Using Technology to Encourage a Healthier Lifestyle in People with Down's Syndrome

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Abstract. This article reports on the development of a mobile app developed to Encourage Healthier Lifestyles, with emphasis on food intake, by People with Down's syndrome.

The system started by considering generic guidelines on designing technology for people with Down's syndrome investigated by a previous European project. Then it developed the product using the User-centred Intelligent Environments Development Process, an iterative method of gathering stakeholders' views to involve them in co-designing the product.

The project produced a mobile app which was validated with the intended final users and gathered positive feedback.

The experience also provides further insights which can inform developers of future similar technological solutions.

Keywords: Ambient Assisted Living, People with Down's syndrome, mobile technology, healthy eating.

1. Introduction

Technology is finding its way through society and increasingly intertwining with our daily lives: from using mobile applications to control lighting in the house remotely to tracking health related issues, socialization apps, fitness apps, and many more. It is becoming increasingly challenging to build these technologies, as engineers need to rely on a mix of system components, which are complex on their own and even more when combined. Although this is not entirely new in the Computer Science and Information Communication Technology fields, which have been developing systems of increasing complexity for decades. Still, one challenge that is inherently hard and long standing is that no single system can address all needs for all individuals given that each group of intended users and stakeholders have their own priorities, needs and preferences.

There has been a recent surge on apps focusing on helping humans with different health related conditions, as well as others apps on improving well-being and lifestyle. However, not all citizens are given the same level of attention. Organizations leading on innovation often focus on apps which target more numerous sectors of society to maximize the chances of safely recovering investment and generating profit as soon as possible. As a result some groups of citizens with the highest specialized needs which constitute a smaller percentage of the market are usually left behind, widening the digital gap between some sectors of society.

This development has been focused on assisting people with Down syndrome (PwDS) [1, 2], a group of users which has been side-lined by technologists. A recent significant European project [3] and other research around the world (see for example, [4]) provided progress on fundamental insights as well as on the development of technological infrastructure to develop systems for PwDS. However, not many apps are available yet, especially food and exercise related, and those which were available in the market for the general public were not considered suitable by our stakeholders (more on this in a later section).

Our system aims for simplicity and practical effectiveness, adopting previous good practice guidelines for design when available, for example from POSEIDON [3, 5]. However, we moderated those technological guidelines with feedback and insights provided by our highly specialized stakeholders group: the Down's Syndrome Association UK through their nutrition and sports specialists, as well as people with Down's syndrome and their families.

In the next section we provide more details about the intended group of main beneficiaries and how their needs and preferences relate to technology and to a system which aims to help have a more positive relation with food and sports. Then we explain about the current technological landscape explaining current apps which at first sight may seem relevant, however they fail to meet basic requirements from our specific main beneficiaries. We then explain the product developed, the feedback collected and a summary of strengths and further areas of development to support future developments in this area.

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2. Users profile

Down's syndrome started to become officially recognized medically as such after 1866 when English doctor John Langdon Down published a description of the condition and its common congenital chromosomal anomaly which occurs when there is one extra copy of chromosome 21 in cells of the human body. This condition can affect the physical development and learning abilities of people with Down's syndrome (PwDS). As such they usually have special needs in some areas of life. A syndrome implies means a number of specific characteristics express in each individual with different degree of intensity, from very little to significantly. PwDS have strengths and weaknesses as anyone else and although statistically they tend to be affected more than the rest of the population in certain areas of health and quality of life, they have considerably improved their positive experience of life thanks to a greater understanding of their condition and progress in medicine in general [5].

Down's syndrome affects people of all ages, races, religious and economic situations. Although some of them present significant learning difficulties, in general they all have capacity to learn significantly, successfully graduate from colleges and even in some cases from University. Although they tend to find learning of abstractions harder than the average of the population, given more time and favouring processes and using elements which are more suitable to them, they can achieve more than the population commonly assume. Most of them have the same general behaviour than other people of their age group. This includes also their willingness to use technology, especially for those of younger age. Some of them actually create strong bonds with technology which helps them to achieve goals [5, 6].

On the other hand, given a combination of physical characteristics, cultural and social restrictions imposed into them, and some learning challenges, PwDS tend to develop obesity, and all the negative consequences this bring to the health and social dimensions of an individual's life [7, 8]. Hence, there is a good motivation on helping them understand food consumption better, an important dimension on any individual with weight excess. Managing food intake is best complemented with an increase in healthy physical activity. So encouragement to engage more often on sporting activities is perceived as an adequate complementary strategy for the system we developed.

2.1 The POSEIDON project

The EU funded research project *Personalized Smart Environments to increase Inclusion of people with Down's syndrome* (POSEIDON) was a three years research project involving various European organizations from research, IT industry and Down's syndrome support groups. Its main goal was to set the foundational layers for the development of technological solutions which can help improving the lives of PwDS through Information and Communication Technology (ICT). The emphasis was on supporting solutions which can lead to a more independent life and foster their inclusion in society. The assumption being that having PwDS more involved in education, work, and social activities will benefit everyone.

In order to understand and develop digital tools to enhance autonomy and independence for PwDS, stakeholder feedback gathering activities were run. These activities included questionnaires, workshops, interviews, as well as short and extended pilots. For example, an initial online questionnaire with 35 questions in English and translated in German and Norwegian addressed to PwDS and their carers was rolled out and answered by approximately 500 individuals in various countries in Europe [6].

Amongst the various interesting findings was the reassurance that PwDS, especially younger generations, are generally familiar with ICT equipment, and many of them very keen on exploring and using ICT, including apps in mobile phones, especially for gaming. This has shown the interest of PwDS on ICT related options and the potential to use that as a tool to help them. POSEIDON focused on scenarios such related to a more independent lifestyle, for example, to be guided to go to school, work, a supermarket, a meeting with friends and be able to take a bus, pay for food or services, meeting and eating at a restaurant with friends.

The POSEIDON project was not focused on apps per se. Some apps were explored, however they were not considered as an end on their own, rather prototypes which illustrated how the more fundamental principles, methods and tools developed by the project could be applied. Applications of any nature were tools to show the usefulness of a more fundamental set of principles and ICT architectures and innovations. Some of the fundamental principles have to do with design principles or tools for bigger companies to develop complex systems, and amongst the most practical ones we can list the following:

- Navigational app: helps PwDS guide themselves from A to B based on preconfigured routes with verbal and written instructions, pictures, and video clips with instructions;
- Calendar app: helps them remember things during the day. For example, to remember what

time they have to go to school and what are the things they need to put on the back bag;
- Money Handling app: helps to increase their understanding of money value and change;
- Shopping app: helps them before they go shopping remembering how much money they need and what they have to buy.

There was a late attempt exploring the healthy food aspects in connection with the Shopping App, however, when shown to our stakeholders group their perception was that it was too complex and we needed to start somehow afresh and simpler, gradually growing from there.

