POSEiDON

PersOnalized Smart Environments to increase Inclusion of people with DOwn's syNdrome

Deliverable D2.3

Report on Design of HW, Interfaces and Software

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Executive summary

This deliverable presents guidelines for the development of hardware, software and interfaces within the POSEIDON-project. Therefore, social, personal and technical factors affecting abandonment and adoption of assistive technology are discussed. Subsequently guidelines will be outlined which have to be applied to make information easy to read and understand and since need to be utilized within POSEIDON´s development. In addition to those general guidelines the next section focus on the characteristics of people with Down`s syndrome while linking them with results from previous studies regarding the computer usage of people with Down syndrome. Since people with Down`s syndrome represent a very unique and heterogeneous target group not all guidelines will prove applicable. Therefore, the following section outlines the design process within the POSEIDON-project stating the importance of a user centred design approach and providing some basic principles which were implemented to ensure the development of a technology meeting the requirements of people with Down`s syndrome. The next section presents the technological innovation within the POSEIDON-project starting with an illustration of the state-of-the-art-technology. Afterwards, it is described how the POSEIDON-project has progressed beyond this state-of-the-art. Before the conclusion, the co-working process with primary and secondary users and some experiences gained within the POSEIDON-project in the pilots are shown.

Contents

1 Introduction

Design principles are fundamental concepts on developing things, like hardware, software, environments, objects, systems etc. for a specific group – or in the case of universal design: for any user. Guidelines on design are meant to facilitate the product development within a user-centered approach, having the potential users and their requirements, abilities and limitations in mind to offer a product, which can in the end meet their needs.

A good design in technology development can ensure, that the developed solution is easy to use and useful for various situations or user specifications, which is indispensable when it comes to an adoption or abandonment of technology.

Especially regarding assistive technology, which aims “to increase, maintain or improve capabilities of individuals with cognitive, physical or communication disabilities” (Marshall 2010), there needs to be an easy-to-use, attractive, non-stigmatizing and customized solution to avoid frustration and rejection. Research showed for the US, that one third of the purchased assistive technology is abandoned – unfortunately these studies don’t consider very different types of assistive technology, but still point out, that it needs to be ensured, that this technology can meet the user’s characteristics and expectations instead of just being an (useless) obstacle in daily life (Dawe 2006, Phillips/Zhao 1993, Ceaparu 2004).

This deliverable offers some basic guidelines for the development of POSEIDON`s hardware, software and interfaces while also stressing the need for necessary adaptions if those guidelines don’t prove applicable during the pilots. It furthermore serves as a foundation for the work packages “Context Awareness” and “Human Computer Interaction” since the presented guidelines and design approach are fundamental in the development of a technology meeting the needs of people with Down`s syndrome.

2 Abandonment and adoption of (assistive) technology

There are several factors, which influence technology acceptance, especially when it comes to adopt assistive technology. Not all of them can be controlled by designers or developers, but their work still has a great impact on the usefulness and significance of technology use. Therefore, to develop a technical assistance, which is meant to give an appropriate support to a disabled person one should concentrate on the potential user’s requirements and needs to understand when, how and why technology is used or not. An inclusion of the target group (incl. different stakeholders or users) into the developmental process for assessing specific requirements and getting an understanding of the target group is indispensable to understand and address the specific cost (effort)-benefit (support) calculation.

If one has a look at the different components, which can have an impact on technology acceptance, one could identify three main fields: social, personal and technology-related factors.

2.1 Social factors

First, there are cultural factors like the access to technology in general, but also specificities in dealing with disabilities within a society – is it a stigma, is it socially acceptable, what kind of technology is commonly used (Lin 2003)?

Concerning the user's environment, the technology used by other significant persons have an impact, as they might be role models for the user. Furthermore, the expected help given by others when using a technology seems to influence the readiness to use technology, e.g. when it comes to customize a device for the user or if problems related to the technology occur (Venkatesh 2003, Kintsch/DePaula 2002). On the other hand, the expectations of others towards the performance of the user with devices can have an impact on his/her willingness to use an assistive technology (Wessels et al. 2003).

Finally the general technology acceptance is also influenced by socio-demographic factors, like age, gender, education or financial situation (Venkatesh 2003, Lin 2003). Regarding the age, it is known that the understanding of technology use and its usefulness as well as the self-confidence in operating technology of younger age groups is different compared to older age groups (Jakobs et al. 2008, Czaja et al. 2006; Rogers/Fisk 2010). There is also a gender gap reported in polls and studies: Men are more likely to own and use technology. They appear more self-confident and less stressed in a situation of technology use (Broos 2005). Educational background and financial situation are widely positively correlated factors, which also have impact on technology use and facilities: the more educated a person is and the better his/her socioeconomic status, the more technology is used and owned (Mollenkopf/Kaspar 2002).

2.2 Personal factors

This concerns the experienced and felt need for assistance the potential user has, and addresses the discrepancy between the desired and the current situation – and the belief, that with the help of technology one can overcome this distance. Research showed that it makes a difference, whether the person faces congenital or acquired disabilities. The latter are less likely to accept assistive devices as they remind them of their lost abilities. The probability that the assistive device is seen as something that stigmatizes is high and can lead to abandonment (Kintsch/DePaula 2002, Scherer/Galvin 1996).

Experiences gathered while using technology influence the expectations regarding the own competence of using it and the received benefit. Thus, the willingness of using technology is influenced. In addition, users who feel self-confident in handling as well as having the feeling of control about a device are more likely to go on using it (Venkatesh 2003). If so, technology can empower the user.

Furthermore, one can see that there are several other psychological preconditions, which make a successful technology usage more or less probable. Research found out, that these are for example human factors like frustration tolerance, self-efficacy, readiness to assume a risk, a "trial-and-error"-mentality and general insecurity or anxiety towards technology use. There also seems to be the personal tendency for emotional maturity, great inner motivation and the quest for independency for those, who accept using assistive technology (Scherer et al. 2005; Scherer 1998, Czaja et al. 2006).

2.3 Technology factors

As mentioned before, the ease of use and aspects of usefulness of technology have a big impact on the acceptance of an appliance (Davis 1993, Venkatesh 2003). Aspects of universal design are a good base to start from when it comes to designing technology for people with special needs – although one should go a bit further. Different degrees of limitations in daily life, especially those experienced by persons with Down syndrome, require more than a "design for all"-approach. The highly individual needs must be considered. These needs include diverse capabilities (in the sense of the variety of cognitive, sensory and physical aspects of the disability), but also different contexts and environments of assistive technology usage e.g. inside the home, outside, usage alone or with the help of others. If one wants to support or compensate specific fields of competencies, developers must ensure, that, although there are different preconditions, technology can always give the appropriate support. The possibility to customize is very important: It facilitates an adaption to individual requirements and use contexts to cover a wide range of need for assistance (DePaula/Kintsch 2002; Sutcliffe et al. 2003).

One should also concentrate on already known or used technology to keep the barrier in learning how to operate a new device as low as possible. If this is not feasible, one should at least try to keep the labour of learning how to use the new system low. This could, for example, be reached by designing a very simple, intuitively usable system, which does not require a huge amount of effort in dealing with it.

Another issue is the reliability and durability a technology should provide. Especially assistive technologies, which are developed to give aid in everyday life situations must ensure to run without problems all the time and therefore also need to be fault-tolerant. The user needs to experience, that he/she can rely on the system. One should consider, that this technology in most of the cases will replace another kind of assistance-system (e.g. help given by significant others), which might have worked fine so far. If a new system (although it might be useful) causes more problems than it can solve, it will less likely be used to replace an already existing one. If a technical problem occurs, technology should be simple enough to solve the problem in short time, because the user is dependent on it (DePaula/Kintsch 2002).

Technology must be non-stigmatizing, should be unobtrusive and in the end also fun to use. Users will use the technology more likely if they feel proud about using it. They must not feel more handicapped, because the device makes a need for support too obvious to others. Therefore, aesthetical aspects and an age appropriate design must be considered carefully (Parette/Scherer 2004, Venkatesh et al. 2003, DePaula/Kintsch 2002).

3 Information for all

In the project “Pathways to adult education for people with intellectual disabilities“ (Inclusion Europe 2009) standards were developed to make information easy to read and understand to enable people with intellectual disabilities to take part in lifelong learning programs. These standards provide one general orientation for the development of POSEIDON and therefore are presented in the following section.

3.1 General Standards for easy to understand information

The following standards apply whenever there is the need for easy to understand information (Inclusion Europe 2009) and therefore should be applied by POSEIDON:

Words:

- Use easy to understand words that people know well.
- Do not use difficult words. If difficult words are needed, always explain.
- Use well known examples when explaining things.
- Use the same word to describe the same thing.
- Do not use difficult ideas such as metaphors.
- Do not use words from other languages unless they are well known.
- Avoid using initials.

- Percentages and big numbers are hard to understand.

Sentences:

- Keep sentences short.
- Speak to people directly (using “you”).
- Use positive sentences rather than negative ones where possible.
- Use active language rather than passive language.

How to order your information:

- Always put your information in an order that is easy to understand and follow.
- Group all information about the same topic together.
- It is OK to repeat important information. It is OK to explain difficult words more than once.

3.2 Standards for written information

In addition to those general standards for easy to understand information, there are more specific standards for making written information accessible, which are presented in this section.

Writing:

- Always use a font that is clear and easy to read.
    - This means you should:
        - Never use serif fonts.
        - Never use writing that is too close together.
        - Never use writing that is too light and does not print off well.
        - Never use italics.
        - Never use a special writing design.
- Always use large writing (at least the size of Arial 14).
- Do not write whole words in capitals.
- Try to use only one type of writing in your text.
- Underlining can make the text harder to read.
- Where possible, avoid writing in colour.

