Icon based Indoor Navigation

Is icon based navigation a good method for indoor wayfinding?

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ICON BASED INDOOR NAVIGATION

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Humans today rely heavily on navigational aids on their smartphones to find their way. These aids have shown to be decreasing our ability to learn routes since the interaction with the environment is minimal. Technology assisting indoor navigation is getting more common, and the same approach, which has shown to impair spatial ability, is used there, and will most likely result in the same problems. In the current study an application was developed that uses landmarks represented as icons to guide the users. The application was tested in a wayfinding task and compared to a control group using text instructions. Time for completing the route, wayfinding errors and route knowledge were measured and compared between groups. The results show that the text group had a faster walking time, but no significant difference was found in the other measurement. The route knowledge test turned out to be too difficult for the participants. The conclusion of the study is that icon based indoor navigation works but more research needs to be done to test if it facilitates spatial learning.

Människor idag förlitar sig mycket på hjälpmedel i sin smartphone när det kommer till att navigera. Dessa hjälpmedel har visats minska förmågan att lära sig hitta, eftersom interaktionen med omgivningen minskar drastiskt. Teknologi för inomhusnavigering blir mer och mer vanlig, och samma metod används, vilket kommer skapa samma problem. I den här studien utvecklas en mobilapplikation som använder landmärken i form av ikoner för att guida användaren. Applikationen testades sedan i ett navigationstest och jämfördes med en kontrollgrupp som använde textinstruktioner. Tid, färdvägskunskap och fel mättes och jämfördes mellan grupperna. Resultatet visade att textgruppen hade en snabbare tid, men det var ingen signifikant skillnad i de andra mätningarna. Färdvägskunskapstestet visade sig vara för svårt. Slutsatsen av studien är att ikonbaserad navigering fungerar, men mer forskning behövs för att testa om det faciliterar spatial inlärning.

Automated technology assisting us with daily tasks, such as navigation, is widespread today; many people around the world rely on this technology to navigate in their daily life. The technology and the use of it are increasing rapidly and therefore it is important to research how it affects us. When it comes to navigation, research has shown that navigational assistance has a negative impact on our spatial ability and makes us reliant upon the technology in navigational tasks (Burnett & Lee, 2005). This shows that finding a balance between human and technology is important if we do not want to lose our cognitive ability in an automated world.

The first part of this paper will look at previous research and what has been found regarding navigation with landmarks and indoor wayfinding. The second part will explain how an application for indoor navigation that uses landmarks was developed. The third part explains the procedure of the experiment where the application was tested against written instructions and how data was collected. The fourth part contains the results from the experiment and then the results are finally discussed.

As said people are quick to use automated aids, such as navigation tools, to speed up our everyday tasks and to decrease our cognitive load (Brügger, Richter, & Fabrikant, 2016). The most common navigation tool today is a smartphone with a navigation app or a GPS-device, showing your position and giving you instructions on how to walk. With the limited view a small screen offers, the rich position feedback and wayfinding instructions the tool gives the user, there is no need to look up and engage with the surrounding environment. This method also leaves little decision making to the human who uses it and thus requires a very low physical and cognitive effort. But the humans' ability to navigate and learn routes decreases (Gardony, Brunyé, Mahoney, & Taylor, 2013).

Research has found that when navigating without a tool, landmarks are important for the navigator (Frankenstein, Brüssow, Ruzzoli, & Hölscher, 2012). Furthermore the most popular way to give and receive wayfinding instructions is by landmarks (May, Ross, Bayer, & Tarkiainen, 2003). In a study by Denis (1999), they found that people navigate using the signs in the subway area. Landmarks and signs were the most important aspects for navigation. Signs are not traditionally seen as landmarks, but as stated in a study by Ohm, Müller, Ludwig, & Bienk, (2014) they fulfil the same purpose as landmarks and will therefore be used as such in this study. In the same paper the authors argue further that if a system can select the most promising landmarks, a lot of new interfaces arise for navigation technology which makes the development of aids that use landmarks easier. It is safe to say that an effective wayfinding method in terms of reported direction quality and usefulness is to use landmarks (Frankenstein et al., 2012; Goodman, Gray, Khammampad, & Brewster, 2004; May et al., 2003; Ohm et al., 2014; Ross, May, & Thompson, 2004).

