Solving way-finding challenges of a visually impaired person in a shopping mall by strengthening landmarks recognisability with iBeacons

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Abstract

Because of reduced visual capacity, mobility and orientation are very challenging for blind and VI people. In addition to VI people, mobility challenges in large complex buildings concerns almost everyone. Accessible design aims to ensure that spaces, applications and contents are accessible for everyone, including people with impaired perceptual capabilities. It is critical that public places and community settings will be designed to be safe, as inclusive as possible and accessible for all. Currently smartphones, navigators and other handheld devices provide location-based technologies to support navigation outdoor and indoor. Many of them are based on visual guiding information like maps to be followed on a device or on info boards. We claim, that by adding multisensory features into environments, and by developing multisensory way-finding solutions, we enhance the potential for smarter interaction and accessibility. This article describes ILSI project and how we developed together with blind and visually impaired persons a smart environment to Itis Shopping Mall in east Helsinki with iBeacons. Environment was tagged with iBeacons that communicated with VI people's smartphone and BlindSquare App. IBeacons were set on locations that had landmark recognized by blind or visually impaired persons.

1 Introduction

According to WHO (2011) there are approximately 285 million visually impaired (VI) persons worldwide. 30 million blind or partially sighted persons living in Europe, and 80,000 of them in Finland (Ojamo 2014). Mobility and orientation are very challenging for the blind and visually impaired persons. Reduced visual capacity challenges persons' spatial problem solving everyday in several ways, e.g. how to receive, perceive, interpret, and process information needed in with the environment. Wayfinding refers to how a person orientates and navigates through an area or a space. Difficulties in wayfinding may cause stress and anxiety, which may lead to situations where blind or visually impaired persons avoid leaving home or visiting unknown, complex places and large-scale spatial environments, like shopping malls, without assistance. In modern cities, wayfinding instructional information is mostly presented in a visual form, which means it is not accessible for blind or visually impaired people. Therefore, it is hard for a blind or visually impaired person to gain a non-visual overview of a new place, and to map its landmarks.

In a modern smart city, getting people from one place to another and orienting them in complex spaces is increasingly complicated. Solutions to help navigation and orientation are closely connected with the technological developments. Currently smartphones, navigators and other handheld devices provide location-based technologies to support navigation when moving outside buildings. Inside buildings, wayfinding and navigation becomes even more challenging, because they are out of reach of GPS tracking. Several technologies are in development for to solve indoors navigation and wayfinding all around the world. Many of them are based on visual guiding information like maps to be followed on a device or on info boards.

We claim, that by adding multisensory features into environments, and by developing multisensory way-finding solutions, we enhance the potential for smarter interaction and accessibility. With ILSI-project (Itsenäistä liikkumista sujuvoittavat tienlöytämisratkaisut) we try to develop smart multi-sensory way-finding solutions, 1) that will ease VI persons' independent translocations and way-finding indoors, and 2) that will increase independent mobility and travelling with public transport. ILSI project has been divided into three phases: I Way-finding and landmarks, II Way-finding and interactive 3D-maps, and III Simulation and verbal maps. This article focuses on phase I. The first phase of ILSI aims to identify and pilot iBeacons' potential for exploitation of multisensory and mobility to facilitate the tracking, routing and mapping solutions. An iBeacon is a type of small-scale network transmitter that instead of using latitude and longitude to define the location uses a Bluetooth low energy signal, which iOS devices detect. (iOS: Understanding iBeacon - Apple Support 30.5.2015; Techopedia 30.5.2015).

ILSI project is run by HAMK:s Multisensory and assistive research group (MATEC). For the trans-disciplinary research purposes to be met, MATEC has created a unique ecosystem way of doing R&D activities with stakeholders. The ecosystem is called MWAY, and it focuses on multisensory way-finding solutions for blind and low vision people (VI). In this ecosystem we have enterprises like MIPsoft, which is the creator of the BlindSquare, blind and low-vision co-creators from Finnish Federation of the Visually Impaired (FFVI) and from local visually impaired people's societies Uusimaa and Häme in Finland. Each actor of the ecosystem has collaborative role in the development process. Especially in ILSI project we believe that people who need assistive technology should be able to experience the solution development as creators, not just as consumers.

