Independent sport for blind and mentally impaired individuals using location based audio messages

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***Abstract*—In this paper we describe the development of a prototype which is designed to help people with visual and mental impairments (VMI) sport independently. The main question was whether people with VMI can understand audio messages so that they can perform exercises without supervisors. Three people with VMI used our prototype to complete exercises without help of a supervisor, 81.8% of the exercises were completed perfectly. We found that the use of location based audio messages seems to be very promising for helping individuals with VMI sport independently, however due to our small sample size we were unable to confirm our findings.**

I. Introduction

At the Bartiméus facility in Doorn are people who suffer from visual as well as mental impairments (VMI). These people have difficulty conducting sports on their own, as they always require assistance. Currently, the assistance is provided by caretakers. Unfortunately caretakers have a limited schedule and thus cannot always free time to aid with sporting activities. This results in a waiting queue, which is not desired. The waiting queue is demotivating for those who would like to conduct sporting activities. The facility in Doorn has a six-hundred meter track made especially for people with VMI. Along the track are places for appropriate exercises for individuals with VMI, such as waving with both arms.

In this paper we describe the development of a prototype which will allow people with VMI to perform the exercises on the track independently. The prototype uses internet of things technology in the form of Bluetooth Beacons in combination with an Android smartphone. 8 Beacons are spread evenly over a track of 600 meters. When an Android smartphone comes within 5 meters of a Beacon, an audio message corresponding to that Beacon is played. This audio message contains verbal instructions for an exercise, in the form of a story. Each audio message can only be triggered once, after that the Beacon transmission for that audio message will be ignored.

Due to mental impairments our participants need a longer time to understand certain situations [1], often a situation needs to be experienced multiple times to fully understand it and what is to be expected of them.

II. Related work

A. Visuals

The term visual impairment is often confused with complete blindness, yet they are quite different. In the Netherlands one is considered blind when someone is able to see less than five percent or when the field of view is limited to ten degrees [2]. This means that some individuals with visual impairments are still able to see a difference in contrast, for instance.

When designing the prototype we thought about using visual elements on the screen with very high contrast. Using narrator applications already present on the device in combination with the high contrast should be enough for people with visual impairments to navigate through the application. However, this only takes into account the visual impairment and not the mental one. We considered that learning to navigate an application would be challenging for people with VMI, and thus it should be avoided. Therefore, we transformed our app into a wearable instead. We will have the smartphone in a jacket and the users will not interact with the screen.

B. Beacons

The Wayfindr application uses Bluetooth Beacons to trigger audio messages for visually impaired people in subway stations, which makes it very similar to the prototype that we wish to create.

Bluetooth Beacons are small devices which broadcast a signal at a regular interval. This signal consists of a unique identification as well as a power level. This power level can be used to estimate the Beacon's distance relative to the device which picks up the Beacon's broadcast. Beacons transmit the signal using Bluetooth Low Energy, as the name implies this method is friendly to battery life. This opens up some opportunities; Beacons can be powered for a long time using a small battery, and because of their small size they can be distributed throughout an area very easily. The exact battery life of a Beacon varies greatly on what kind of Beacon is used, the size of the battery and the rate and power of transmission, but to provide a rough estimate; the Beacons we used were from manufactured by Glimworm IT

B.V., transmission frequency of 2.5Hz, power level of 10%, using a CR2032 Lithium Ion battery.

When Beacons broadcast a part of the message is dedicated to the power level on which the Beacon broadcasts. As the signal spreads the power of the signal drops. When a device picks up the signal it can compare the power of the signal with the originally transmitted power and do an estimate on how far the Beacon is. However, the Beacon's signal can easily be blocked by a wide variety of things, such as: other radio signals like wifi, structures and water. Since humans are mostly water, we too have an impact on signals coming from Beacons. To reduce signal interference we placed the Beacons on a height of 220 cm above ground.