In a previous study by Oliver and Burnett (2008) they tried to develop a learning oriented navigation system that facilitates the development of spatial knowledge as well as minimizes navigational uncertainty. The learning oriented system included features such as landmarks along the route, compass bearings and highlighting previously driven routes. They compared the learning oriented system to a basic system that only displayed distance to turn and a view of each junction. They compared these two using a driving simulator inside a virtual town and measured acquired route knowledge and cognitive map development. They found that participants using the learning oriented system could recall the route better and had better acquired route knowledge. They conclude that navigational systems that are designed to facilitate learning have potential and that including landmarks has a value both for guidance and learning. Gardony et al., (2013) have identified a possible problem with navigational aids in regard to facilitating spatial memory and learning. They found that divided attention between the navigational aid and the environment is enough to impair spatial memory. Oliver and Burnett, (2008) state that more research and new concepts on learning oriented navigational aids are needed that do not require too much attention but still give the user a good enough instruction to effectively navigate in the environment. Since people tend to get lost more often in the complex environment inside buildings than outdoors (Carlson, Holscher, Shipley, & Dalton, 2010) it is important to be particularly careful when designing a navigational aid. As stated above it has

been shown that using current navigational assistance decreases route knowledge, therefore it is not recommended to use the same interface indoors with the more complex environment with changing floorplans.

The focus in this study is therefore to test if icons can be used to give instructions, point out landmarks for the user, and in the process increase the user's interaction with the surrounding environment. A mobile application that does this is to be developed and tested against written instructions. The performance measured by time taken to reach the final destination, errors and hesitations and acquired route knowledge will be compared. The hypothesis is that the group using the application will have a longer average walking time but better acquired route knowledge.

In this thesis the development of the app is also reported since the work behind it is an important intellectual contribution to the current field of study. The application is a result of the previous research that has been done in the field. It is also a proof that this type of navigational aid is possible with the technology of today.

An application for icon-based navigation

In this section the development of the application that was named Inavicon will be described. First the mapping and icon selection is described, and then an overview of the application's main algorithm is outlined.

Inavicon works by showing icons that represent a landmark in the real world to guide the user between waypoints. When a waypoint is reached, the next one is displayed until the user reaches the goal.

Method

Given that this study is not focusing on technology or system aspects, a web search was done to find solutions for easy indoor navigation. The existing tools that best fit the needs for this research are IndoorAtlas in combination with Proximi.io. IndoorAtlas is a service that lets the user map a building by recording the strength of the magnetic field, acoustic signals and other sensory information that can be collected with a smartphone and with that information create unique fingerprints for different locations in the building. The main medium is the earth's magnetic field and how it bounces in the building. Proximi.io is a service that manages the positioning of a device, and lets users add functions, events, and points of interest to a specific location in a space.

Mapping

Maps of the relevant floorplans in the KBC building were provided by Umeå University. However only the map of the third floor in the KBC building was used when mapping since there was no vertical overlap in the route and mapping two floors separately would require beacons that trigger a floor change inside the