Words:

- Do not use difficult words (if so, explain them).
- Be careful when you use pronouns.
- Keep the punctuation simple.
- Avoid all special characters where possible, like \, &, <, § or #.
- Avoid all abbreviations like “e.g.” or “etc.”

Sentences:

- Always start a new sentence on a new line.
- Never split one word over two lines.

- Keep your sentences short.

Writing text:

- Always make sure you give people all the information they need.
- Do not give people more information than they need to understand your point.
- Make sure the important information is easy to find.

Images:

- Many people find it hard to read text. To help them understand your text, you should put images next to it to describe what it is about.
- Always choose images that are clear, easy to understand and go well with the piece of text they are helping to explain.
- Use the same image to explain the same thing.

Standards for electronic information:

Those standards apply especially to information written on computers. Furthermore, it is important to refer to the standards mentioned before.

What your screen should look like:

- Do not put too much information on the screen. Where possible, try to fit all the text on the screen so that people do not have to scroll down to see all the information. If people will need to scroll down, put a text menu at the top. A text menu is a list of the main sections of your text. You should also give the possibility to easily go back to the top of the page at the end of each section.

3.3 Standards for audio information

Besides the general standards for easy to understand information and the more specific ones regarding written information there are likewise standards for making audio information accessible. Those was considered during the development of POSEIDON as well since audio information could play an important role in the usage of POSEIDON for persons who cannot read, read slowly or do not have a good sight since it could provide audio guidance.

- Make sure that the person speaking has good pronunciation and articulates clearly.
- Make sure that the sound has a good volume, not too loud, not too quiet
- Make sure the sound is good, without interference or background noise.
- Make sure the person speaking speaks slowly.
- It is very important to leave pauses at sensible points. This way, people can understand the first part before more information is given to them.
- Make sure the voice of the person speaking is clear, meaning not too low, not too high.
- Allow enough time for people to understand the information.
- Do not hesitate to repeat your information several times.
- The messages given in audio format should always be polite and courteous.
- Make sure that the person speaking does not have an accent which is too strong.

- Always speak one at a time.
- Do not interrupt audio information, for example by advertising.
- Make sure you use words which are easy to understand. For example, do not use dialects.
- You might use a special sound announcing that the following information is in an accessible format.
- Read the text in a way that emotions can be perceived.
- When it is appropriate, the voice should match the character.

The presented standards were developed to make information easy to read and easy to understand and therefore are very important for the development of POSEIDON. Nevertheless, they were not developed with focus on people with Down syndrome or with focus on assistive technology. Therefore, there is the need to verify them during the pilots and if necessary to adjust them to meet the requirements of the target group and to align them with the opportunities and boundaries of the technological devices. Thus, those standards will be deployed and if needed adjusted.

4 People with Down syndrome

4.1 People with Down syndrome: "characteristics"

People with Down syndrome represent a very unique target group since all three major types of capabilities (cognitive, motor, and perceptual) are affected, but the disabilities often vary to a high extent. Furthermore, each person with Down`s syndrome shows individual characteristics and combinations in its limitations; thus, generalizations are impossible. The fact that Down syndrome affects all three fields of human abilities suggests that lessons learned from studying people with disabilities in just one field cannot be applied appropriately to the others. The high individuality represents a major challenge for the technical development and underlines the significance and importance of a user-centred design approach.

Nonetheless it is important to present a general view of the range of limitations associated with Down syndrome, while emphasizing once again the individuality and therefore the need for universal design principles. Despite the wide range of competencies and impairments, common problems of people with Down syndrome are:

- limitations in vision, sensory and hearing skills, including hyposensitivity in touching and problems with fine motor movements
- weak muscles in arms and fingers
- limitations in short term memory and cognition, including problems with verbal auditory memory, hence it is harder to recall information that is heard rather than read
- limitations in communication skills: delayed development of expressive language, while receptive language is superior to expressive language; a relative strength in vocabulary and pragmatics and greater difficulties with morphology and syntax; difficulties with complex conversational skills, reduced speech intelligibility (overview: Feng 2010, Lazar 2011, Bull 2011)

It is important to stress the individuality of POSEIDON's target group and therefore each individual will have their own strengths and weaknesses like anyone else. It is important to recognise both the difficulties a person with Down syndrome has but also their strengths. As McGuire and Chicoine (2006) note, most children with Down syndrome enjoy and learn from social interaction with family and friends. As time goes by, they often have good social and emotional understanding, and most are able to develop age-appropriate behaviour, if this is encouraged and expected. People with Down syndrome generally learn visually; this is probably why reading can sometimes be a strength. This means that they learn best from watching and copying other people, and may find it easier to take in information if it is presented with the support of pictures, gestures, objects and written words. Using their hands, faces and bodies to communicate is another strength and many people with Down syndrome enjoy drama and movement because of this strength. The approach taken within POSEIDON should always build on the strengths of people with Down`s syndrome while keeping the possible limitations in mind.

4.2 People with Down Syndrome as computer users

The possible limitations and characteristics of people with Down syndrome have a major impact regarding the usage of technology and underline the need for usability-focused and user centred design. Since the goal is not only to develop a technology that is easy to use, the technology must also be useful to the user and his/her possible limitations. Regarding the usage of computers by people with Down syndrome the limitations in cognitive, language, and motor skills all have a profound impact on computer usage as e.g. difficulties in memory, processing information, understanding abstract concepts, reading, writing, communication, navigation, typing, and the use of the mouse. These limitations present a major challenge for users and designers as well.

Nonetheless a recent study (Lazar et al. 2011) focussing on the computer usage of children with Down syndrome shows that 72% of the sample started using a computer by the age of five. 99% of the sample had access to a computer at home, other main access points being school and library. Thereby computers are mostly used for learning (80%), entertainment (95%) and communication within ones' peer group members (33%).

Focussing even more on the usage of computers etc. and possible preferences of the target group one can find some interesting suggestions in literature regarding fonts, colours, graphics, animations and buttons (Kirijian et al. 2007), which have to be combined with the standards of "information for all" and tested during the pilots.

Taking the two sources for design guidelines together one can conclude in the overview presented in Table 1. While Kirijian et al. focus on the preferences of people with Down syndrome, the standard "Information for all" focuses on the larger group, people with intellectual disabilities. Kirijian et al. present a study on a group of 10 people with Down syndrome, carefully chosen on the basis of their computer usage. In general, both share the idea of using as simple wording as possible and both strongly suggest the use of photographs and images to support the idea presented with words. However, there are also contradicting statements, like the usage of animations. This is due to the different purpose for which each animation is used. For example, if it is always placed on the screen it can be distracting. On the other hand, some personalized animations used as reward system can be motivating. In general, both share the idea of using as simple wording as possible and they both strongly suggest to use photographs and images to support the idea presented with words. However, there are also contradicting statements, like the usage of animations. This could be understood by the different intention of the animation. Furthermore, a general rule is to avoid everything unexpected, like e.g. pop-up windows.

Table 1 Overview of design guidelines

Guideline subject	Preferences of people with Down syndrome	"Information for all" people with intellectual disabilities
Font	- Bright, adding depth - Large	- Don't use serif fonts, rather Arial, Tahoma

	- Bold - Stylized - No font decoration	- Enough spacing between letters - Don't use italics, underline - Don't use shadows, special writing design - Large, at least like Arial 14 - one font throughout text
Colour	- Darker: blue, purple, grey - Combinations of primary colours with high contrast - Tints and tones - Complimentary colours - No dull colours	- Avoid colours of text
Graphics/Images	- Cleary identifiable - Naturally coloured not digitally manipulated - With people of similar age or older - Action images - Photographic better than illustrated - Fun and whimsical illustrations	- Photographs, drawings, symbols - Don't use images for younger people than the target age group - Clear, not too disturbing to look at - Fit to the text
Animations	- Bright colour - With motion - Animating colour - Personalized	- No animations on screen
Buttons	- Largest was clicked first - Dark background - Light text on top - Expected action clear - Framed - Arrows pointing to buttons - No spatial preference	- Large button to change size of the writing
General on websites		- No pop-ups - No large programs (hardware, internet speed restrictions) - Search tool - Easy-to-read in metadata
Homepage		- Clear what website is about - Phone number - Postal address - E-mail address - Easy-to-read symbol

Navigation		- Clearly show on which part of the website one is - One click to homepage - Same navigation bar on the same place throughout the website - Not more than 7-8 headings
Screen		- Whole text on one screen - No lateral scrolling - Menu of sections at top - Easily return to top - Space between paragraph - No animations
Links		- Words should be links, not pictures - Underline - Hide long link behind word - Blue if not clicked - Purple if already clicked
Words		- Well known - Explain complex words - Use examples - No initials - Do not use metaphors - Do not use word from other languages - Use words in full, no initials - No percentages, no large numbers use “few”, “many” instead
Sentences		- Short - Direct speech - Address in 2nd person e.g. “you” - Positive - Active
Information order		- Group information about topic - Important information at the top - Repeat important information - Repeat explanation of difficult words

All the findings in Kirijian et al. suggest that computers and computer devices are of great importance for people with Down`s syndrome because they can help to increase confidence and motivation through creative activities and web browsing. Using the computer has other benefits as well, including errorless learning, patient and immediate feedback, self-paced learning and independence of learning. It should be also stated that all those benefits and useful features are dependent on developing a technology which meets the heterogeneous demands of the target group.

