APPENDIX

NavAware

Data-centric design of a user-aware navigation agent for blind mobility

Master thesis
by Akari Takada

Appendices

A
Project brief

Appendix A

Personal Project Brief - IDE Master Graduation

TU Delft

Design of an intelligent agent to simplify the travel experience for BVIPs — project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 24 - 02 - 2022 — 20 - 07 - 2022 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

"Travel, transport, and mobility" is an important and common issue blind and visually impaired people (BVIPs) face in their daily lives. Other than human guides, guide dogs, and white canes, BVIPs use electronic travel aids (ETAs), which are devices with sensors, and smartphone applications for assistance during travel, as shown in figure 1. A combination of these tools help users tackle the various challenges in travelling, including environment understanding, obstacle avoidance, street crossing, and use of public transportation (El-taher et al., 2021) (figure 2). Technological advancements in sensor technology and computing power of smartphones have rapidly increased the development of ETAs and smartphone applications to assist BVIPs in mobility. However, the user acceptance has remained low due to problems in usability and proper analysis on the user needs (Cuturi et al., 2016). This has resulted in the increasing number of "disability dongles", or products that are well-intended but ultimately an useless solution.

The main problem for both BVIPs and smartphone applications lie in the complex interface. First, there is a lack of integration amongst the different applications, which forces users to search for the information they need themselves. For example, one visually impaired individual mentioned having to constantly switch between Google Maps for navigation and Blindsquare for intersection navigation (Swobodzinski and Parker, 2019). Second, current interfaces are not designed based off of scientific studies that provide information on how BVIPs understand spaces (Cuturi et al., 2016). This results in interfaces that provide unnecessary or information that is hard to understand. Therefore, for the travel aid to enable BVIPs to navigate and travel independently, the right information needs to be communicated at the right time in a simple manner through audio and haptic interfaces without causing cognitive overload.

This project started as a collaboration between the Expressive Intelligence Lab (EIL) at TU Delft and Bartiméus, a large Dutch expertise organization for the blind and visually impaired. Marco Rozendaal, the director of EIL and chair of the project, has been researching the human-agent interaction of intelligent, data-intensive products that leverage information from itself, the environment, and users, to work more efficiently and effectively. An agent is a technology or object that can not only automate time-consuming stages of information processing (e.g. finding, sorting, analysing information), but also acts as if it has its own motivations. Paul de Nooij, the mentor from Bartiméus, provides expertise on VIPs in mobility as well as connections with the BVIP community in the Netherlands. This collaboration led to a proposal that an agent-based interface, which is increasingly being implemented to simplify the user interaction of data-intensive products and services, could also benefit BVIPs in mobility. This topic has been previously explored through a group of students in the Advanced Concept Design (ACD) course.

The insights from the user research that was done in the ACD course as well as the extensive amount of literature on assistive devices for BVIs gives me an opportunity to implement the research and empathising phase for this graduation project through a slightly different approach: data-centric design. Jacky Bourgeois, the mentor of the project, conducts research on ethical and collaborative design methods that leverage behavioral data at the Data-Centric Design Lab. In collaboration with users, behavioural data during navigation will be explored and analyzed to find additional insights.

There are two main limitations that need to be considered in this project: the COVID pandemic and language differences. In this project, the user sessions will play a vital role. Special considerations should be made in regard to health during user testing and also while gathering participants. In addition, it can be predicted that many of the participants are more comfortable speaking in Dutch. As I do not speak Dutch myself, proper screening of participants who are comfortable speaking in English will be conducted.

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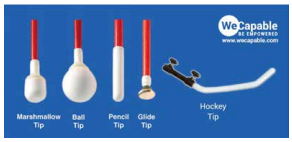
Appendix A

Personal Project Brief - IDE Master Graduation

TU Delft

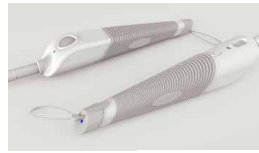
introduction (continued): space for images

White cane



Guide dogs

Electronic travel aids



WeWALK

Smartphone applications

Blind Square
Navigation through audio, points of interest, and safe intersections

Microsoft Soundscape
Navigation through Soundscape spatial audio

Lazzus
Navigation app that allows exploration of surroundings

be my eyes
Connects BVI with sighted volunteers

wayfindr
Indoor navigation

moovit
Route planning for all modes of transportation

Google Maps
Route planning and navigation apps with acessibility options

image / figure 1: Overview of tools BVIPs use while travelling.

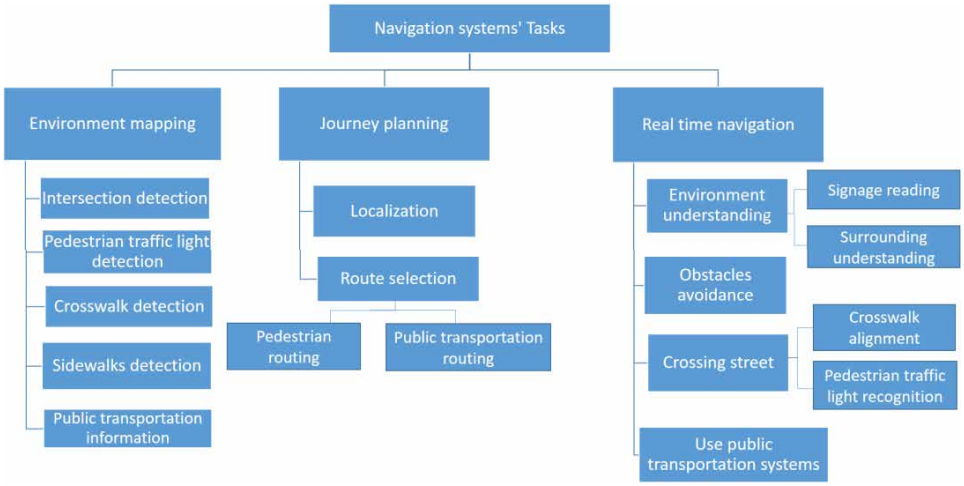


image / figure 2: Tasks that support BVIPs in mobility (El-taher et al., 2021). Additional tasks were added.

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PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

The issue that is addressed in this project is the complex interaction of smartphone applications made to assist BVIPs in mobility. The complexity arises from the lack of an interface that filters and selects relevant information based on the context and needs of the users, leaving the users searching for information themselves. The scope of the project is defined by the following aspects.

1. Product
This project will focus on the user interaction with an intelligent agent. Therefore, the software and electronics or sensors that the user does not directly interact with (e.g. sensors for environment understanding and obstacle avoidance) are out of the scope.

2. User group
The target group will be limited to severely visually impaired or blind individuals, who cannot rely heavily on visual cues. This group will be referred to as BVIPs.

3. Travel
Amongst the several components regarding travel, the project will focus mainly on route selection and real-time outdoor navigation when walking. A specific scenario (e.g. crossing streets, using public transport) is intentionally not chosen, since this is one of the issues that are to be addressed.

4. Location
The product should be designed for navigation in the Netherlands.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

Investigating the effectiveness of an intelligent agent for BVIPs in mobility. This will be done through a conceptual design of an intelligent agent developed through a data-centric participatory approach. The main focus will be on the human-agent interaction, rather than the actual interface of the intelligent agent.

The main direction for solving the problem of the BVIPs having to constantly search for relevant information while travelling, will be to explore the use of an intelligent agent. Intelligent agents are equipped with abilities to sense the user and environment, autonomously act on the collected data, communicate with the user and each other, and learn (Cila et al., 2017). Therefore, intelligent agents act as if it is a partner, rather than a tool.

As interaction with intelligent agents has never been investigated before in the context of mobility for BVIPs, the main question to be answered is: Are intelligent agents effective for simplifying the process of obtaining information and improving the travel experience for BVIPs?

In order to investigate this question, a conceptual design of an intelligent agent will be created. This will also serve as the final result of the project. In addition, as an attempt to gain in-depth insights that cannot be obtained through traditional user research methods such as interviews and observations, behavioural data will be used as a material to build upon the participatory design process.

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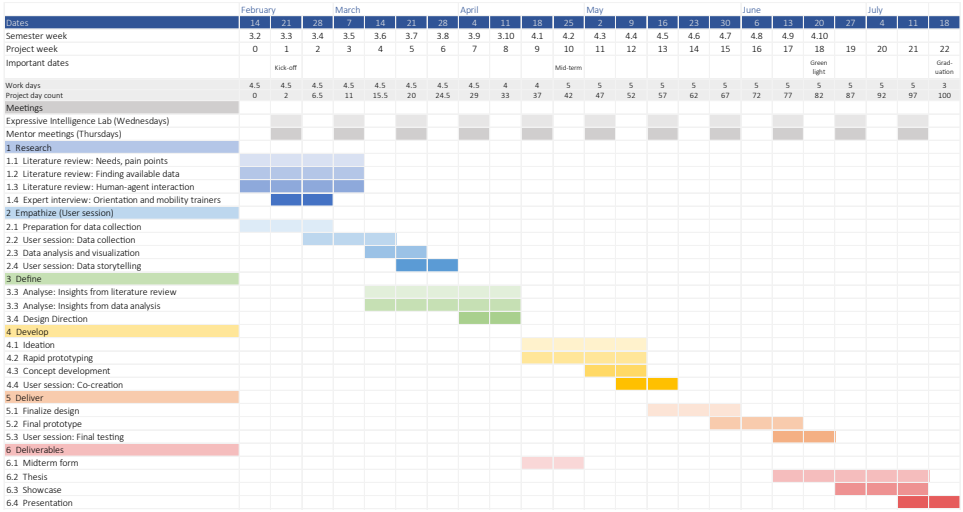
PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 24 - 2 - 2022 20 - 7 - 2022 end date



Approach

1. Understanding capabilities of users and the agent, as well as the needs and desires of the user.
 • Define the situations that should be understood.
 • Understand the information people have access to and need to understand the situation.
 • Understand how they connect the information to build knowledge.
 • Understand the information the agent has access to.

Method: User session and literature research

2. Determine how the agent will support the users by defining intentions and tasks of both the user and the agent.
 • Understand underlying biases, interaction expectations, and decision-making styles of the user.
 • Define the intentions of the agent.
 • Define the tasks of the agent.

Method: Analysis of information from previous stage

3. Design of agent behaviors and interaction.
 • Explore different ways of portraying the intentions through the behavior.
 • Investigate how the user perceives the agent.
 • Evaluate if and how the agent improves the travel experience for users.

Method: Ultra rapid prototyping, Wizard of Oz prototyping, and user session

Parallel activities: Teaching assistant during Quarter 3 (4 hours per week for 8 weeks)

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MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

Motivation

My motivation for this project comes from my future goal of being able to design interactions of intelligent, data-intensive products. My personal interest in an interface that doesn't rely on visuals was also a driving factor.

