driving?
 - If they do: Proceed to #2
2. What device do you use when you need navigation directions while driving?
 - Professional GPS devices, (Garmin, TomTom, etc)
 - In-dash/car GPS
 - Smartphone apps (Google Maps, Apple Maps, etc.)
 - Physical maps
3. What kind of device do you prefer for driving navigation ? Why?
4. Have you ever encountered a situation where you needed to change your route on a navigation device while driving?
 - [If yes] Can you describe/walk me through your last time needing to reroute your navigation device while driving?
5. (If the user doesn't pull over to operate his phone/GPS/other devices)
6. Do you think it's dangerous to pull over while operating a navigation device? Why?
7. What other ways do you think you could use to change routes on your navigation device while driving?

- (In comparison to now)
8. When you are focused on using your GPS device, what specific problems do you have while driving?
- Anything regarding changes in your regular operation of driving?
9. Can you describe a time where a navigation device made your driving experience longer than it should?
- Harder than it should?
10. Do you have anything else you want to say? Or do you have other experience with your navigation device that you'd like to share?

5. Interview Transcripts

5.1: User 1: GE

Interviewer: Scott

Interviewee: GE

Age: 25 years old

Driving Areas: SF Bay Area + San Diego, CA

Driving Experience: ~10 years

GPS Usage Frequency/Experience: 5 years. 4-5 times a week.

1. Do you use navigation while driving?

- Every single time I need to have my navigation on while I drive. I am not someone who is very good with directions.

2. What device do you use when you need navigation directions while driving?

- In the past, before I had a smartphone, I used the regular GPS made by some company called V7 (I think). It wasn't that accurate, I would run into a lot of problems. In the past I used it less frequently; I would print out directions and looked at an overview before I got here. Now I use my smartphone because it has a GPS on it and it is pretty accurate

3. What kind of device do you prefer for driving navigation?

- My smartphone. I use Google Maps on my Smartphone, in the past it was iPhone and it was Apple's navigation.

4. Have you ever encountered a situation where you needed to change your route on a navigation device while driving?

- There are some times when I accidentally go on a route -- I miss my turn, so it automatically recalculates. There are also times when I just change my destination in the middle of my trip. So I would just enter in the new address while I drive.

5. Can you describe/walk me through your last time needing to reroute your navigation device while driving?

- When I'm going somewhere, and in the middle of going there, I think of a better place to go to, I stop the current navigation and then I go back. Before you enter in a new address, you have to stop the current navigation. So I stop it, and then I type in the new address.
- This is what I do now - however in the past with the iPhone, Siri was IMO more user-friendly than Samsung's S Voice. When I wanted to change directions in the past, I would use Siri, and go "Give me directions to, ...etc"

6. So you're saying when you use Siri, you talk to it, using more of verbal/audio instructions?

- Right. Give me directions, 1, 2, 3, 4 street drive.

7. And your Samsung phone?

- I type it.

8. So you say you change directions on your phone while you drive. Is that correct?

- Yes, however it doesn't happen very often. Technically I'm doing something illegal. Actually I don't think it's illegal...?

9. Do you think it's dangerous to type in a new destination while driving?

- I think it depends on the person.

10. What is a benefit that GPS provides you while driving, compared to when you drive without one?

- My GPS gives me step by step instructions. As someone with bad direction sense, I feel very secure when it tells me when my next turn is. I don't have to be afraid when I miss it - it reroutes immediately, and I just make a next right, and make a detour. But if I don't have a GPS, I would not be able to get to my destination. Like I said before, I have to print out directions unless I was already familiar with where I was going to. I would call my friend to give me directions, ask him "Hey how do I get there?" But that never happens because we all have smartphones.

11. Are there any difficulties you might have with a GPS?

- There were a few times in the past where a GPS took me to a completely different location. That was frustrating.

12. It wasn't your intended destination?

- Yeah. It takes me not to where I want to go. THis doesn't really happen nowadays.

13. What do you find easy about rerouting a GPS device while driving?

- In the past, what made it difficult was that it would search for satellites for way too long for my GPS to find out where my current location is. I think what's "easy" about the current GPS is that if I need to change directions, it just gives it to me immediately and tells me how to get there from my current position.

14. When you reroute on a GPS device today, it just gives you the new directions instantaneously?

- I don't run into any problems.