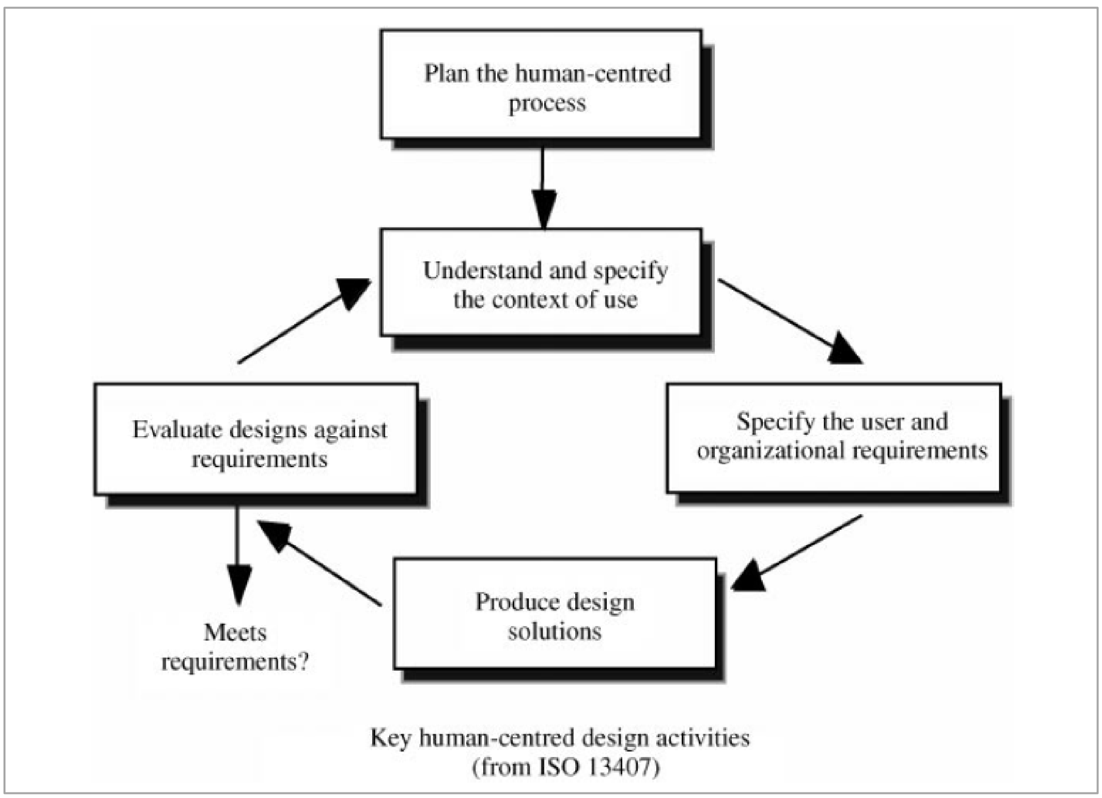
5 Designing technology for people with Down syndrome

5.1 User centered Design

As stated before the main challenge while developing a technology for people with Down syndrome is the heterogeneity regarding the limitations of the users.

A technology that provides assistance and empowerment without being a burden should be the main reference point developing technology for people with Down syndrome. Encouraging autonomy stresses the need for a useable and useful technology, which is easy to use and meets the user's expectations. Therefore, the development based on a user-centred approach. This includes the following steps: planning the human centred process, specifying the context of use, specifying user and organisational requirements, producing design solutions and evaluating design against user requirements. This process should be iterated until the solutions meet the target group`s requirements. (see the illustration below; Maguire 2001)

Figure 1: Human centred design cycle (Maguire 2001)



5.2 Principles of Universal Design

Universal design can be defined “as the design of products and environments that can be used and experienced by people of all ages and abilities, to the greatest extent possible, without adaption” (Story 1998, p. 4). The main goal is to make things usable for everyone in any condition, situation or environment. This goal should be accomplished by applying the following seven principles and their related guidelines:

PRINCIPLE ONE: Equitable Use

The design is useful and marketable to people with diverse abilities.

Guidelines:

- 1a. Provide the same means of use for all users: identical whenever possible; equivalent when not.
- 1b. Avoid segregating or stigmatizing any users.
- 1c. Provisions for privacy, security, and safety should be equally available to all users.
- 1d. Make the design appealing to all users.

PRINCIPLE TWO: Flexibility in Use

The design accommodates a wide range of individual preferences and abilities.

Guidelines:

- 2a. Provide choice in methods of use.
- 2b. Accommodate right- or left-handed access and use.
- 2c. Facilitate the user's accuracy and precision.
- 2d. Provide adaptability to the user's pace.

PRINCIPLE THREE: Simple and Intuitive Use

Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.

Guidelines:

- 3a. Eliminate unnecessary complexity.
- 3b. Be consistent with user expectations and intuition.
- 3c. Accommodate a wide range of literacy and language skills.
- 3d. Arrange information consistent with its importance.
- 3e. Provide effective prompting and feedback during and after task completion.

PRINCIPLE FOUR: Perceptible Information

The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.

Guidelines:

- 4a. Use different modes (pictorial, verbal, tactile) for redundant presentation of essential information.

- 4b. Provide adequate contrast between essential information and its surroundings.
- 4c. Maximize "legibility" of essential information.
- 4d. Differentiate elements in ways that can be described (i.e., make it easy to give instructions or directions).
- 4e. Provide compatibility with a variety of techniques or devices used by people with sensory limitations.

PRINCIPLE FIVE: Tolerance for Error

The design minimizes hazards and the adverse consequences of accidental or unintended actions.

Guidelines:

- 5a. Arrange elements to minimize hazards and errors: most used elements, most accessible; hazardous elements eliminated, isolated, or shielded.
- 5b. Provide warnings of hazards and errors.
- 5c. Provide fail safe features.
- 5d. Discourage unconscious action in tasks that require vigilance.

PRINCIPLE SIX: Low Physical Effort

The design can be used efficiently and comfortably and with a minimum of fatigue.

Guidelines:

- 6a. Allow user to maintain a neutral body position.
- 6b. Use reasonable operating forces.
- 6c. Minimize repetitive actions.
- 6d. Minimize sustained physical effort.

PRINCIPLE SEVEN: Size and Space for Approach and Use

Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.

Guidelines:

- 7a. Provide a clear line of sight to important elements for any seated or standing user.
- 7b. Make reach to all components comfortable for any seated or standing user.
- 7c. Accommodate variations in hand and grip size.
- 7d. Provide adequate space for the use of assistive devices or personal assistance.

Please note that the principles of Universal Design address only universally usable design, while the practice of design involves more than consideration for usability. Designers must also incorporate other considerations such as economic, engineering, cultural, gender, and environmental concerns in their design processes. These Principles offer designers guidance to better integrate features that meet the needs of as many users as possible and are crucial in the process of developing a technology for such a heterogeneous potential target group like people with Down`s syndrome.

5.3 User Interface Design

Designing a fitting user interface is a complex challenge. One should pay attention to the following ten general principles for designing user interfaces, which are based on the principles of universal design with focus on interfaces:

Principle 1: Learnability

The user interface should be easy to use from the first time a user interacts with it. There should be no need to learn a new functionality or new ways of interaction. The system should be based on recognition rather than the need to recall previous experiences

Principle 2: Efficiency

The number of steps a user takes to complete a task should be as few as possible. The need for horizontal and vertical scrolling should be kept to a minimum. Helping tools (e.g. Wizards etc.) should be used to simplify complex interactions. Real world metaphors should be used where applicable. Less is more – leave stuff out, if it is not really needed.

Principle 3: Error recovery

The system should be designed so that it is hard or even impossible for a user to make mistakes. However, when a user mistake occurs, this should be clearly communicated with information on which actions to take to continue the use of the system. If there is a system error, this should also be communicated in a clear way, with simple and understandable information to the end-user. All error messages should be useful. The system should provide guidance on how the user should recover from the error.

“Poseidon-Advice”: Instructional Demonstrations: When animations about “how something works” were shown, participants did not understand that they should wait until the demonstration was over before trying it, even when text instructed them to wait.

Principle 4: Simplicity

Tasks frequently performed should be easy to do, and less common tasks should be possible to do. Unnecessary functionality should be avoided. The layout and design should be as simple as possible. The navigation should be narrow and shallow, providing only necessary functionality. For this, we need to understand profoundly the context of when and where our users will use the system.

Principle 5: Mapping

What the user expects to happen should happen. There should be a mapping between the conceptual model the user has of the system, and how the system actually works.

Principle 6: Visibility

The most important information should be most visible, and less important information should be less visible. When using a touch interface, no button should be smaller than the user's fingertips.

Principle 7: Feedback

The user should be in control of the interface and not the other way around. The system should provide quick responses. If the response will take some time a progress bar or some other useful information should be provided. Speed and responsiveness are crucial for the user experience. In today's computing environment one second is an "eternity" to wait for response from the system or application. If a system does not respond within a reasonable time frame, the users will assume there is an error and try again, or press other buttons that will nullify existing action causing confusion and a bad user experience.

Principle 8: Consistency

Identical items and identical functionality should always be displayed and behave the same way across the entire system/application.

Principle 9: Satisfaction

The users should enjoy using the system/software. The software should perform its expected tasks well and nothing more. If one would like to perform another task, one would most likely use another application or system.

Principle 10: Predictability

When a system follows the principle of predictability, the user would know what to expect from the system: The behaviour is consistent throughout the application/system/service. With a consistent user interface, the user will not experience surprises. When a user presses a button or invokes a service, it should be evident for the user what to expect, and it should also be evident how the results will be presented. To ensure a predictable user experience, it is important to understand the targeted users' expectations and the conceptual models they have for the system they are using. If we design a system based on a different conceptual model than the one of the end-users', the user interaction and how they use the system will never match the anticipations of the developers, and the system will score low on usability and expectations of the users. If the system is designed following the conceptual model of the end-users, we will get a high score on usability, because the behaviour of the system is what the end-users predict. The system and the user interaction follow the users' expectations. Ideally there should not be any surprises for the end-user when using the system. If something unexpected happens, the methods for solving the unexpected should be predictable and well known by all users.

