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Developing Navigational Services for People with Down's Syndrome

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Abstract—**The ability to commute and travel alone is an important skill that enables people to be more independent, and integrated with society. People with Down's Syndrome often experience low social integration, and low degree of independence. As part of the European Commission funded POSEIDON project, we want to explore how context-aware, and assistive technology can enable users with Down's Syndrome be more independent, including the ability to commute alone to a place of interest. In this paper, we report on our current progress in developing navigational services within the context of the POSEIDON project. We carried out a semi-structured qualitative evaluation of an early version of our navigational services with 6 individuals with Down's Syndrome, and report on our findings.**

I. INTRODUCTION

Down's syndrome (DS) is a neurodevelopmental disorder, which is caused by the presence of either a copy, or part copy, of chromosome 21. DS has a prevalence of 5 in 10,000 [1], or in more recent statistics, one per 1,000 live births for England and Wales [2].

A person's ability to travel and move around their community is essential for their participation in society. Independent travelling ability enables a person to better access to their community, friends, and activities. By being independent, a person's self-determination and quality of life are enhanced [3]. People with DS often experience low social participation, sometimes this is linked to the challenges presented by travelling alone in a city. These two challenges feed each other creating a negative circle. Due to challenges in independent travel, often people with DS need a carer or parent to travel with them, which can put strain on the other individuals.

As part of the POSEIDON project [4], we are attempting to increase the inclusion of people DS in society through the use of technology. One component of this technology includes navigational services, which aims to support more independent travel by people with DS. In this paper, we describe a navigational application developed as part of a larger project architecture, and report on an early validation of its effectiveness in help people with DS navigate routes.

II. RELATED WORK

Spatial navigation and route learning for people with DS and general intellectual disabilities (ID) has gained attention in recent years. Mengue-Topio et al. [5] experimented with virtual environments to assess the ability of route learning, and being able to make shortcuts between two locations was carried on 18 adults with ID and 18 adults without disabilities. This experiment comprised of the exploration of two routes until each adult reached a learning criterion. They were then placed at different points and were asked to find the shortest route to another point. It was found that participants in both groups could learn routes, but those with ID often could not find the shortest path. Other uses of virtual environment based experiments include the work of Purser et al. [6]. The authors investigated the development of route learning and the use of landmarks in DS, Williams syndrome (WS), and typically developing children between the ages of 5 and 11. This study involved two experiments using virtual environment mazes. The first investigating the development of route learning, and the second assessing the use of junction, path and distant landmarks. It was found that the participants with DS generally had the largest deficit in route learning compared to the other two groups of users. Other research considering route learning includes the works of Courbois et al. [7]. This study investigated how landmark selection by people with ID differs with those without disability. An experiment was carried out with individuals with ID and those without, whereby they were first guided along a route in an unfamiliar location. The users were then ask to guide the experimenter along the same route while informing the experimenter which objects and features they found useful for wayfinding. It was found that there were significant differences between both user groups for non-permanent landmarks, distant landmarks, and non-unique landmarks.