application. IndoorAtlas' tool MapCreator2 was used to map the route, running on a Nexus 6 with Android 7. Only one floorplan is shown in this report (see Figure 1), because all plans were all almost identical.
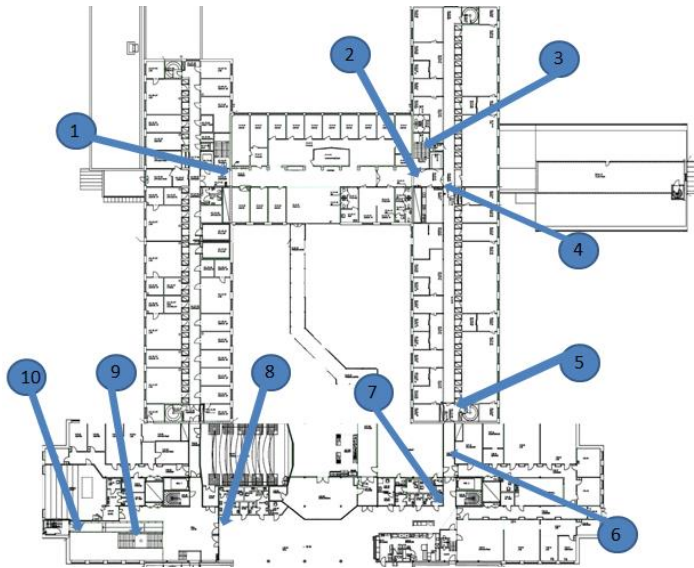

Figure 1 Floor three in the KBC and chemistry building. The checkpoints used in the app and test are marked out.

Icons

When the route was mapped research was done on what objects or places to make icons of (e.g. what may serve as a landmark indoors).

Earlier research has shown that landmarks indoors can be divided into four categories (Ohm et al., 2014).

- Architecture: Pillars and fronts
- Function: Doors, stairs and elevators
- Information: Signs and posters
- Furniture: Tables, chairs, benches and vending machines

These categories were used when the icon-objects were picked, together with customized criteria for the icon navigation concept. These criteria were: Not too many of other similar objects at a close distance; objects should be clear, obvious and relatively easy to spot; objects should be visible from the earlier icon's position.

When the landmarks had been chosen, Flaticon.com was browsed to find fitting icons. All icons come from the user Freepik. Some of the icons were then customized to better fit the environment (e.g. door icons got a text with the name it had printed on). Figure 2 shows all icons that were used in the study.
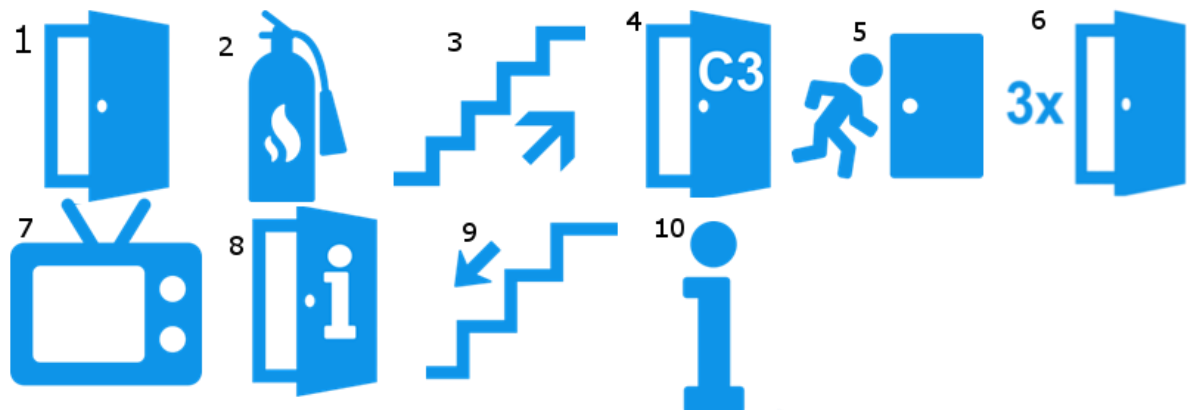
Figure 2. All the icons that were used, in order of the route.

The fire extinguisher (2) and television (7) belong to the category Furniture. The doors with text on (4 and 8), the emergency door (5) and the 'i' (10) belong to the category information. The doors (1, 4, 6, and 8) also belong to the category Function together with the stairs (3 and 9).

The icons are marked out with their corresponding numbers in Figure 1. Due to the one-floor-mapping described earlier in this article they are all marked out on the same floorplan.