15. Do you experience a "Route recalculating"... etc at all?

- The satellites locate you pretty quickly nowadays, and while you're driving, it already knows your location, so when you enter in a new location, it gives it to you immediately.

We have 4G now, and the GPS tracking device is way more advanced than in the past. So it's easy to track where you are - it's fast.

16. On a scale from 1 to 10 (1 easiest, 10 hardest), how easy do you find using a smartphone as a GPS device while driving?

- I don't understand what a difficult situation would be like. Here's a situation: when I actually drive with a person, every time the passengers asks me if they should hold the phone for me, because they all assume it would be easier. However for me it's not easier, I like having the GPS right in my lap, or right where I can see, and if someone's holding it, I cannot see it. Majority of the time, when someone's holding it, and navigating me, it does not work. I would often not know which turn I'm supposed to make, or they would forget to tell me that a turn was coming up. If I had the GPS, I would be able to know right away, for example, it would show me, how far I was expecting a turn, I can just look at it real quickly, as opposed to asking them. I think the communication for them to be my eyes is more difficult.

17. What other ways do you think you could use to change routes on your navigation device while driving? (In comparison to now)

- I don't think it's the GPS problem, I think if it ever malfunctions, it has to do with the smartphone because oftentimes my phone would freeze, and has nothing to do with GPS. To improve it, right now the routes they give you are not the most efficient route. Even though it's Google, for some reason, very often, they give you a route that's longer than you need to take. Google once gave me directions to go in a circle.

18. So you would say that the routes they gave you were not the most efficient.

- The engineers need to rewrite the algorithm - calculate a better route

19. And you hold your phone and operate it while you drive?

- Yeah I do. Even though it's illegal--is it?

20. Why do you feel safe using the phone while you drive if it might be illegal?

- I feel that laws are created because someone got into an accident and they want to prevent it from happening again. There are so many drivers out there, it's bound to happen to someone who is driving while using their phone. I would say I'm really good at driving, and I'm really fast and perceptive, so I don't worry too much.

21. What other ways do you think you could use to operate your smartphone while driving? (Since you hold it)

- If I weren't holding it, I would put it somewhere where I could see it, so I would either put it on a mount or in the cup holder.

22. Do you have anything else you want to say? Or do you have other experience with your navigation device that you'd like to share?

- I wanted to mention that I really like the feature about notifying you when a turn is coming up. This became really prominent when GPS devices first came out, it was the most rational thing to implement into this sort of device. People would not know when a turn is coming up. Everytime 100 feet before your turn, it would remind you. Sometimes I've had devices where they reminded me too much. In 400 feet, you need to turn. 200 feet.

Turn now. Too many times! That makes my experience a lot easier, because I would be distracted and I would forget when my turn was, or be unfamiliar with the streets around me. Having them telling me when I should expect to turn is very helpful.

5.2: User 2: JC

Interviewer: Scott

Interviewee: JC

Age: 26 years old

Driving Areas: San Diego + Irvine, CA

Driving Experience: 7 years

GPS Usage Frequency/Experience: 3 years. 4-5 times a week.

1. Do you use navigation while driving?

- Yes I do.

2. What device do you use when you need navigation directions while driving?

- I use my Google Maps and Navigation app on my smartphone (Samsung Galaxy S4).

3. Have you ever encountered a situation where you needed to change your route on a navigation device while driving?

- Yes.

4. Can you describe/walk me through your last time needing to reroute your navigation device while driving?

- Last time I was driving to work from my new place, but I went in a different direction from the original route, so then I had to reroute it. I was lost for a little bit because I had to wait for it to reroute. But then it was ok.

5. Did the smartphone give you directions wrong the first time?

- No, it wasn't wrong. I just took the wrong direction it was telling me to go.

6. The smartphone gave you a set of directions, why was it not clear to you?

- Usually when it tells me a certain direction, like North/West/South/East, I don't really know what direction that means. Left, or right, and that's confusing.

7. When you had to reroute your GPS device, how did you do it?

- It reroutes by itself, but sometimes you have to wait for it. Sometimes that isn't good, if there's no stop sign or red light and then you're still waiting for it, but you have to keep going. You have to wait for it to reroute. So that's inconvenient.

