A Collaborative Talking Assistive Technology for People with Autism Spectrum Disorders

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Abstract. Autism spectrum disorders (ASD) are characterized by difficulties of socialization, disorders of verbal communication, restricted and stereotyped patterns of behaviors. Firstly, the paper reports tools of the user-centered design (UCD) used as well participants involved in the design of interactive collaborative system for children with ASD. Then, we describe the UCD deployed to design a vocal communication tool (VCT) between an adult with ASD and his family caregivers. The analyses of interviews demonstrate a strong need for a collaborative assistive technology based on voice interaction to avoid the family caregivers repeating the same sentences to the adult with ASD and, to create a friendly atmosphere at home. Observations in a real life environment demonstrate that the VCT is useful and accepted by the adult with ASD and his family. The work is not complete and issues such as designing a spoken dialogue system in the smart home need further works. The study of the type of voice synthesis (human or text-to-speech synthesis) is also an open question.

Keywords: User-centered design · Assistive technology · Autism spectrum disorders

1 Introduction

The term "autism" was introduced by the Swiss psychiatrist Bleuler in 1911 to designate people who are schizophrenic folded on themselves, disconnected from reality and excluded from all social life [1].

Autism spectrum disorders are characterized by a triad of impairments [2]: difficulties of socialization, disorders of verbal communication, restricted and stereotyped patterns of behaviors and interests. Firstly, people with ASD suffer from qualitative alterations of social interactions. These disorders are not a lack of interest or willingness on the part of the family to help the person with autistic disorder, but a problem of social skill that prevents him interacting with them. Most people with autism also suffer from communication disorders and these difficulties appear in very different ways. People with autism also exhibit stereotyped and repetitive behaviors. This autism characteristic intervenes differently according to the age or the cognitive abilities of

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people. In this regard, stereotyped body movements or stereo-typical use of objects are more frequently observed.

There are a lot of assistive technologies (AT) devices for children and adults with autism. Putnam et al. [3] have reported on results to elucidate information about software and technology use according domain (education, communication, social skills, therapeutic, entertainment and scheduling) were 31 applications out of 45 are dedicated to the education domain and designed for the personal computer. They also suggested considering sensory integration issues by allowing users to set colors and sounds as design consideration. This study shows that there are few assistive devices to help the family caregivers to help them for activities of daily living. To fill these gaps, we have designed a collaborative voice communication tool (VCT) between an adult with ASD and his or her family by implementing a user-centered design method.

In this paper, we first present the user-centered design tools to design assistive system for people with ASD. Next, the needs and the use context extracted from interviews of family caregivers will be reported as well as the different versions of the prototype. Then lessons from real use observation of VCT will be discussed. Finally, perspectives of this study will be described.

2 The User-Centered Design Implemented for ASD

According to ISO 9241-210 [4], the user-centered design is defined as follows "*Human-centred design is an approach to interactive systems development that aims to make systems usable and useful by focusing on the users, their needs and requirements, and by applying human factors/ergonomics, and usability knowledge and techniques*".

The purpose of the UCD is to respond to better to user needs, is an iterative process as shown in Fig. 1.

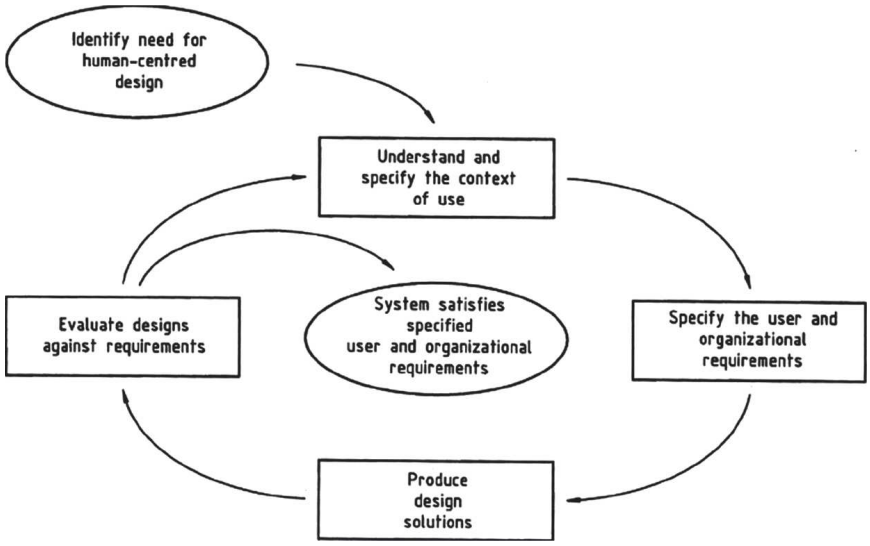

Fig. 1. Diagram of the user-centered design cycle according to ISO 13407 [5].