ILSI's piloting was done inside *Itis Shopping Mall* east Helsinki, in Finland, and later it will also be done around the context of bus and rail platforms, subways and buses. The results will be used in the development of intelligent transport environments and guidance systems for all commuters. By creating stress-free travel-chains, the mobility environment's multi-sensory intelligence and safety improves everyone's, and especially the VI persons', independent mobility and making commuting a more comfortable experience.

2 Setting the conceptual stage

2.1 Wayfinding and landmarks

Wayfinders utilize environmental information, instructions (e.g. verbal or pictorial) and their spatial and cognitive abilities in order to make wayfinding decisions (Montello 2005). People's behavior and experience depends on the images that they create of the wayfinding environment (Lynch 1960). Cognitive maps, defined as comprehensive representations of the environment (Dows & Stea 1973), contain knowledge about landmarks, route connections, distance, directions, and may also have non-spatial attributes and emotional associations (Montello 2001). The complexity of wayfinding decisions is characterized by the structure of the environment, as well as the goals and personal characteristics of the wayfinder. As the number of wayfinding options increases, the complexity of a decision point also increases. To sum it up theoretically, Giannopoulos & al. (2014) propose a model that incorporates environmental, instruction, and user factors of the decision situation.

Lynch (1960) defines five elements of the urban space, which are needed for the creation of cognitive maps in wayfinding process: paths, edges, nodes, districts and landmarks. To make sense of these elements, Gibson (2009, 37) gives four types of wayfinding strategies that makes places easier to understand and navigate: *1) Districts systems* – a place is divided into meaningful zones for use of signs and maps, and specific destinations are clustered within those districts; *2) Streets provide the wayfinding metaphor*, easily recognizable corridors and pathways form a comprehensible network across a space; 3*) Connectors are simple pathways* that connect all of the destinations within one location; *4) Landmark strategies direct people to major nodes,* like elevators or primary destination points. According to Richter & Winter (2014), landmarks have features that make them stand out to be recognizable from the environment. They structure mental representations of environments by forming anchors that serve as markers or reference points in mental spatial representations. Landmark knowledge is information about environmental features in their spatial and temporal context. We use them emotionally to confirm that we are on the right route. Routes are defined as ordered sequence of landmarks (Magliano et al. 1995). Landmarks also tell you when you arrived to the destination. Overall, the wayfinding system links people together, by guiding them through the same space with a system of communication (Gibson 2009, 46-55).

As, due to the lack of sight, mobility and orientation are challenging for the blind and VI persons, different tools have been developed to help inquiring about the environment and ease anxiety and fears related travelling, e.g. electronic travel aids, 3-D models, haptic maps and verbal descriptions (Brock 2013, 44). According to Fletcher (1980), blind people navigate mainly using route strategies in new spaces. Worsfold and Chandler (2010) describe four principles that bind way-finding together, and which we rely upon when making journeys: *1. Getting information and using it* - identifying information sources, being able to access that information in a way, that a person can understand. The relevance and usefulness of the information is important to allow a person to continue the journey. *2. Orientating within the environment* - gathering information to understand a person's current position relative to their surroundings. This involves understanding what is around you and the direction you need to go. Typical questions asked might be: Where am I? Where is (person or object)? *3. Navigating within the environment* – moving through the environment to the intended destination from point A to B. This may or may not be a planned route. Typical questions asked might be: Am I on the correct route? Have I passed the place I needed to be at? Verbal instructions containing landmarks enable more efficient wayfinding, less error prone direction estimation and higher navigation performance (Roger et al. 2011). *4. Entrance and Exit Identification* - the ability to identify an entrance or exit to either an internal environment or a vehicle that a person can navigate to and through it. These make it possible to continue the journey.

2.2 Accessible Shopping Mall for all

Thanks to services being centralized to places where people move around, Shopping Malls have now become more and more like service centres providing a variety of services. When asking VI people of their use of Shopping Mall's services, typically they say they do not use them. This is particularly the case for elderly visually impaired men. Women and younger VI people would like to go, but feel uneasy to go alone. Young people would like to engage in activities much like other young people do, mothers of families would like to get around, do shopping and find the best sales. Instead of independent shopping, VI people rely instead on social support such as friends, relatives, volunteers, or store employees. When these individuals are unavailable, VI shoppers have to reschedule or postpone shopping trips. Kulyukin & Kutiyanawala (2010) have analysed VI people's experiences when they are shopping alone. When they go to supermarkets by themselves, they experience delays, waiting for store employees to assist them. Some staffers are unfamiliar with the store layout, others become irritated with long searches and requests to read aloud product ingredients. Because of challenges of wayfinding in large public buildings, corporations are investing significantly to create large-scale indoor mapping databases. Especially in the case of public buildings or publicly accessible buildings (e.g. a shopping mall or an airport), having access to the interior geography can allow creation of innovative businesses or services with high economic and/or social benefits. *Accessibility*, also known as design for all or inclusive design, aims to ensure that spaces, applications and content are also accessible for people with impaired perceptual capabilities. It is critical that public places and community settings are designed to be safe, as inclusive as possible and accessible for all.