8. So you drove to the wrong place, so you were just waiting for the GPS to recalculate?

- I had to drive slower. I was also in a rush to get to work so it was inconvenient for me in that situation.

9. Do you have an experience where you had to reenter a new address into the smartphone?

- Yes.

10. Can you describe what happened?

- It was kind of dangerous, because in the middle I had to unexpectedly change the address. But since I'm on the highway, it's really hard to change it. In the end, I went off the exit to change it, but it was unsafe because I was trying to change it at the same time because of time constraints and I was trying to do it quickly. But it was unsafe, so I actually just didn't do it and went to the nearest exit to do it there. That took more time. That was in the end more inconvenient.

11. When you are focused on your GPS what specific problems emerge while driving?

- I have split attention. My awareness of other cars and any changes on the road are reduced.

12. Anything regarding changes in your regular operation of driving?

- I'm not always looking at the road.

13. Why do you think it's dangerous to operate the smartphone while driving?

- When you're driving, you have to be aware about everything around you. There's something happening in front of you, behind you, next to you. Sometimes even for just 1 second, something can happen. I wish there was using something like voice to change it, but maybe there is and I didn't know about it. Something that I don't have to type or look at the phone, when I'm looking at the phone I'm not focusing on the road, and that's already pretty dangerous.

14. What other solutions besides voice would you propose?

- I feel like that's the only way. If you want to push a button, you still have to look at the phone. I need something where I'm not looking at my phone. To be honest, even voice is distracting from driving.
- Maybe presetting numbers corresponding to addresses, so you just have to say the number, and that's really fast and easy. But you would have to know the number... so you can't do too many, or you'll lose track. Maybe buttons in different areas, you just have to press it to change it. Not on your phone though, it has to be somewhere on your car. I don't know how that would work. It has to be something that minimizes your distraction. I still want to be as focused as possible while driving while not being distracted by changing something last minute.
- Besides voice - you know how you can choose radio stations, you can press the arrow up and down, since that's the same thing. It's something we're familiar with. We can do it for addresses too, maybe. 1 is for this radio station, press the arrows to go "I want to change it to this address." Something familiar.

15. Can you describe a time where a navigation device made your driving experience longer than it should?

- Sometimes the directions are inaccurate and I end up going in circles. Having to do it myself, so that takes longer.

16. When the GPS gives you the wrong directions, ...

- I have to keep looking, and driving around, I have to keep circling around and figuring out where I am. I have to do it myself. It takes a lot longer.

17. Do you have anything else you want to say? Or do you have other experience with your navigation device that you'd like to share?

- In the end, I use GPS a lot. I like to know what the traffic is like. It's annoying when I don't know what the closest streets are. I don't have time to look at maps, but it's faster than opening up a paper map and looking at it. In the end, I would still use it, but I don't feel like if I don't have to change addresses, I might take longer. There's pros and cons. It's something I use everyday almost if I'm going somewhere new. It does save time, it gives you the fastest route and traffic information. It has made my driving a little more dangerous. When I see something unexpected, I might focus more on that than the road. Safety concerns should be implemented into redesigning a GPS.
-

5.3: User 3: DD

Interviewer: Xiaoyue

Interviewee: DD

Age: 50 years old

Driving experience: ~10 years

GPS usage experience: ~4 years

1. Do you use navigation while driving?

- If it's somewhere I'm not familiar with, I would certainly use navigation.

2. What device do you use when you need navigation directions while driving?

- I sometimes use in-vehicle GPS. But I prefer map app on a smartphone. Occasionally I use physical map too.

3. What kind of device do you prefer for driving navigation?

- Smartphone>in-vehicle GPS>physical map

4. Have you ever encountered a situation where you needed to change your route on a navigation device while driving?

- There are lots of times when I drive to the wrong road. I usually find that out until I see on my GPS that I'm beginning to deviate, but then I have already made mistakes. I could only continue to drive on in the wrong way and wait for my GPS to recalculate.

5. Can you describe/walk me through your last time needing to reroute your navigation device while driving?

- I have not encountered a situation where I need to set a new address while driving. If that happens, I would pull over, stop inside a white line, and use my 4-way flashers. Then I would set a new destination with my GPS.