2.2 Specific Needs and Preferences

This is one area of application where system personalization acquires more importance. The aim of personalization is to provide services which are closer to what the user expects and aligned with the users' preferences. This was another important contribution from the POSEIDON project which explored this issue [1, 2, 6]. Amongst those taken into account are the following challenges and strengths of PwDS which can then be translated into features to avoid and to maximize:

Challenges:

- They may have reduced vision and hearing;
- They may have difficulty with motor skills;
- They may have difficulty with the short-term working memory, with learning, abstract thinking and problem solving;
- They may have difficulty reading, and some do not read at all;
- They may have difficulty adapting existing knowledge into new situations or contexts.

Strengths:

- They are often visually oriented end users;
- They can master many activities of daily life with appropriate support or through repeating training over an extended period;
- They are keen users of information technology, including smart phones and tablet PCs.

Studies show that adults with DS are more likely to be obese compared to their peers. This can be as a result of hypothyroidism, but it can also be due to excessive dietary intake in relation to the level of physical activity. There are many strategies to prevent this, such as reducing portion or avoiding snacks, but the most effective strategy [8] is to empower the users monitor their own weight and physical activity and their eating habits.

Research also shows there are many simple and basic day to day life habits or transitions that are simple to others but found to be difficult for people with DS, particularly the basic of use arithmetic and numbers [9].

Still, contrary to popular perception, most PwDS have busy lives, are willing to try new things and develop good rapports with certain activities they enjoy and by extension with the technology that enables them [10]. For example the following statement from secondary users (a parent of a PwDS) at a POSEIDON workshop is representative of many of them "*He is so proud when he does something by himself. Being independent would be a huge boost to his self- esteem and give him the confidence to try harder challenges.*". Having an independent life without the need to depend on adult supervision is the most important step for them and this is the part where POSEIDON is introducing ICT to unable them have that transition.

3. Related Apps Review

In this section we summarize existing and commonly used applications for healthy eating and diet control we considered in our preliminary surveys. All of these are available online. We highlight some of their main features, compare them, and try to identify what could be adopted in our case.

MyfitnessPal: This application is based on a substantial food database, listing over 5 million different foods, a calories counter.

It uses numbers, calories, charts and diagrams to show the user progress and the number of calories they have burned by running, walking or any other exercises. The interaction with the system is slightly involved for our target beneficiaries, for example when login into the application and even the initial sign up process takes 5 minutes before being able to use the application. Background and text colours make it default to read the information, charts and graphs are not easy to understand. Access to Food Database of 5+ million foods could be confusing.

FatSecret: it helps the user to keep track of their food, exercise and weight, using online food and nutrition databases and connect people globally.

It includes a barcode scanner and auto-complete functions, integration with Fitbit, an exercise diary to record all the calories you burn, a diet calendar to see your calories consumed and burned, and a weight tracker. It also provides reminders for meals, weigh-ins and journals. Users are required to add personal information, such as name, age, weight, height. This app requires the user to read and understand each section, images and bright colours are used. The user needs to setup goals by manually entering the data into the application for accurate calculations of calories. Not all the features are available for the user to use free.

Lose it!: the app focuses on showing how many calories each item contains, allowing the user to scan the barcodes of the foods and it automatically shows fat, sugar and other ingredients. It also encourages users to eat more fruits and vegetables simply by giving challenges. The system connects trackers, apps, and devices, e.g., Fitbit. Some of the colours

used for text are disturbing the eyes of the users and makes it hard to read, and links are overcrowded.

My Diet Coach: this application motivates the users by allowing them to create and customize an avatar. It provides helpful tips and tricks for common weight loss setbacks. Emphasis is on image (including self- motivational photos). It provides daily inspirational quotes, reminders and challenges. It requires the users to add their personal information, such as name, age, weight, height, and requires the user to read and understand each section. It allows sharing personal information online, e.g., user photo and location. Not all features are available for the user to use free. The user needs to setup goals by manually entering the data into the application for accurate calculations of calories.

MyNetDiary: it is a paid application which forecasts user daily weight loss based on calorie deficit, including food, exercise and steps. It offers weekly diet analysis, recipe editor. It requires the user to read and understand each section, images and bright colours are used. The application is not clear on how it could be used, although it is not overloaded with the text or buttons but it lacks indications.

Healthy Food: allows the user to check food calories and understand what each portion of the food contains, such as vitamins, minerals and nutrients. It allows the user to create a profile using their personal information and to record what they are eating to keep them aware and altimetry keep them in shape. Each page is loaded with information and images, and once clicking on the images it will open a second window content the item information, each button or link is squeezed which makes selecting a page challenging. The UI is designed in such a way it assumes a lot of implicit knowledge.

MANGO (Meeting A Nutrition Goal when Out): is one of the latest apps to appear (currently in App Store only) and is based on work reported in [4]. The app focuses on supporting PwDS when eating away from home, for example, at restaurants. On the most immediate benefits the app supports increasing the awareness of PwDS on healthier or not so healthier food/drinks options which are identified with a colour code (red/yellow/green). There are also longer term, and more educational in nature, goals on building awareness on those food groups. The app offers an option to screen off potentially dangerous food (e.g., related to allergies). It also includes a visual reward feature which can be used for reinforcement learning and teams for peer support. Some elements are more complex to process and be able to enjoy by the target user group and will require support from carers, for example to understand the nutrition tips provided and to use the payment feature.

Table 1 provides a summary comparison. The parameters measured in the table refer to the main objectives of this project. Some problematic issues emerged in almost all of the applications: small buttons, buttons close to each other which increase potential for making mistakes, some colours are disturbing for users to read, text size is small, not clear labelling of the pages, overloading content, and, making user uncertainty of the next step.

PwDS are unlikely to be able to use the above listed applications without struggle or a family/carer assistance. There are many other applications available to download from App Store and Google Play also designed to burn calories and provide guidance on how to exercise, recording weights for a wider range of users, however because of their design they exclude people with special needs.

The POSEIDON project created good guidelines, however, their products did not address the functionality and simplicity required from the stakeholders of this project. Hence our project decided to use as much as feasible from POSEIDON but starting the project afresh and with the aim to target less functionality with a less crowded interface, which is easier to understand, and leave for future project revisions the possibility to carefully add more functionality.