The first phase of ILSI aims to identify and pilot iBeacons' potential for exploitation of multisensory and mobility to facilitate tracking, routing and mapping solutions. Objectives of the ILSI first phase were:

1. What kind of wayfinding information do VI people use in Shopping Malls?
2. What kind of multisensory wayfinding and guidance information should be made available?
3. How should guiding information be technically provided?

3 Study

3.1 Itis test bed

ILSI project 's first phase took place at inside *Itis Shopping Mall* east of Helsinki, in Finland. The research test bed area was the oldest part of the *Itis*. This part was chosen as a test bed because it has connections to subways and buses, through bus and rail platforms.

3.2 Focus group of collaborative VI informants

Blind and VI persons taking part in this first phase were voluntarily recruited via Iiris, The Service and Activity Center for the Visually Impaired, and from local VI people's societies of

Uusimaa and Häme. The focus group of informants consisted of 5 VI persons, of which 2 were men and 3 women aged 21-45 years. All had previous experience of using smart mobile phones and different apps, like BlindSquare (BSq) navigation. In addition to this informant group, ten volunteers took part in testing and provided feedback for iBeacons, such as clarity of hearing and navigation messages at the implementation stage.

3.3 Data collecting and analysing

1. **Videotaping known and unknown route walks.** Data was collected by videotaping five VI volunteers' known and unknown route walks, and these were analysed by using theme based content analysis (Neale and Nichols, 2001). *Known route walk* is walking in a familiar environment. Known route walk describes how a visually impaired person uses landmarks and waypoints and other information available in an environment. This known information is important wayfinding information that a VI person is able to provide for another VI person. *Unknown route walk* is walking in an unfamiliar environment with help acquired from the environment beforehand or while walking in an environment. It describes challenges and problem solving of VI persons.

   The test routes walked by informants at *Itis* test bed (local Shopping Mall in east Helsinki) were 1) from S-market or Iiris end's door by the Pasaasi (main corridor) to the R-kioski (local kiosk) or Talking ATM at the Bulevardi Square. 2) From the information point of the shopping mall to the second floor pet store Faunatar by using elevator or escalator. 3) From Pet Store Faunatar back to S-market or Iiris end's door by using elevator or by using escalator. An example of test routes at *Itis* test bed is shown with red dots and direction indicated by an arrow (picture 1). Minor route options were allowed, such as the choice between using the elevator or escalator. With known route walks, VI informants were instructed to give description to other VI informants of the route, important landmarks and other wayfinding information they found useful in order to get from where they are to the destination. With unknown route walks informants were instructed to use all guidance instructions the same way they normally did, e.g. ask sighted people. The purpose of this was to gather data of wayfinding instructions used, how they were helpful, and what challenges still remain. Each VI informant walked routes individually, and was videotaped individually. Video documents were transcribed, encoded in numerical order from 1 - n and themed (Table 1).

   Table 1. Analysis, encoding and theme finding for videotaped route walks.

Codes	Themes:	Descriptions
RO1…n	Route's instructions:	What kind of wayfinding instructions and signage were found from routes, and was the VI person able to use them. If yes, how.
RM1…n	Route's landmarks:	What kind of landmarks and waypoints were recognised and used by VI persons. In what way does a blind or visually impaired person use audio, tactile and olfactory information that helps recognize landmarks? The focus was on gathering information of how VI persons face and solve way-finding challenges in a shopping mall.

RiB1…n Route's needs for iBeacons: Where were the needs for multisensory wayfinding information recognised.

RS1…n Observations for smart verbal route maps: – What needs to be considered when defining verbally a route map or giving verbal wayfinding instructions.

Picture 1. An example of the test route walked at Itis Shopping Mall test bed.