Technological devices and software for navigation have been proposed for people with dementia. iWander [8] is a mobile application on the Android platform to allow people with dementia to navigate while allowing their caregivers to monitor their patients remotely. Data is constantly collected and evaluated using Bayesian network techniques to estimate the probability that the patient is wandering, and the situations severity. Once the situation has been evaluated a number of actions can be taken based on the situation: providing directions home, sending a notification and location to the caregiver, provide a line of communication between patient and caregiver, and finally a party call to include the patient, caregiver, and emergency services. Other navigation support includes the use of auditory instructions [9], [10]. In this work, a HTC PDA application was developed using TomTom 6 SDK, creating a version of TomTom with no menus, and all functions and status bars removed, except remaining distance to the next decision point. Furthermore, every caregiver recorded 43 words for the experiment, to be used as auditory instructions.
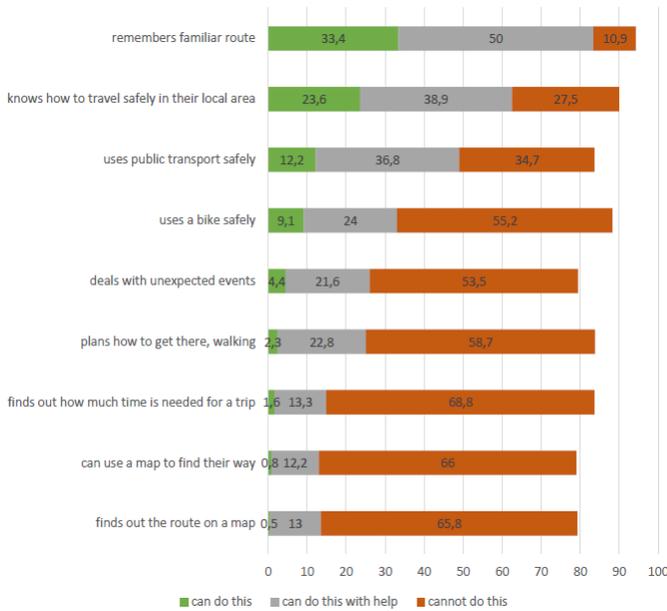
Fig. 1. Requirement feedback regarding travelling about (in percent of responses)

It was found that using familiar voices improved navigation performance compared to unfamiliar voices. Other navigational aids for people with dementia include the use of tactile devices [11]. This device is a belt worn by an individual to provide directional cues through the 4 vibrating motors aligned to the front, back, left, and right positions of the wearer's torso. This belt has global positioning, three axis compass, inertial sensor, power management, battery, and algorithmic executive processor technologies integrated. During route travelling, in real time, the system evaluates the individual's progress and updates the directional cues until they reach their destination. This device was tested by 12 people with dementia aged between 61 and 87 years inside a hospital. This involved 4 routes with 24 waypoints through the hospital corridors. The device was then rated 4.9 and 4.5 on a 5 point Likert scale for its ease of use and comfort.

While there is research studying how people with DS handle spatial tasks including route learning and navigation, we know of no research that proposes the use of navigation technologies to aid navigation for people with Down's Syndrome, or intellectual disabilities.

III. POSEIDON PROJECT

The POSEIDON[1] Project [4], focuses on the task of bringing some of the latest technological advances to increase inclusion in our society for people with DS. One of the core challenges we are tackling in the project is to assist people with DS when they leave their house. People with DS often travel with a parent or carer, which can place additional strain on the parents or carers. Some individuals can travel alone, but they can become distressed if an unforeseen event happens. In this project, we hope to enable more individuals with DS

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[1]POSEIDON stands for PersOnalized Smart Environments to increase Inclusion of people with DOwn's syNdrome
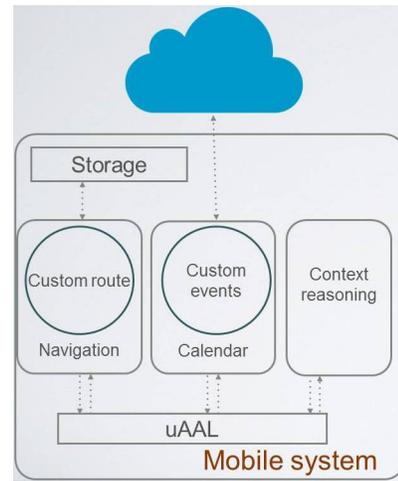

Fig. 2. Mobile System Architecture

to travel alone without distress, therefore making them more independent.

A. User Requirements

During POSEIDON, user requirements were gathered. This was carried out using a combination of focus groups, interviews, and questionnaires. Our focus groups involved 4 people with DS early in the project, and 9 people with DS in a later focus group. Interviews were carried out on 29 people with DS. Finally, for our interviews we received responses from 397 families with at least one person with DS. Here we wish to highlight our findings related directly to the topic of this paper.

It was found that travelling about was of considerable difficulty to our user group. Interestingly, more than half of those responded can remember a familiar route, know how to travel safely, a use public transport safely when they at least receive some assistance as shown in Figure 1.