Table 1. Applications comparison

	MyfitnessPal	**FatSecret**	**Lose it!**	**My Diet Coach**	**MyNetDiary**	**Healthy food**	**MANGO**
Registration required	√	√	√	√	√	√	√
Records weight	√	√	√	√	√		
Reminds to weigh			√				
Weight feedback	√	√	√	√	√		
Simple info display				√		√	√
Simple interface				√			√
Easy to reach features				√		√	√
Easy to understand				√			
Easy to read				√			√
Tracks calories	√	√	√	√	√	√	
Reminds to exercise			√				
Customizable weight goals	√	√	√	√			
Customizable exercise goals				√			
Profile creation		√	√	√	√	√	√
Scale connection		√	√	√			

4. Project Definition

DSActive is a branch of the Down's Syndrome Association UK[3] which focuses on encouraging more active and healthier lifestyles for PwDS. The main requirement was to create an easy to use and easy to understand application. After initial meetings it was agreed to develop an app "*To provide information on a healthy diet and to help PwDS to make informative choices about their diet. To offer participants the chance to track their food consumption to reduce their awareness of their diet. To offer participant the chance to track their activity to increase their awareness of how much activity they do each day. To produce an app which is usable and suitable to the needs of PwDS over the age of 16*". The app was meant to be useful not only for those with reading and writing abilities but also the group of users without the abilities to read and write. Further communication provided more specific guidelines in terms of symbols and colours. For example, replacing numeric calculations of the calories with smiley faces in three different colours, each colour would represent how healthy or unhealthy their food was and measuring their progress by showing how many smile face they have achieved.

The aim was to develop an 'Easy Read'[4] style and easy to understand mobile application to help PwDS make healthier choices on their eating and reduce unhealthy eating, give them healthier option throughout the day and encourage healthy eating, raise awareness of the unhealthy foods, and, as a consequence, help them lose weight.

The research was then focused on conducting an analysis, design, test and evaluation of the application. To achieve that we first had to understand the common problems of people with Down's Syndrome are facing with using the already available healthy eating application. Next it was necessary to find a solution to eliminate those obstacles by creating design to provide healthy eating advice, healthy recipes, and a way of tracking food consumption, ultimately offering the freedom of making healthier eating choices using the application by themselves rather than being told so by their care takers and parents. Some of these problems are explained in later sections.

4.1 Ethical Issues

The use of modern technology which is more closely related to individuals' daily life has brought some ethical concerns much more often to the forefront of design and development. Developers were not so used to considering these and they were mostly concerned with developing and testing code. However, there is increasing social responsibility expected from IT products. The eFRIENDS framework proposed in [11] aimed at providing an easy guide which can be effectively embedded in the development processes of modern technology. The eFRIENDS concept advocates the development of systems in a manner which is explicitly aligned to user-centred priorities empowering users of a system. Basically it asks developers to explicitly consider in their strategy the consideration of nine main areas of ethical concerns and address them with explicit requirements: 1) non-maleficence and beneficence, 2) user-centred design, 3) multiple user groups, 4) privacy, 5) data protection, 6) security, 7) autonomy, 8) transparency, and 9) equality, dignity and inclusiveness. We abide to those principles. Our system aimed at enhancing the health of users and providing a system giving priority to simplicity and safety overall.

Our system is primarily addressed to PwDS, however it also takes into account carers which have an alternative interface where they can help by updating the meals and activities lists as well as understanding how the user is performing and if there is something they can do to help. The project has been one of co-creation with stakeholders and substantial user-centred effort was placed on the understanding of preferences and needs of the main users and on the specific features which makes current technology more useful to them. The system is simple, which facilitated reliability testing. In this version we stayed away from connections with social networks, payment sections and geo-tagging which are prevalent on other fitness apps and open up potential security issues for this users. Privacy was also safeguarded with access only for the primary user and one other associated which has a different interface. Data cannot be shared in social networks or otherwise in this version and future versions should look carefully into this balancing it with security. Healthier individuals which make better lifestyle choices, including more often in sporting activities increase their possibility of social interactions and inclusion. Giving more decision power to make healthy choices supports the independence of these users, and also relieves carers from part of the continuous attention. The system has been conceived transparently, aiming at simplicity and reliability, which is more suitable to the target core user base. It has also been designed simply enough so that it can be used by a wide range of users with different levels of capabilities. Some of the main features are summarized in Table 2.

[3] https://www.downs-syndrome.org.uk/

[4] www.gov.uk/government/publications/inclusive-communication/accessible-communication-formats#easy-read-and-makaton

Table 2. Selected Features.

Features	Actions
Adding as a portion	Allowing the users to choose each item as a portion.
Images	All foods, drinks and snacks displayed as image rather than just text.
Calories	Instead of counting calories, healthy options are display with a green happy face and unhealthy ones with a red unhappy face.
Flexible GUI design	Software must be flexible with any types of android devices or screen resolutions size.
Summary	Shown by the end of each day. Week and months yearly still to be decide.
Reviews	Users will be able to give their views and feedback
Choosing from list	Allowing the user to choose the available food, drinks and snacks from the list.
Adding more options	Users and admin should be able to add or remove items from list (e.g., foods, drinks and snacks).

4.2 Requirements

By "stakeholders" we refer to those having an interest or need closely related to the project [12]. For Ambient Assisted Living type of projects these can be roughly grouped into three main levels,

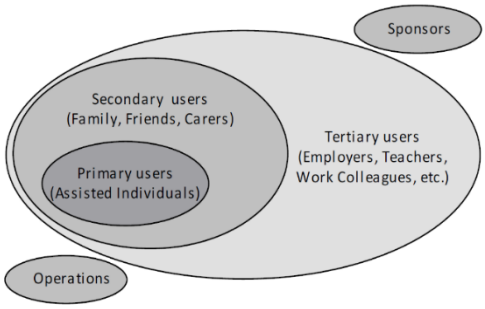

Fig. 1. Categories of Stakeholders [13]

In Figure 1 Primary stakeholders represent the individuals who are directly affected and the application is aimed for, in this case, PwDS. Secondary stakeholders are those in direct contact with people with Down's Syndrome, involved directly in their life, such as relatives and professional carers. Tertiary stakeholders are those who are less involved with the day-to-day life of the primary users and these are usually from educational, work or health care backgrounds, such as school teachers, employers and work colleagues. In our project given the restricted time and resources available we focused only in Primary (Main Users/ PwDS) and Secondary (Admin/Parents) users. The meetings conducted with stakeholders highlighted certain desirable features and expectations which were translated into functional requirements, for example:

- Admin/Parents section: allowing the admin to add more healthy eating option for the specific users. Checking what are the best healthy option for the day, considering main meals of the day, display graphically items to the users, allow parental/admin check, allow users to receive notification if some of the important items have not been used (e.g., water), allow parent to make comment and add more choices;
- Main Users/ PwDS: Allowing the users more foods in the list when they want, being able to see main daily meals, to access the app in any Android operated mobile device, to see their progress, to choose from the list provided for them as a portion.

Examples of non-functional requirements identified:

- The system will record the daily eating of the user after the user submit data to the system;
- The system should be functional and available to users 24 hours per day;
- The system must have a friendly and self-explanatory interface to prevent misinterpretation of the information given;
- Admins should have access through a user friendly web application;
- The system should be based on commonly available technologies such as Java, SQL, and favour open mobile platforms such as Android.