2. **Reflective group discussions.** Immediately after each walk, reflective group discussions of feelings, experienced obstacles and other observations during the walk were held. VI informants, video-capturing assistants, technology experts and researchers participated in these discussions. The purpose of the discussion was to add reliability and understanding for observations and experiences of the test walk. Discussions were recorded, and analysed using theme based content analysis (Neale and Nichols, 2001).

   All videos were transcribed as texts, and were sent to informants to read and re-reflect on their observations for co-creation workshop.

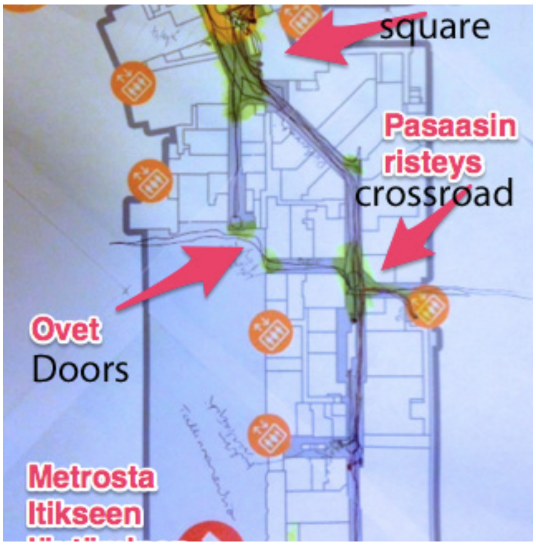
3. **Co-creation workshops.** One month after walks we held co-creation workshop to evaluate landmarks found, waypoints and instructive information needed in order to be able to go around at the Shopping Mall. Based on this co-creative workshop, the strongest iBeacons were located.

4. **Testing and iteration.** iBeacons' testing and iteration was made for about three months to refine locations and wayfinding messages with BlindSquare. Approximately twenty voluntary BlindSquare users took part in iteration at Itis Shopping Mall.

4 Results

4.1 The most challenging areas of the Shopping Mall

Each informant's route walks were analysed from video documentation and re-tracked on the test bed's map. This way the most challenging areas of the Shopping Mall could be defined visually (Picture 2).