In my bachelors, I have explored interaction design from an engineering perspective at a robotics lab that specializes in haptics and force feedback control. However, since the research was focused on the technical aspects, I felt disconnected to the users and could not imagine how the research would be applied in real-life. This is what drove me to come to TU Delft and learn industrial design engineering. This project is an opportunity for me to explore a similar field from a design perspective with more emphasis on the interaction than the technology behind it. Nevertheless, being able to design the interaction of a data-intensive product still requires experience and understanding of the mechanisms behind the intelligent system. Hopefully, this graduation project will result in a product that will demonstrate my interests and some experience in designing the interaction of intelligent, data-intensive products.

Personal Ambitions

1. In depth knowledge on the interaction design of physical products from a design perspective
2. Experimenting with how data-driven design can benefit my design process
3. Practical knowledge and skills of designing an data-intensive systems

References

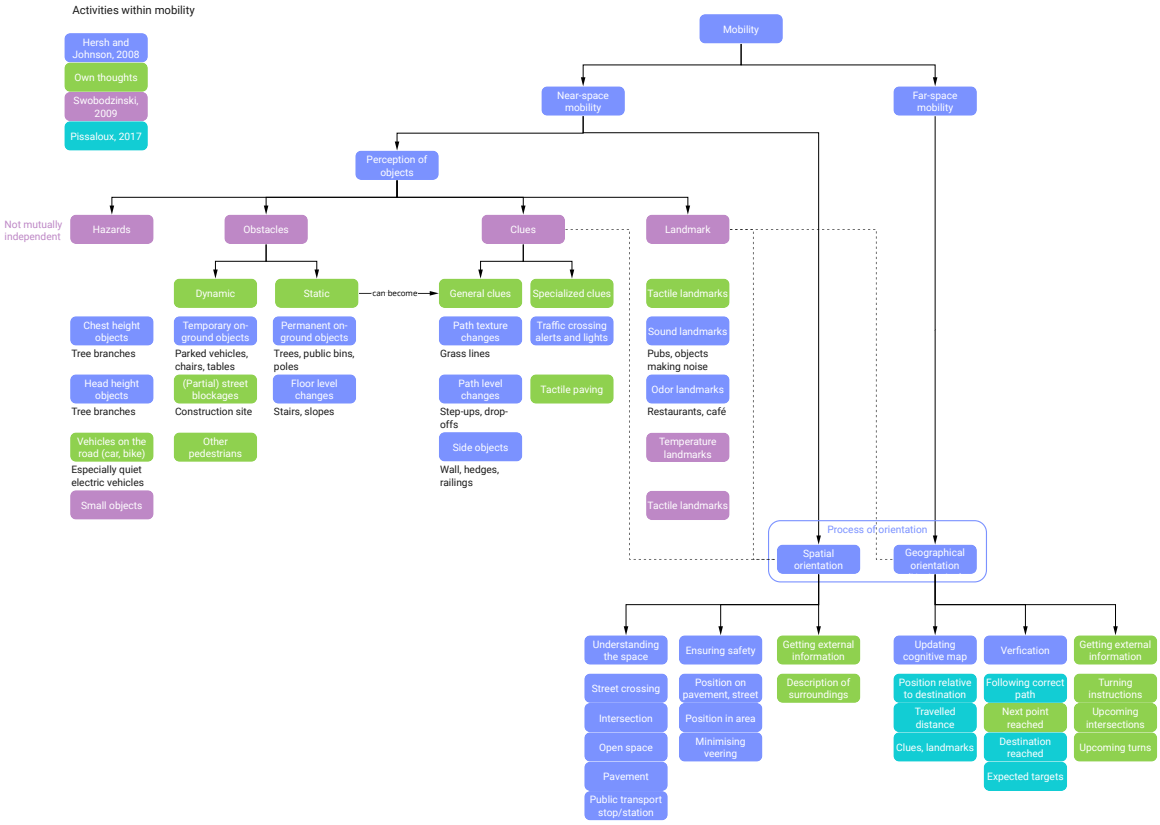
Cila, N., Smit, I., Giaccardi, E., & Kröse, B. (2017, May). Products as agents: Metaphors for designing the products of the IoT age. In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (pp. 448-459).
Cuturi, L. F., Aggius-Vella, E., Campus, C., Parmiggiani, A., & Gori, M. (2016). From science to technology: Orientation and mobility in blind children and adults. Neuroscience & Biobehavioral Reviews, 71, 240-251.
El-Taher, F. E. Z., Taha, A., Courtney, J., & Mckeever, S. (2021). A systematic review of urban navigation systems for visually impaired people. Sensors, 21(9), 3103.
Swobodzinski, Martin. & Parker, Amy T. A Comprehensive Examination of Electronic Wayfinding Technology for Visually Impaired Travelers in an Urban Environment: Final Report. NITC-RR-1177. Portland, OR: Transportation Research and Education Center (TREC), 2019.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

B
Brambring's travel model

Appendix B


Activities within mobility
Hersh and Johnson, 2008
Own thoughts
Swobodzinski, 2009
Pissaloux, 2017
Mobility
Near-space mobility
Far-space mobility
Perception of objects
Not mutually independent
Hazards
Obstacles
Clues
Landmark
Dynamic
Static
can become
General clues
Specialized clues
Tactile landmarks
Chest height objects
Tree branches
Temporary on-ground objects
Parked vehicles, chairs, tables
Permanent on-ground objects
Trees, public bins, poles
Path texture changes
Grass lines
Traffic crossing alerts and lights
Sound landmarks
Pubs, objects making noise
Head height objects
Tree branches
(Partial) street blockages
Construction site
Floor level changes
Stairs, slopes
Path level changes
Step-ups, drop-offs
Tactile paving
Odor landmarks
Restaurants, café
Vehicles on the road (car, bike)
Especially quiet electric vehicles
Other pedestrians
Side objects
Wall, hedges, railings
Temperature landmarks
Small objects
Tactile landmarks
Process of orientation
Spatial orientation
Geographical orientation
Understanding the space
Ensuring safety
Getting external information
Updating cognitive map
Verfication
Getting external information
Street crossing
Intersection
Open space
Pavement
Public transport stop/station
Position on pavement, street
Position in area
Minimising veering
Description of surroundings
Position relative to destination
Travelled distance
Clues, landmarks
Following correct path
Next point reached
Destination reached
Expected targets
Turning instructions
Upcoming intersections
Upcoming turns

C
User Research 1: Informed Consent Form

Appendix C

Informed Consent Form

Participant information

Hello! You are being invited to participate in a research study titled 'User experience analysis of blind and visually impaired individuals in urban mobility through behavioral data'. This study is being led by Akari Takada for a master's thesis, with support from Jacky Bourgeois and Marco Rozendaal from TU Delft and Paul de Nooij from Bartiméus.

The purpose of this research is to understand the problem areas, information needs, and behaviors of blind and visually impaired people when they navigate in an unknown outdoor environment through behavioral data. This will be a starting point for us to explore if and how smart devices can be useful to assist outdoor navigation.

You will be taking part in the following 4 activities regarding the navigation of unfamiliar urban areas.

1. Online questionnaire (5 min)
   This short questionnaire will ask about demographic information, as well as information about your visual impairment and travel habits.

2. Navigation task (in Rotterdam) (60 min)
   We will schedule a day for the navigation task and meet at Rotterdam Blaak station. When we meet, we will place an Apple Watch on your wrist and an iPhone in your pocket. You will also be asked to carry a backpack with a GoPro mounted to it. The researcher will act as the navigation system that will give you basic turn-by-turn directions to the destination. You will be able to ask questions as well if it is necessary.

   During the task, the heart rate and accelerometer sensors on the Apple Watch will collect data on heart rate and cane movements. The GPS, barometer, and magnetometer on the iPhone will collect data on location, altitude, and body orientation. Finally, the GoPro will be used to record a video of the environment in front of you. A few photos may also be taken.

3. Post-navigation interview (in Rotterdam) (30 min)
   After the navigation task, we will walk to a nearby library for an interview. We will ask about your experience while doing the navigation task. This interview will be recorded and transcribed.

4. Follow-up interview (30 min)
   The final follow-up interview will be held within a week after the navigation task and after analyzing your data. We will ask you to answer some questions regarding our interpretation of the data analysis. This interview will also be recorded and transcribed.

As with online activity and collected data, the risk of a breach is always possible. To the best of our ability, collected data will be anonymized and remain confidential. We will minimize any risks by storing contact details separate from research data, using a secure drive for data storage, and collecting data through platforms secured by TUDelft.

Appendix C

Anonymized data and findings will be used for my master's thesis and may be shared with other researchers through publications and presentations.

Your participation in this study is entirely voluntary and you can withdraw at any time. There will be no negative consequences for withdrawing.

As a gesture of gratitude, we would like to send you a 15 euro bol.com gift card after the final activity through email.

Contact person: Akari Takada

Explicit Consent Points

1. I have read, or someone has read, the study information and I understand the content. I have been able to ask questions about the study and my questions have been answered to my satisfaction.
2. I consent voluntarily to be a participant in this study.
3. I understand that taking part in the study involves:
    - Online questionnaire
    - Navigation task
    - Post-navigation interview
    - Follow-up interview
4. I understand that I can refuse to answer questions and can ask for activities to be stopped at any point during the study with no negative consequences. Data collection software will be turned off and devices will be removed immediately.
5. I understand that taking part in the study involves collecting specific personally identifiable information (name, email, phone number, photos) and associated personally identifiable research data (gender, age, visual impairment condition) with the potential risk of my identity being revealed.
6. I understand that taking part in the study involves collecting and processing biometric data (health rate) and behavioral data (cane movement, travel speed, body orientation).
7. I understand that taking part in the study involves collecting video footage (that is anonymized) of the environment in front of you.
8. I understand that collected data will be anonymised and stored on secure platforms provided by TUDelft to minimise the threat of a data breach and protect my identity in the event of such a breach.
9. I understand that personal information collected about me that can identify me, such as my name, email address, and phone number, will not be shared beyond the study team and will be destroyed as soon as the master thesis project is completed.
10. I understand that after the research study the de-identified information I provide will be used for my master's thesis and may be shared with other researchers through publications and presentations.
11. I give permission that my responses, views, or other input can be quoted anonymously in research outputs.
12. I give permission that unrecognisable photos can be used in research outputs.

Appendix C

Please express your consent to the above-mentioned points by sending a reply to this email that states "I give consent."

D
User Research: 1 Manual

Appendix D

User session 1 – Manual

- *Set iPhone to do not disturb*
- *Ask Margo to take some photos of the experiment with her phone*
- *Ask Margo about the pronunciation of streets*

INTRODUCTION

Today, we'll be doing two tasks. The first one is the navigation task. Afterward, we'll go to a nearby library and do an interview.