There are some general implications for designers:

- Provide clear guidance, feedbacks and rewards.
- Don't underestimate the impact of images. Visual learning strategies work best.
- Remember that everything means something. People with Down syndrome scan everything on a page in an attempt to garner meaning and direction. Everything will be interpreted in some way by the user, whether any meaning was intended or not.
- You have the means to teach skills, empower and support.

In the deliverable D4.1 chapter 5-8 are principles and POSEIDON recommendations are formulated for the interface based on the here presented principles.

6 Technological innovation

In this section, we briefly outline what comprises the technological innovation of the POSEIDON project. Building upon rationale created in the proposal phase and additional insights gained in the starting phase of the project we are introducing the current state-of-the-art before the project, plans early in the project and results of the project.

6.1 State-of-the-art

The state-of-the-art in technology was collected from five different domains - inclusive technology, context awareness, adaptive interfaces, virtual reality and Ambient Assisted Living (AAL). On the following pages we will introduce the different domains and discuss their current limitations.

6.1.1 Inclusive Technology

Inclusive technology facilitates the integration of citizens into the fabric of daily life by providing solutions that alleviate a specific shortcoming of the user and enables participation. The scope of potential solutions is huge and often common technological devices may be used for this purpose. In POSEIDON, we aim to reuse existing technology, such as smartphones and tablets, as well as build upon technology that has already been in development by the different partners, such as the interactive table (CapTap) of Fraunhofer.

Touch-screen smartphones and tablets have become commonplace. There is solid evidence that our primary users can use them and they feel very comfortable with them (cf. D2.1 Requirement Analysis). The touch interface allows for intuitive, natural interaction with a GUI and is available in various form factors and price categories. Applications may use integrated wireless connectivity with 3G, 4G and WiFi and sensors such as GPS and camera. The devices come with support for multimedia, text-to-speech and maps, all very useful for POSEIDON. A smartphone allows advanced online applications to be used anywhere, while tablets provide larger screen space.

6.1.2 Context Awareness

Context awareness describes the use of environmental or status information to understand the state of a system and inform decision-making (Dey 2001). Most solutions use a closed loop that registers the context within a certain domain, e.g. home automation systems that react on sensor input. The advent of GPS equipped smartphones has caused a plethora of location-aware applications, such as augmented reality browsers and navigation solutions [Gellersen et al 2002, Anagnostopoulos et al 2007, Bouzeghoub et al. 2009]. While those systems are becoming more powerful, they typically rely on location as sole context. Recent solutions, such as Google Now combine data from numerous sources to provide personalized higher-level services. Some sources include search history, calendar entries, contact information and location. While the resulting service has a high level of personalization, the aspects of privacy and security are only leniently covered.

POSEIDON aims at using a certain set of information about the user - a restricted profile and information provided by the system itself to generate higher-level services. This solution is less intrusive while still enabling a sophisticated level of personalization and adaptation. Consequently, the system has to be more intelligent to learn from previous contexts and to understand when it can be useful, what type of assistance it should provide, when help should be offered and in which way to communicate that help to the user. As the system is supposed to serve the primary users (people with Down syndrome) but also other people who interact with them, for example family members, teachers and employers, the system needs different type of awareness for different users. An important part of this awareness is related to safety. The system should be able to receive through the interface an indication from the person with DS that s/he is feeling in an unsafe situation. Also, the system should autonomously be able to sense the perceived level of safety and make this information available to relevant co-users of the system. Research in context-awareness has been prolific [Bettini et al. 2010, Beigl et al. 2011; Ye et al 2012; Bhatt et al. 2012]. However, they require high level of language training to be programmed or specific dedicated functionality implemented in a specific device. For example, to achieve geo-fencing through wearable technology or to achieve the type of inclusive services which are a priority in this project. Knowledge representation in this area has been enriched with some ad-hoc contributions, for example Smart Homes ontologies for Ambient Assistive Living like the one used in [Mu*ñ*oz et al 2011] and context ontologies like SOUPA (Chen et al 2004). Other areas we consider is the realm of temporal reasoning. This is by ontological query languages that incorporate temporal reasoning, for example C-SPARQL (Barbieri et al 2010)

6.1.3 Adaptive interfaces

Adaptive interfaces change modality, layout and elements according to user preference either manually or automatically, triggered by a changed context [Schneider et al. 1993]. This allows the interface to be conformant to specific user needs. Mostly it is required to change presentation and navigation according to requirements. This research area has been in development for several years. An important topic is the modelling of the user either autonomously or via user input [Langley 1999], allowing to control the interface according to specific context. Considering our tackled scenarios, a combination of both methods is viable using a combination of prior knowledge as ground truth and autonomous adaptation based on the current context. In terms of graphical user interfaces many frameworks nowadays support a good separation of layout and logic. Particularly active in this regard is the W3C that provides guidelines and languages that attempt to facilitate inclusion and provide support for adaptive interfaces via descriptive languages such as CSS and its officially sanctioned extensions. It is viable to use previous research done in this area [Sullivan 2000] to select best practice and adapt it according to our specific scenarios. Adapting user interfaces to specific user groups is an ongoing challenge, e.g. supporting children affected by autism [Magee2010]. Some evaluations have been done on the challenges posed by current computer interfaces to people with Down syndrome [Feng2010, Lazar 2011] with some interesting outcomes on identifying what may be more useful in terms of communication and safety, there is still much to do, especially with the adaptation of interfaces to contexts, preferences and needs.

6.1.4 Virtual Reality

Virtual Reality provides a computer simulated experience of a physical reality [Rheingold 1991]. This experience can be more than visual and may include stimuli of other senses. There have been interesting advances in the complexity of environments which can be recreated by adding equipment (e.g. headsets [Hoffman 2004] or haptic interfaces [Colwell 1998]) and also in the complexity and quality of the physical realities being recreated (e.g. flight simulators for training pilots). There has been a recent interest in the exploration of mixed realities (virtual and physical) and how this relates to Smart Environments for work and education [TI-JAISE]. There has been numerous application in the domain of providing learning [Strickland et al. 1996], training [Bryanton et al. 2006] and distraction [Gershon et al. 2004] for different medical conditions. There are various frameworks available aimed at providing virtual reality applications for specific user groups that provide the required level of adaptability

[Tramberend et al. 1999; Gibson 2004]. They have been proven useful in training and learning scenarios [Huang2010].

6.1.5 Ambient Assisted Living

Ambient Assisted Living (AAL) refers to aware environments and services that support users in need of assistance [handbookAAL]. In the last decade, the challenges of the demographic change have become more apparent and programs such as the European AAL Joint Programme have raised awareness in both scientific community and industry to develop technological solutions. The majority of solutions are aimed at the specific challenges related to elderly users - providing platforms and singular services and solutions. Smart environments that incorporate sensors and actuators that perceive and control their surroundings are used to realize and augment services in this domain, using unobtrusive home automation networks and embedded systems. Again, most applications aim at elderly users.

6.1.6 Solutions on market

There are some products existing in the market that are aimed specifically at persons with cognitive disabilities. Endeavor Desktop and Endeavor Talker[1] facilitate the distribution of individualized content to persons accessing these software tools with simple user interfaces. TextHelp[2] is a leading system for providing ICT based reading and writing support. Additionally, there is a variety of different learning programs available that make use of intuitively controllable tablet applications. Some examples are Build it up[3], Emotions[4] or PCS Bingo[5].

6.2 Progress beyond state-of-the-art

In this section, we quickly describe how we tried to improve in these different areas to provide a viable progress beyond the state-of-the-art without redundant development, focusing on efficient use of existing systems given the available resources. Regarding the inclusive systems, we outline on how the systems should be used within POSEIDON. The technical development and methodological advancements focus on the user group of children and families with Down syndrome and their specific requirements that are analysed in other parts of this document. We have reused existing technology such as smartphones and tablets, providing new applications for such devices. The focus was to use the versatility of those devices, adapt them and enable a personalization for users with Down syndrome. Deliverable D4.1 (Interface Strategy) is relevant for the user interface aspect of the work on inclusive systems.

The work on an interactive table was also an important part of the work on inclusive systems. This work allows a regular table to be used to detect hand gestures. The CapTap interactive table uses capacitive proximity sensors to detect the free-air gestures by evaluating the change in capacitance when a conductive body approaches the sensors. Using touch events simplifies the adaptation of point and click interfaces to the interactive table, where

[1] http://www.ablelinktech.com/index.php?id=21

[2] http://www.texthelp.com/

[3] http://itunes.apple.com/us/app/build-it-up/id421839260?mt=8

[4] https://itunes.apple.com/gb/app/aba-flash-cards-games-emotions/id446105144?mt=8

[5] https://itunes.apple.com/gb/app/pcs-bingo/id453920859?mt=8

capacitive sensors detect where the hand points and touch events detect a click by using a microphone. Additionally, hovering, keeping the hand still above the surface, also executes a click event, entirely touchless. State-of-the-art has been extended by building a working interactive table prototype, developing the firmware and API (see D4.3 – Interactive table, D5.2 Prototypic systems), creating the Moneyhandling Training Application (see D4.1 Interface strategy, D4.5 HCI user and developer manuals) and connecting it the Home Navigation System. Up until now five scientific publications document the extension of the state-of-the-art addressing processing algorithms, prototype development and evaluation and interface design (see R3 – Report on scientific progress).