5. Development Process

Our User-centred Intelligent Environments Development Process (U-C IEDP) [14] combines waterfall and agile approaches [15], and keeps stakeholders at the heart of the development and reminding the developer along the progression of the important stages. The process, depicted Figure 2, is performed clockwise and there is a total of three main stages (or inner loops) in each full cycle, which initially starts at the centre figure by interviewing the stakeholders and goes clockwise.

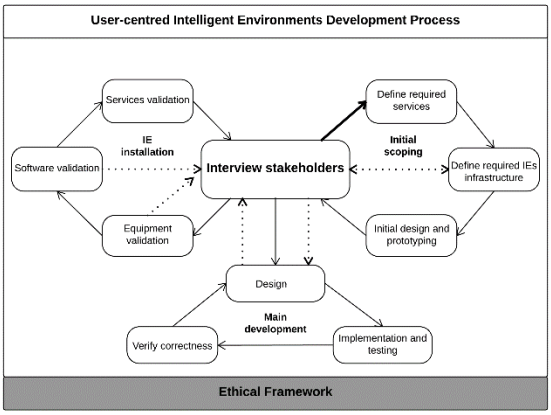

Fig. 2. Categories of Stakeholders [12]

These steps were applied in this project as follows. *Interviewing stakeholders:* our project included direct and regular meetings with DSActive and

indirect (through DSActive) obtaining feedback from primary users to understand their needs. After each of the internal process loops indicated in Figure 2 there was an opportunity to gather feedback, presenting prototypes of evolving maturity.

Initial Scoping (upper right):

- Define Required Services: translation of the information gathered into planned services;
- Define Required IEs Infrastructure: defining equipment and technologies to be used;
- Initial Design and Prototyping: design incremental prototypes to gather feedback from stakeholders.

Main Development (lower centre):

- Design: with directions from the scoping stage a more detailed system architecture can be created to inform the next stage of development and coding;
- Implementation and Testing: coding is increased and developers and DSActive staff tested software, hardware and human-computer interfaces before being approved to be presented to primary and secondary stakeholders;
- Verify Correctness: no formal methods were used here, correctness was testing focused.

Installation/Deployment (upper left):

- Equipment Validation: Whilst the development stage tested more the software functionality, at this stage other aspects such as connectivity and interfaces are also considered, in a more holistic assessment;
- Software Validation: here the focus of assessment was on software performance and possible bugs in specific items of functionality;
- Services Validation: here the focus of assessment was on each category of stakeholder obtaining the services in the form they expected.

5.1. Other Design Considerations

This overarching strategy was also supplemented with usual Software Engineering conceptual aids such as Use Case Diagrams and Personas [15, 16]. Three examples of personas describing the diversity of needs from main users are provided below.

Persona 1: Persona 1 is a representation of a PwDS who is currently in employment, has finished school and in the process of becoming a qualified first aider, he is currently struggling with his weight and would like to be able to use an application to reduce his weight by understanding his diet.

Name: James S.
Age: 22
Location: London
Status: Single
Occupation: Coach Assistance
Goals: stay healthy, reduce his weight, track their food consumption, create awareness of their diet.
Challenges: understand how to use a diet app, understand healthy diet.

James S. finished school at the age of 18 and managed to secure a position as coach assistance in DSActive London. He was at time of contact is working toward getting his NVQ level 2 to become a qualified first aid to continue as coach assistance. He is putting on some weight and struggling to use the current available application for diet control as the information regarding calories in each portion provided in the application is very complicated to understand. As a coach assistance, it would be very helpful if he can understand what foods are healthy and which once to avoid so that he can be slimmer. Technology awareness is summarized in Figure 3.

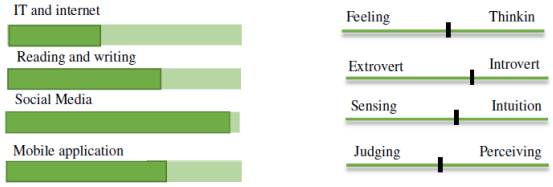

Fig. 2. Technology Awareness profile for Persona 1

Persona 2: represents a student with DS who is currently in education and has a better understanding of ICT equipment but is still unable to use currently available application to understand his diet because it is difficult for him to understand and the way the application is working and the information is written in small font.

Name: Adel T.
Age: 17
Location: Birmingham
Status: Single
Occupation: Student
Goals: finish his education, get good grades, track food consumption
Challenges: to distinguish between healthy and unhealthy food, be able to choose my own food and drink.

Adel T., is currently doing his level 1 certificate in IT at Birmingham College. She is friendly, polite and has a kind personality. She is very good with using ICT equipment such as a mobile phone or a computer and helps his friend with using the computer when she is at the DSActive office in London. Unfortunately, she finds it difficult to use available diet applications, to understand what foods are good for her, and she does not feel confident registering to any of these application using her personal information. Technology awareness is summarized in Figure 4.

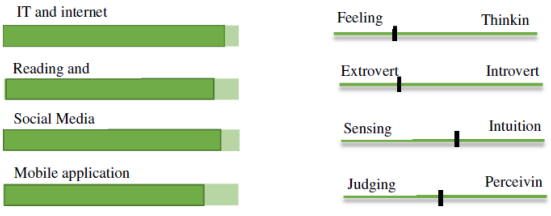

Fig. 3. Technology Awareness profile for Persona 2

Persona 3: is representing a PwDS unable to read and struggling to use any of the available application to understand his diet. He can move relatively well around in his vicinity within Leeds and meet his friends when he wants to without having to ask for assistance.

Name: James O.
Age: 35
Location: Leeds
Status: Single
Occupation: unemployed
Goals: be able to find a job, be more independent, be in control of my diet, reduce weight.
Challenges: cannot read and write, impossible to use diet app, track my daily consumption.

James O. is currently looking to work as a kitchen assistant in a DSActive branch in Leeds. For him the default learning source would be a book or more traditional software to understand more about foods, drinks and snacks because he cannot read. Therefore, for him to be more independent and find a job as kitchen assistant it would be very helpful if he could use something more adequate which will support his job, independence, and track his own daily food intake. Technology awareness is summarized in Figure 5.

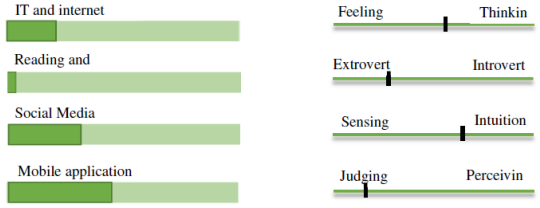

Fig. 4. Technology Awareness profile for Persona 3

Inspired by all the above considerations the purpose of this development was to design an application which can help raise awareness of harms and benefits of food and drinks in a practically useful way. That is, for this cohort of users, rather than showing different numbers and graphs which are mostly confusing for PwDS the aim was to provide a simplified yet useful first approach to the problem. None of the applications reviewed earlier on fit well this description of having a simple and easy to use user interface and to be able to design such an application following a specific principle was one of the priorities in this project.