The route will start here, and the destination is a cafe called joy espresso and more. The route is about 250m. Please navigate until you find the door of the cafe. I will be walking slightly behind you and act as the navigation guide who will provide minimal directions to the destination. If you start feeling uncomfortable and need more information to navigate, you can ask me questions. Please note that this navigation is by no means perfect, and the navigation device will not intervene unless it is dangerous. However, it could provide some additional information that a normal navigation system cannot.

During this task, I'll be collecting some data through an Apple Watch, GoPro, and iPhone. It will collect data on your heart rate, location, travel speed, body orientation, cane movements, and video footage of what is in front of you.

Before I put these devices on you, do you have any questions?

- *Put devices on*
    - *GoPro – Turn it on and then place on backpack, check if it is paired with iPhone, place on side that they are not holding the cane, make sure cane movements are showing*
    - *Apple watch – Turn workout mode on, start SensorLog, place on hand they are holding the cane*
    - *iPhone – Start GoPro, start SensorLog, then lock screen, mind orientation when putting it inside bag.*
- *Allow time to get used to it*

Do you feel comfortable with the devices on?

Ok great, now let's start the navigation task.

- *Clap to get devices all synced up*

NAVIGATION GUIDE

- *Rules of navigation guide:*

Hello, I'm your navigation guide. I will provide the minimum directions to the destination. If you start feeling uncomfortable and need more information to navigate, you can ask me questions.

You have entered the destination, Joy Espresso and More, on Groenendaal 493. The destination is 170 m toward ? o'clock. (Destination confirmation and distance)

Appendix D

Right now, you're at Rotterdam Blaak station. (Current location)

Proceed 22m at ?? o'clock, and then turn right onto Kolk. (Preview)

Approaching Kolk, turn right. (Instructions)

Proceed for 8 m, and then turn left onto Blaak. (Preview)

Approaching Blaak, turn left. (Instructions)

Proceed on Blaak for 120m. (Preview)

Approaching Mariniersweg. Continue on Blaak for 48m, and then turn left onto Mariniersweg. (Preview)

Turn left. (Instructions)

Proceed on Mariniersweg for 48 m, and then turn right on Groenendaal. (Preview)

Approaching Groenendaal, turn right. (Instructions)

Proceed on Groenendaal for 22m, destination is on the left. (Preview)

You have arrived at the destination. It is on your left. (Instructions)

Unexpected situations

- When they ask questions
- When it is dangerous

INTERVIEW

Annotation task

- *Prepare video on screen*
- *Hand them earphones or headphones*
- *Turn screen recording on*
- *Record using iPhone*

Now, I would like to conduct the interview.

First, I want to ask about what you were thinking and feeling throughout the navigation task that we just did. I will hand you some earphones and play the video to jog your memory, and whenever something comes up, just say stop. I'm curious to know what your thought process is, what decisions you made, how you understand the environment, and how you feel.

- *Stop screen recording*
- *Make sure to stop and record again using iPhone*
- *Prepare questions on PC*

Follow-up questions

- Motivation for asking a question: Why did you ask ___ ?

Appendix D

- When we were approaching Mariniersweg, I asked you to proceed straight and then turn left, which helped you figure out which side of the road to be on.

Online questionnaire

1. What is your age?
2. What is your gender?
3. What kind of visual impairment do you have?
4. When did you get your visual impairment? Please briefly describe the history of your visual impairment.
5. Do you have any residual vision? If yes, please describe.

6. What is your primary mobility aid?
7. Which hand do you hold/carry your primary mobility aid?
8. What other mobility or navigation aids do you use?
9. What smartphone apps do you use when travelling and for what purpose you use them for? Consider preparation, public transportation, indoor and outdoor travel.
10. Have you received orientation and mobility training?
11. What kind of environment do you live in?
12. How often do you travel to unfamiliar areas?
13. How comfortable are you traveling to unfamiliar areas?
14. When navigating unfamiliar outdoor areas, do you prepare for the trip?
15. How do you usually prepare for a trip that involves outdoor navigation in an unfamiliar area?

Purpose of interview: How does context affect information needs?

What do I mean by context?

- Knowledge-level: prep, unknown, familiar, routine
- Interest-level: interested in learning, not interested in learning
- Perhaps within the route: answer through navigation task

Difference between study and what they usually do in an unfamiliar area

1. How do you usually navigate in an unfamiliar area?
    - What tools do you use to get information?
    - What kind of information does it give you (be specific)?
    - What do you do if the information is not reliable?
2. How was it different from what we did today?
3. What is the most problematic situation when you're navigating in an unfamiliar area?

Effect of interest-level on information needs

4. Say that you want to learn a route in an unfamiliar area. Would this change the way you navigate the route for the first time?
5. When you want to explore the environment rather than navigate in it, what do you do?

Appendix D

Effect of knowledge-level on information needs

6. What are the different phases you go through when an unfamiliar area becomes familiar?
    - Are there differences in the type of information you use?
    - Are there differences in the type of information you want?
7. How do you keep track of all the landmarks you learned?
    - Do you wish there was an easier way to keep track of this information?

Within route information needs

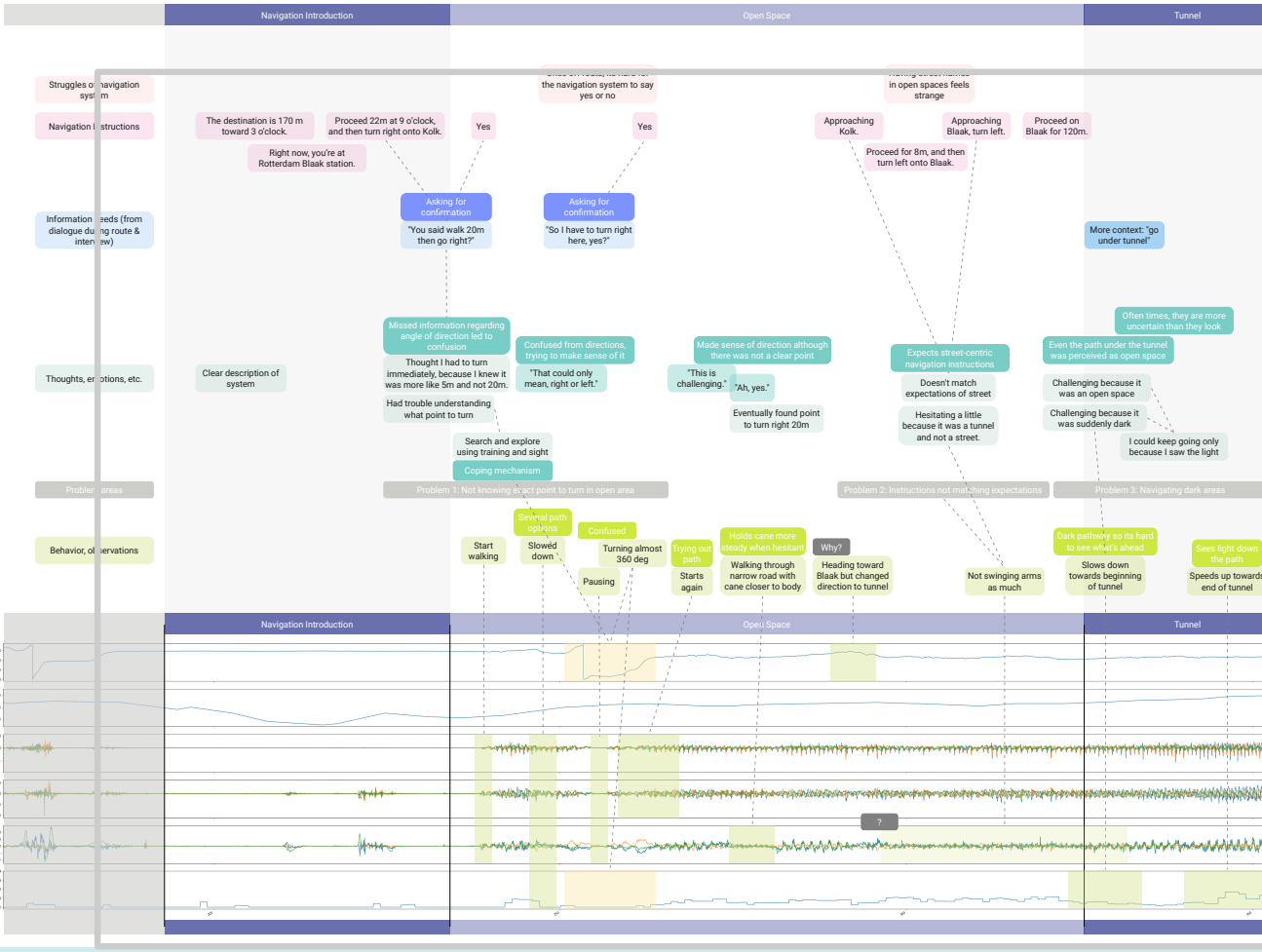
8. Have you ever experienced getting too much information from your smartphone? (e.g. When you are trying to concentrate on sounds from the road.)
9. When do you wish you wish to get more information about your surroundings (e.g. shops, restaurants, etc.)? Are there particular moments? Or is it all the time?
10. How do you navigate in an open space?
11. How do you deal with unexpected changes in a route (e.g. construction site, landmark loss)?

Ok, that is the end of the interview! After today, I will look through the collected data and I will most likely have some follow-up questions for you by next Thursday. Would it be ok if I send you the list of questions through email? I can also just schedule a call with you someday if that is more convenient. After that, I will send you the 15 euros bol.com gift card. I really appreciate your valuable time. Thank you so much!