In terms of context awareness, our system extends the specified ontologies to create a flexible context ontology, which can be easily integrated to user preferences and be informed by the learning of user's habits in a way that it can automatically create context definitions and guide the provision of contextualized help with safety as a core priority. The context specialized ontology and all other context-awareness related packages are offered as Open Source software to facilitate the development of these as well as of new services which can be implemented on top of it. Deliverable D3.2 is the main deliverable documenting our work on content awareness.

Regarding adaptive interfaces, it was decided in the progress that adaptive interfaces were mostly not a good idea for the user group, as interfaces changing by themselves would be confusing. Therefore, we have focused more on personalization. The adaptive and adaptable aspects of our user interfaces are described in deliverable D4.2 (Adaptive Tablet Interface).

Regarding Virtual Reality, we developed a Mixed reality system after firstly experimenting with pure virtual reality. Research in the field, and our own investigation has shown the many people in Down syndrome can struggle with abstraction. This makes the use of VR for route preparation and learning unlikely to make a positive experience for our users. Instead a mix reality solution using real world imagery was found to be more usable by our primary users. This Home Training of Navigational Services application included the following tools: The ability for the secondary user to create/edit routes, and for the primary user to practice each route going through each step and for a game style assessment mode so the secondary user can test his/her primary user on their knowledge of the route. Our Virtual/Mixed Reality work is described in deliverable D4.4 (Virtual Reality System).

The usage of Virtual/Mixed Reality within POSEIDON is novel with the regards that it allows people with Down syndrome to explore, prepare and train to face challenges they are about to face daily life. They can do this in a safe environment (e.g. at home) and extract tips and guidance which our system uses to guide them in the real experience.

POSEIDON innovates in AAL by combining the context generated in smart environments and external sources to provide a service that is tailored specifically towards persons affected by Down syndrome. This includes the guiding of the development process by overarching concerns on ethics, security, and privacy. These and other important design principles collected from final users first hand through our workshops and pilot studies provided a valuable source of information to future developments aiming at this segment of the population or similar ones. In the early phase of the project we collected various sources for the different types of applications already on the market and presented it to potential users in the workshops, to get a feedback on the expected impact and evaluate certain features for their use in POSEIDON. The contributions are summarized in Table 2.

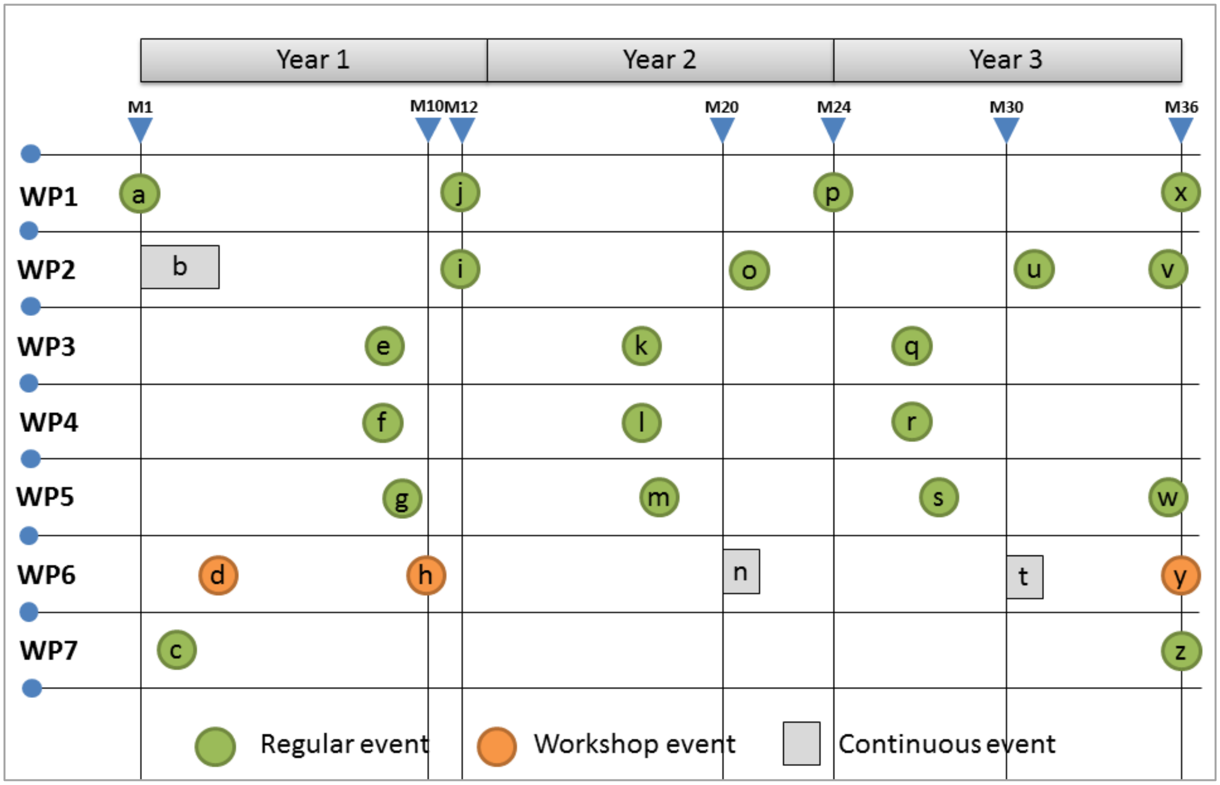
Table 2: Summary of contributions from POSEIDON to different areas.

Area	State of the art	POSEIDON contribution
Inclusive Technology	• Input support systems • Dynamic touch interfaces • Haptic feedback	POSEIDON selects and adapts a set of technology specifically aimed towards supporting persons affected by Down Syndrome
Context awareness	• Location aware system • Big data systems	POSEIDON extends ontologies and languages to cater the specific requirements of users affected by Down syndrome (user profile including capability modelling)
Adaptive interfaces	• Accessibility guidelines • Descriptive user interfaces	While truly adaptive interfaces were deemed potentially confusing, POSEIDON provides easy to personalize interfaces, specifically adapted for people with Down Syndrome.
Virtual Reality	• Can provide reasonably good quality recreations of a real environment • It is educational and fun	POSEIDON adapts the idea to increase knowledge and confidence of people with Down syndrome about the real-life situations they will face (in the navigation function).
AAL	• Primarily aims at elderly users • Platforms for smart environments	POSEIDON makes use of platforms and smart environments and provide AAL use cases specific for people affected by Down syndrome (emphasis on ethical uses, security and privacy as a high priority guiding element of the final system produced).
Products in market	• Focused solutions • Connectivity technology	POSEIDON offers a broader solution aimed at a range of different types of users (primary, secondary and tertiary) and including smart environment and smart interaction assistive technology

6.2.1 Capturing requirements

In coordination with the user workshops the innovation and development cycle of POSEIDON followed the collection and refinement of the requirements gathered. The technical partners are closely cooperating with the requirements gathering process by mutual involvement in the different meetings. For example, the technical coordination also participated in our user workshop, and at the different technical meetings partners from requirements gathering are included in the agenda with presentations.

Figure 2: Important steps in the POSEIDON project



This strong collaboration as planned in the DoW is an important pillar of the POSEIDON project and ensures consistent influence of requirements on the technical development and specific pointers for the requirements gathering process from the technical partners. For reference, we have added the overview of important steps in POSEIDON as shown in Figure 2. The requirements gathering phase (b) culminates in the first user workshop (d) that is shortly before the technical kick-off of the project (not in figure) that leads to the first development phase, whereas work packages 3, 4 and 5 are creating their individual systems leading to an integrated prototype (g) that is showcased in the second user workshop (h) in order to gather feedback on its usability. After advancement based on the feedback and recommendations and refined requirements resulted of pilot studies refined POSEIDON services are showcased in a third user workshop (y). This cycle iteratively continues throughout the runtime of the project, with development leading to a user study, leading to refined requirements for the next development cycle.

7 Co-working with primary and secondary users

Technology design needs to consider a set of cognitive and physical abilities to achieve optimal performance. A 3D representation of a real environment might fail to communicate effectively to people who do not have the ability to abstract concepts and worlds. In order to upgrade the lives of some, technology has to be designed for diversity and ability. In developing useful technology, there are several phases to consider: design, development, testing and publishing. Usually, the stakeholders are just considered in the testing phase. However, when the aim is to increase independence of people with cognitive disabilities, a continuous involvement of both, developers and stakeholders, is necessary for creating more relevant products.

A successful product, which people with Down syndrome can benefit from, is based on iterations that lead to a refinement of the functionalities and design. Because of the varying range of capabilities and difficulties of the target population, developers need to maintain an updating loop of the proposed solution, in which they consider the feedback of a significant number of stakeholders. In POSEIDON, we used U-CIEDP, an iterative co-design methodology that brought together all the involved stakeholders (primary users, caregivers, therapists and developers). We involved stakeholders through a variety of activities (see Table 3). These include questionnaires, interviews, project pilots, workshops with primary and secondary users as well as with the Project Advisory Committee. Initially, we wanted to understand and be able to conceptualize the needs and specific issues of the stakeholders. Then, we produced solutions that address the observations we made in the first step.

To validate the design and content of our proposed system, we asked stakeholders to use and experience it. All these sessions were analysed in detail in aspects related to functionality, user interaction, and quality of experience. Each interaction of the users with our system brought new insights about our stakeholders through this analysis, but also through the provided feedback.

It is important to highlight that the different events which facilitated interaction or gathering of feedback from stakeholders were organised mostly following the lead of the Berlin Institute for Social Research (BIS), one of the partners of the POSEIDON project. Although the type of interactions to have, their frequency and their timing were planned and agreed with most of the partners of the project, BIS provided the protocols of interaction with the stakeholders, especially the documents, including surveys, to use when presenting and gathering information from stakeholders (Schulze and Engler, 2016; Schulze and Zirk, 2014).