Philips and Zhao [6] related that almost one third of all users' AT were completely abandoned. This high rate of abandonment ascertained that a large percent of AT devices are not meeting users' needs. Consequently, there is a strong demand for practical, customized and reliable AT. The difficulty to collect and to understand the needs of disabled person is often described in the literature. The ISO 9 241-210 standard [4] and Philips and Zhao [6] recommend an active involvement of persons who will use the AT. Since the persons with ASD cannot express their needs and the context use due to communication and behavior disorder, family and professional caregivers [7] are involved in the UCD. Guffroy et al. [8] suggested involving the family, professional and human environments that are part of his or her ecosystem. One approach is to integrate this ecosystem into the user-centered design method.

The next section reports assistive technologies for person with ASD (See Table 1). Table 2 illustrates UCD tools and actors involved in the design of AT for people with ASD.

Table 1. Examples of assistive technology (AT).

AT	Autism spectrum disorders	Aims of AT
çATED [9]	Learning disabilities Life skill functioning	Digital tablet time management for children with ASD of learning
vSked [10]	Life skill functioning	Interactive and collaborative visual scheduling system on touch screen for autism classrooms
iCAN [11]	Communication skills	Teaching-assistive tablet application for parents and teachers to teach functional communications based on PECS [12]
HANDS [13, 14]	Social interactions Life skill functioning	Mobile cognitive support application for smartphones based on pervasive technology design
ECHOES [15]	Social interactions Learning disabilities	Touch interactive whiteboards allowing multi-modal 3D and socially realistic environment

The increased interest in the potential of technology in the context of autism is motivated by the recognition of autistic people's affinity with computers and more recently tactile devices (See Table 1). The studies presented above have confirmed their utility and efficiency as a means to support and develop social and interactional skills in children with ASD. The five studies have been conducted within a school environment in order to optimize the opportunities for contextual design. These studies were primarily designed to explore usability and acceptability factors of assistive tools designed to help children with ASD with communication, social and life skills development. The ECHOES project has worked on a technology-enhanced learning

Table 2. Examples of tools illustrated by the user-centered method for the AT.

AT	Methods used	Participants in UCD
çATED [9]	Interviews for need expression Observation in the evaluation phase	Interviews with mediator Conception: Engineer… 7 children, a teacher and two auxiliary School Life
vSked [10]	Interviews of therapists and educator: Observations of interactions between teachers and students Design Focus group discussions in the evaluation phase	Educators (n = 10), therapists (n = 3) and autism specialists Designer team plus an autism specialist and a teacher Stakeholders of all types (neuroscientists, special educators, assistive technology specialists and private therapists)
iCAN [11]	Interview questions for need expression Field notes, interviews, and transcripts for the evaluation phase	8 parents and 3 special education instructors 11 children, special education instructors, parents and therapists
HANDS [13, 14]	Teachers questionnaires; Child and parent interviews, first prototype [13] Classroom observations, teacher interviews; teacher questionnaire; semi-structured interviews parents and children in the qualitative interpretivist evaluation, second prototype [14]	9 teachers; 10 children and parents in two schools 15 teachers; 6 parents; 10 children with ASD in four specials schools; 26 children used the second prototype
ECHOES [15]	Series of workshops for idea generation and sensory exploration Observations phases for the design (mok-ups; storyboardings) And reflection phase for the design Observation sessions to collect data in the evaluation phase	Parents, children with ASD and teachers Children who are involved in ECHOES-like activities Practitioners and clinicians providing interpretation of the children's behaviors All stakeholders primarily led by the participatory team (researchers, practitioners, technology experts, plus parents and children with ASD)

environment with the participation of young users with ASD during the participatory design. The HANDS project [13, 14] has adopted the principles of persuasive technology design [16]. cATED [9] and vSked [10] are interactive and collaborative visual scheduling systems which demonstrates that visual schedules have positive impacts on individuals with ASD. Four of the five applications develop tools to support activities of daily living while the iCAN project proposes a tablet-based system that adopts the successful aspects of the traditional PECS (Picture Exchange Communication System) [12] to teach functional communications. All these systems incorporate advantageous

features of digitalization, visual and sometimes multimodal (visual and voice) representations. However, no system is dedicated to adults with autistic disorders.