- *Stop voice recording*

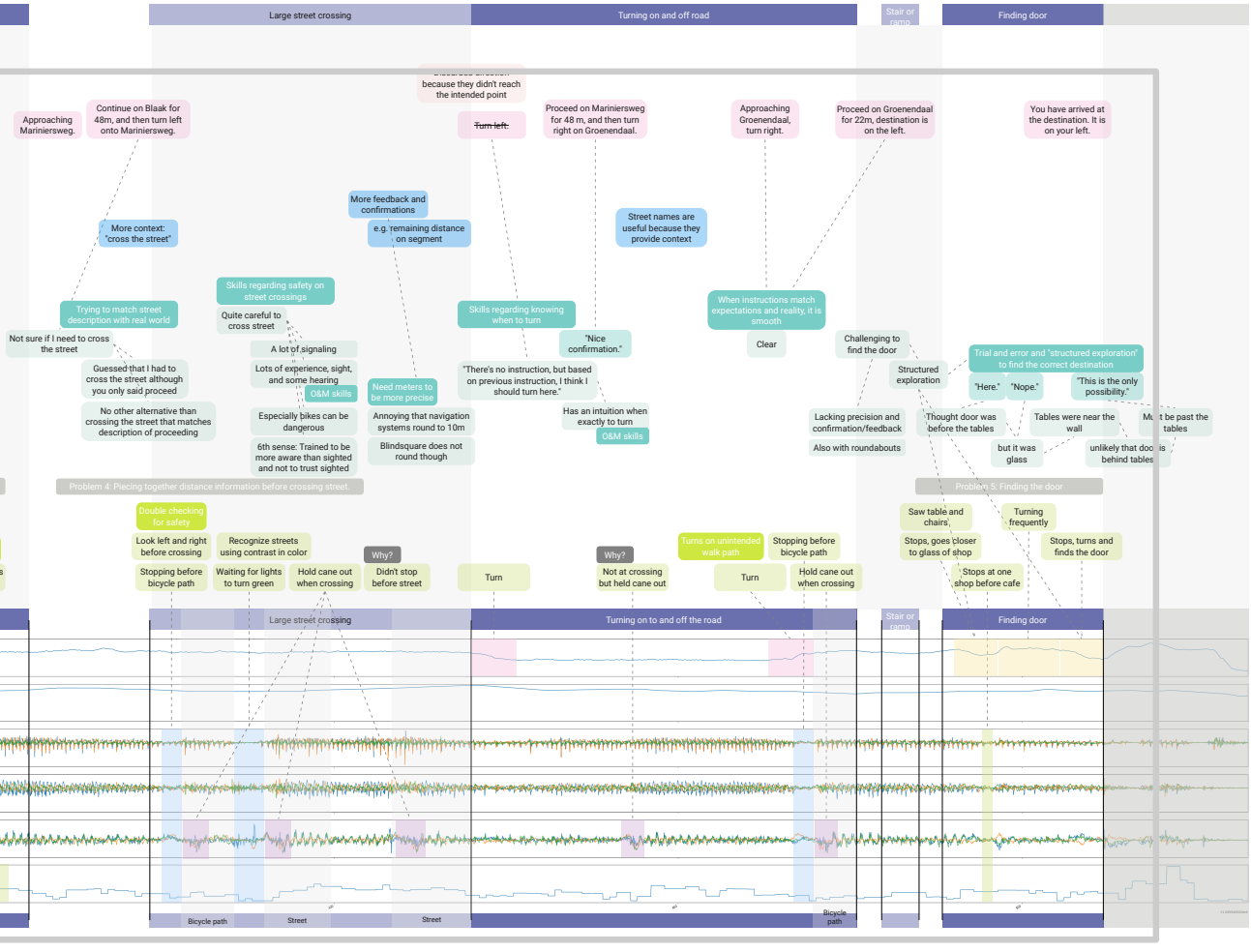
Appendix D

E
User Research 1: Journey Maps



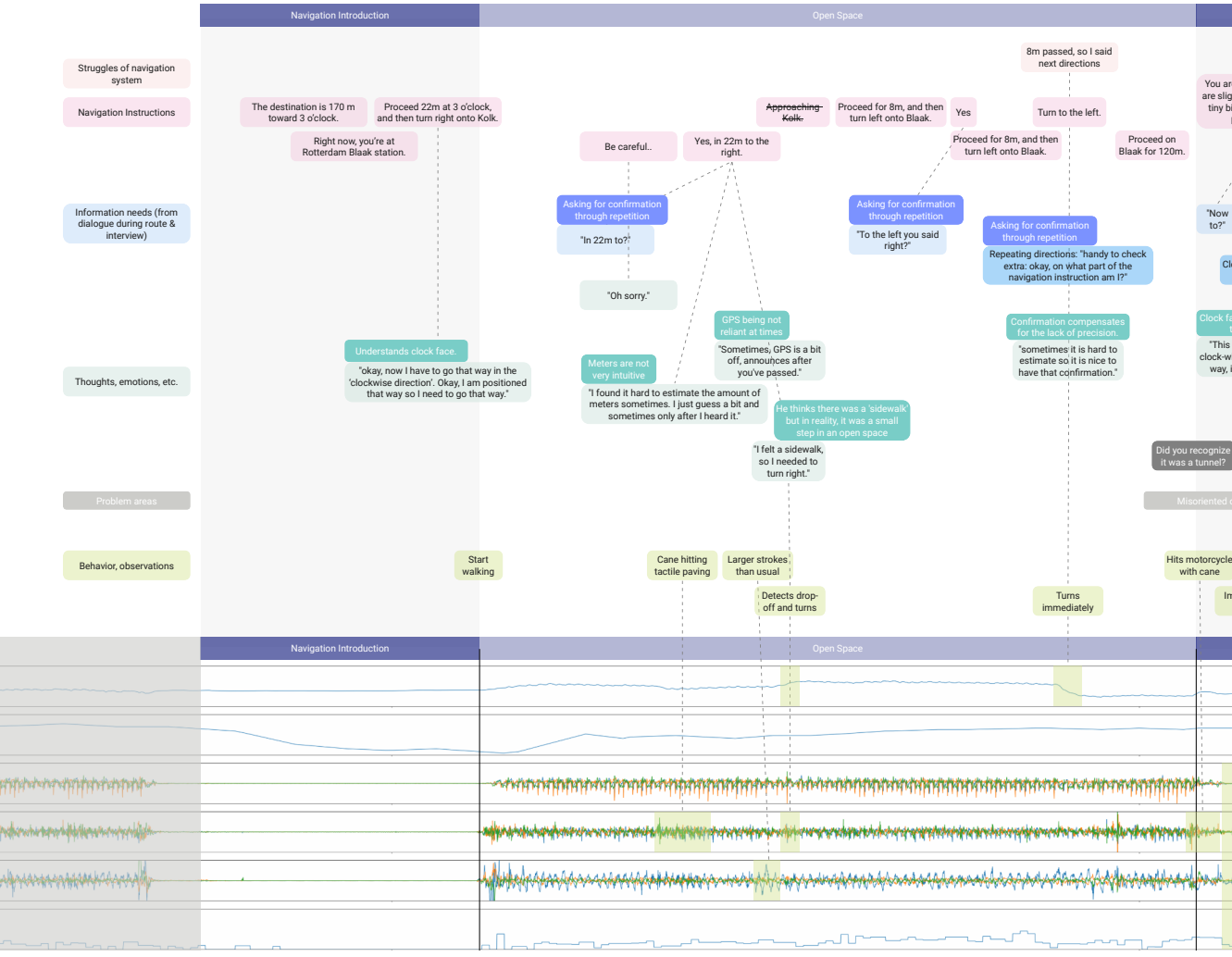
Appendix E

P1

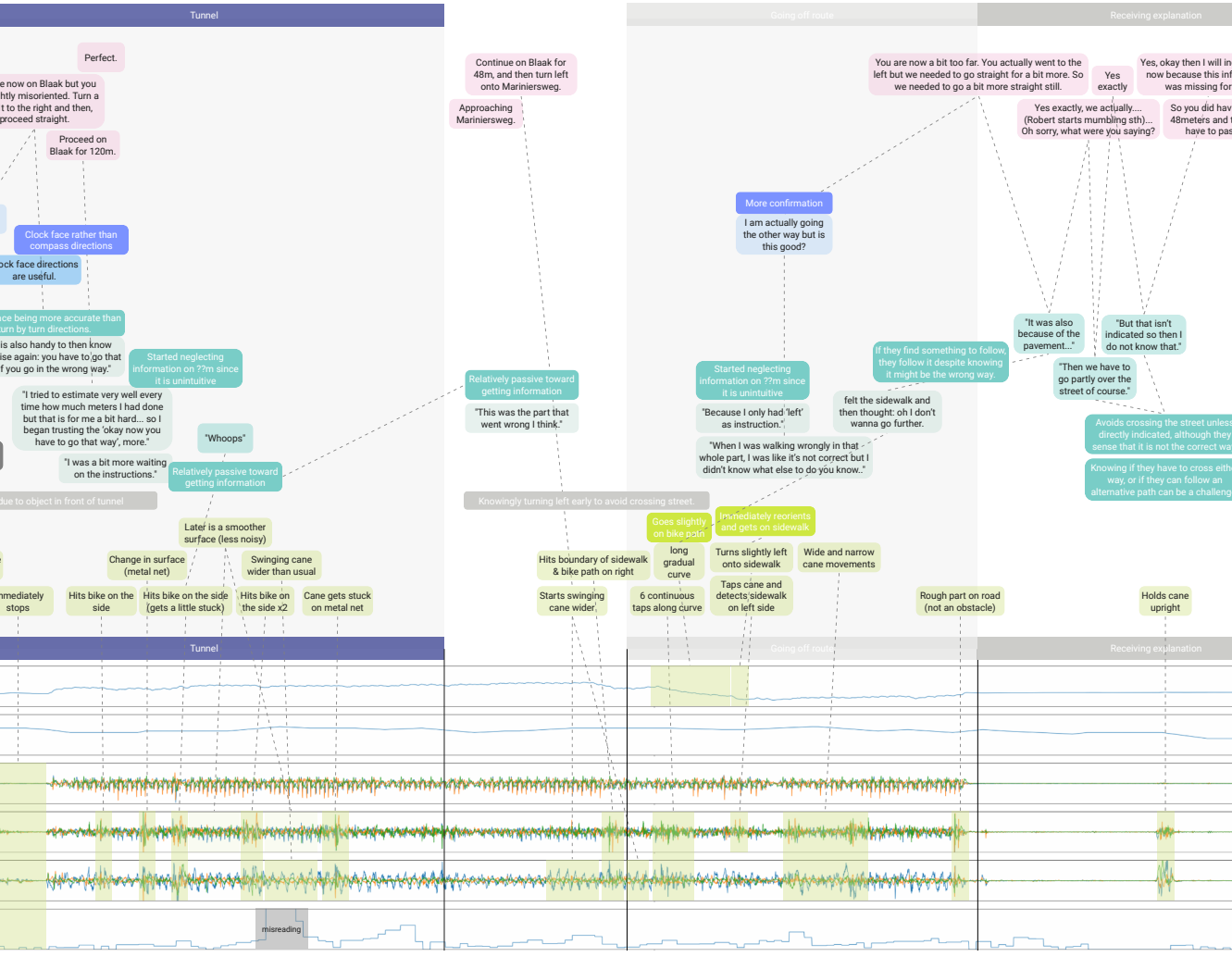


Appendix E

P2 part 1

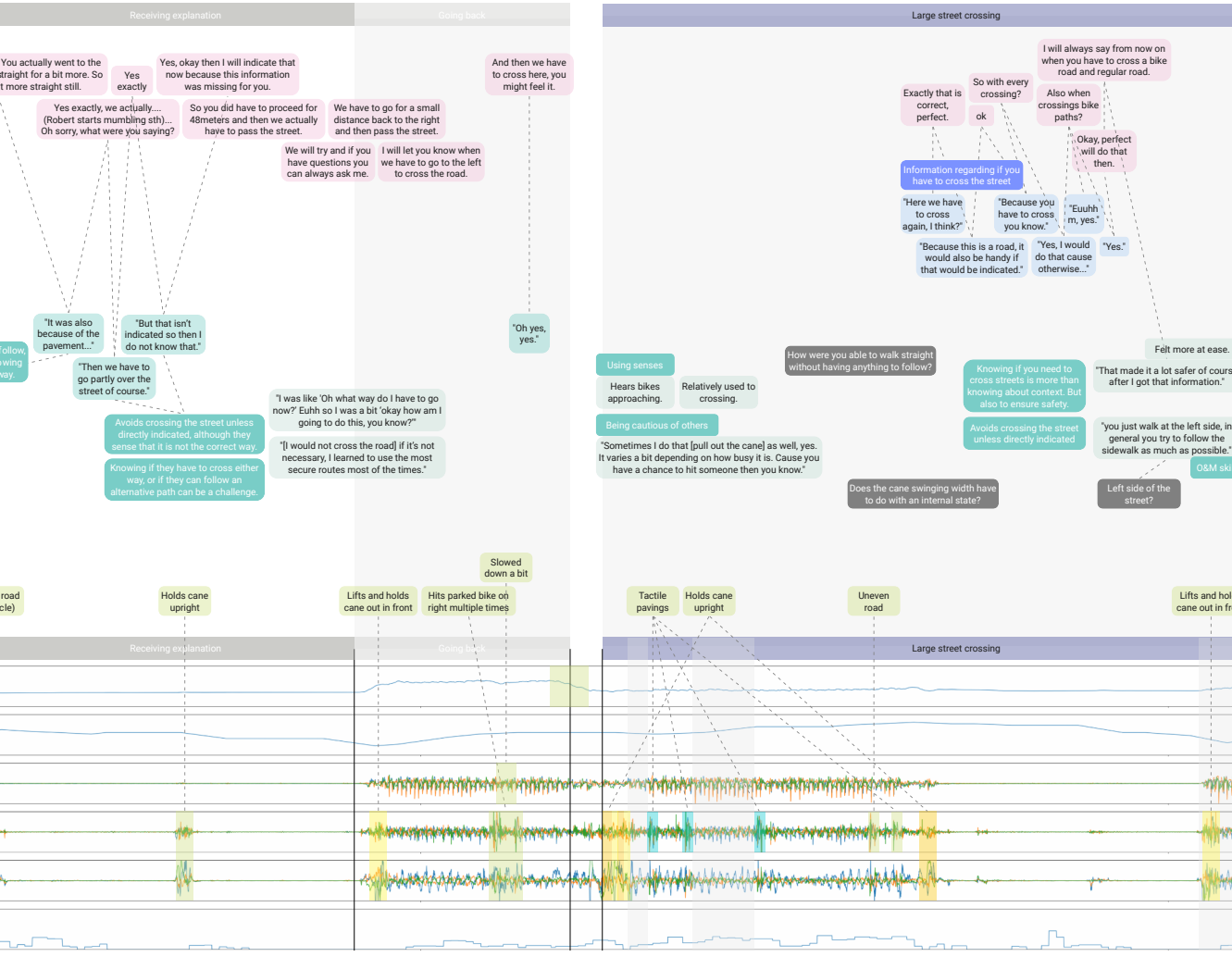


Appendix E

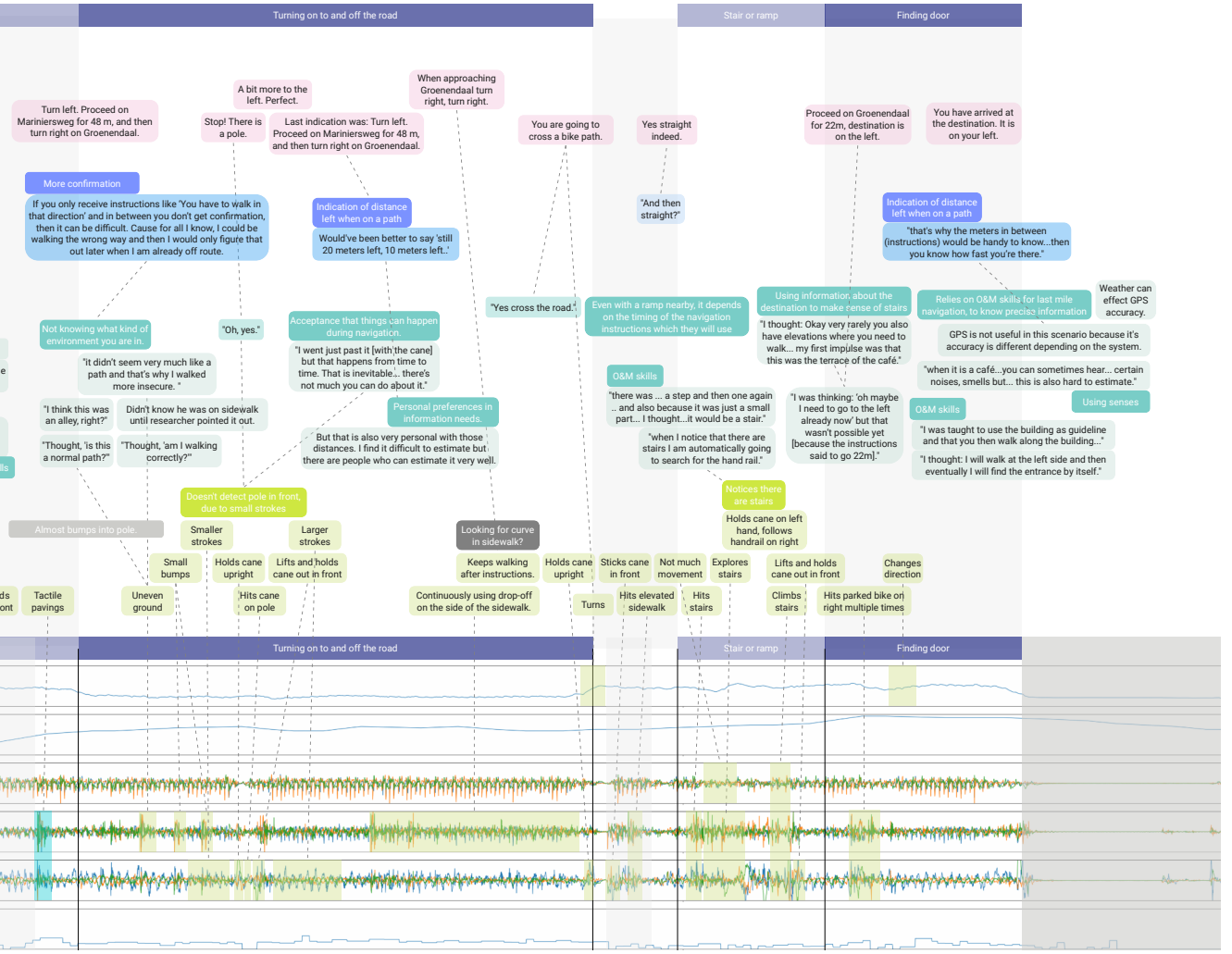

Tunnel
Going off route
Receiving explanation
Perfect.
Proceed on Blaak for 120m.
Clock face rather than compass directions
Started neglecting information on ??m since it is unintuitive
"Whoops"
Relatively passive toward getting information
Later is a smoother surface (less noisy)
Change in surface (metal net)
Swinging cane wider than usual
Hits bike on the side
Hits bike on the side (gets a little stuck)
Hits bike on the side x2
Cane gets stuck on metal net
Continue on Blaak for 48m, and then turn left onto Marinierswег.
Approaching Marinierswег.
Relatively passive toward getting information
"This was the part that went wrong I think."
Knowingly turning left early to avoid crossing street.
Hits boundary of sidewalk & bike path on right
Starts swinging cane wider
Goes slightly on bike path
long gradual curve
6 continuous taps along curve
Immediately reorients and gets on sidewalk
Turns slightly left onto sidewalk
Taps cane and detects sidewalk on left side
Wide and narrow cane movements
Rough part on road (not an obstacle)
Holds cane upright
You are now a bit too far. You actually went to the left but we needed to go straight for a bit more. So we needed to go a bit more straight still.
Yes exactly
Yes, okay then I will in now because this inf was missing for
Yes exactly, we actually.... (Robert starts mumbling sth)... Oh sorry, what were you saying?
More confirmation
I am actually going the other way but is this good?
"It was also because of the pavement..."
"But that isn't indicated so then I do not know that."
If they find something to follow, they follow it despite knowing it might be the wrong way.
"Then we have to go partly over the street of course."
Started neglecting information on ??m since it is unintuitive
"Because I only had 'left' as instruction."
felt the sidewalk and then thought: oh I don't wanna go further.
"When I was walking wrongly in that whole part, I was like it's not correct but I didn't know what else to do you know.."
Avoids crossing the street unless directly indicated, although they sense that it is not the correct wa
Knowing if they have to cross eith way, or if they can follow an alternative path can be a challeng
misreading