5.2 POSEIDON Design Principles

Throughout this development the POSEIDON User Interface (UI) design principles [17, 18] will be followed as they have been tested through other existing POSEIDON applications:

Principle 1 - The User Interface is suitable and usable by all people with diverse abilities;

Principle 2 - Accommodating wide range of abilities and preference. Users should be able to change fonts, colour, image contrast, etc.;

Principle 3 - Simple UI design to allow users to navigate and use the application regardless of their knowledge, experience, language or abilities, (use of correct amount information not overloading with unnecessary text, images locations and the button or navigations links, format shown in Table 3);

Principle 4 - Information visibility. The system should be able to communicate with the users regardless of their ambient conditions, (considering users abilities, the information should be displayed in a meaning full manner by using recognized symbols, images and texts);

Principle 5 - Error prevention. Minimizing problems for the user when entering wrong information, the system should allow user to recover without going all around);

Principle 6 - Size and space for user approach of use, icons and text should be spaced out to give the user freedom of use with confidence with fear of making the wrong selection;

Principle 7. Consistency throughout the design. Identical design in all the pages should be maintained to avoid user's confusion and frustration;

Principle 8 – Satisfaction. The system should be enjoyable for the user this could be achieved by system behaving what the user expects;

Principle 9 – Predictability. The user should know what to expect next, and this could be achieved by constancy of the system design, where a user presses a button for a service that specific service should be actioned or information to be display in this regard.

Table 3. Poseidon (UI) design guideline

Feature	Preferences of people with Down syndrome	MyDiet Control
Font	Bright, adding depth, Large, Bold, Stylized, No font decoration	Yes
Color	Darker: blue, purple, grey. Combinations of primary color, with high contrast. Tints and tones. Complementary color.	Yes
Graphics/ Images	Cleary identifiable. For people of similar age or older. Action images. Photographic better than Illustrated. Fun and whimsical illustrations.	Yes
Animations	Bright color. With motion. Animating color. Personalized	No
Buttons	Largest was clicked first. Dark background. Light text on top. Expected action clear. Framed. Arrows pointing to buttons. No spatial preference.	Yes

POSEIDON Colours: Part of the POSEIDON User interface design principles is the colour palettes (Table 4) for the system background, which are recognized and used in all the POSEIDON applications. These will be maintained in this application as it will help all the primary users using the POSEIDON application to be familiar with the patterns and colour.

As well as following the POSEIDON overall design principles other input was considered and applied as well, such as Nielsen's Heuristics Design principles [19].

Table 4. Poseidon recognised colours

Colour	RGB code	Hex code
Black	R : 0 G: 0 B: 0	#000000
White	R: 255 G: 255 B: 255	#FFFFFF
POSEIDON Turquoise	R: 53 G: 132 B: 140	#008080
POSEIDON Orange	R: 241 G: 165 B: 50	#F1A532
Red	R: 255 G: 0 B: 0	#FF0000
Blue	R: 28 G: 120 B: 204	#1C78CC
Grey	R: 174 G: 167 B: 159	#AEA79F

6. System Development

A combination of Nielsen's heuristics and POSEIDON principles were used to create a user centric and functional application.

One of the most important elements that has been looked at during the design of this application is the visual design, because as mentioned earlier PwDS tend to have visual challenges so the look and feel of the app was simplified. The colours in Table 4, which are POSEIDON favoured colours and can create resemblance between the POSEIDON products, were given priority. Our main users have difficulties when reading, therefore using symbols and characters that are easy to understand and read is very important. Throughout this development a combination of POSEIDON approved words with symbols, icons and images is used. POSEIDON provides developers with an extensive catalogue of icons, which are freely available to developers.

One challenging part of the development was finding a simple way to communicate the benefits and harms of specific food and drinks to the primary users. Almost all of the available applications that are used for diet control are calculating calories on portions and these calculations are off-putting for users in general, especially for our main intended users. Based on the specialized input from our tertiary users (DSActive staff) this information was presented by using three emojis: happy smiley face in green associated with healthy food, inexpressive face in yellow associated with average food and sad face in red associated with bad food, inspired by reported successful use of these colour codes in diet management [20] and also addressing a concern that some PwDS may get too focused on calories counting.

The foods, drinks and snacks are presented in portions with images and once the user is selecting the number of different portions they have eaten it is stored and the totals shown in the Eaten Today page, which is at the bottom of all the pages in the application. If the user selects a majority of a specific category of food, then they will see the corresponding emoji as feedback.

Our tertiary stakeholder requested that no log in is required for the user and that data should be stored in the individual user device to reduce data confidentiality breaches. User activity on what they have consumed is stored in each individual user's devices and once the application is deleted all the data is erased with the application.

Next we explain the main features and functionality of the system through a number of screen shots. First we provide an account of the main user side of the system in the app itself and then an explanation on how the system can be managed through the admin interface which can be accessed through a browser. Given our system is about food and to reduce ambiguity, we will refer to the main visual units under consideration as a "page" instead of as a "menu".

As soon as users open the application they will be automatically taken to main section of the application of the four main meals displayed in the centre of the screen with large images and clear text with white background with four alternative options in the lower part of the screen (Figure 6).

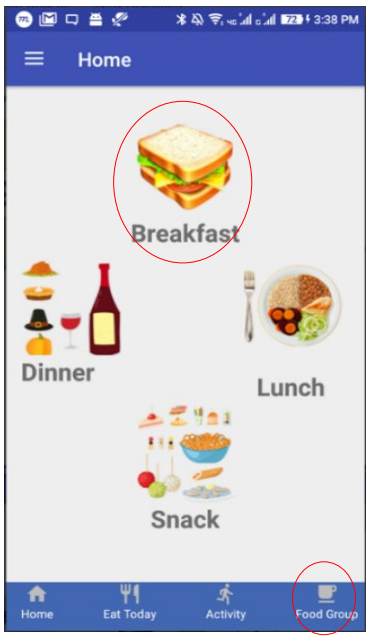

Fig. 5. Main page

Graphics inspired on POSEIDON design principles were used in the application to help users understand the options. The user can select any of the activities by clicking on the icons, which are clearly displayed with space between them to avoid mistakes and frustration to the users while selecting.

The interface design is consistent throughout the pages and clearly labelled to keep the user informed of the page they are currently in. Specific standard icons from the POSEIDON and other international standards (e.g., 'Easy Read') are used.