C. Audio

As mentioned previously, the Wayfindr application uses sound to help their users navigate. Whenever a user comes in range of a Beacon it triggers an audio message on the smartphone that the user is carrying. Wayfindr started testing at the London underground and were very successful, winning multiple technology awards. The audio messages which they used describe the environment very objectively, e.g. "there are stairs on your right." An objective message is hard to understand for people who suffer from mental impairments because it is too sudden. Messages are much easier to understand for people with VMI when they are given context. A better way to phrase the message from earlier would be: "do you hear the footsteps? People are going up and down. There must be stairs on your right."

D. Haptics

There are quite a number of products available that use haptics, vibrations, to help navigate users [3]. In most cases these devices consist of multiple vibrating parts, each vibrating part denotes a direction. A haptic belt has proven to be "a successful approach for guidance" [3]. The advantage of using haptics is that the user is able to concentrate on his or her surroundings as he or she normally does, but is supported with additional information from senses previously unused. For example, the Wayfindr application from earlier uses audio to help their users navigate, but the users rely on sounds very heavily already to find their way; it thus requires concentration. The cognitive load to process simple haptic signals, e.g. a short pulse, is lower compared to processing speech in the form of audio. The user is able to navigate normally, with additional info from feeling vibrations.

E. Mental impairment

To get a better insight on how to interact with individuals who have VMI we interviewed Bartiméus, an organisation which has significant experience in helping people with VMI. In this chapter the findings of that interview are displayed. All information gathered in this interview is denoted by [1].

People who suffer from mental conditions rely on habits. For example, when you are having breakfast the fork is always on the left of your plate and the knife is on the right. If these conditions change it can lead to confusion. This aspect is only strengthened by the fact that our target group is not just mentally impaired, but visually as well. This makes the use of habits even more important. [1]

People with mental conditions are significantly slower in understanding new situations. This does not mean they can never understand a certain concept; it just means it will take them a significant of time to do so. However, some things are simply too hard. For example, counting can be a challenge. People with mental impairments will be able to feel vibrations but they will be unable to understand complex vibrations [1], i.e. a combination of multiple vibrations with a specific purpose.

Whilst existing applications for navigation seem promising they are all made for individuals who do not suffer from any mental impairments. The Wayfindr concept is sound, it is just not designed for users with mental impairments. Understanding audio messages may take some time for people with mental impairments, they may need to hear the message multiple times before they fully understand it. This effect is strengthened if the message is without context [1], sudden. Therefore, it is important to take care with verbal instructions when designing applications for individuals with VMI. The audio instructions in our prototype build a narrative around the message to explain why the message is important, this way the message makes much more sense and is easier to understand.

III. Methodology

This research is aimed at obtaining qualitative data using literature research, talking to experts on multi-handicapped individuals and experimental research.

As shown in the previous section, there are not many applications which help visually impaired live more active and independent. For mentally impaired individuals we could not find something concrete and those two combined exists near to nothing. For visually impaired individuals, some use haptic feedback with guidance and others use audio messages. Haptic feedback in the form of vibration stimuli is proven to be an effective way of guiding visually impaired, as it is very intuitive [4]. With our users however, after talking to experts we concluded this to be too hard for the users to properly understand. We now use vibrations to announce the start of an exercise, but more complex meanings to different vibrations were too hard, according to the experts. The audio was proven to be very effective. If given in a narrative way, it can greatly motivate the user and make the exercises more fun to complete and redo.

For the experiment we had made a spreadsheet with possible behaviour on one side and on the other side was a timeframe of 30 seconds. The possible behaviour that was

	Standing still	Walking	Flinches	listening	Does exercise	Exercise is incorrect	Doesn't do exercise	Stops completely	Needs correction	Leaves the path
00:30										
01:00										
01:30										
02:00										
02:30										
03:00										
03:30										
04:00										
04:30										

Fig. 1. Possible behaviour spreadsheet

noted on the spreadsheet is shown in figure 1. Every 30 seconds we would write down the behaviour.

Therefore six research questions were defined, which will be explained in the upcoming paragraphs.

A. Understanding spoken messages

The first research question was:

- To what extent can an individual who is visually and mentally impaired understand the spoken messages?

The users were asked to walk the course and were informed that they would be prompted audio messages and perform the exercises according to the message. These audio messages were story-type exercises.