The Table 2 reports the tools used to design assistive technologies. Observations of children with ASD in classroom and interviews of teachers and therapists are the most commonly used tools for understanding the context and expressing the needs. Sometimes parents are involved as in the project HANDS, ECHOES and iCAN. The information gathered from these data made it possible to highlight the functionalities and characteristics of the designed systems. The qualitative evaluation of the first prototype [13] has identified a number of improvements that have been introduced in both the design and implementation for the second version of HANDs prototype [14]. The ECHOES project has implemented a participatory design process that involves young children with autistic spectrum disorders. It is interesting to point that "the children with ASD play the role of informants rather than fully fledged design partners" [15]. In çATED [9], the researchers have integrated the stakeholder mediator who facilitates the communication with the children with ASD and the other participants in the design of the çATED system. The presence of the mediator is very important to present the demands of the user, to choose the solutions and to evaluate the assistive technologies.

These studies also demonstrate the close collaboration between the researchers and the school and medical practitioners in the design process. Another point is to mention the different roles of stakeholders in understanding the demand, the behavior of persons with ASD, participating in the design and evaluation of the designed system. All these systems include enhanced ecological environments with and in schools.

Table 2 shows the importance of taking into account the children's ecosystem with ASD in designing systems that support the development of social and interactional skills. Few systems that relieve caregiver interventions exist for adults with ASD. We propose to describe the approach implemented for the design of a voice communication.

3 Methodology

This part describes the UCD approach implemented for the design of the VCT. Consecutively, interviews, prototyping and observation phases of the UCD are described.

3.1 The End-User

Christophe, 32 years old, is a person with ASD (communication, social participation and behaviors disorders) as defined in [1]. During the week he lives in an adult rehabilitation center for people with ASD. He spends the weekend with his family. His family caregivers wish to have a vocal communication tool for assisting them. Christophe is very soliciting his parents to get permission to do an action. This solicitation is very time-consuming and tiring for them. His family caregivers expressed the need of the VCT.

3.2 Interviews

Firstly, requirements and context use have been defined to specify the utility sought by the end-users of the VCT. Three interviews were conducted with his family (sister, mother and father). The questions were oriented to know his abilities of communication, his social participation skills, his preferences of sounds and colors, his favorite objects and the requirements of the VCT.

For the expressive communication, Christophe speaks in isolated words, for instance “drink”, “chocolate”, “cake”, “pee”, etc. He does not have the capabilities to make syntactically correct sentences. The parent’s answers are also simple: such as “put” and “yes just go”.

His social participation is very limited. Christophe interacts only with people he knows and especially with his mother who loves to touch her. He prefers to play alone even in the living space. He is unable to make decisions alone, he always ask permission to drink, to take an object, … He is always waiting an answer to his requirements from his family environment. He likes to listen to soft music, Christmas songs, and watch TV. He is attracted by the red color that corresponds to the color of his spinning top and loves any shape that rotates such as spinning top and spinner.

The interview’s analysis states that Christophe always asks an agreement or a confirmation from this family to do an action. He may repeat the request without break until he or she receives a response from his or her family environment. This social behavior can be generated anxiety, tiredness or cognitive overload to the family.

The analyses of interviews demonstrate a strong need for a collaborative assistive technology based on voice interaction to avoid the family caregivers repeating the same sentences to the adult with ASD and to create a friendly atmosphere at home.

3.3 Design of the VCT Prototype

From the understanding of context use and the needs expressed by the whole family, a prototype has been designed. The first version of VCT (see Fig. 2) consists of:

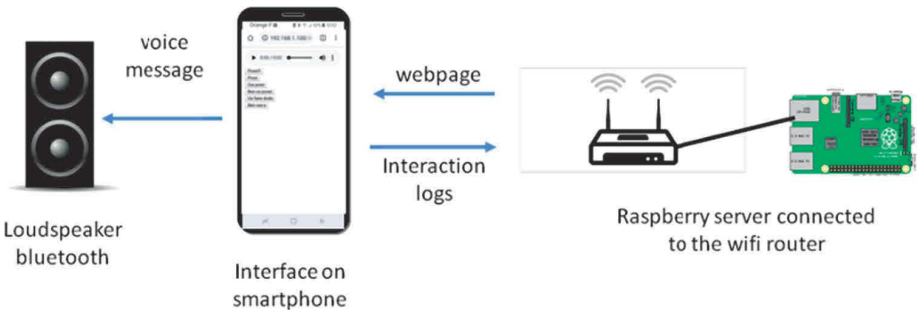

Fig. 2. VCT infrastructure.