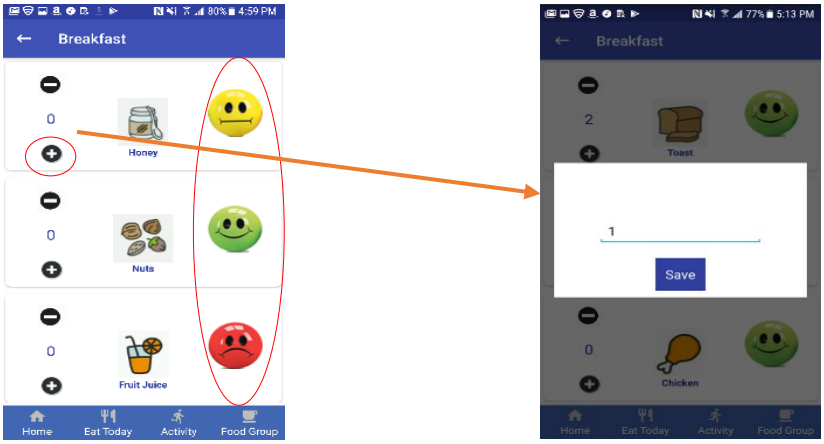

Fig. 7. Left: Breakfast page. Right: adding portions.

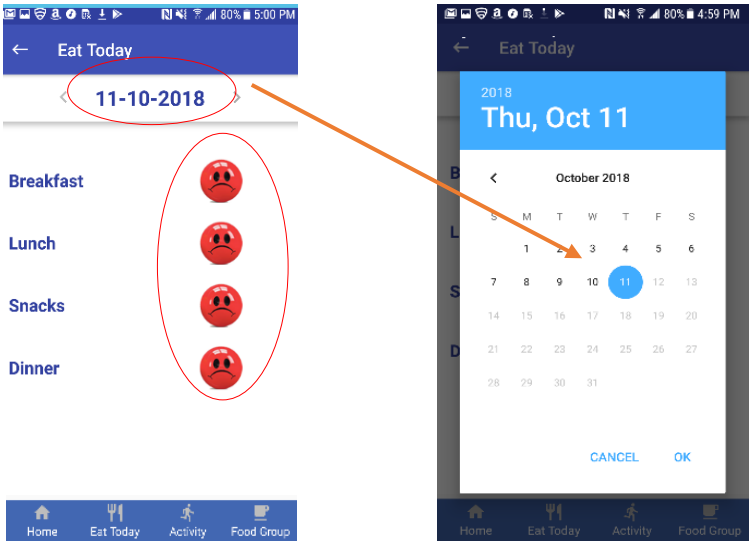

Fig. 8. Day summary

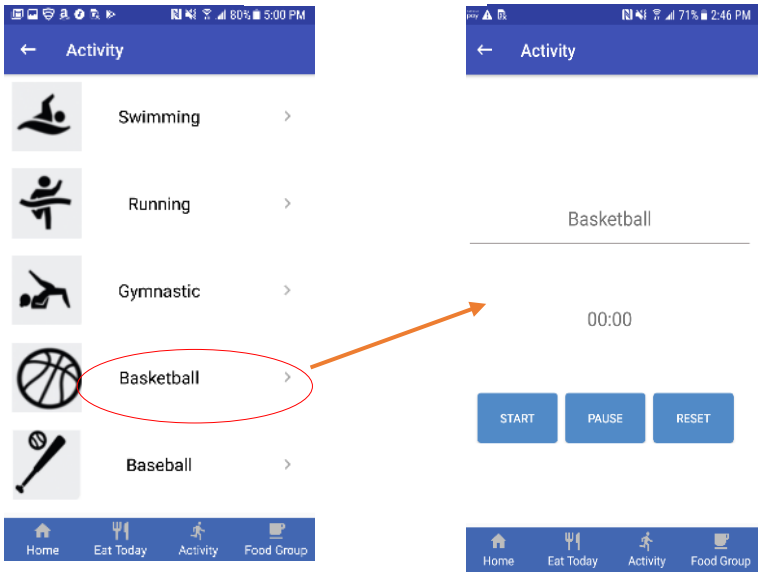

Fig. 9. Left: Activity Page. Right: Activity summary

The user can add by clicking on the plus button and elect the number from list or just enter the amount by using their phone keypad (Fig. 7). This feature is useful however it brings an interesting challenge for this group of users given the challenges some of them face with numeracy, for example, counting and also differentiating between portion sizes and a teaspoon of honey compared with a tablespoon of honey. Whilst more and more options and menus can be added to help differentiate amongst these, this may affect the overall complexity and usability of the product as a whole, there is an optimal balance somewhere for which no one may have an objective definitive answer that works for all. These icons are used to describe the food perceived benefit. At the end of each day or during the day the user can monitor his/her intake and can also check a previous date using the calendar displayed on the top of the screen (Fig. 8). The user can select the calendar by simply clicking on the date, and a new window will open where the user can choose a date if they wish to or just cancel. If the user consumed and added an unhealthier option, or if they have not recorded anything, they will receive an upset face as feedback. The activity icon or section will take the user in a new page, where user can record the time they have been playing (Fig. 9). By clicking the food group section, a new page (Fig. 10) will open, where different food groups such as fruits and vegetable, drinks, etc., are displayed.

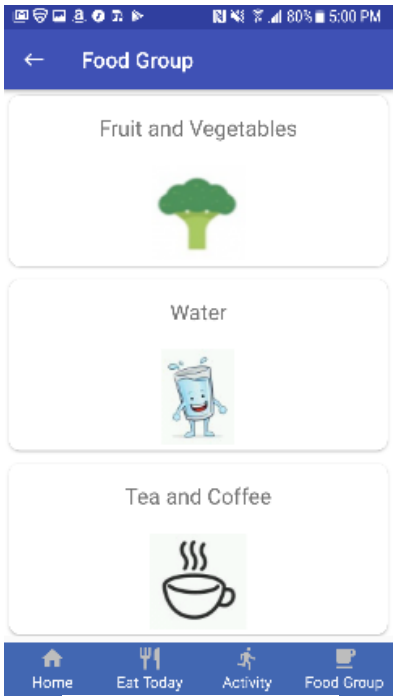

Fig. 10. Food groups

If the user clicks on any of the food groups, a new page is shown with information about that specific group, such as why you should have them how often to have and what amount of it is recommended, etc.

People with Down's Syndrome are more likely to forget how each step works. Therefore, the app is designed with a maximum three steps to get the user where they want. Nevertheless, PwDS can become disorientated within the system and get confused if they have to navigate through a large number of screens or levels of depths within the system screens navigation structure. This was addressed by not only keeping the depth off navigation to a sensible number of 'no more than three' but also providing the user an easy option to return to the home page by using the icon at the bottom left of the screen.

The Admin panel is available online and only the authorized person has access to the credentials to login and make changes, add or removed an activity or filed. Once the changes have been made the app should be updated in the phone and all the changes should be implemented in the application. Using the username and password admins can login and be presented with a dashboard where they can edit, add and/or remove the following: Food groups, Items (foods, snacks and drinks), and Activities (Figures 11, 12 and 13).

Of course there are challenges in selecting the granularity of this concepts. The current concept is that users of this system will be able to match the main components of each meal, and if a meal consists of a plate with meat and vegetables they will indicate they have both. For users with different degrees of intellectual understanding and there is always the possibility of adding more food groups and more specific pictures. However, there is no single solution for all and we believe the answer to this challenges is in the family personalization of the app to the capabilities of their member with DS.