Geofences

A geofence is a virtual geographic boundary defined by GPS coordinates that enables the application to trigger a response when a device enters or leaves a particular area. Proximi.io's web tool was used to place geofences on the floorplan at the sites where the icon-objects were. Each geofence is supposed to be responsible for triggering the changing of icons in the app.

Development tools

When all the preparation was done the development of the application started. Java and Android Studio were used to create the application. The application was tested on three phones; Nexus 6 with Android 7, Samsung Galaxy 5s and Sony Xperia z5 premium. The Proximi.io API was used for the positioning and geofences – listening.

The implementation

Code

The application was named Inavicon. Two activities were created, one menu-activity and one main-activity. Inavicon starts by showing the menu-activity where it displays a start button as shown in Figure 3. When it is pressed the main-activity starts. A listener to Proximi.io's API is created and Inavicon asks the phone for various kinds of permissions. The listener listens for position updates (e.g. the phone position has changed since last update) and for geofence entrance.

A path is also created. Here a path-finding algorithm should be implemented, but since our implementation is only a proof of concept, the path is hardcoded. Checkpoints are created along the path. A checkpoint represents a geofence, location and an icon. The checkpoints are stored in an array and methods for accessing them and their methods are created. See Figure 4 for an overview of the functionality.

When a proximi.io geofence is entered and the listener detects this, Inavicon compares that geofence name to the expected checkpoint's name and if they match, an animation takes place (a green square appears behind the icon to give the user some feedback). When the animation is done the app displays the next checkpoint's icon and the path moves its current Array-position to next checkpoint.

If there are no more checkpoints in the path a message to inform the user that they have reached their destination is displayed.
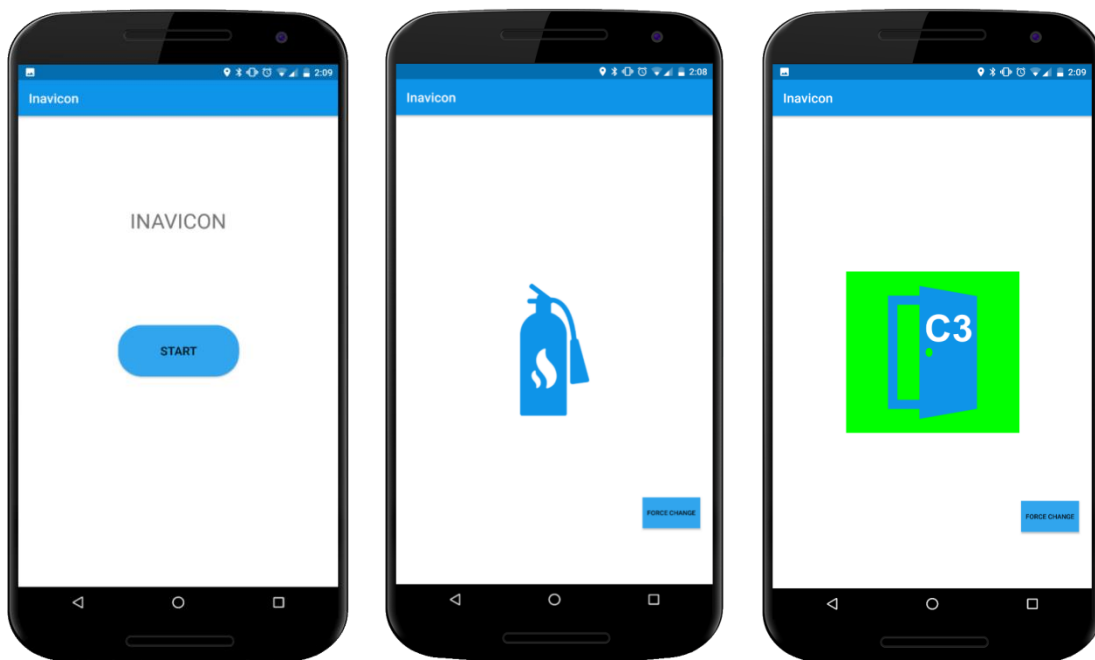