Appendix E

P2 part 2

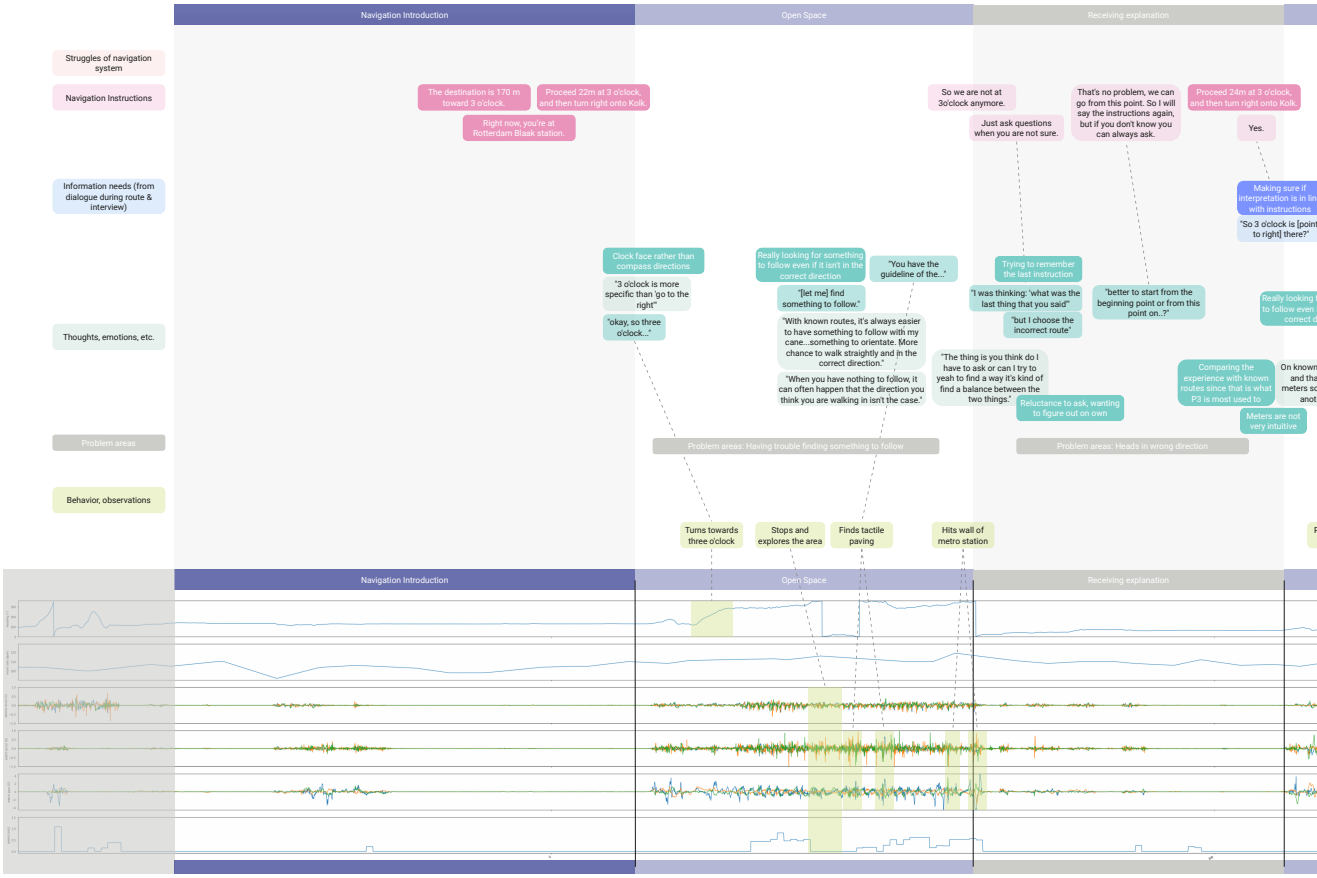


Appendix E

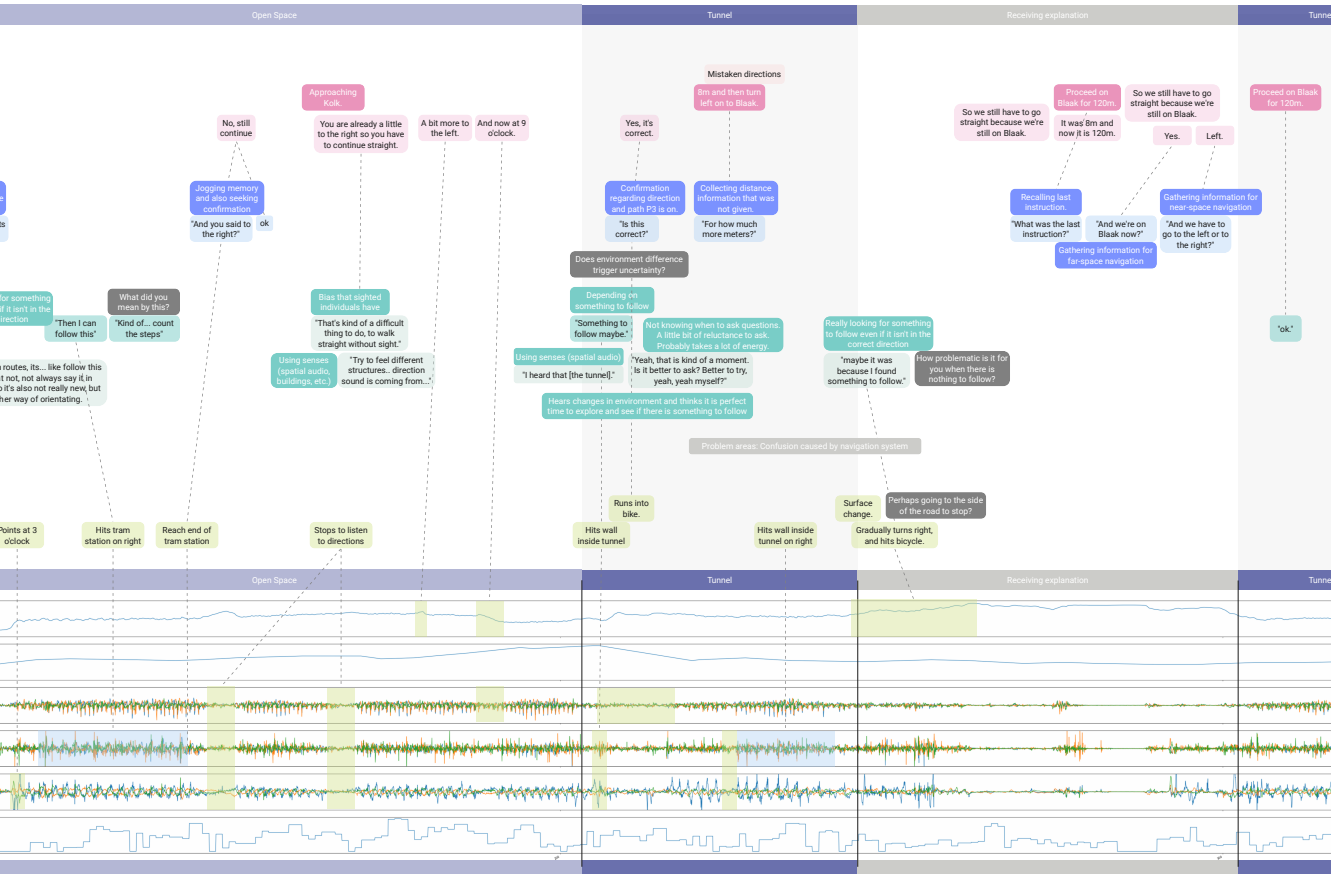

Turning on to and off the road
Stair or ramp
Finding door
Turn left. Proceed on Marniersweg for 48 m, and then turn right on Groenendaal.
A bit more to the left. Perfect.
Stop! There is a pole.
Last indication was: Turn left. Proceed on Marniersweg for 48 m, and then turn right on Groenendaal.
When approaching Groenendaal turn right, turn right.
You are going to cross a bike path.
Yes straight indeed.
"And then straight?"
Proceed on Groenendaal for 22m, destination is on the left.
You have arrived at the destination. It is on your left.
More confirmation
If you only receive instructions like 'You have to walk in that direction' and in between you don't get confirmation, then it can be difficult. Cause for all I know, I could be walking the wrong way and then I would only figure that out later when I am already off route.
Indication of distance left when on a path
Would've been better to say 'still 20 meters left, 10 meters left..'
Indication of distance left when on a path
"that's why the meters in between (instructions) would be handy to know...then you know how fast you're there."
"Yes cross the road.'
Even with a ramp nearby, it depends on the timing of the navigation instructions which they will use
Using information about the destination to make sense of stairs
"I thought: Okay very rarely you also have elevations where you need to walk... my first impulse was that this was the terrace of the café.'
Relies on O&M skills for last mile navigation, to know precise information
Weather can effect GPS accuracy.
GPS is not useful in this scenario because it's accuracy is different depending on the system.
Not knowing what kind of environment you are in.
"Oh, yes."
Acceptance that things can happen during navigation.
"I went just past it [with the cane] but that happens from time to time. That is inevitable... there's not much you can do about it."
"it didn't seem very much like a path and that's why I walked more insecure. "
"I think this was an alley, right?"
Didn't know he was on sidewalk until researcher pointed it out.
"Thought, 'is this a normal path?"
"Thought, 'am I walking correctly?"
Personal preferences in information needs.
But that is also very personal with those distances. I find it difficult to estimate but there are people who can estimate it very well.
O&M skills
"there was ... a step and then one again .. and also because it was just a small part... I thought...it would be a stair."
"when I notice that there are stairs I am automatically going to search for the hand rail."
"I was thinking: 'oh maybe I need to go to the left already now' but that wasn't possible yet [because the instructions said to go 22m]."
O&M skills
Using senses
"I was taught to use the building as guideline and that you then walk along the building..."
"I thought: I will walk at the left side and then eventually I will find the entrance by itself."
Doesn't detect pole in front, due to small strokes
Notices there are stairs
Holds cane on left hand, follows handrail on right
Almost bumps into pole.
Smaller strokes
Larger strokes
Looking for curve in sidewalk?
Small bumps
Holds cane upright
Lifts and holds cane out in front
Keeps walking after instructions.
Holds cane upright
Sticks cane in front
Not much movement
Explores stairs
Lifts and holds cane out in front
Changes direction
Tactile pavings
Uneven ground
Hits cane on pole
Continuously using drop-off on the side of the sidewalk.
Turns
Hits elevated sidewalk
Hits stairs
Climbs stairs
Hits parked bike on right multiple times
Turning on to and off the road
Stair or ramp
Finding door