6. On a scale from 1 to 10 (1 easiest, 10 hardest), how easy do you find using a GPS?

- 8.5

7. On a scale from 1 to 10 (1 easiest, 10 hardest), how easy do you find using a smartphone as a GPS device while driving?

- 9

8. On a scale from 1 to 10, how satisfied are you with your device when you reroute?

- GPS: 8.5-9

9. Can you describe a time where a navigation device made your driving experience longer than it should?

- Yes. When I have to use a GPS, I doubt if it is leading me the shortest way. I might spend more time driving because it's not an optimized route, but as long as I follow it I feel safe in that at least I will eventually get there.

10. Do you have anything else you want to say? Or do you have other experience with your navigation device that you'd like to share?

- I am really bothered by going to the wrong direction because I have not enough clues when I am about to exit, or at an intersection. That happens a lot. I have absolutely no idea why I end up at a wrong way.
 - Road changes all the time, but updating in-vehicle GPS is a pain. That's a major reason why I prefer a smartphone: they always have the latest map.
-

5.4: User 4: YL

Interviewer: Wang

Interviewee: YL

Age: 22 years old

Driving experience: 4 years

GPS usage experience: 2 years

1. Do you use navigation while driving?

- Yes.

2. What device do you use when you need navigation directions while driving?

- I use Google Maps on my iPhone before I start driving. During driving, I use Garmin GPS device.

3. What kind of device do you prefer for driving navigation?

- I prefer Garmin GPS device

4. Have you ever encountered a situation where you needed to change your route on a navigation device while driving?

- Yes.

5. Can you describe/walk me through your last time needing to reroute your navigation device while driving?

- I never reroute my device while driving because that can be distracting. I will pull over to reset the device.

6. On a scale from 1 to 10 (1 easiest, 10 hardest), how easy do you find using a GPS?

- 5

7. On a scale from 1 to 10 (1 easiest, 10 hardest), how easy do you find using a smartphone as a GPS device while driving?

- 6

8. On a scale from 1 to 10, how satisfied are you with your device when you reroute?

- Garmin: 8; Google Maps on the iPhone: 7

11. Can you describe a time where a navigation device made your driving experience longer than it should?

- The Garmin GPS device doesn't show the traffic conditions as the iPhone does. So Garmin chooses a short route for me but it takes a long time because of the heavy traffic.

12. Do you have anything else you want to say? Or do you have other experience with your navigation device that you'd like to share?

- I found Garmin GPS device quite useful because it always show you which lane to drive on. The driver can change lane and be prepared in advance.
-

5.5: User 5: CW

Interviewer: Wang

Interviewee: CW

Age: 23 years old

Driving experience: 5 years

GPS usage experience: 2 years

1. Do you use navigation while driving?

- Sometimes, only when I'm driving to unfamiliar places.

2. What device do you use when you need navigation directions while driving?

- "Here" map. A integrated app of Nokia.

3. What kind of device do you prefer for driving navigation?

- GPS with voice guide

4. Have you ever encountered a situation where you needed to change your route on a navigation device while driving?

- Yes. When I missed a turn or went into a wrong way.

5. Can you describe/walk me through your last time needing to reroute your navigation device while driving?

- I was driving to the Chinese grocery with my friend, and he misguided me to the wrong way and I had to reroute my navigation.

6. On a scale from 1 to 10 (1 easiest, 10 hardest), how easy do you find using a GPS?

- 9

7. On a scale from 1 to 10 (1 easiest, 10 hardest), how easy do you find using a smartphone as a GPS device while driving?

- 9

8. On a scale from 1 to 10, how satisfied are you with your device when you reroute?

- 8.5

11. Can you describe a time where a navigation device made your driving experience longer than it should?

- One of my friends was driving to D.C. from NYC one day (I was in the car), and he set D.C. as his destination point, but somehow that trip took us 7 hours (which should only be about 3 hours max). The reason was that he mis-set the GPS to go the cheapest route (which means with the least amount of toll gates), and obviously it would definitely take much longer time.

12. Do you have anything else you want to say? Or do you have other experience with your navigation device that you'd like to share?

- Since I do not have a data plan for my smartphone, and most of the GPS devices in the market are very crappy, I prefer phones with navigation apps that can function under the situation of having no wi-fi or cellular access. And this is why I like the “Here” map app of Nokia because it can navigate even without wi-fi or cellular.