Figure 3 The final design of the application. To the left is the start screen, in the middle an example of an icon to look for and to the right is a checkpoint that was just reached.
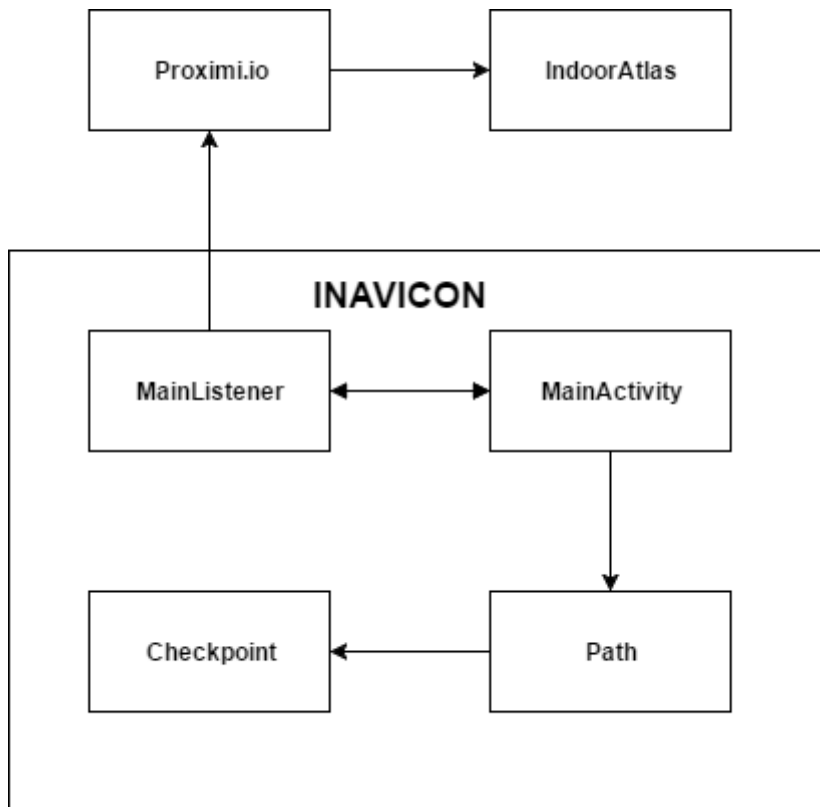
Figure 4. An overview of how Inavicon works.

Performance

Inavicon worked best on the Nexus phone. The app worked on the other two test phones, but the Nexus phone had more accurate positioning. On the Nexus the app and positioning performed well most of the time but sometimes there was a problem with the positioning and communication with the Proximi.io API and the positioning got delayed, which caused problems if this occurred when a geofence was about to be entered. However, the problem could be solved if the application user stopped for a few seconds, so that the position updates could catch up with the current location.

The empirical study

In order to test the hypothesis a study was conducted were the Inavicon app was tested against written navigation instructions. Written instructions are a common method for giving instructions and are well researched. The written instructions are even more useful if they use landmarks in combination with left/right instructions (Padgitt & Hund, 2012). The instructions used in this study incorporated the same landmarks as used in the application.

The test took place in the KBC -/Chemistry – building at Umeå University Campus (See Figure 1 for a detailed floorplan). Participants did not know their navigation

goal, and the route used was artificial in the sense that it was created for this experiment and that frequent visitors would not necessarily use this path to reach the final destination.

Method

Participants

The test contained two groups with a total of 25 participants. One group of 13 participants used the app and one group of 12 participants used written instructions they read from a text-message. A requirement for participating in the study was that the participant had no prior knowledge of the building where the test took place.