Appendix E

P3 part 1

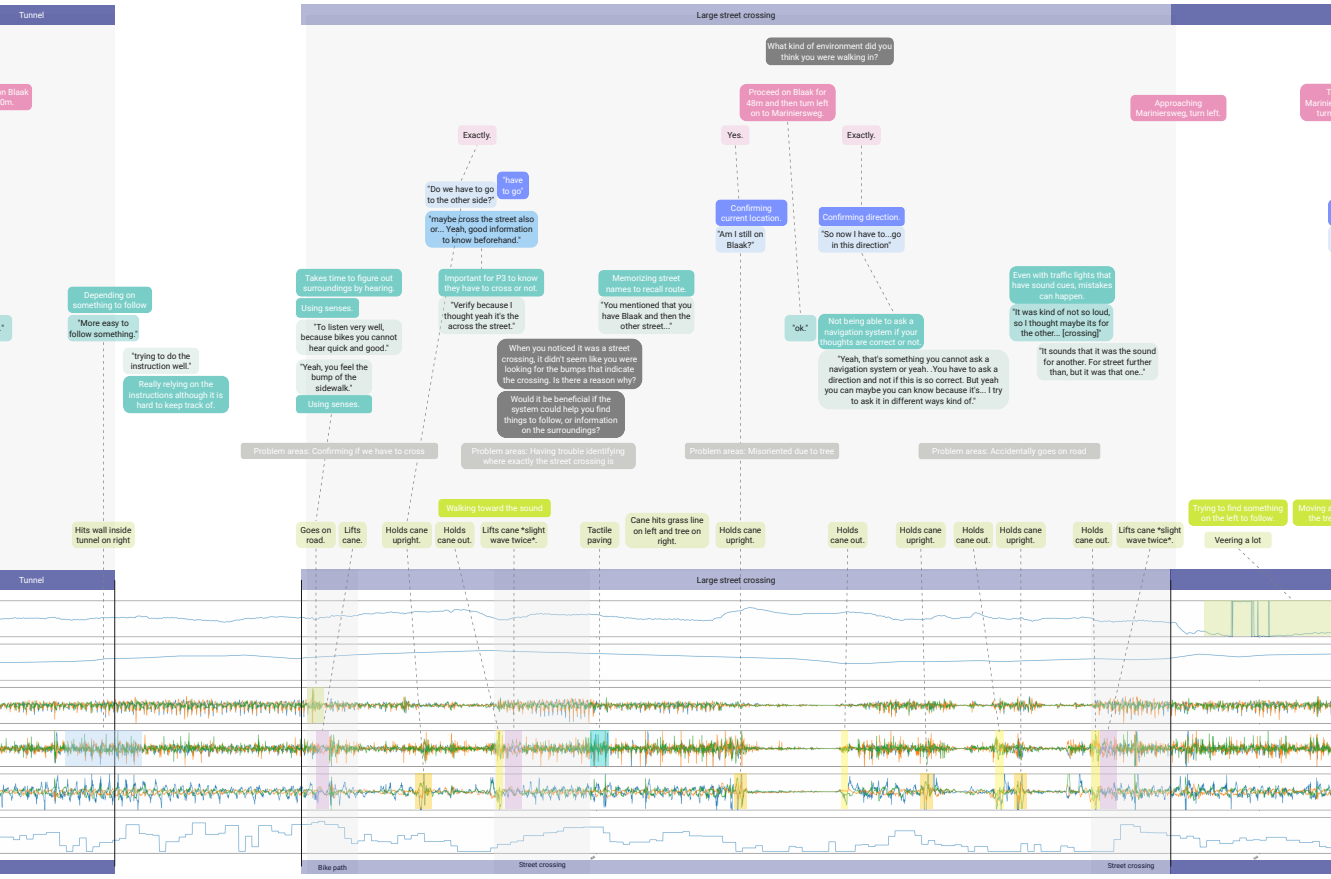


Appendix E


Open Space
Tunnel
Receiving explanation
Tunnel
Approaching Kolk.
No, still continue
You are already a little to the right so you have to continue straight.
A bit more to the left.
And now at 9 o'clock.
Jogging memory and also seeking confirmation
"And you said to the right?"
ok
Bias that sighted individuals have
"That's kind of a difficult thing to do, to walk straight without sight."
Using senses (spatial audio, buildings, etc.)
"Try to feel different structures.. direction sound is coming from..."
What did you mean by this?
"Kind of... count the steps"
"Then I can follow this"
Points at 3 o'clock
Hits tram station on right
Reach end of tram station
Stops to listen to directions
Mistaken directions
8m and then turn left on to Blaak.
Yes, it's correct.
Confirmation regarding direction and path P3 is on.
"Is this correct?"
Collecting distance information that was not given.
"For how much more meters?"
Does environment difference trigger uncertainty?
Depending on something to follow
"Something to follow maybe."
Not knowing when to ask questions. A little bit of reluctance to ask. Probably takes a lot of energy.
Using senses (spatial audio)
"I heard that [the tunnel]."
"Yeah, that is kind of a moment.. Is it better to ask? Better to try, yeah, yeah myself?"
Hears changes in environment and thinks it is perfect time to explore and see if there is something to follow
Problem areas: Confusion caused by navigation system
Runs into bike.
Hits wall inside tunnel
Really looking for something to follow even if it isn't in the correct direction
"maybe it was because I found something to follow."
How problematic is it for you when there is nothing to follow?
Surface change.
Perhaps going to the side of the road to stop?
Gradually turns right, and hits bicycle.
Hits wall inside tunnel on right
So we still have to go straight because we're still on Blaak.
Proceed on Blaak for 120m.
It was 8m and now it is 120m.
So we still have to go straight because we're still on Blaak.
Yes.
Left.
Recalling last instruction.
"What was the last instruction?"
"And we're on Blaak now?"
Gathering information for near-space navigation
"And we have to go to the left or to the right?"
Gathering information for far-space navigation
Proceed on Blaak for 120m.
"ok."
Open Space
Tunnel
Receiving explanation
Tunnel

Appendix E

P3 part 2



Appendix F


Turning on to and off the road
Stair or ramp
Finding door
Approaching Groenendaal, turn right..
Proceed on Groenendaal for 22m, destination is on the left.
The destination is a little further.
Yeah but there is nobody so I was seeing if you understood by yourself or not. But we can also go back on the sidewalk.
You just turned right so you will proceed, continue on this street for 22m. The destination will be on the left.
Misunderstanding directions.
Perhaps too much information at once because she picks up the last instruction.
"So Marinierswegis not here?"
"Oh, so I have to go to the left or...?"
Width of the sidewalk can be useful to know.
"Oh I now walk on the street."
"You have to walk there and not the street of course.."
"I thought it was too small to walk."
"Sometimes it is easier to follow the, part that goes over the street.."
"So logically you have to pass the street.."
Using senses.
"It was kind of busy, and with the bicycles. Walk slower. Maybe I can hear where the door is. But of course, you can also ask."
Depending on something to follow
"I found something to follow, and I thought 'oh, is this then the correct way to go in'."
Did you use where the navigation voice was coming from?
Depending on something to follow
Problem areas: Not knowing width of path
Problem areas: Finding the destination
Heading towards left side.
Hits elevated sidewalk on left.
Following drop off of sidewalk.
Holds cane upright.
Holds cane out.
Lifts cane *slight wave twice*.
Using the grass line as a cue.
Holds cane upright.
Stops at shop before the destination.
Uses hands more to see what obstacles there are.
Turning on to and off the road
Stair or ramp
Finding door
Bike path

F
User Research 2: Informed Consent Form

Appendix F

Informed Consent Form

Participant information

Hello! You are being invited to participate in a research study titled “Desirability study of a user-aware navigation system for blind and visually impaired individuals traveling in outdoor urban environments”. This study is being led by Akari Takada for a master’s thesis, with support from Jacky Bourgeois and Marco Rozendaal from TU Delft and Paul de Nooij from Bartiméus.

The purpose of this research is to test if a navigation system that changes the information it provides according to the user’s behavior is useful for blind and visually impaired people when they navigate in an unknown outdoor environment.

You will be taking part in the following 3 activities regarding the navigation of unfamiliar urban areas.

1. Online questionnaire (5 min)
   This short questionnaire will ask about demographic information, as well as information about your visual impairment and travel habits.

2. Navigation task (in Rotterdam) (60 min)
   We will schedule a day for the navigation task and meet at Rotterdam Blaak station. When we meet, we will place an Apple Watch on your wrist, an iPhone in your pocket, and some bone conduction earphones. You will also be asked to hold a second iPhone and carry a backpack with a GoPro mounted to it. The navigation instructions will be given through the text-to-speech function on a second iPhone and you will be able to hear the instructions through the earphones.

   During the task, the accelerometer sensors on the Apple Watch will collect data on cane movements. The GPS, magnetometer, and accelerometer on the iPhone will collect data on location, travel speed, and body orientation. Finally, the GoPro will be used to record a video of the environment in front of you. A few photos may also be taken.

3. Post-navigation interview (in Rotterdam) (30 min)
   After the navigation task, we will walk to a nearby library for an interview. We will ask about your experience while doing the navigation task. This interview will be recorded and transcribed.

As with online activity and collected data, the risk of a breach is always possible. To the best of our ability, collected data will be anonymized and remain confidential. We will minimize any risks by storing contact details separate from research data, using a secure drive for data storage, and collecting data through platforms secured by TUDelft.

Anonymized data and findings will be used for my master's thesis and may be shared with other researchers through publications and presentations.

Your participation in this study is entirely voluntary and you can withdraw at any time. There will be no negative consequences for withdrawing.

Appendix F

As a gesture of gratitude, we would like to send you a 15 euro bol.com gift card after the final activity through email.

Contact person: Akari Takada Email: A.Takada@student.tudelft.nl Phone: 0613394112

Explicit Consent Points

1. I have read, or someone has read, the study information and I understand the content. I have been able to ask questions about the study and my questions have been answered to my satisfaction.
2. I consent voluntarily to be a participant in this study.
3. I understand that taking part in the study involves:
    - Online questionnaire
    - Navigation task
    - Post-navigation interview
4. I understand that I can refuse to answer questions and can ask for activities to be stopped at any point during the study with no negative consequences. Data collection software will be turned off and devices will be removed immediately.
5. I understand that taking part in the study involves collecting specific personally identifiable information (name, email, phone number, photos) and associated personally identifiable research data (gender, age, visual impairment condition) with the potential risk of my identity being revealed.
6. I understand that taking part in the study involves collecting and processing behavioral data (cane movement, travel speed, body orientation).
7. I understand that taking part in the study involves collecting video footage (that is anonymized) of the environment in front of you.
8. I understand that collected data will be anonymised and stored on secure platforms provided by TUDelft to minimise the threat of a data breach and protect my identity in the event of such a breach.
9. I understand that personal information collected about me that can identify me, such as my name, email address, and phone number, will not be shared beyond the study team and will be destroyed as soon as the master thesis project is completed.
10. I understand that after the research study the de-identified information I provide will be used for my master's thesis and may be shared with other researchers through publications and presentations.
11. I give permission that my responses, views, or other input can be quoted anonymously in research outputs.
12. I give permission that unrecognisable photos can be used in research outputs.

Please express your consent to the above-mentioned points by sending a reply to this email that states “I give consent.”

Appendix F

G
User Research 2: Manual

Appendix G

User session 2 – Manual

FORMATTING

- **Information about the research or other notes:** Don't translate. It's enough to read through it.
- **Procedures during the task:** Don't translate. It's a reminder for me to remember the procedures to be done.
- **"Script":** Translate. This is a rough script for what to tell the users during the session. The bold is just to emphasize some things.