7.1 Questionnaires/Interviews

The aim of this phase was to assess the requirements of people with Down syndrome and to bring up any significant issues that need to be addressed. The requirements analysis was done using different methods: questionnaires (people with Down syndrome and caregivers) and face to face interviews with the stakeholders. BIS conducted an initial web-based questionnaire to almost 400 parents, from three different countries. The answers were used to analyse the type of technologies people with Down syndrome use, the level and type of support they need when interacting with these technologies. Additionally, focus was put on their living situation to identify how they travel, manage time, handle money and communicate. All this information was used in proposing a set of scenarios and personas that were meant to illustrate the aspects targeted. The scenarios presented characteristics and possible daily activities of people with Down syndrome from different countries.

Table 3: User Engagement Activities during POSEIDON

ID	Type of Involvement	Month Number	No. of Main Stakeholders involved
W1	Workshop	2	5 PU 5 SU
Q1	Questionnaire	2-4	400 SU
W2	Workshop	10	5 PU 7 SU
A1	Advisory Committee	12	3 TU/O 4 SU
W3	Workshop	14	13 PU
P1	Pilot 1	20 - 23	9 PU 9 SU
P2	Extended Pilot	25	26 PU
A2	Advisory Committee	26	3 TU/O 5 SU
P3	Pilot 2	31	9 PU 9 SU

7.2 Workshops with Stakeholders

The first project workshop took place at the beginning of the project. Different technological solutions were presented to the primary users (VR games controlled through Wii control, mouse/keyboard or tablet). The aim of this interaction with people with Down syndrome and caregivers was to explore user engagement with different technologies and their quality of experience.

These initial observations were used to create a mock-up of the system with a set of proposed interaction methods. This first prototype was introduced to the users during a workshop that took place in Mainz, Germany in month 8 with participants from 5 countries. We conducted a set of experiments with PUs over 2 days with the intention of assessing the usability of our first prototype and the advantages and disadvantages of using specific proposed technologies.

This workshop was followed by a series of shorter workshops (half a day long), held primarily in London, additional ones also in Germany and Norway. These events were meant to facilitate the design of the product's functionality and interface. Developers participated in these meetings to gain a deeper understanding of the necessary modifications.

Additionally, there were complementary workshops with the Project Advisory Committee, a group of experts which provided useful insights by sharing their expertise, and also a quality check.

7.3 Project Pilots

Over the course of the POSEIDON project, there were two pilots of one month each, and a single day extended pilot. These pilots were carried out in the UK, Norway, and Germany. During the month-long pilots, three families from each of the countries were selected to participate in the evaluation.

The process involved screening of potential families through a questionnaire, to check on their suitability for the pilot. Once the families were selected, users were given diary sheets, as a way of documenting their use of the POSEIDON system. Main topics were: who used it, what they liked and did not like. Each family received four visits. In the first visit project developers and Down Syndrome Interest Associations (DSA) monitors went to get to know the families and establish a good relationship with both PU and SU. Information sheets and consent forms were distributed and completed. Following this, the Home Training of Navigation Services application, POSEIDON Mobile application, POSEIDON Context Reasoner and Carer's web were installed and setup for the users. Over the course of the pilot, different interviews and questionnaires were completed to gain feedback of the different systems. Moreover, usage of applications was logged, which allowed us to see how many times the users used each component of the system and how they benefitted from it.

For the extended pilot, in a similar fashion, different day events were held in all three countries. A total of 26 people with Down syndrome took part with 10 in the UK, 13 in Germany, and 3 in Norway. During the extended pilot, there were three items we wanted to evaluate: new functionality added to the different systems including more contexts being handled in the POSEIDON mobile application, a new learning and assessment mode in the Home Training of Navigational Services, and further tests of the Money Handling application.

Our method of co-design based on continuous feedback from the stakeholders allowed developers to maintain a strong connection with the stakeholders and to gain a better understanding of the way primary users interacted with different features.

8 Service Refinement and Evolution

The U-C IEDP method is based on several small and big project iterations and frequent interactions with stakeholders. In this section, we explain how the POSEIDON concept, in the form of successive prototypes, was being shaped through the different stages of the U-C IEDP method. The project was planned in three main iterations leading to three evolved versions of a system prototype. Table 4 provides a summary of the activities.

8.1 Prototype One

8.1.1 P1 - Initial Scoping

As central to all the main loops in the U-C IEDP, we started gathering the expectations of the stakeholders. Initially, this happened in the form of a questionnaire (Q & U1) to people with Down syndrome and their parents. This gave the team feedback about the activities to support. It was found that the participants were often quite capable of carrying out different tasks, including navigating, if with some support. It was felt that areas of achievable tasks with assistance were likely to be a more successful target of development. The first workshop (W1) covered the stages "Define Required Services" and "Define required IE infrastructure" from the U-C IEDP. The technical teams translated the information gathered from the stakeholders into services that were useful for them, during the first workshop. Developers proposed a set of services to support the main activities in which people with Down syndrome required help, according to the questionnaire. The questionnaires were also discussed to determine the most suitable technology for people with Down syndrome and their parents, selecting the devices and interfaces that materialised the IE. Finally, a requirements document was produced, as a contract between all the stakeholders, defining what POSEIDON would do. After the first workshop, the teams prepared the initial design and started preparing the first prototype. Based on related work, developers mocked up a potential future state of the system.

8.1.2 P1 - Main Development

This first design was discussed in a technical meeting in month 5 with initial ideas. The teams gathered both feedback and suggestions from the national Down Syndrome Associations based on these ideas. Based on this feedback, the development teams identified areas that needed to be refined, defined and clarified. In the second workshop (W2), the developers introduced a mobile navigation system, using Google Directions for route data. This data was supplemented with photos of the specific Google waypoints, to see if photos helped them navigate. A racing game was also developed for use with a large interactive table, to assess the participant's motor skills, and whether they find the interaction device enjoyable to use.

8.1.3 P1 - IE Installation

The second workshop also covered the whole "IE Installation" loop of the U-C IEDP. The users were instructed on how to use the system. The event was held in Mainz, Germany including 5 people with Down syndrome. Some of the feedback highlighted the need of considering time management. During the second workshop, the prototype was tested to gather feedback about the Primary Users using the devices. It was found that using automatically generated directions from services including Google Directions did not give sufficiently understandable directions for navigation. Based on this finding, it was decided that secondary users should have the ability to customize the routes, adding their own text and photos to the decision points. Using textual commands, the secondary users can add additional information that can be useful to the primary user including what side of the road to be on, whether to cross at particular places etc. It was found also that the PUs enjoyed using the smart table touch device as an interface device.

8.2 Prototype Two

8.2.1 P2 - Initial Scoping

As input for the "initial scoping", during the interview to the stakeholders, the families presented daily activities of primary users with an emphasis on areas where they need more support.

8.2.2 P2 - Main Development

For prototype two several changes had been added to the POSEIDON system. First, routes for the user could be designed in the Home Training of Navigation Services application by the secondary user. This allows secondary users to tailor the routes by adding custom waypoint instructions, and photos to assist the primary user. These routes are then synchronised to the main POSEIDON application using POSEIDON web services. Other developed services include a specialised calendar service which allows the user to keep track of their events, and add additional data to events including linking personalised routes. A website for use by the SU was created, named Carer's web. On this site, the carer can view where the PU is, alter POSEIDON personalisable features, and also edit calendar events. Other developed services include a context reasoner, which can determine different contexts to assist the user in the main POSEIDON application, including weather information on navigation destinations. Lastly, a game for practicing money handling was created for the primary users, which paired with a smart table.

8.2.3 P2 - IE Installation

Prototype two was tested during Pilot 1 and Extended Pilot 1 (P1). There were technical difficulties with using the smart table in the participants' houses. As it proved too difficult for the families to use without technical supervision, it was not used. The calendar functionality was overall positive, however some PUs required their SUs to input the events due to impaired literacy skills. The main POSEIDON mobile application was viewed as promising and useful. There was feedback that there were some concerns regarding safety, similar to those reported in Kramer et al (2015). It was decided that additional steps should be addable to a route, instead of just editing the Google given instructions. The PU and SUs were positive about the use of context-awareness to drive different notifications to the user including if specific clothing was necessary based on weather conditions.

8.3 Prototype Three

8.3.1 P3 - Initial Scoping

Questionnaires from Pilot 1 were used as the first stage of the initial scoping in the U-C SDP, “Interviewing the stakeholders”. During pilot 1, users demanded more personalisation possibilities when defining a route (due to insufficient number of decision point provided by Google Directions). Also, they demanded some other features for ensuring the wellbeing of the primary user, e.g., when s/he gets lost. Taking this feedback, the developers redefined the required services to have a new approach for route creation: secondary users take photos of the routes in the streets, and they are automatically translated into a route by using the GPS coordinates from the place they were taken. Following this, developers created the definition of the infrastructure, by adding new context awareness. The creation of new contexts was complemented by a questionnaire conducted to 130 families that have children with Down syndrome. Two new contexts were identified: “When the primary user is standing still for a long time” and “when the primary user needs assistance with the navigation”. Finally, the initial design for the final prototype began.