Another practical challenge is in the truthful reporting of accurate number of portions. There is only so much developers can do to address human honesty in relation to habits. This problem is not exclusive to PwDS reporting on their daily habits. Also, other citizens on special diets, in addiction programmes or on rehab may tend to adjust their reported consumption to please people around them and to gain social acceptability. In the case of PwDS we usually have in their families important allies though. At the current state of this project we count on secondary and tertiary users to train, guide and to check primary users use the system in a way that reflects reality for their own good.

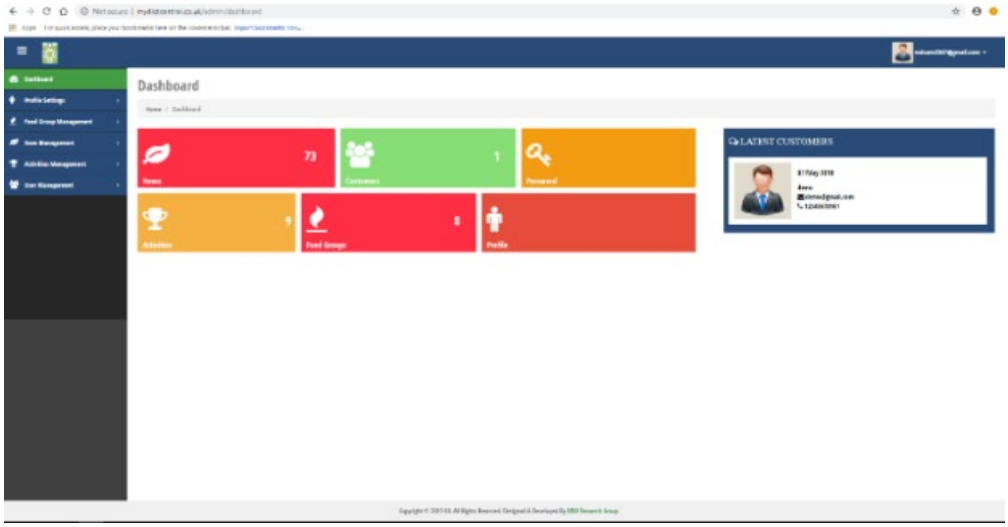

Fig. 11. Dashboard

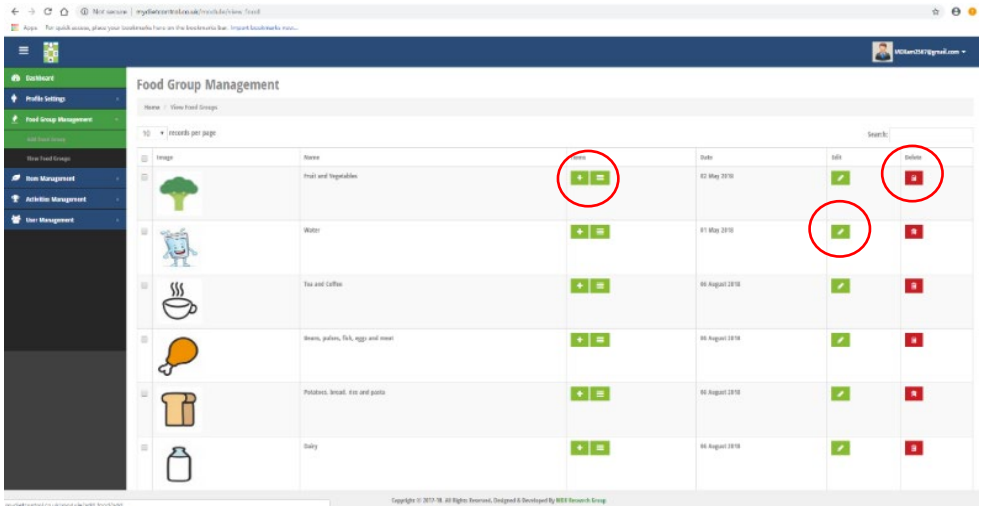

Fig. 12. Food Group Management

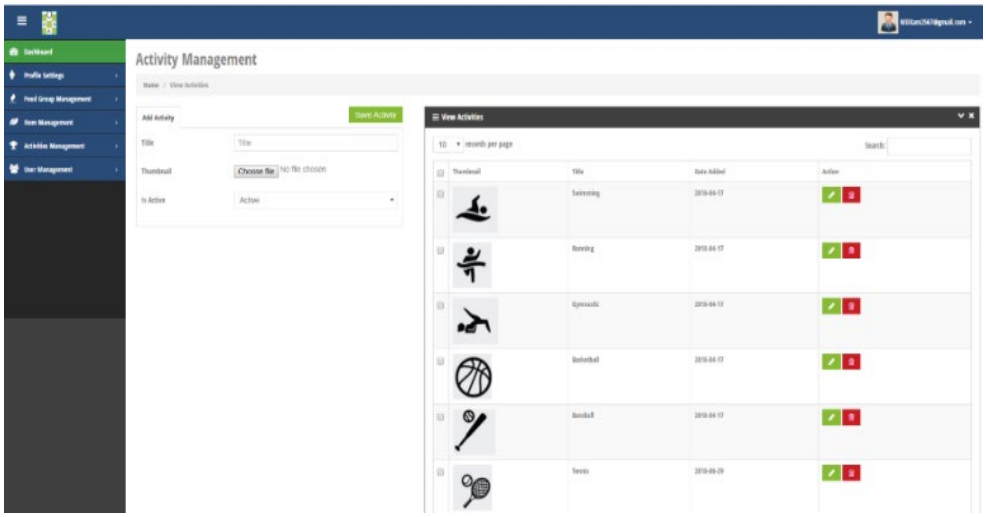

Fig. 13. Activity management

Progressive validations were carried out to examine and confirm that the hardware, software and services were developing according to the expectations. According to the U-CIEDP methodology (Fig. 2) validations are made in each internal loop by consulting stakeholders and also full iteration validations can be conducted to keep track of the overall evolution of the system.

During the 'Initial Scoping' internal loop (right hand side of Fig. 2) compatibility of application with hardware (mobile phones and laptops) and operating systems (focus on Windows/Mac and iOS/Android) was checked routinely and also the feel and look aspects. During the 'Main Development' internal loop (lower centre of Fig. 2) the main functionality was tested against errors, this was not performed with PwDS but by developers and DSActive staff. During the 'IE Installation' internal loop (left hand side of Fig. 2) services validations were performed including PwDS.

Validations were planned and agreed with DSActive who was very familiar with the participating users. Material, time, and process was carefully considered because of the specific group of participants for this project. Our project greatly benefitted from the periodic workshops DSA-UK organizes. Validations were carried out in two stages. Firstly, services were checked by DSActive staff and only after their approval it was considered to be presented to the primary users. Then, DSActive staff attended some of these and offered participants (PwDS and their parents/guardians) to provide feedback which was then conveyed to the developers team.