RESEARCH QUESTIONS

- **RQ1** Do information needs change when they are "following route" vs "reorienting on route"?
  - **H1-1** When travelers are "following route", they need more information that supports near-space mobility (environment descriptions).
    - **Reason** They are focused on far-space mobility and would want to know what to expect in their near-space mobility.
  - **H1-2** When travelers are "reorienting on route", they need more information that supports far-space mobility.
    - **Reason** They are focused on near-space mobility, and it is hard to keep track of far-space mobility.
- **RQ2** What information do the users want control over? What information do the users want to be notified?
  - **H2-1** Information regarding micro-level structural information (Common street structures) should be pushed.
    - **Reason** This information is especially important for their safety.
  - **H2-2** Turning point should be pushed.
    - **Reason** This is fundamental information needed to follow a route. It will also prevent them from having to keep on pulling information on the direction.
  - **H2-3** Directions should be pulled.
    - **Reason** Simple sound that encapsulates 'direction' and 'confirmation', no matter where you are on the road is important but having it constantly there can be a little distracting.
- **Other questions**
  - Could descriptive micro-level structural information reduce the number of audio cues needed in the navigation? And let users focus on surroundings when they need to?
  - Are there any other behaviors that can be identified?

- *Set iPhone to do not disturb*
- *Make sure iPhone is not on save low power mode*

Appendix G

- *Connect bone conduction headsets to iPhone*
- *Connect regular earphones to iPad*
- *Link hotspot and start pythonista*

INTRODUCTION

This will take place on one of the benches near Rotterdam Blaak station. The participant will be sitting on one of the benches.

Tasks

Today, we'll be doing two tasks. The first one is the navigation task. Afterwards, we'll go to a nearby library or a bench, get a nice coffee or tea, and do an interview. It will take a maximum of 2 hours, but we will try and finish in one and a half hours.

Purpose

We are doing this study as an effort to make navigation with app-based systems more useful and intuitive. The specific goal of this study is to better understand the relation between your behaviors and the information you need.

NAVIGATION TASK

Explanation of the purpose

For the first navigation task, you will start here, and walk to the destination, which is a cafe called Joy Espresso and More. The route is about 250m.

Adjust volume

Now, let me show you how the prototype works. You can think of it as a typical navigation app. The prototype runs on a smartphone, and it will give you verbal descriptions as well as audio cues. You will listen to them through some bone conduction earphones. These earphones don't go inside your ear, so you will still be able to hear the outside sounds. Can you put these on? *Hand them bone conduction earphones, briefly explain where the ears go*

I am going to play a demo sound. *Play demo sound* Is the volume ok for you? *(Akari on iPhone) Adjust volume*

Demo of the navigation app

Now I will teach you how to use this navigation app. We will walk around the station once to demonstrate all the features. It is extremely important that you understand how to use the navigation system so don't hesitate to ask as many questions during this demonstration.

Let's start walking in this direction.

Walk until turning point

When you reach a turning point, you will hear something like this. *(Akari on iPad) "Turn towards your right", participant slowly turns* Then you can turn slowly and when you are oriented in the correct direction, you will hear a confirmation sound *(Akari on iPad) Play sound*.

Appendix G

Walk for a bit and them stop them

The navigation system will also tell you information on common street structures, such as bridges, streets, and stairs. Let's say there are a few stair steps in front of you right now. In such a case, you will hear something like this. *(Akari on iPad) Walk down the stairs ahead*.

To review, the 'turning points' and 'street structures' are the two types of information that will be announced by the navigation system. On the other hand, you will also be able to receive two types of information from the navigation system at any point on the route.

You will hold the smartphone in the hand you are not using the cane. *Hand over the smartphone* There are two buttons on the smartphone you can use to get information. I think it is the easiest to press the buttons with your thumb. *Make sure they readjust the way they are holding the smartphone*

The button that is further from your body will give you audio cues or beeps that indicate the direction you should be heading. After you press the button, if you are not oriented in the correct direction, you will hear something like this *(Akari on iPad) Reorient.* When you hear this, turn your body slowly until you hear the confirmation sound *(Akari on iPad) Play sound.* If you are oriented in the correct direction, it will just play the confirmation sound. Let's try it out. Try pressing the button further from your body. *They press button, (Akari on iPad) "reorient", participant moves, (Akari on iPad) play sound* Please note that there might be a slight lag with the confirmation sound, so try to move slowly, or repeat the process.

The button that is closer from your body will give you a description of the environment you are in. Try pressing the button closer from your body. For example, let's say you are on a busy street with a lot of shops. In this case, if you press the button closer from your body, you will hear something like this *(Akari on iPad) You are on a pedestrian path with shops on both sides.*

Now, let's practice. The navigation system is going to guide you around the station, so try pressing on the buttons whenever you want to.

Guide them along path. Answer any questions they have.

Important note: Only tell them about the type of information that is announced, and not when they should press the button.

Test their understanding

That's all for the explanation on how the prototype works. Do you remember which button you should press to get the audio direction cues?

And which button you should press to get the audio descriptions?

Safety

Please note that we didn't aim to make the navigation system perfect and there will be some moments you will have to figure out on your own. If there is a dangerous situation, the navigation system will say… *(Akari on iPad) "Stop"*. I (Margo) will also be following you just to make sure you are safe but try to ignore me during the task as much as you can.

Reviewing main consent points

Appendix G

Walk for a bit and them stop them

The navigation system will also tell you information on common street structures, such as bridges, streets, and stairs. Let's say there are a few stair steps in front of you right now. In such a case, you will hear something like this. *(Akari on iPad) Walk down the stairs ahead*.

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Reviewing main consent points

Appendix G

Since we are trying to understand your movements or behaviors throughout this task, we would like to wear an Apple Watch, iPhone, and GoPro. The Apple Watch and iPhone will collect data on your location, travel speed, body orientation, and cane movements. Is this ok with you?

Meanwhile, the GoPro will take video footage of what is in front of you, which we will use to analyze the results. We will also take a few pictures to use for reporting. Is this also ok with you?

If you want to stop the task at any moment, you can stop and raise your hand. Do you understand?

Devices

I will put the devices on now.

- *GoPro – Turn it on and then place on backpack, check if it is paired with iPhone, place on side that they are not holding the cane, make sure cane movements are showing*
- *Apple watch – Start SensorLog, place on hand they are holding the cane*
- *iPhone – Start GoPro, start SensorLog, then lock screen, mind orientation when putting it inside bag (put on right side of the user).*

Do you feel comfortable with the devices on?

Ok great, now let's move to the starting point and get started with the navigation task.

- *Restart Pythonista on both iPhone and iPad before navigation task starts*

INTERVIEW

- *Turn microphone on*
- *Open Microsoft forms on PC or tablet*
    - *Part 1 - https://forms.office.com/r/aJDnPsqjkL*

RQ1 Do information needs change when they are "following route" vs "reorienting on route"? (Regarding **H1-1** and **H1-2**) -> Measuring information needs by asking how useful each information was numerically.

- We are first going to go over the navigation task from the start, and I am going to ask why you requested information, and the usefulness of all the information that was provided. No worries if you have the same answer for some of the questions or if you pressed a button by mistake. Just try to reflect on the situation and answer whatever you recall.

- [Pulled] Environment description (For ALL instances)
    - Here, when you pressed the button and the app said "____ (Repeat what the app said)", what triggered you to press the button for the 'environment description'? (Short answer)
    - Did the app give you information you expected? (Yes/No)
    - How useful was this information on a scale of -3 to 3? -3 being not useful at all and 3 being very useful. (-3 to 3)
    - Why was it useful/not useful? (Short answer)
- [Pulled] Direction (For ALL instances if possible, if there is too many, ask all at once)

  - Here, when you were ___ (description of situation), what triggered you to press the button for the 'direction'? (Short answer)
  - How useful was this information on a scale of -3 to 3? -3 being not useful at all and 3 being very useful. (-3 to 3)
  - Why was it useful/not useful? (Short answer)
- [Pushed] Common street structures (For ALL instances)
  - How useful was the information regarding 'common street structures' on a scale of -3 to 3? -3 being not useful at all and 3 being very useful. (-3 to 3)
  - Why was it useful/not useful? (Short answer)
- [Pushed] Turning points (Ask all at once)
  - How useful was the 'turning points' audio cue on a scale of -3 to 3? -3 being not useful at all and 3 being very useful. (-3 to 3)
  - Why was it useful/not useful? (Short answer)

- *Open Microsoft forms on PC or tablet*
  - *Part 2 - https://forms.office.com/r/nE7eJfNHf8*

RQ2 What information do the users want control over? What information do the users want to be notified?

- The next set of questions are about the control you had over some of the information. For the 'direction' audio cues and 'environmental descriptions', you pressed the buttons to get the information. Therefore, you had control over this information. On the other hand, for the 'common street structures' and the 'turning points', you did not have control since it was automatically given to you.

- [Pushed] Common street structures
  - Did you like that the 'common street structures' were announced automatically? Or do you prefer having control over this information? (**H2-1**) (would rather have control/ would rather have it automated)
  - Why? (Short answer)
- [Pulled] Direction
  - Did you like that you had control over the 'direction' audio cues? Or would it be better if the app constantly gave you this information? (**H2-3**) (would rather have control/ would rather have it automated)
  - Why? (Short answer)
  - (If they mention they would like to have it announced automatically and constantly) Wouldn't it be distracting if there are constant beeping sounds when you are navigating?
- [Pulled] Environment description
  - Did you like that you had control over the 'environmental descriptions'? Or would it be better if the app automatically gave you this information every time you were in a new environment? (would rather have control/ would rather have it automated)
  - Why? (Short answer)

- [Pushed] Turning points
    - Did you like that the 'timing to turn' was announced automatically? Or do you prefer having control over this information? (**H2-2**) (would rather have control/ would rather have it automated)
    - Why? (Short answer)

- *Turn microphone off*

Ok, that is the end of the interview! I will send you the 15 euros bol.com gift card when I get home today. I really appreciate your valuable time. Thank you so much!

NAVIGATION INSTRUCTIONS

(intro)
Destination set to Joy Espresso and More. Reorient to find the direction.
(common street structures)
Do not walk down the stairs ahead.
Go through the tunnel ahead.
Cross the bike path and zebra crossing ahead.
Cross the zebra crossing and bike path ahead.
Cross the street ahead.
Walk up the stairs ahead.
(end)
Destination is on your left.

(demo)
Is the volume ok for you?
You are on a pedestrian path with shops on both sides.
Walk down the stairs ahead.

(environmental descriptions)
You are in an open space with some planted trees.
You are inside a tunnel under some buildings.
You are on a large street.
You are on a wide pedestrian island with some planted trees. Green space on left, traffic on right.
You are on a wide sidewalk with some planted trees. Traffic on left, green space on right.
You are on a small street.
You are on a small pedestrian path. Shops on left, green space on right.

(demo)
You are on a pedestrian path. Rotterdam Blaak train station on right, Blaak metro station on left.
You are on a pedestrian path. Rotterdam Blaak train station on right.

(other)
Reorient.
Turn towards your left.
Turn towards your right.