6. Competitive Analysis

1-5 scale		Visual Perception				Audio Perception Discriminability from the environment/the background (the Hz.)			Cognition / Attention		Control		Training		Features		
(Reference)	Legibility	Contrast	Discriminability	Language Support		Enunciability		Cognition workload reducibility	Easiness of selecting a destination	Easiness of renaming 1, easier to cancel because of extra operations due to the number of buttons and slow responses of the touch screen	Easiness of onboarding	Screen Size	Connectivity	Information display			
Toyota Solara Navigation System (in-car)	2, the resolution is low. 4, good enough resolution, and good choice of text, font, font size, etc. Except for the confusions while approaching an intersection with several levels with different attitudes	3, not perfect choice of red and green on black background 4, good color scheme that makes it contrasty.	4 Texts are clear, but some colors on the map are a little bit less discriminable	1 Only English and French	4 Quite discriminable	4 Easy to understand		2, the position of the screen is relatively far from the windshield which distracts more	2, hard to operate due to the number of buttons and slow responses of the touch screen	1, easier to cancel current navigation are needed	2, need a certain amount of effort to learn		2 It even lost the connection on freeway.	3 Provides basic navigation information			
Garmin GPS Portable GPS Navigator (nuvi 40LM)	4, good enough resolution, and good choice of text, font, font size, etc. Except for the confusions while approaching an intersection with several levels with different attitudes	4 good color scheme that makes it contrasty.	4 Texts are clear, but some colors on the map are a little bit less discriminable	5 Excellent! 31 text languages 30 keyboards 13 voice languages	4 Quite discriminable	4 very clear voice with medium speed		4 The position is just at the near windshield, but still need some time to receive information	4 Need to be done by multiple touches which is hard and dangerous during driving	4 Toyota and better auto-complete that speed up the process	4 Quite easy to use, all instructions and input interactors and self-explicit and understandable		3 It loses satellite reception in some tunnels or isolated areas A few times it cannot connect satellite on the street or in the garage in cities	4 Except for the traffic information			
Google Maps Navigation (Beta)	http://en.wikipedia.org/wiki/Google_Maps	5, good color	4 Texts are clear, but some colors on the map are a little bit less discriminable	5 Excellent. Using in-built language pack from iOS or Android	4 Quite discriminable	3.5 annoying female voice, moderately fast speed		3 Position can be held by hands, which is not meant as a primary device so may suffer from casual use if there is no equipment to support it	4.5 Voice input available. Need to tap screen once to exit navigation, then tap text field and enter a new destination	4 Can also search by name (e.g. restaurant name). Voice input available	4 Quite easy to use, all instructions and input interactors and self-explicit and understandable	2 Based on size of phone	5 Data connection & GPS Signal may include Extended Precision Orbit, which speeds the fix,[9] and/or Wi-Fi positioning system where GPS is unavailable	5 Distance, Estimated time of arrival, traffic view, satellite view, street view, nearby amenities, route(s) to destination, turn-by-turn directions			
Physical Map	1. Text is small. Sometimes even affected by printing quality.	4 dark text colors on light background, large text and bolded text 3. Usually poor contrast. Also depends on printing quality. Color changes with time goes by	2 Very low discriminability in dim environment	1. One single language	0. N/A	0. N/A		1. Requires a lot of workload, since the driver has to hold the device with one hand or both hands when referring to it	1. Hard. Have to manually look for destination	1. Hard. Have to manually plan a new route	5. No special training needed	0. N/A	1. Limited and static display with tiny characters.				