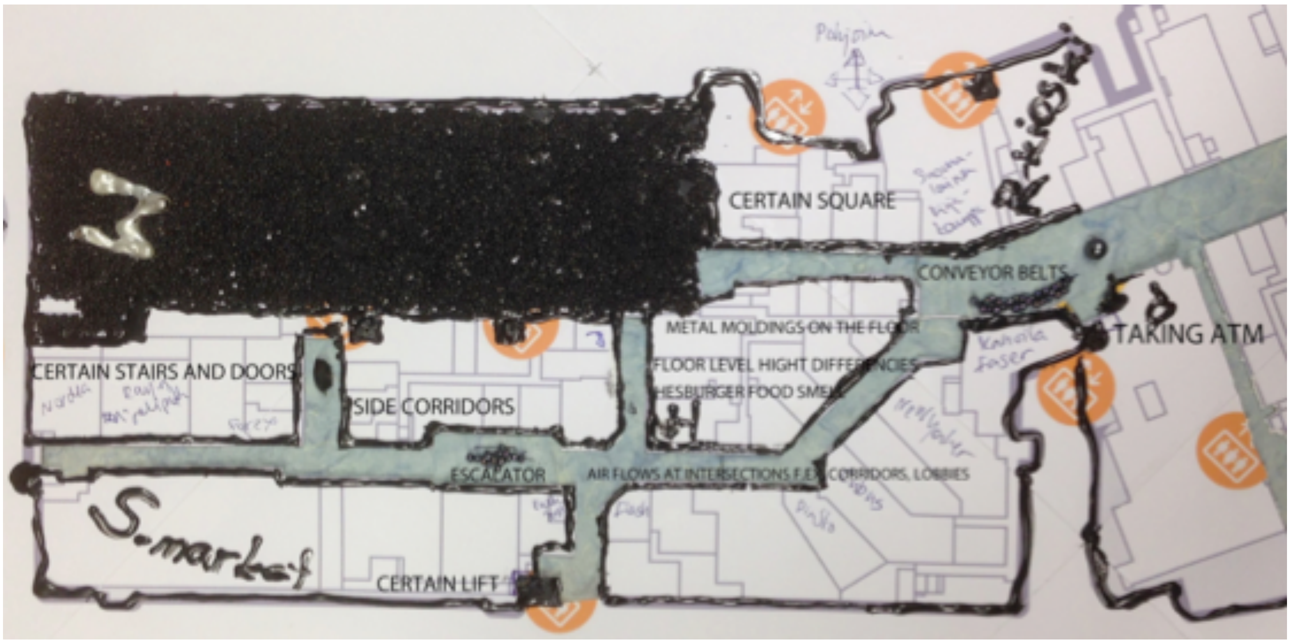


Picture 2. The most challenging areas of the Shopping Mall's test bed

The most challenging areas were: 1) Several undefined doors which were close to each other. Adjoining doors without any recognisable features are difficult to distinguish from one another. 2) Squares with plenty of point of interests close to each other. In echoing spaces and indefinite-shaped open spaces, it is difficult to identify one's own position in relation to others, especially to a number of corridors and doors. 3) Crossroads where crossing corridors are not fully aligned. Wayfinding advice with reference to intersecting hallways, which are vaguely definable relative to each other, is difficult to discern. These areas caused confusion and feeling lost for VI informants.

4.2 Wayfinding information and landmarks found by VI informants

From the data we found landmarks and potential landmarks that could become actual landmarks if coupled with social or emotional meaning, such as through a community gathering or event. Landmarks and potential landmarks have been collected to a handmade 3D-map that was made to present tactually the most important landmarks for VI informants (Picture 3) and (Table 2).



Picture 3. Landmarks found by VI persons and described on a handmade 3D-map.

Table 2. Landmarks found by VI persons.

Recognised as potential landmarks	Recognised landmarks
Certain stairs and doors	The Iiris end door
Side corridors	Hansa Bridge's side corridor
Escalators, Conveyor belts	Pasaasi conveyor belts to floors -1 and -2
Crossroads, corners	Hese's corner (Hesburger's food smell)
	S-market's corner (sound of shopping carts)
Corridors junctions	Pasaasi and Diagonaali junction
Certain lifts	Lift next to Talking ATM (sound)
Certain Square	Tallinnan aukio / Tallinna's square
Certain metal moldings on the floors	Talking ATM
Floor level height differences	Info point

Some actual landmarks were recognised as stronger and more important than others, e.g. The Iiris end door, Pasaasi and Diagonaali junction, Hese's corner, Info point and Tallinna's square. The weaker ones were described in relation to these stronger ones.

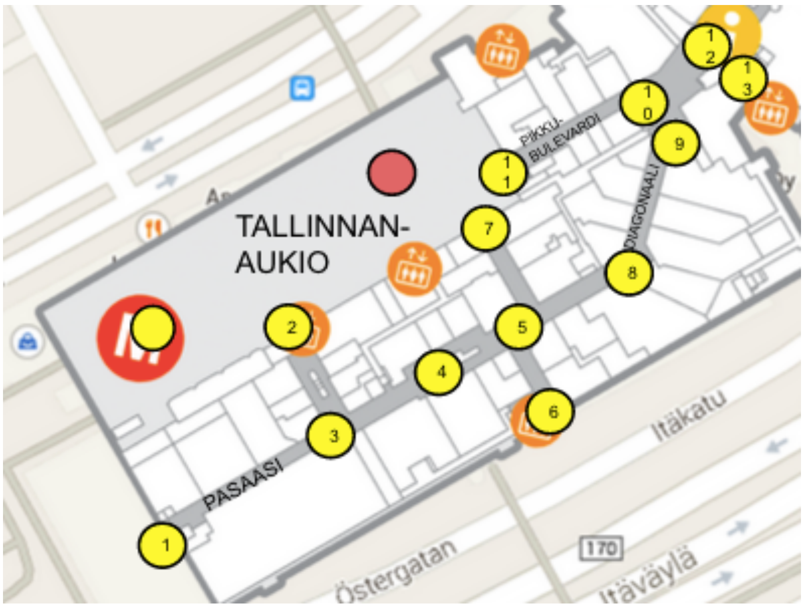
4.3 Needs for multisensory wayfinding information and iBeacons' location setting

What kind of multisensory wayfinding and guidance information should there be? How should guidance information be technically provided? Based on data from video-documents and the co-creation workshop, multisensory wayfinding information needs were defined. VI informants described iBeacon-mediated wayfinding information needs on several levels. To sum up the needs, there should be information of the place "where am I?" and the direction "where I'm heading to". There are also different needs based on familiarity of the environment.