Material

The phone used was a Motorola Nexus 6 with Android 7.0. The text instructions were read in the Android Messenger-application (SMS), and the navigation app used was the one developed within the project (Inavicon). Behaviour was recorded in a notebook by the experimenters, and for the memory test 14 pictures were printed out in A5 format. A python-script was written to correct the test according to the rules, which can be read about later in this article.

The experimenters used a digital wrist watch to time the participants.

Instructions

The participants got instructions that they should walk from the starting point and follow the instructions that they had on the phone until they reached the end of the instructions. The participants were asked to walk in a slow, controlled pace; this was necessary for accurate positioning by the application. The group using text instructions received the same walking instructions for validity. The application group also got instructions about the app and how to deal with it, e.g. "Keep the phone horizontally in front of you and when you turn, always turn the phone with you". The participants were told that an experimenter would shadow them during the wayfinding task, but were not told about any of the data that the experimenters would record.

Data collection

How the participants behaved during the wayfinding task, including errors and hesitations, was written down in a notebook by an experimenter that shadowed the participants during the experiment. An error was counted if the participant had made an incorrect decision. A hesitation was counted if the participant was uncertain and did not move for five seconds or longer. Participants were also timed.

A semi-structured interview was conducted when a participant reached the final destination which was the 'Service center' in the KBC building. Depending on which group the participant belonged to different questions were asked. The purpose of the interview was mainly to investigate how participants perceived the

application, its usefulness and what they would like to see improved. Both groups were asked about what strategies they used when navigating and what they thought about the route. The interview data was then analysed with a thematic analysis.

In the memory task the participants were given a stack of photos and asked to pick out the pictures of scenes they thought they had seen or walked past on the route during the wayfinding task. There were 14 pictures and 7 were correct. When the participants had made their choice, they were asked to place the pictures in the chronological order that they had seen or passed them.

A template for correcting the memory test was taken from Oliver & Burnett, (2008). The maximum amount of points was 17, and minimum amount was -14 points.

- +1 scene correctly identified as being seen (pulled out of the stack of photos)
- +1 scene correctly identified as not seen (i.e., left in the stack)
- -1 scene incorrectly identified as seen
- -1 scene incorrectly identified as not seen

- +1 3 photos in correct order
- +2 4 photos in correct order
- +3 5 photos in correct order

Results

Results from navigation and route knowledge test

Data from one participant was excluded because they failed to follow the instructions.

The time it took for each group to reach their destination had a high variance, indicating that performance of participants varied widely. The app group had an even higher variance than that of the text group. This reflects the fact that the application's stability varied between participants sometimes displaying the icon too soon or too late.

The scores for the route knowledge task were lower than expected and showed a high level of variance, with 6 participants scoring 0 points by picking as many correct images as incorrect ones. The average time and score for the route knowledge test are shown in table 1.

The group navigating with the help of the application was slower than the group using text instructions. A t-test for independent measurements showed that there was a significant difference in time between the application group and the text group ($t(22) = 2.965$ $p = 0.007$). The effect size was strong for the independent variable with a Cohen's $d = 1.24$.

There was no difference between the groups regarding the amount of errors and hesitations made by the participants during the test showing that the type of instructions had little effect on the amount of errors and hesitations made. An independent samples t-test showed that there was no significant difference in hesitations or errors between the app group and the text group, hesitations $t(22)$ =0.587 $p = 0.563$, errors $t(22) = -1.053$ $p = 0.304$.

The application group had a better average score on the route knowledge test but a t-test for independent measurements showed that there was no significant difference between the application group and the text group ($t(22) = 0.227$ $p = 0.820$).

Table 1. A table showing the statistical results.

Group	Time (seconds)	Route knowledge	Errors	hesitations
app	328.15 (72.25)	4.31 (3.79)	1.15 (0.9)	2.31 (0.855)
text	261.17 (44.21)	3.83 (2.55)	0.92 (0.669)	2.58 (1.084)

Result from interviews

The thematic analysis resulted in five themes which were: Points to improve, text comments, app comments, inadequate instructions, and strategies for recovery of errors.