Figure 6.1: Competitive Analysis Table

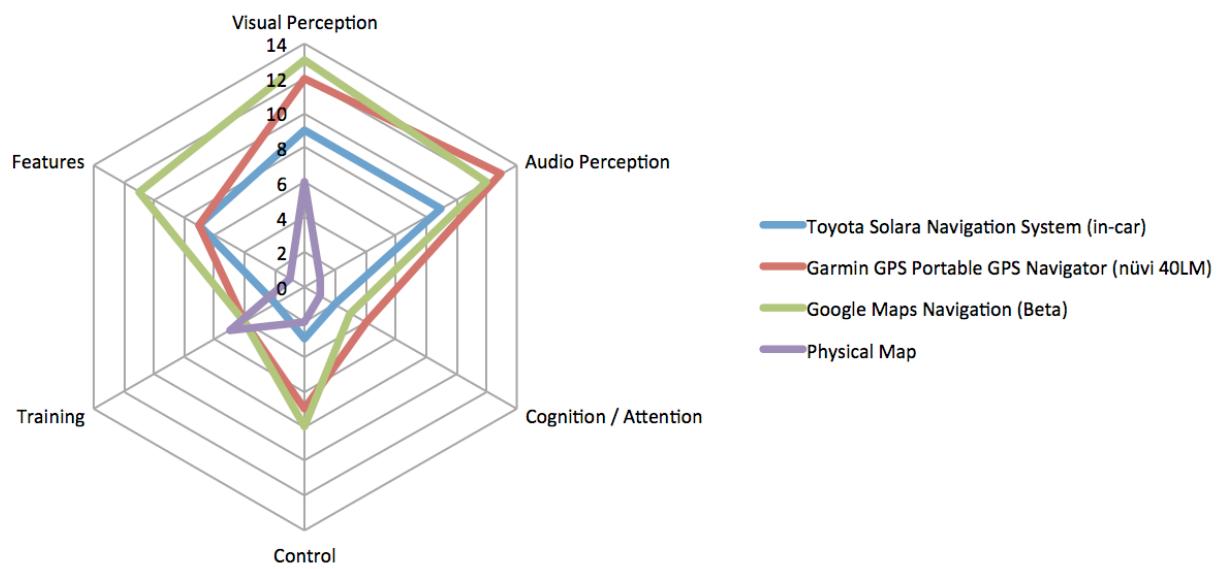


Figure 6.2: Competitive Analysis Visualization

7. Photographs of Current Device



Figure 7.1: Garmin GPS device (model nüvi 40LM) during live navigating operation

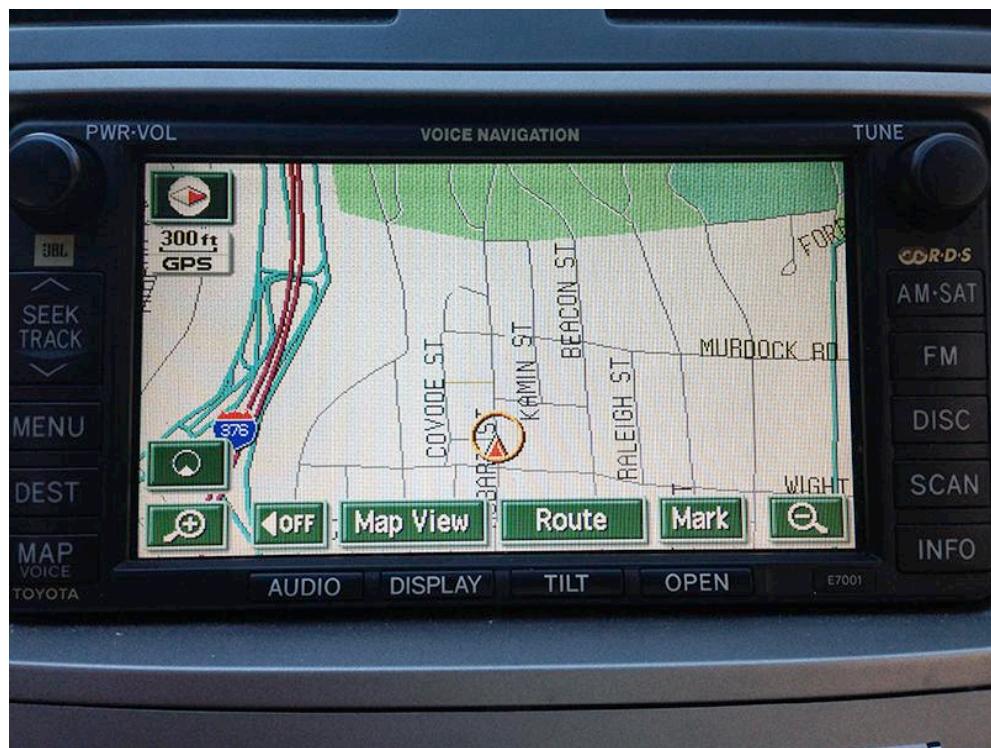


Figure 7.2: Toyota Camry Solara in-car GPS system during live navigating operation