As a result, we created four levels of information mediated with iBeacons and captured via smartphone and with BlindSquare. If the environment is not familiar to you, the first level names the place where you are. At this level you can look around, and it will name all directions as landmarks nearby. The second level will add what is ahead of you. The third level will give you more verbal descriptions of what is around you, so you can look around. The last level is for those who are familiar to the environment, e.g. if you go the same way every day, you do not need that much information. Landmarks are classified into different categories, and each category has its own voice tag. So in the last level there are only sounds informing you of your arrival to the landmark. In case you need more information, you simply stop and listen. During iBeacons testing and iteration with BlindSquare, information was refined further.

Based on data from video-documents and the co-creation workshop, needs for multisensory wayfinding information were found in several areas. Firstly, urgent needs were found in most challenging areas described in chapter 4.1: 1) Several undefined doors which were close to each other, 2) Squares with plenty of point of interests close to each other, 3) Crossroads where crossing corridors are not fully aligned. As already discussed in chapter 4.1. these areas had several reasons why they caused confusion and feeling lost. For sighted people, there were signage and visual landmarks, e.g. the name of a corner store that instructed wayfinding. For VI people these areas had no wayfinding information, thus multisensory information provided with iBeacons were highly recommend by VI informants. Secondly, landmarks, especially the weaker ones were hoped to become easier to recognise with complementary multisensory wayfinding information that could be provided by iBeacons. So landmarks were made more recognisable with auditory features provided with iBeacons.

After the co-creation workshop, iBeacons were first located at places described with yellow dots in Picture 4. During iBeacons testing and iteration with BlindSquare, places were re-organised and refined several times, but mainly the setting stayed original.



Picture 4. iBeacons setting after co-creation workshop with VI informants.

4 Conclusions – "First time in years I could do shopping on my own"

Because of reduced visual capacity, mobility and orientation are very challenging for blind and VI people. In addition to VI people, mobility challenges in large complex buildings concerns almost everyone. Accessible design aims to ensure that spaces, applications and contents are accessible for everyone, including people with impaired perceptual capabilities. It is critical that public places and community settings will be designed to be safe, as inclusive as possible and accessible for all. In the beginning of the article we claimed, that accessibility aims could be met by adding multisensory features into environments. By developing multisensory way-finding solutions we created space for smarter interaction that eventually work for all people. Within ILSI-project, we developed together with blind and visually impaired people wayfinding solution that is based on landmarks. And as we know, landmarks are essential for any spatial reasoning and for any spatial communication. Typically people use landmarks quite naturally. Defined by Richter & Winter (2014) landmarks have features that make them stand out to be recognizable from the environment. Landmarks exist also for the blind and visually impaired people, though they are recognised by sounds and tactile characters.

We developed a smart environment to Itis Shopping Mall in east Helsinki. Environment was tagged with iBeacons that communicated with VI people's smartphone and BlindSquare App. IBeacons were set on locations that had landmark recognized by blind or visually impaired persons. We added sounds and messages into weak landmarks mediated by iBeacons. Messages have several levels of information developed together with VI people.

After a six-month pilot, we asked three of our blind and visually impaired informants what they think about this kind of multisensory wayfinding solution. Here are some comments to describe ways that landmark-based and iBeacon mediated solution work in practice:

- ”It makes it possible, and much easier, to get around independently. You're not so dependent on the help of an assistant."
- ”It encourages and gives a kind of certainty in moving around, even in strange, unknown places."
- ”It's also more convenient to do business, when you know where you are, where you need to go and how to get there. This saves time when you're not totally lost all the time."
- ”It also creates a certain sense of security when you know you are "on the map"."
- "It's so helpful in perceiving the environment, at least for me, I'm a low vision person. Typically your concentration will be used for moving alone…for searching possible signs to read to get the information. And when you finally find it, you realise that you cannot see it. Now I don't need to see it, I can hear it."
- "And in unknown places. With these Blind-Square landmarks, you're not always dependent on other people. For example in setting up timetables … it's always up to the assistant, if it suits him or her, not if it suits me."
- "And if iBeacons are used in advertising, I don't mind advertising. I'd like to know and hear about how much I'd save money, if I'd do the shopping today (laughing). "
- "Today I felt so excited and good! I went to *Lidl* store at *Itis* to buy some applepies. For the first time in years I could do shopping on my own … with BlindSquare telling me exactly where I was."

To sum up opinions, our VI informants felt that this solution eases independent interactions and helps not only way-finding but also capturing environmental information that was previously out of reach.

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