Points to improve

Under the theme Points to improve people thought it would be good with more feedback such as a vibration or a tone when a checkpoint has been reached, because it happened that participants reached their destinations without noticing that the icon switched to the following icon. Participants also said that they would like an overview of the icons and see the progressions between them. A more consistent distance between each icon was requested or something that indicates how far it is between each icon so that you get a clue for where to look. An approximation of direction was brought up by some participants; they meant that sometimes the icon could represent more than one object in their surroundings and a direction indicator would help them make their decision.

Some landmarks that the icons represented were easier to spot than others. A few were hard to spot. Thoughts about better icons were also mentioned. For example, the icon representing an emergency door was difficult to interpret; it could also represent the action "exit a door". One participant pointed out that not all icons have to be blue.

One participant thought that it was hard to understand how to interact with the application. Instructions like "now go to..." in text form was requested.

Text comments

Under the theme 'text comments' some participants pointed out that the text was hard to read and that it was necessary to read it multiple times. It also happened that participants skipped chunks of it and walked the wrong way. Then the participant felt it was necessary to walk back and read the text again. Some participants found it difficult to read and walk at the same time and had to stop to read the text again.

A few participants reported that they memorized the text instructions and that they only had to read it a few times.

Many participants liked the fact that the text instructions were split into paragraphs which made them easier to read. One participant reported that some people are used to walk and read from the phone at the same time.

A miss in the instructions that was brought to live during the tests was that the sentence "walk to the door with an 'i' on it" had gotten malformed in the sending phone and the 'i' had gotten the uppercase form 'I'. This confused some users in the text-group which thought it was the letter 'L' or the number 1. But again, all users found their way.

One participant strolled off the described route and switched floors early in the experiment and then "freestyled" from there, which was technically and theoretically possible. The participant mentioned later in the interview that they skipped a part of the instructions and took a risk to find a more fitting way. This would not be possible with the icon-based app as it looks and functions today.

App comments

Under the theme app comments participants reported that they liked the app design. It was "visually pleasing with pleasant icons". Some participants reported that the application felt intuitive and that they liked the concept of icon based navigation.

Many mentioned that they would like to use the app in the real world. "It would require a smaller cognitive load compared to classical maps since an indoor environment contains "multiple floorplans". The participants pointed out that the application was particularly good when the icons represented good and clear landmarks and not so good when participants experienced that there was more than one possibility that the icon could represent. There were also some negative thoughts; some participants did not like the concept.

The performance of the app was overall on an acceptable level. A few users had problems with that the app could not find all checkpoints, and sometimes the icons changed a bit too fast or a bit too slow. And when this happened users reported that it was somewhat frustrating. But when the app worked participants thought it was so good that they did not need to look down and could focus all attention on the environment.

A few users did not trust the app fully, and when for example looking for a stair they found the correct one, but continued to look if they could find more than one. These participants later said that if they could practise some more with the app they would be more confident in how it worked and could go faster.

One participant mentioned that they automatically put out place reference points with help of the icons that they could later remember and retrace. The same participants also said "The app helps you find, but above all it helps you learn the building and navigate in it through these reference points".

Inadequate instructions

Under the theme Inadequate instructions findings showed that the icons not always were optimal. The icon for "emergency exit" could be better. It was often mistaken for "go out through a door". Overall the door icons were hard to understand. From the researchers' perspective, a door always meant "go out through the door" while some participants thought it meant "go to the door". Another icon that was unclear was icon "3 x Doors" that meant "go through three doors". It was in a corridor with a poor range of landmarks to use and the number of doors you walked through differed based on if you included the first door in your counting or not.

Participants also said it was hard to see the "i door", but everyone found it. The text group had a problem with the fact that the 'i' in the text was uppercase, but on the door it was lowercase.

Strategies for recovery of errors

Under the theme Strategies for recovery of errors participants had similar techniques. When they thought that they were wrong, they went back to the last point they were sure that they were on the right route. They also mentioned that when there were multiple alternatives to choose from they thought about how they would give instructions for that specific location and chose the most plausible alternative. Some participants reported that they used instinct to navigate.