We also found that more than half of those responded use tablets (85%) and smart phones (56.4%). Because of this, we want to investigate if smart devices can be a good candidate for giving the support our user group requires for travelling about.

B. Navigational Services Implementation

The overall POSEIDON architecture can be broken down into two separate systems: A stationary system, and a mobile system. The stationary system is primarily used for carers to edit routes, and for the people with DS to practice different configured routes. The mobile system on the other hand, is used by the person with DS to help guide them on their route, and to keep track of their daily events. The mobile system is made up of 3 main components, as shown in Figure 2.The first component is a calendar application, a modified version of the AOSP[2] Calendar application. The second component is a centralised context-awareness engine. The role of this engine is a centralised point where context data from all applications can be gathered, and reasoned together to inform application
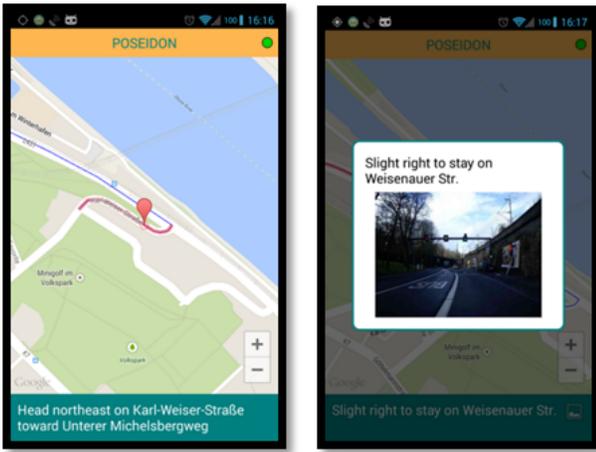
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[2]Android Open Source Project

Fig. 3. Navigation Screenshots

Fig. 4. Map representing the route in Google Maps

adaptations and reminder prompts. All knowledge for the POSEIDON system is conceptualised using ontologies extended from the SOUPA ontologies [12].The third component is the navigation application, described next. Communication between each of the components is handled using universAAL [13].

The mobile navigation was an application developed the Android platform, shown in Figure 3. It was developed on top of an internal application development framework by Tellu AS. The application gives the ability to navigate between common routes saved in the application. The main navigation UI is broken up into two main parts: A map showing the route with the current step being highlighted, and the directional instructions shown at the bottom. At several key steps in each route, instructions prompts are given including a relevant photo. These have to be taken and added to the route by the carer for it to be used in the application. Importing directions data is carried out semi-automatically. Basic routing data is firstly generated using OpenTripPlanner. OpenTripPlanner (OTP) is an open-source platform for route planning web applications. After the basic data is downloaded, it can be edited to add additional information, and to link the photos required at particular steps in the route. Context data related to the navigation app are also sent to a cloud service, which can be used by carers to locate their protégés.

IV. VALIDATION

In this section, we describe the validation we carried out on the navigation application following its requirements gathering, and development.

A. Methodology

Six people with DS consisting of two females and four males participated in the study. The mean age of the group was 24.6 years (SD = 6.07). The participants were gathered from different countries; two from Germany, one from Luxembourg, one from Portugal, one from Switzerland, and the last from Ukraine. The participants were informed about the study, and gave their consent to take part in it. Documents transcribed in Easy Read were given to both participants, and their guardian or carer to ensure they understood the study.
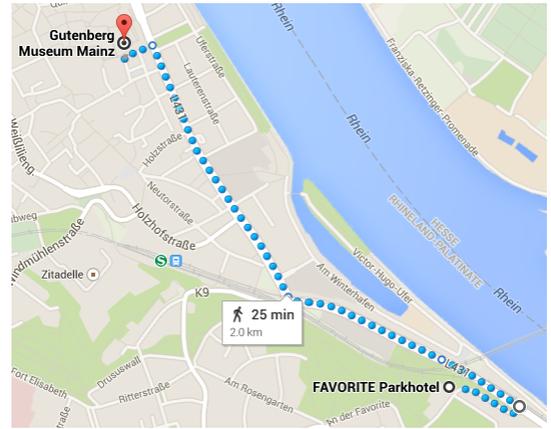
The experiment took place in the city of Mainz, Germany. Each of the participants were brought and stayed in a common hotel where the task began. The task was for them to use the navigation application to guide them to the Gutenberg Museum, a route of 2.0 km, as shown in Figure 4. This route contained both waypoints requiring walking, and taking a local bus. None of the participants had any previous experience of this route. The participants were split into three groups of 2, with each group being accompanied by their carers to assist them to understand the application, to ensure they travel safely, and to help collect feedback on their experience.