- Loudspeakers connected to smartphone which sends the voice message to be broadcast;
- A Webpage as interface;
- A raspberry which hosts the application’s web pages and interaction data.

From the need's analysis, only six messages were identified corresponding to the main confirmation messages pronounced by Christophe's family. These speech acts are "put", "yes put", "put!", "of course put", to action such "go to sleep", "yes just go". The Christophe's mother recorded these messages in quiet environment in MP3 format. This design choice is justified because Christophe interacts most often with his mother. Each URL (Uniform Resource Locator) of the web page is linked to one message (see Fig. 3). The url selection is made by a pointing click. This selection can be made by anyone present at Christopher's home. Then the vocal message is sent to the loudspeaker and the interaction log to the raspberry server.

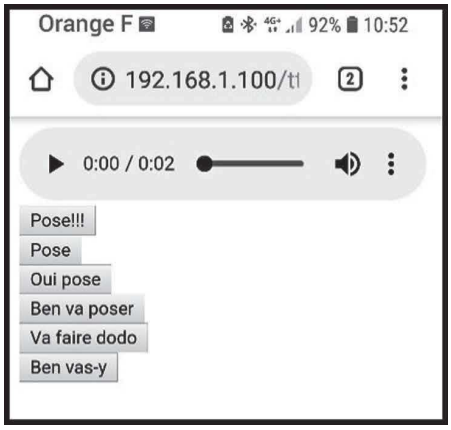

Fig. 3. VCT interface.

4 Experimentation

The aim of this experiment is to: (1) observe the behavior of Christophe when the VCT will answer him instead of his mother; (2) identify new requirements for another version of the VCT prototyping based on these observations.

4.1 Context of Use

The VCT is installed in the mother's office and the loudspeaker is placed on the dining table (see Fig. 4). The mother and the father are doing their daily activities in the kitchen or in the office. Christophe is often in the living room watching television and playing in parallel with his spinning and his hand spinner. He moves around in the whole house and he stays more times in the living room. The wizard of Oz will select the appropriate url to answer to Christophe. The wizard of Oz is also in the living room on the other side of the table (see Fig. 4). He is known to Christophe as a family member to preserve a known family environment. This configuration was chosen to facilitate Christophe's social participation.

The solution based on Wizard of Oz was chosen before implementing VCT based on a spoken dialogue system. These first trials must have before to prove the usefulness and acceptability of VCT by Christophe. Christophe's parents were instructed not to respond to his confirmation requests to complete the task.