Figure 7.3: Toyota Camry Solara in-car GPS system during address input operation

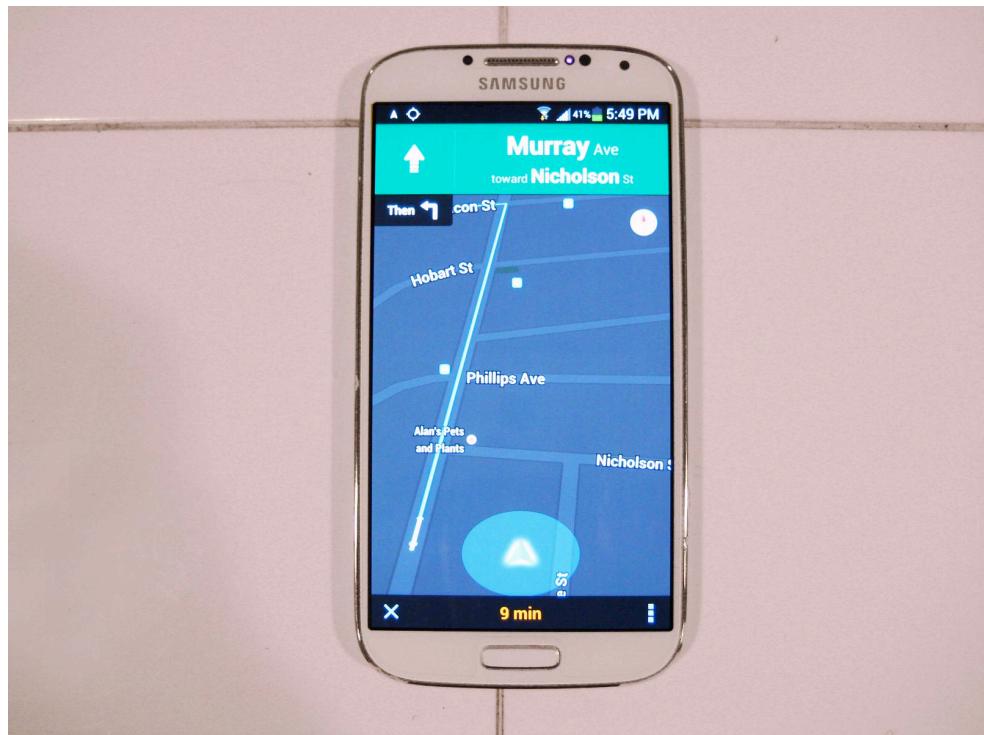


Figure 7.4: Google Maps Navigation app on smartphone during live navigating operation