The users were observed by the researchers while performing the exercises. The researcher carefully watched the participant and judged whether the audio command was executed well. All observations were written down for every 30 seconds. After the experiment a short semi-structured interview was conducted about the experiences of the user and their opinions about the application.

B. Correctly following instructions of spoken messages

The second research question was:

- To what extent can an individual who is visually and mentally impaired correctly act upon the instructions of the spoken messages?

correctly follow the instructions of the spoken messages? The users were asked to walk the course and were informed that they would be prompted audio messages and perform the exercises according to the message. These audio messages were story-type exercises.

The same methodology was used as with the previous subsection.

C. Understanding of vibrational stimuli

The third research question was:

- To what extent can an individual who is visually and mentally impaired understand the vibrational stimuli?

The users were asked to walk the course and they would be given a vibration upon reaching an exercise or navigation point. The users were observed by the researchers while performing exercises. The researcher watched the user carefully and judged whether the user acted upon the vibration (user stops walking when given a vibration and starts listening for the message to come).

After the experiment a short semi-structured interview was conducted about the experiences of the user and their opinions about the application.

D. Design of the wearable

The fourth research question was:

- Is the jacket able to keep the smartphone in place during all the exercises the users do and prevent the smartphone getting lost?

For this, we did a small pilot and also shook the jacket heavily, no loss of device was noticed. With the user test we had similar results.

E. Visual elements for the visually impaired

The fifth research question was:

- To what extent can visual elements be used on the screen of a smartphone, when the focused users are people with a visual impairment?

To answer this question we have done literature research. Most of this was about individuals with only a visual impairment, but our users also have a mental impairment. We did factor this in during the research, but kept an open mind for reputable sources, which only look at visually impaired, because research done for our specific users is really scarce.

F. Visual elements for the mentally impaired

The sixth research question was:

- What is a good way to instruct a person with a visual and mental disability while given instructions through an interactive prototype?

To answer this question we have done literature research. Most of this was about individuals with only a visual impairment, but our users also have a mental impairment. We also talked with a few experts on our usergroup.

IV. Experiment

In this section we will describe the goal of the experiment, what materials we have used and how we set it all up.

A. Goal

The goal of the experiment was to get insight into the level of understanding the users have on instructions given through speech from a mobile device. We also want to see if the users understand what they should be doing when certain messages were given.

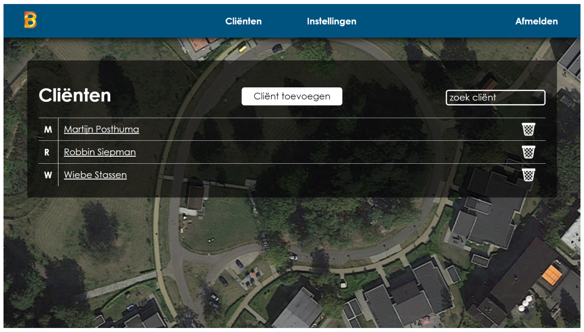

Fig. 2. Website

B. Participants

All participants are visually and mentally impaired. One person also had a physical impairment and completed the experiment in a wheelchair.

C. The experiment

To make the users feel at ease and comfortable, the research is done with the employees at hand and only one or two participants at a time.

1) Understanding of instructions: The understanding of instructions was tested by looking what the users would do when a spoken message occurred. If they listened for a bit and started doing the exercise correctly, they could understand the message. If we saw other behaviour, like just standing still, we would ask them if they could hear the message clearly and then ask them if they could understand what they are supposed to be doing. If they could hear the message, but executed the exercise improperly, they could not understand the spoken message. Before the test, we asked the user if they were excited to start exercising, so we could see their motivation. After each usertest, we would ask the user if they enjoyed using the wearable, so we would know if their mood affected their behaviour during the test.

2) Understanding of vibrational stimuli: This was tested by questioning the users about the vibrations.

3) Experiment: The experiment consists of a smartphone with our app installed. The user walks with the smartphone on an egg shaped track. First, an account will be made for every user on our website, see figure 2.