8.3.2 P3 - Main Development

For prototype three, an improved version of the POSEIDON navigation application was introduced. In this application, further improvements to navigation and calendar handling were included. An application for creating routes was developed for mobile devices. This was due to added complications in making the user create the routes on a static computer at home. With the route creator application, the SU can walk the intended route, taking photos, and automatically tagging decision points with their current location. Money handling assistance has been improved, by the creation of a mobile application, which the user can take with them to local shops for purchasing various goods. It allows them to not only practice picking the correct money for particular items, but can also assist them in notifying them how much money they need to take, and what money denominations are required to pay for a particular shopping basket. Additionally, the context reasoner provided in the previous prototype has been extended with personalisable contexts, allowing different context settings to be tailored to suit the user. An updated version of the Home Training of Navigation Services was developed to include the ability to add new decision points to routes, add voice commands, and further assessment modes to allow the PU to train a route more. The online Carer’s web included more personalisation features, the inclusion of Money handling to let the SU setup shopping lists for use with the mobile application. Lastly a new querying service based on previous events allows the PU and SU to compare how well they have navigated previously over different time windows.

8.3.3 P3 - IE Installation

Prototype three was tested during the final Pilot 2 of the project. During Pilot 2 (P2), developers guided users to learn how to use the POSEIDON ecosystem. The pilot was used to validate the equipment, software and other services. In all, pilot participants appear to find the vision for POSEIDON applications a good idea. This generally led to high motivation by participants at the start of the pilot. Over the course of the pilot, there were indications of users favouring particular services, especially the application for route making, and main navigation application. Particularly, secondary users enjoyed the ability to easily customise the route with their primary users, adding photos, and customised instructions.

Calendar services were considered a usable feature by some participants. Because many participants are often very busy with a lot of different activities, they enjoyed using the service instead of a hand-written diary. Secondary users also gave positive feedback for the ability to monitor how well the primary user navigates using the learning module.

Feelings towards services to improve money handling were slightly more strained. While there was positive feedback regarding the applicability of such a service, it was a service that users most struggled to use. This appeared to be a combination of issues including how intuitive it was, and early teething problems when it was deployed. For example, some users appeared to struggle with setting up the system: adding the different items, prices, and calendar event for the shopping journey.

Towards the end of the pilot, to encourage the use of all the services, an integrated scenario was devised. This scenario involved the primary user going to a supermarket to go shopping. To achieve the scenario, the secondary user would need to prepare the route, create a shopping list on the carer's web, and setup a calendar event. These scenarios were completed with issues, which largely were with the money handling application.

Overall, we believe the pilot was a positive experience, however it was observed that the participants many have underestimated the amount of time regarded to learn to use the new services. We also found some motivational issues in the second half of the pilot. Part of this motivation was caused by some participants having smart phones already, and not wanting to use the test devices in addition to their phones. This could have created a barrier to users using some of the available services to them.

Table 4: Relation between the U-C IEDP stages, event types and products in the POSEIDON project

U-C IEDP Main Loop	U-C IEDP Secondary Loop	Prototype 1		Prototype 2		Prototype 3	
		Event Type	Outcome	Event Type	Outcome	Event Type	Outcome
Initial Scoping	Interview Stakeholders	Q U1	Feedback about important activities to support, 'way finding' considered fundamental. Development Framework outlined.	U3	Families presented daily activities of primary users emphasizing where they needed more support. Importance of Calendar and money handling identified.	Q U5	a) routes created automatically based on photos GPS coordinates b) Improve HNS feedback modes. Devel. Fr. revised.
	Define Required Services	W1	A set of services to address the suggested activities. Emphasis in safety.	A1	Emphasis on health issues.		Need to replace Google Directions
	Define required IEs infrastructure	W1	The initial infrastructure consisted of stationary and mobile computing and VR.	A1	Given preference to equipment and interfaces which help PUs sight		Issues with the use of interactive table
	Initial design and prototyping		Developers gathered first potential components, HCI mock ups, and virtualisations.	A1	Navigation system should give more emphasis to sight		Alternative route handling with Google MyMaps
Main development	Interview Stakeholders	U2	Feedback on first navigation support services is reviewed	U4	Validation of real-world imagery and context of places.	U6	Need for better customisation of routes
	Design I		First navigation exercises designed	W3	Mixed reality solution analysed	A2	Lack of wayfinding apps
	Implementation and testing		Initial testing done in labs	W3	Navigation with customized metadata	A2	Created customised routes
	Verify correctness		Problems detected with the usefulness of routes provided by Google maps	W3	No metadata for some GPS points	A2	Problems with public transport Identified
	Design II		More clear strategy in complement of VR at home and mobile services outdoors	W3	Design of games to assess user knowledge of routes	A2	Check overall prototype with ethical framework
IE Installation	Interview Stakeholders	W2	PU confident of learning how to go to a new destination using HNS based on real world imagery. Suggesting importance of time management.	P1	Lack of route personalization possibilities (insufficient decision points provided by google directions) leads to new approach to create routes based on GPS coordinates of photos	P2	Product was well received overall. Calendar reached maturity. Development Framework more mature.
	Equipment Validation		Increased focus on the phone; add audio guidance. Issues of PUs matching real world imagery and virtualisations	P1	Interactive tables presented challenges to configure and use. Issues with computer versions.	P2	Interactive table was not used. Focus on home training and outdoor apps
	Software Validation		Delay showing the customised information	P1	Improve assessment modes of training for navigation.	P2	Issues with money handling app.

					Importance of a mobile app for handling money.		
	Services Validation		Lack of accuracy in directions provided by Google leads to personalised directions	P1	Issues with Google Directions accuracy	P2	Specific personalisation options identified

9 Experiences gained within the POSEIDON project

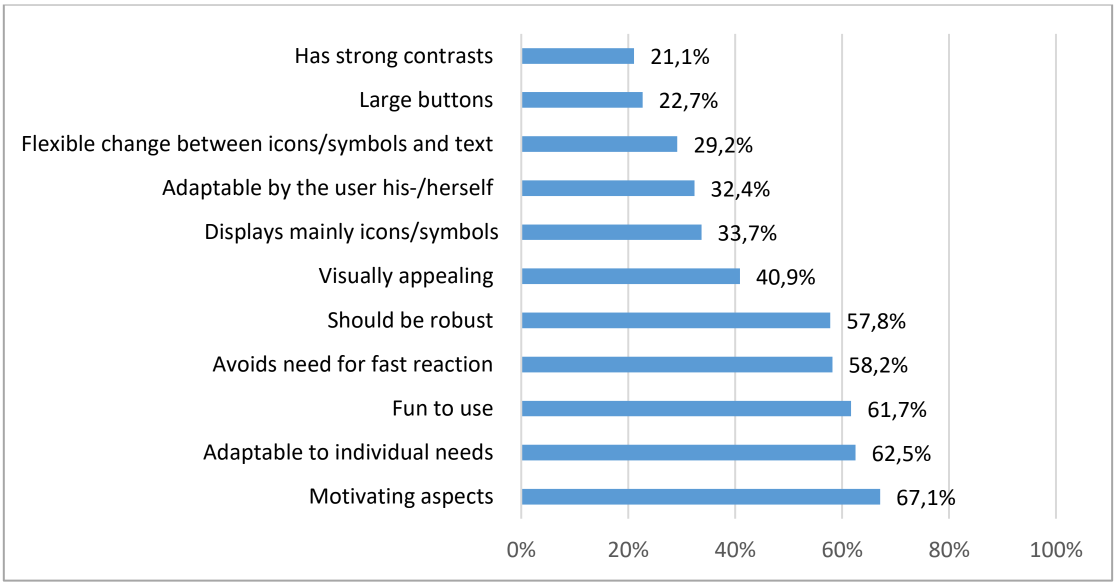
9.1 Requirement analysis

As a first step in the POSEIDON project, we performed a requirement analysis. Therefore, an online questionnaire, which was meant to be completed by relatives or professional carers of people with Down syndrome, was prepared for every participating country. A link to the poll was placed at the national DSA's websites. Up to the deadline after four weeks 181 completed questionnaires were collected. Aiming for even more input the poll was not closed after this first deadline with the result that almost 400 questionnaires were completed (cf. D2.1 Requirement Analysis).

One part of the questionnaire was about the characteristics of the assistive technology, which will be developed within the project. It was asked, how important several aspects with regard to features, hardware and design are to be helpful for the person with Down syndrome. Options were given and asked to be assessed on a 4-item-scale from "not important" to "very important".

The following charts give an overview of the topics discussed in the questionnaire. The analysis just shows the aspects, which were assessed to be "very important".

Figure 3: What should the design be like (just the category «very important»)?

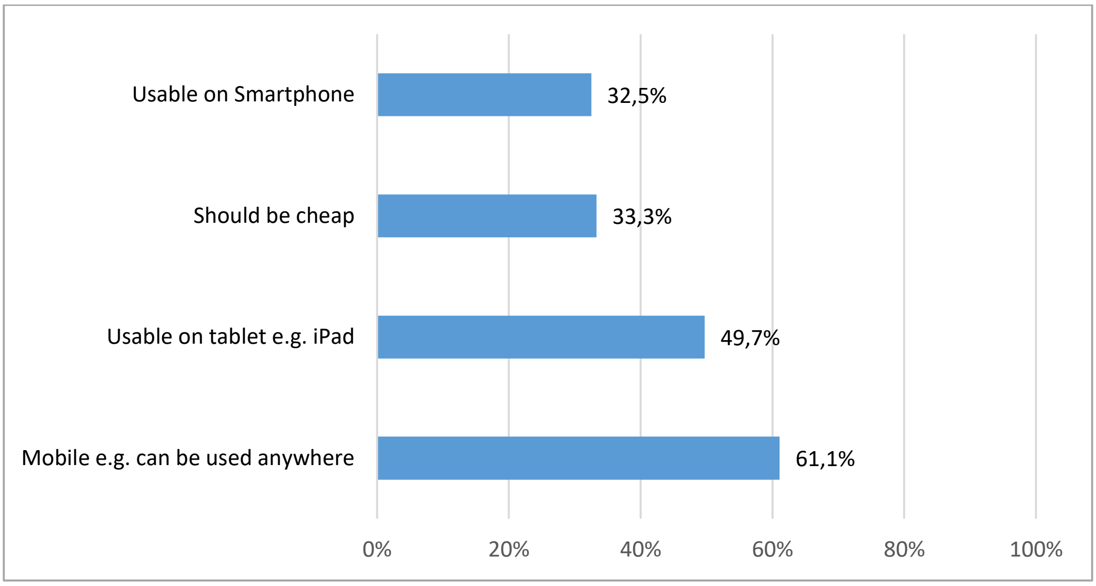


Having a look at the question, how the design should be, it becomes obvious, that motivation to and fun in using the technology are two main aspects, which are assessed by almost two thirds of the respondents to be most important. It is more likely that an assistive technology is integrated into daily life routines, if it makes fun and, as these aspects relate to each other, motivates to use it.