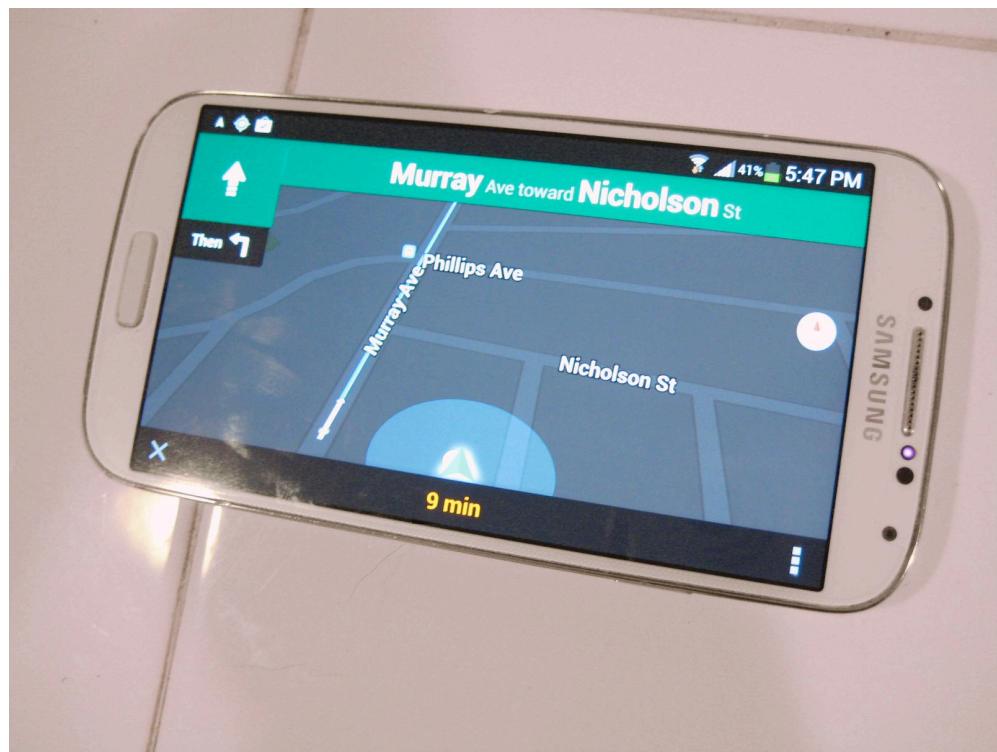


Figure 7.5: Google Maps Navigation app on smartphone during live navigating operation



Figure 7.6: Paper map of Pennsylvania - overhead view



Figure 7.7: Paper map of Pennsylvania - close-up view

8. Redesign Sketch

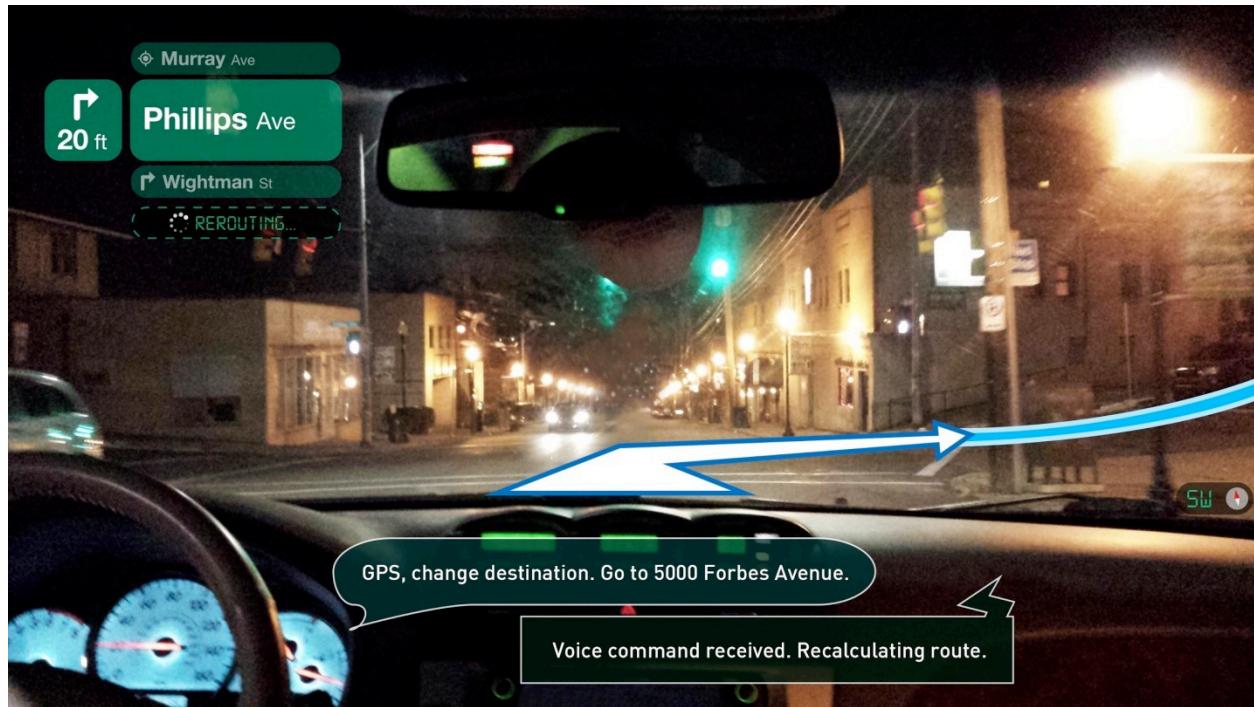


Figure 8.1:

Redesign prototype involving a windshield displaying live navigating operation.

- (1) Augmented reality heads-up display (top)
- (2) Storyboarding rerouting via Audio Input (below)