For every exercise exists one audio message, which tells the user how to execute the exercise, these audio messages are the "standard" audio messages and will be used for every user, but you are able to change the audio messages for each individual if you desire so. The audio messages follow a story for each exercise, because the users get more motivated by using this method of announcing and explaining exercises in a narrative way. The smartphone is inserted in a jacket worn by the participant. The experiment starts once the user gets outside of the building and onto the track. On some spots on the track (4 in total) are exercises (figure 4). Five meters before they reach this point, the smartphone will vibrate and give some spoken messages to the user. Five meters before the exercises, there will be a different message, which we labeled as a navigation message. This message starts with the story that is connected to the exercise. One user is in a wheelchair and it is possible to change their personal settings so the application does not notify them for the exercise they are passing. The care takers will join the walk and help the users if they have any trouble.

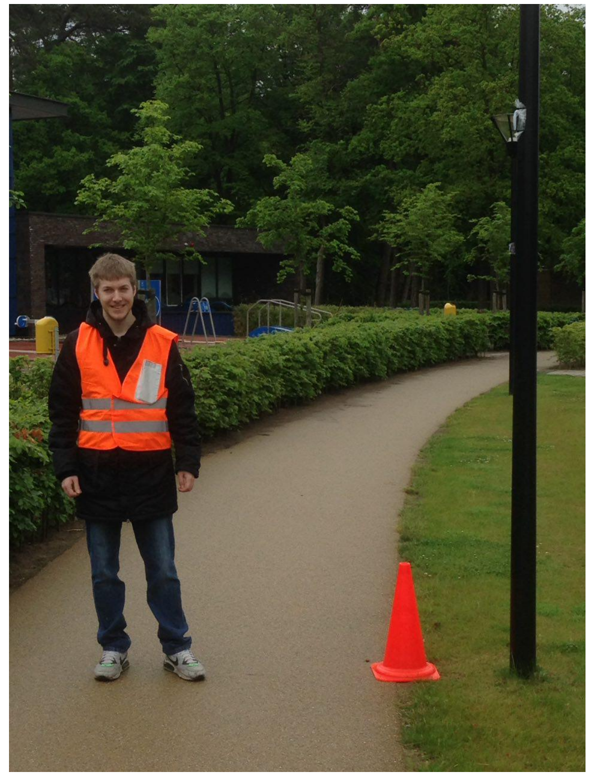

Fig. 3. Individual with jacket, mobile phone in pocket.

D. Material

In our experiments, we used an android application, that we have developed together with multiple BLE (Bluetooth Low Energy) Beacons. The android application ran on a motorola moto G5 smartphone with android 7.0 installed. In the application, you select the required Beacon range you are searching. The Beacons were hung in an airtight plastic bag on a lamppost at approximately 2,2 meters high, as this is the most efficient height for Beacons to transmit (see related work section). The Beacons were adjusted with the Glimworm android application for android 4.1.

In figure 4 you can see how the Beacons were mounted on lamp posts, spread across the track.

V. Results

Our sample size is n=3. Every participant is denoted as a P, for privacy reasons. We conducted three test runs. The first

Fig. 4. Beacon on the track

run was solely with P1 (Participant 1). The second test was P1 together with P2. The third test was with P3, who was in a wheelchair.

In every test the participant is required to circumvent the track once and whenever an audio message appears the participant tries to execute the instructions in the message. Each message is preceded by a vibration. The actions of the participants are observed and written down every thirty seconds.

A. P1

In the first test with P1 we explained what was going to happen: the mobile device "speaks" to the participant whenever the participant reached certain points along the track. The participant walked with a supervisor, but the supervisor does not intervene; the supervisor was there for safety and not instructions.

Three Beacons along the track were faulty (2 navigation Beacons and one exercise) and thus did not trigger a message on the mobile device in time. Therefore the Beacon success rate is $5/8 = 62.5\%$. On two exercises we decided to wait a bit until they did trigger. P1 sometimes noted that the smartphone was quiet for a long time, asking if the phone "had gone to sleep". When a Beacon does not trigger it does not have a significant impact on the experiment since it has no impact on the participant. It does mean that there is less data available.