Another important aspect seems to be the opportunity to adapt the technology to individual competencies and wishes. As mentioned above, these highly differ within the target group and sometimes change greatly over time, so there seems to be a need for individual customization.

One other main aspect is, that the technology should not require a fast reaction given by the user. This one addresses some difficulties people with Down syndrome experience, like visual problems and processing speed – both might lead to some more time needed to identify appropriate opportunities for reactions.

Figure 4: What should the hardware be like (just the category «very important»)?



With regards to the hardware it is obvious that a tablet is preferred compared to a smartphone. 50% say, it is very important, that the technology runs on a tablet PC. This might have two reasons: On the one hand did the general requirement analysis (see deliverable D.2.1) show, that using a tablet (62% are using apps on tablets, 46% own one) is more common among people with Down syndrome than using a smartphone (45% are using apps on smartphones, 28% own one). This information as well as the one given in the design-section of the questionnaire seem to refer to the fact, that due to the commonly reported problems with the eyesight and fine motor skills, it seems to be easier to operate things on a bigger screen.

On the other hand, the graph shows the wish for a mobile solution given in POSEIDON, which might be a challenge for future development. It seems like there is a compromise needed between a screen that is big enough, and hardware that is not too heavy und huge to be carried around.

However, although the tablet was preferred in the requirement analysis, we chose the smartphone as the primary platform for assistive applications. This is because it is not feasible to bring a tablet with you at all times. An application which delivers aid when the primary user is out and about needs to be on a fully mobile platform.

9.2 Pilot 1

In the second year, the POSEIDON team conducted a first pilot study in all three participating countries. All in all, nine families tested the POSEIDON system in their homes for at least four weeks. Quantitative and qualitative methods were used to evaluate the systems. Participants were observed when using the systems and interviewed afterwards, they filled in questionnaires and wrote diaries after using the systems. The results indicated that most of the families liked the ideas behind the POSEIDON system, but that there was still room for improvements. Some improvements regarding the above-mentioned design principles will be discussed here.

The principle of learnability describes that user interfaces should be easy to use from the first time a user interacts with it. This was true as far as possible for the interface of the calendar app for almost all users. Primary users did not need to learn new functionalities when using it. So, it can be assumed that the use of the system was mostly based on recognition rather than on recalling previous experiences. However, when searching for a certain day, the efficiency could be increased. When doing so, primary users had to push the "next" button again and again. So, the number of steps it took could be reduced by displaying a month view and the possibility to switch between months.

Simplicity means that tasks being frequently performed should be easy to do. When entering events in the calendar, users could be enhanced by an option to enter repetitive events.

The current status of the calendar view displays only one day. Some primary user would prefer a week or a month view since they like to know in advance which appointments they have. Following the principle of visibility, most important information should be visible. Since what seems to be important for primary users might vary, they should have the option to choose their preferred view.

As mentioned above, speed and responsiveness are crucial for the user experience. When navigating outside, important information came up far too late. The navigation app aims to provide real-time help. That means, when arriving at a decision point, pictures must appear on time. During the pilot, some pictures that have been entered appeared far too late, sometimes even after a certain step.

All POSEIDON systems could be improved regarding their satisfaction. Increasing the experienced satisfaction can be done by eliminating frustration. The users should enjoy using the system/software. One problem occurred when using the calendar on the smartphone. One primary user was not able to turn the alarm off. This resulted in frustration. The user should always know what to expect from a system and how to influence the outcome, which is in line with the principle of predictability. As mentioned above, ideally there should not be any surprises for the primary user when using the system.

During the pilot, some of the primary users got frustrated by getting too negative feedback. People with Down syndrome can get frustrated easily by receiving negative feedback. This was true for some of them when doing the Home Navigation or the Money Handling Game. When doing the Money Handling Game, a thumb down was displayed when the primary user payed too little for a certain product which was demotivating for some of them. Since the POSEIDON team wants to have primary users who enjoy using the systems, feedback strategies, especially regarding negative feedback, must be considered.

In D4.1 we show how the feedback from pilot 1 has led to improvements of the interface in pilot 2.

9.3 Pilot 2

In year three a second pilot study was conducted in all three participating countries. Nine new families took part and tested the POSEIDON system in their homes for at least four weeks. As in pilot 1 quantitative and qualitative methods were used to evaluate the usability and acceptance of the POSEIDON system.

For Pilot 2 we had as a goal to provide stable systems. In order to achieve this for the interactive table, where the instabilities were responsible by non-deterministic hardware malfunctions, drastic changes to the hardware would have been needed. These changes extended the scope of designing a working prototype. To maintain the functionality, the Moneyhandling Training has been changed into the form of an app, integrating it into the POSEIDON main app.

In this second pilot the system worked more reliably than during the first pilot and again all the families like the idea behind the POSEIDON applications and the POSEIDON vision itself and mentioned a lot of advantages. Some important improvements regarding the design principles were mentioned.

The principles of Universal Design describe that the design should accommodate a wide range of individual preferences and abilities. In pilot 2 it became clear that some users had problems adding appointments into the calendar because of their understanding of the clock and time. Therefore, it was recommended to have the possibility to change from a 24-hour to 12-hour clock and to have an icon of a sun or a moon to indicate if it is evening/night or morning/daytime.

Especially the Route Creator app could be improved regarding its simplicity. The current status of the app demands to take new pictures for every new route. It would be easier for cares to reuse pictures that were already taken and to take parts of an old route when creating a new one.

In the wallet of the shopping assistance, bills and coins were not on the same page. The arrow for entering coins disappeared when the font size of the phone was increased. For users, it was not intuitive that the black arrow takes the user to the coins. Following the principle of visibility, most important information should be visible. Therefore, bills and coins should be on the same page.

As already mentioned above in Pilot 1, speed and responsiveness are crucial for the user experience. Especially for the Home Navigation System and the Money Handling Game these points should be considered for further development. It has always taken a long time until the games started which caused a bad user experience. For the carers, it was difficult to keep their children patient that they do not lose interest to use the apps. Additionally, as in pilot 1, important information and pictures of decision points came up far too late when navigating outside. It is important for further development that information appear on time.

In pilot 1 it was criticized that Primary Users got frustrated by getting too negative feedback. This was solved in further development. In pilot 2 the users wished to get even more feedback, especially in the Money Handling Game. To increase the positive reinforcement and make the game more interactive they wished to hear a happy sound when the amount is correct. Moreover, there could be feedback when paying too much for the product - not only the symbol for getting change and an acoustical feedback to try again.

All in all, also in pilot 2 some recommendations from potential end-users could be gained to improve to design from POSEIDON applications to make them more user-friendly and to finalize the POSEIDON design. (cf. D6.4 Results of Pilot 2)

10 Conclusion

This deliverable presented the outlines of the design of hardware, interfaces and software within the POSEIDON-project and its user centered approach.

First social, personal and technological factors were displayed which influence abandonment and adoption of (assistive) technology. Standards are presented to make information easy to read and to understand for people with intellectual disabilities which were considered in POSEIDON´s development. In addition to those standards, designing principles for people with Down syndrome are presented like the User Centered Design, The Universal Design and The User Interface Design. Despite presenting standards, it must be stated that all of those were adjusted to the results of the pilots which showed what was not applicable to the needs of the primary users. The result of the pilot regarding the design are furthermore presented in this deliverable. Through the pilots, it became clear that especially developmental activities regarding feedback, speed and responsiveness of the systems were necessary. Obstacles and problems in these areas lead often to frustration and consequently to the fact that users cannot enjoy using the system or even not willing to use them. These are also areas which are very important for the user-friendliness and needed much adaption because of the special characteristic of this user group.

The state-of-the art are presented for the design of hardware, interfaces and software focusing on people with Down`s syndrome and also the progress beyond. Following the areas of technological innovation were presented.

We report also on the application of the User-Centered Intelligent Environments Development Process (U-C IEDP) to support the co-creation of a system which fosters inclusion of individuals with special needs into society. The project exercised the U-C IEDP methodology in several ways, both through its micro and macro loops. Core to the method used is the frequent interaction of developers with stakeholders. We provided details of the nature of these interactions, their relation to the different stages of U-C IEDP, and also of their effect in the services being produced. This has kept the specific related user groups informed of the evolution of the project. It has allowed different project stakeholders to be involved in different iterations until each of them has secured some level of benefit from the project. For example, primary and secondary users have voiced needs, preferences and concerns, and the companies involved are more confident their product will be satisfactory for the intended market niche. Developers are more reassured their work will be well received and useful.

The application of the methodology was overall successful fulfilling the needs of a diversity of stakeholders and flexibility to adopt promising options appearing at different stages and to side-line others when the evidence was not favourable.

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