B. Feedback

While undertaking this validation, different feedback was collected by both observing the participants, and dialogue with both the people with DS and their carer. In terms of our feedback, we received feedback in primarily two different areas: *safety*, and *directional assistance*. Safety feedback relates to the ability of the participants to navigate to their destination safely. Directional assistance feedback on the other hand relates to the applications ability to help guide them along the correct route to their destination.

1) Safety: Observational feedback attained during the tests highlighted important safety considerations. Firstly, it was found that our participants focused strongly on the device, particularly the map of the user interface. This meant that often, they rarely looked around at their surroundings. When crossing the street, the participants sometimes needed to be reminded to check the road is safe to cross. A similar issue was found by Hettinga et al. [10] when attempting to use visual navigation assistance to people with mild dementia. We believe that instead of taking away all visual assistance, we should perhaps consider how to bring the users attention back to their surroundings. This could be through the use of visual prompts, or using auditory information when the user is close to crossing the road.

Another safety related issue also related to crossing the road involves counter information to which they have been taught. We were informed by the participants' carers that to ensure their protégés cross the road safely, they are taught to only cross at pedestrian crossing points. Because much of the navigation instructions for walking are used from the driving

instructions, there are no instructions of safe places to cross. To overcome this issue, we think the carers will have to edit the route instructions themselves.

2) Directional Assistance: Valuable feedback to help support directional assistance was also gained. Firstly, it was found that similar to issue of getting directions to only cross at pedestrian crossing points, the users had difficulty in knowing which side of the road they needed to be on to catch a bus at the following step. For many people without DS, it may be more obvious which side of the road to be on for public transport based on the direction they need to travel. This issue relates more back to the navigation instructions, just like the issue of safe road crossing. Once again, due to a lack of navigational information from direction services e.g. OpenTripPlanner or Google Directions, this information must be added by the carer.

One issue we found with the use of a map in the application is that the participants often had difficulty translating turns indicated in the map to movements they needed to make. This was not unsurprising based on the requirements gathered, as shown in Figure 1, where by only 13% responded can use a map to find their way, even with assistance. We think that there are improvements to the map that could give more spatial knowledge to assist them. The first is automatic map orientation. This is normally a normal function in commercial navigation software. While it lowers cognitive demand for people without DS or ID, many can still navigate without it. For people with DS however, we believe this is a crucial feature due to their spatial awareness and visual-spatial working memory deficiencies [14]. Other changes considered include the use of 3D maps or satellite imagery, to help give more spatial knowledge to understand the direction they need to travel.

Other important feedback includes the use of images during the journey. While observing and questioning the participants, it appeared that showing images during particularly steps of the route proved useful. As discussed earlier, our participants have more difficulty translating actions based on the map. The images helped the participants find the correct direction far more efficiently. We believe these should be used more throughout the route, to help them better understand the needed direction of travel.

V. Discussion

Recent research suggests people with Down's Syndrome is more capable than people believes and that they can be more productively immersed in society, which will also increase their self-esteem. The POSEIDON project is investigating different ways to support this group of citizens and their families. One service which was highlighted as a pillar for independence in our gathering of requirements was the support for more independent mobility.

This paper explains our first prototype to support people with Down's syndrome and the evaluation of this prototype by people with Down's syndrome moving within a city. This assessment was very positive as the system proved useful and at the same time gave us information on features which can be further improved. These are now part of our focus and they mainly relate to better ways to convey the information so that it adapts to subtleties in the environment, for example, turning

the device around or guiding the users to cross through a zebra line.

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