When the audio messages triggered, P1 executed the exercises correctly with a rate of

$$3\ (triggered\ exercises)\ /\ 3\ (executed\ correctly) = 100\%$$

Not only did we observe the necessary movement to complete an exercise we also noted that P1 was finding joy in participating.

After circumventing the track we had an open discussion on what P1 thought it was like. P1's reaction was overwhelmingly positive and was extremely happy that we allowed P1 to participate. P1 did note that some of the audio messages could be rephrased better to avoid confusion and noted that the fact that some Beacons did not function properly was disappointing; P1 missed out on some of the story.

B. P1 and P2

For the second test we had two individuals with VMI who would circumvent the track together. Again a supervisor would be present, but for safety only. Whilst both individuals were given a jacket, only P2 was given a mobile device. This was done because playing sounds simultaneously would be confusing, which could happen if the phones triggered from a Beacon out of sync.

One exercise Beacon along the track was faulty and thus did not trigger a message on the mobile device. P1 did note that they had missed out on some audio messages that P1 did hear in the first test round. This means the Beacon trigger success rate was $7/8 = 87.5\%$

When the audio messages triggered, P1 and P2 executed the exercises correctly with a rate of

$$6\ (triggered\ exercises)\ /\ 6\ (executed\ correctly) = 100\%$$

Note that there are 6 triggered exercises, 3 for P1 and 3 for P2. Note that this percentage is the same as with the previous test, P1 alone, but in this case less Beacons failed, but they were navigation Beacons. As mentioned previously P2 was the only one who was getting vibrations, but we did not observe a notable difference in behavior of P1 and P2. The full results of the rest can be seen in figure 5

After circumventing the track we again had an open discussion. P2 said that the vibrations could be felt, and P1 said that the audio was perfectly hearable despite the mobile device not being in P1's jacket. Again there was some disappointment that some messages did not play.

C. P3

For our last test we had an individual (P3) who was in a wheelchair, which would make some of the exercises impossible; we had an exercise where the individual is required to tramp on the ground. Nevertheless P3 was

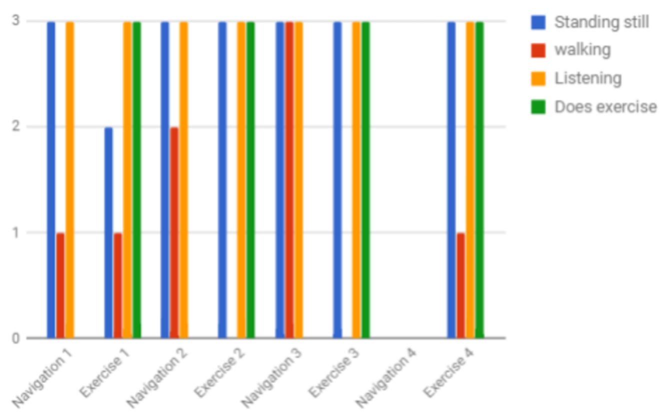

Fig. 5. Results P1 and P2

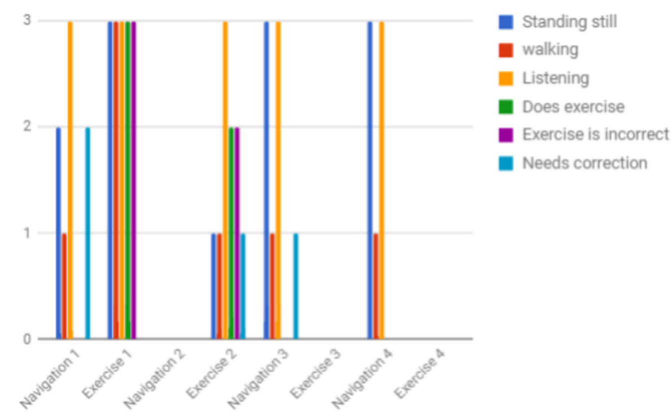

Fig. 6. Results P3

motivated and wanted to try it out. We gave him a jacket, but due to P3 wheelchair is was impossible to secure the jacket tightly, because of this the vibrations are harder to feel. Again a supervisor would be present.