The app was also used to test directions with. Participants that got lost sometimes used the app and walked to a place they thought could be right to see if the application reacted to their new location. If it did not they walked back and chose one of the other possible directions.

Discussion

The purpose of this study was to test if icon based navigation is a good assistance for indoor navigation. The study concluded that people can find their way with the assistance of an icon based navigation tool. However, if it really is a useful method of giving instructions remains unclear.

There was no significant difference between the two groups regarding route knowledge, errors and hesitations, but there was a significant difference in time. The group using the application performed significantly slower than the group using text instructions. This might follow from that users of the application stopped more often and for a longer time searching for the next landmark. This may also indicate that icon based navigation facilitates a behaviour that requires more time. However, Inavicon is in its first generation and there are more things to take into consideration, such as design and better technology. Participants argued for a richer interface with distance and directions displayed. The distance has actually shown to be an important parameter when navigating indoors (Frankenstein et al., 2012). Both groups were found to have normally distributed walking times, showing that there was a variance in walking speeds. Both groups were told to walk in a slow and controlled pace; this probably had an effect on the time of the participants making both groups slower.

In this study, the app was sometimes unstable and did not change the icon on time, which resulted in confusion and longer stops, and sometimes it changed too early, which was also confusing to the users. This could be avoided with better technology. More accurate positioning allows for smaller geofences that reduce the risk of the application triggering an icon change too early, but this relies on more frequent position updates that do not lag behind the device's current position. The participants relied on the application confirming that they had reached the correct landmark, when the application is unstable it does not respond the way the participants expect it to and they cannot be sure that they reached the correct landmark.

The study cannot conclude that one type of the tested instructions is better for acquiring route knowledge than the other. The test scores were lower than expected and varied widely indicating that the test was too difficult.

The behaviour of the participants during the experiment was very similar in both groups, most of the errors and hesitations made by the participants were made at the same locations, independent of group, indicating that these places were difficult to navigate and instruct for. These two locations were nodes that had multiple alternatives and no good landmarks. The problems in the text group could have been minimized if the instructions had included more directions in terms of left and right. These kinds of instructions can also be given inside of the application by calculating bearing, and might be necessary if the application is to be effectively used in the real world. Perhaps the distance can be of more use, as said in Frankenstein et al., (2012). Although with more information updating in real time the attention of the user might be drawn to the application during use, decreasing the cognitive effort and increasing the split attention which hurts the acquisition of route knowledge (Gardony et al., 2013). Furthermore the findings from the interview and errors showed that the doors were the hardest icons to interpret. In a study by Ohm et al.,(2014) they found that people most often looked at functional landmarks (e.g. doors) but the usefulness of functional landmarks to navigate by is questionable. Doors are a common object indoors and often there are multiple doors to choose from, so unless the door in question looks very different from

other doors it is hard to specifically describe them in such a way that it becomes a useful landmark. Therefore it is not safe to say that what people look at the most are the best landmarks.

Despite the problems that arose all the participants found their way in a reasonable time. A majority of the participants using the application reported that it was a good and pleasant solution to navigate with icons. They reported that the icons were nice and the app was pleasant to use. The participants requested more feedback in terms of direction and distance to the next icon, and also the possibility to see the path / history to get a better mental representation of the path and also to plan the way to faster reach the goal instead of waiting for the next instruction to appear. The text group had the entire instructions visible at all times whilst the app group only saw the current instruction. This, we have concluded, forced the app group to stop at each checkpoint.

The application uses an universal language of icons which might make it suitable for people with cognitive impairments that have trouble using maps and written instructions (Chang et al., 2010).

With all this stated further research is recommend to investigate if icon based navigation is better than current navigation assistance at facilitating learning and acquiring route knowledge by constructing a better route knowledge test than the one used in this experiment and comparing the concept to current navigational assistance.

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