Because validations were always made at DSA premises in activities they already organized periodically, ethical aspects of each validation followed DSA regulations and included the usual participant information sheet, consent forms, anonymization of results, etc. These documents were presented in both ways traditional writing for parents/guardians and 'Easy Read' for PwDS. All the participants, their families and their caretakers were contacted and Participant Information Sheets as well as Consent Forms were used. The Participant Information Sheet presented and explained the application, invited users to participate, provided contact information about the organizers, and explained how to withdraw from the programme, how their data will be used and stored.

The feedback provided through the last trial with open ended question that was organized by DSActive is shown in Table 5. Participants of the final trial were satisfied with the overall approach and strategic direction of the application. Requests for improvement were mainly in the direction of adding more item options to the lists.

Table 5. Assessments Log

Participants	Positive Outcomes	Aspects for improvement
PwDS 1	Liked the app, found it easy to use, learned more about healthy food, found it easy to record activities engaged in	More food choices, more activity choices
PwDS 2	Liked the app, found it easy to use	Larger text, larger images/icons
PwDS 3	Liked the app, found it easy to use, learned more about healthy food, found it easy to record activities engaged in	No dancing icon within activities
PwDS 4	Liked the app	More food choices, more drinks choices
PwDS 5	Liked the app, found it easy to use, found it easy to record activities engaged in	More activities
PwDS 6	Liked the app, found it easy to use, learned more about healthy food, found it easy to record activities engaged in	More foods, more activities

7. Final Discussion and Conclusions

We described the motivations to design a system which supports people with Down's syndrome towards making healthier choices in relation to feeding and related physical activities. An android application was created to be used by the primary users and a supporting system was also provided for carers to personalize it and configure it to the needs of the main user and beneficiary.

Previous experience gained with major, and first of its kind, European project POSEIDON was important as a base and provided supporting resources in terms of design. This included graphics and guidelines.

As part of the project, a comparison of existing applications in the market was made and contrasted with stakeholder requirements. One of the main steps was to remove the typical confusing calculations and heavily text-based applications in the market and using instead a more graphical and intuitive interface.

Three are mainly two discernible groups of apps we considered in this article. The first and more

abundant group are those related with the "fitness industry" in general. The second group includes the MyDietControl system reported here and the recently developing MANGO, which are more specifically designed and concerned with serving people with Down's Syndrome.

The former group is more abundant and to some extent more technologically sophisticated, which is not necessarily a good thing for this specific group of target users. These apps tend to put more emphasis on quantitative aspects of the process (recording calories intake, tracking calories consumption and tracking weight) and connecting with social media, and using GPS tracking. Their design options are sometimes guided by branding concepts, can be based on "more is better" strategies which lead to an abundance of text, high number of features crowded into a screen, and many menus with many levels, in a bid to beat their commercial competition.

The second group is more specialized, invested more time on finding out user needs, follow specific principles of design more based on images and simplicity, acknowledge certain areas of support which are more important for PwDS, carefully choose fonts, colours, imagery, and a more limited number of features in a given screen and navigation simplicity in general trying to focus attention on essential services.

Both MyDietControl and MANGO focus on classifying food with colour coding into big intuitive general categories. MyDietControl focuses more on nutrition understanding and link with exercise whilst MANGO is more supportive for a PwDS taking a meal of home as it includes payment support. MyDietControl has a complementary MoneyLearning app developed by POSEIDON, however that app does not allow yet payment with a card as MANGO does. This feature of payment together with the social sharing are amongst the two features which distinguishes MyDietControl with MANGO. Both the POSEIDON and MyDietControl projects consciously opted for not including these two features because of security concerns. Instead, POSEIDON and MyDietControl rely on a separate MoneyLearning app to help understanding of money and on a privately managed (and extremely simple) social network where families of PwDS can share information.

As with every development there is always more that can be done. Some of the possible improvements that were requested by the users after testing were:

- Adding more food, snacks and drinks options;
- Adding more activities in the activity section;
- Making the test, images and icons larger.

Other improvements suggested by secondary and tertiary stakeholders were:

- Adding activities that are real live tractable using sensors and GPs technology. The POSEIDON project explored some;
- Giving users the rights to add or remove some of the items that are not in his\her interest;
- Gamifying the application by enabling users to compete with their friends in healthy eating or and activities they do and adding prizes and recognitions;
- Adding chat rooms allowing users to communicate with each other.

Some improvements are perhaps more on the intelligent personalization arena and can form an interesting follow-up for commercial and academic developers, for example, the way the colour coding is automated. For the time being it is manually configured by the secondary users (family or guardians) through the configuration panel they have secured access to. This can be automated having access to a database of foods and their perceived nutritional value, however, it has to be taken into account that 'even an excess of a good thing can be a bad thing' and that there could be food allergies to take into consideration so there is here another interesting link with personalization.

Also the range of options at the moment can be expanded and personalized by each family group however, we admit this is labour intensive in the current version. In a hopefully better future there will be databases of foods available and families can have greatly simplified the task to drag and drop foods they need to customize the system for the primary users.

Another opportunity for expanding the functionality of this system is in automating the ways physical activity is tracked. Although physical activity is an important part of the healthy living picture the emphasis in this project was on food intake as a first step.

Some other suggested improvements (e.g., Can tertiary users such as teachers help with tracking food consumption?) may require taking more measures in terms of user privacy, security and safety, therefore they need careful consideration. Their successful implementation depends as much on Computer Science as on the community around the IT product.

As with any digital tool tackling a serious societal issue, it is almost impossible to get it perfect in a first attempt. There is only so much we can achieve with the app. We aimed at guiding (to a certain realistic level), help gathering data about feeding patterns and, probably the most important of all benefits was bringing food intake to a more conscious level in daily decision making

The history of Computer Science has been constructed in iterative small expansions, adding layer upon layer of services, and this one is no different. Now there is a basis to grow from, we know much more about the requirements and how

they work. We expect this system to be expanded in the future.

One important aspect of working with people with Down's syndrome developers need to be prepared for is diversity. Contrary to the tendency of society to simplify and label, developers will find they have a wide range of capabilities, preferences, lifestyles, and aspirations. This means that, as usual, there will be 'no one size fits all' solution and invariably the solution will not be a solution for all of them. On the other hand, they have been neglected by the digital industries and most of them will benefit greatly with even simpler solutions.

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Ethics statement:
i. The interaction with stakeholders for validation was performed by DSA-UK during their activities and following their internal ethical procedures.
ii. Funding was provided by DSActive, a branch of DSA-UK
iii. Conflict of Interest Declaration: the Authors declare not to have a conflict of interest in relation to the content of this article.
iv. Ethical approval: see (i)
v. Informed consent: see (i)

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