P3 was very fast, so fast in fact that the Beacons had difficulty keeping up. We had multiple Beacons that did not trigger, 3 out of 8 did not function (2 exercise Beacons and 1 navigation). Thus the Beacon success rate was $5/8 = 62.5\%$. P3 did not seem to notice, however.

Most of the Beacons that did trigger had a positive result, P3 did the exercises to the best of his ability. However there were some setbacks as well. On the exercise where the individual is required to tramp on the ground P3 did nothing. The supervisor then suggested that P3 could use his hands to mimic his legs. P3 tried that and that went well, but we still classified that as an incorrect execution of the exercise. Also P3 required multiple corrections from the supervisor to follow the track as seen in figure 6.

When the audio messages triggered, P3 executed the exercises correctly with a rate of

$$2\ (triggered\ exercises)\ /\ 0\ (executed\ correctly) = 0\%$$

After circumventing the track we had an open discussion. P3 noted that it would have been hard to do without a supervisor present.

D. Combined results

The total amount of exercises that were triggered by the Beacons during our test was:

$$3(P1\ alone)\ +\ 6(P1\ with\ P2)\ +\ 2(P3)\ =\ 11$$

From the amount of exercises that were triggered the amount correctly executed was:

$$3(P1\ alone)\ +\ 6(P1\ with\ P2)\ +\ 0(P3) =\ 9$$

Which makes a success rate of:

$$9\ (correct)\ /\ 11\ (total)\ =\ 81.8\%$$

VI. Discussion

From the results of our study, we have seen that the application used in our experiment was helping the VMI individuals complete the exercises. Guiding people with sound was proven to work in our experiment as well as previous work [5]. Guiding people with haptic feedback was proven useful in previous work [4], but was not able to guide the VMI users.

Guiding people with visual elements was not something that was proven useful; the VMI users can't do exercises properly while holding a mobile device as it obstructs their movement or because they are not able to grasp onto the mobile device properly.

This study has some limitations, namely the small amount of participants and our experiment was influenced by minor hardware problems.

VII. Conclusion

We found that the use of location based audio messages seems to be very promising for helping individuals with VMI sport independently, however due to our small sample size we were unable to confirm our findings.

From previous work we were able to conclude that visual elements on a smartphone would be undesirable.

Haptic feedback (vibrations) was successful in helping people with visual impairments navigate, as well as audio messages. However, the current use of haptics is too complex for people with mental impairments to understand. Hence, in our prototype we only used haptics as a warning system for an upcoming audio message. This method proved to be effective, but due to our small sample size we were unable to confirm our findings.

Audio messages have been successful in helping blind people navigate, but they are very sudden and objective. This is why we used story based audio messages to reduce the mental strain required for understanding the message. We found that this story based technique was very effective, we found that $81,8\%$ of the exercises were completed perfectly. However, due to our small sample size we were unable to confirm our findings.

VIII. Future work

On our track we used navigation audio messages, but they were solely used to circumvent the track. We believe that the prototype could be used to allow navigation to other areas, as well. However, in its current use we could use the track and a story to help people with VMI understand the context. When an audio message is triggered without context the user might not understand what is going on. It would be interesting to see how an out-of-context audio message would affect behaviour of VMI individuals. And does initiating an audio message with a haptic signal improve the comprehension in people with VMI?

In our prototype we used the vibrations of the smartphone, but using very simple vibration motors an haptic sleeve could be made. Although complex vibrations are still a challenge for VMI individuals, perhaps with a sleeve on either arm it can be understandable. It would be interesting to combine haptic sleeves with the current prototype. This information could be used to find out the dependance on vibrations versus the dependance on audio messages.

IX. Acknowledgements

We would like to thank Stichting Bartiméus for providing us with users for the experiment, a place to perform the experiment, providing experts about our user group and giving feedback on our prototype. And lastly we would like to thank the users that have participated in the experiments.

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