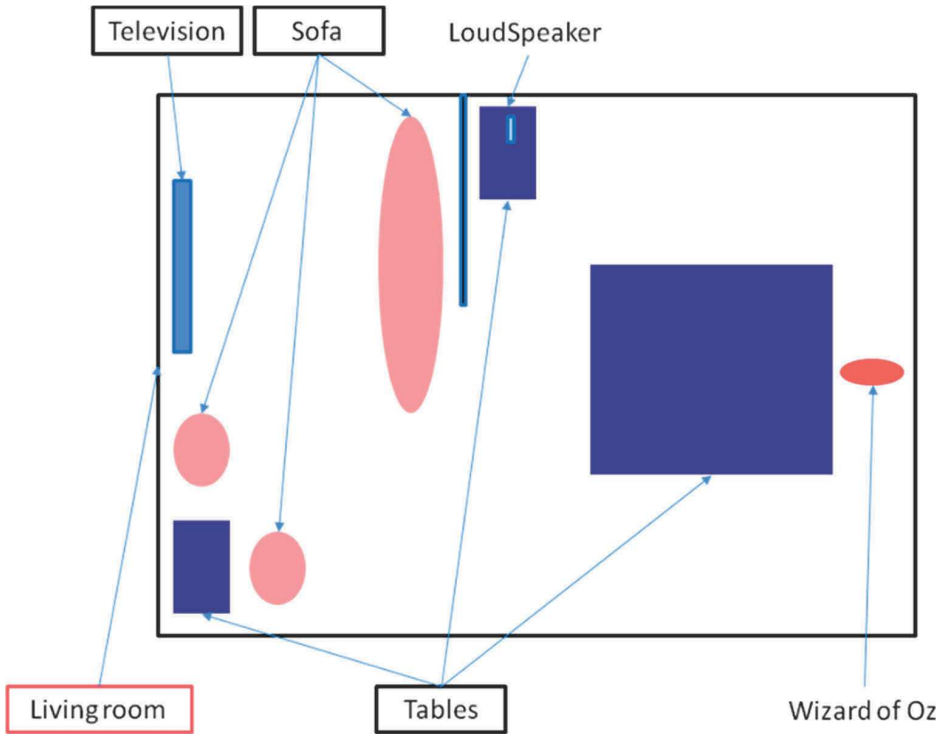

Fig. 4. Observation environment.

4.2 Observation

Observation 1: (2h 30)
The situation caused confusion: in fact, the mother responded spontaneously when she was with her son in the living room. The sound level (high noise level) of the messages was also considered too high by Christophe's parents because it made them startle. The sound level was adjusted by the wizard during the experiment.

However, Christophe obeyed the message content broadcasted by the loudspeaker: twice for the request to put his spinner and twice for the request to put the hand spinner. At this end of this observation, the mother strongly wants messages to be automated broadcasting to relieve her nervous tension due to her son's strong demands.

Observation 2: (3h00)
The experiment conditions are the same than during the previous observation. Christophe's parents haven't replied to Christophe's permission requests. The wizard tells him with the system. Christophe requested more permissions than the previous observation session: "go to the bed", "go to the toilet" and "put the hand spinner" or the "spinning top". During the session, Christophe made 23 requests (78.8% of requests to "put", 17.39% to "go to bed" and 4.34% to "go to the toilet"). He was more and more receptive to the VCT system especially to put something and go to the toilets. For the permission "go the bed", Christophe asked several times his mother who answers him "seat down" whereas the VCT system tells him several times (13 answers during 4 min) "go to sleep". Christophe has to go and see this mother before he accepted the permission given by the system. The parents think Christophe will get accustomed to the system's orders. Experiment 3 could not be carried out because of Christophe's great fatigue.

4.3 Discussion

Both Christophe's parents reported that the VCT is useful and very interesting for them and for Christophe. They also think that Christophe will accept this assistive technology in the future.

Christophe was surprised and worried (observation 1): he tried to identify where the voice message came from (Verbatim of his mother: "No, at first he was looking for where the sound came from. He was looking at me. And then he saw that I wasn't answering. Then he got used to it"). He watched his mother by wincing. Christophe has smiled to the wizard (observation 2) who demonstrates that he has totally under-stood and accepted the VCT. He is also pleased with the relevance of the response. The observations showed that the list of vocal messages is sufficient. Indeed, for the pre-test a loudspeaker, round and red, Christophe's favorite shape and color) was given to him with the aim of accepting it as one of his favorite objects. This loudspeaker was hidden.

These Christophe's behaviors confirm that it is more efficient to integrate loudspeakers in the smart home than to design a spoken dialogue in one of his favorite numeric object. The impact of the presence of the person in the living room, who recorded the voice messages, on Christophe's behavior must be studied. Several possibilities are to be considered: (1) recognition of the person present in the room and broadcasting of recorded sound messages from another family member not present; (2) restitution of messages with voice synthesis from texts with a woman's or man's voice path.

Christophe's parents wish to have a spoken dialogue system that would respond to Christophe's requests, and this in any room of the house.

5 Conclusion

The related works related that there is a great lack in assistive technologies in obtaining consent from adults with ASD to their ecosystem (family and professional caregivers). We conducted a UCD method based on interviews, prototyping phases and some first observations in real-life environments of the assistive technology VCT. VCT is a spoken tool that responds by means of a voice message to authorization requests from a person with social interaction disorders. In the tested version it is a wizard of Oz who selected the appropriate voice message. The empirical observation showed that the VCT is useful and accepted by the person with ASD. The parent interviews also show the usefulness for them, freeing them up for their daily activities.

Clearly, the work is not complete, and issues such as designing a spoken dialogue system in the smart home need further works. In this perspective, we will also have to study the adaptation of the voice of the synthesis system from texts to the people present in the house as well as the sound level according to the ambient noise of the house. It is clear that the study of the use of the VCT tool in rehabilitation center is also a path to explore.

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