Accessibility of Different Natural User Interfaces for People with Intellectual Disabilities

Melinda Braun*, Matthias Wölfel*, Gregor Renner†, Christian Menschik‡
*Karlsruhe University of Applied Sciences, Germany, {melinda.braun,matthias.woelfel}@hs-karlsruhe.de
†Catholic University of Applied Sciences, Freiburg, Germany, gregor.renner@kh-freiburg.de
‡Furtwangen University, Germany, christian.menschik@hs-furtwangen.de

***Abstract*—Digital technologies have many advantages for users, such as virtually unlimited access to information, entertainment, and communication. Most modern human-computer interfaces are developed under the assumption that they will be used by a person with typical physical, intellectual, and perceptual abilities. Although some operating systems already include accessibility features, in most cases the effective use of the respective interface can be severely restricted if a person's abilities deviate from this norm. To what extent the class of 'natural' user interfaces—including touch, voice and touchless—are accessible to people with intellectual and possibly motor disabilities is an important but not yet investigated question. Therefore, this paper investigates the current accessibility of these three interface types. First, we conducted a field study to figure out how the target group interacts with these types of interfaces in general. Second, quantitative data on cognitive and motor skills was collected using parts of the Questionnaire for Observing Communicative Skills - Revision (OCS-R) which is widely used in institutions for people with disabilities in Germany. Finally, the accessibility of each interface type was analyzed with the help of the data obtained from the questionnaire and an expert survey, which determined the important and unimportant skills required for each interface. These findings show how usable different types of natural user interfaces are for this target group.**

***Keywords*-touch user interface; voice user interface; touchless user interface; accessibility; cognitive disabilities; intellectual disabilities; digital divide**

I. Introduction

Digital technologies have many advantages for users, such as virtually unlimited access to information, entertainment, and communication. Although these opportunities would also be relevant for people with *intellectual disabilities* (ID), for this target group it is particularly difficult to use *information and communication technology* (ICT). This results in a *digital divide*—a separation between users and those who are excluded from usage due to various constraints—between people with (primarily intellectual) disabilities and the "networked ordinary citizen" [1]. We refer to persons with ID, following the *World Health Organization* (WHO), as persons with "significantly reduced ability to understand new or complex information and to learn and apply new skills (impaired intelligence)" [2]. This includes a spectrum from persons with mild learning disabilities and reading and writing skills or people using simple language, to persons with profound intellectual disabilities, e.g. without apparent language comprehension or intentionality. This may imply access barriers to use digital devices, as they are mainly developed under the assumption that they will be used by a person with typical physical, intellectual, and perceptual abilities. Although some operating systems already include accessibility features, in most cases the effective use of the provided interface can be severely restricted if a person's abilities deviate from this norm. It is interesting to note that this effect is not exclusive to people with disabilities, but now also includes your heritage or the regions where you grew up, as, for example, the dialect you speak is not well understood by automatic speech recognition [3].

Although there are a lot of configuration options available today, it has not yet been investigated to what extent new types of interfaces and their configuration options can be used by people with ID. While traditional interfaces required simple algorithms that could be easily written in code, new interfaces rely on pattern recognition which requires training data. The problem within this training data in particular lies in its sparsity and bias as it covers only the general public.

For *people with disabilities* (PWD), access to information may be limited by barriers, such as access to spoken information for deaf people, written information for blind people, or writing with a pen or typewriter for people with motor disabilities. On the one hand, ICT has created new barriers in its development, on the other hand, assistive technologies have opened up new possibilities, such as screen readers, braille lines and braille keyboards for blind people. Special keyboards and/or special input systems with a single sensor in combination with a scanning process via the alphabet, as used by Stephen Hawking, enabled people with severe motor disabilities to participate via the computer in a completely new way.

In addition, more and more interfaces types have been developed over the last decades—from keyboard and mouse to speech or gesture and now even brain-computer-interfaces—this variety can make it difficult for many PWD to use certain technologies and to select which of those technologies can be usable or adapted to fit their particular needs. Therefore, more research is needed to study the use of different interfaces by people with ID and different cognitive

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or motor abilities needed to use those interfaces today. This can help to find out what interfaces are suitable for individuals with different ID or what needs to be adapted in those interfaces. This paper provides a first glance at what abilities are needed to use different types of interfaces.

II. Related Work

Current research on technological equipment of people with ID indicates that the target group rarely uses smartphones or other digital devices. Research on structural barriers has shown that people with ID often do not have access to technological devices and often live in institutions that don't provide internet access [4], [5]. Individual problems in computer-aided thinking and digital competence make it difficult for people with ID to use structurally complex digital devices. As research also shows, ICT can have many benefits for people with ID in terms of participation in the physical world. ICT can be used to increase participation in social interaction [6], in indoor pathfinding [7], in access to leisure activities [8], in teaching skills for daily living [9], and even as a replacement for *augmentative and alternative communication* (AAC) devices [10].

The *universal design approach* (aka *design for all*) was developed to make it easier for PWD to access standard commercial technologies, since these technologies are often cheaper to purchase and are updated more regularly than special assistive technology. This approach aims to design and develop systems that can be used by everyone, no matter the physical or cognitive abilities. Since the abilities of users are very diverse, it is almost impossible to take everything into account when designing technologies, but some mistakes that make access to technology difficult for certain groups of people can be avoided [11].

Education and skills training are common areas where digital devices are used by people with ID. In order to develop an e-training platform for the target group on which the use of common applications such as Facebook, YouTube or WhatsApp can be trained, Ferreras et al. found that the most common problem preventing the target group from using ICTs is the difficulty in finding suitable apps and that they lack knowledge on how to use them [12].

Due to a large number of different technologies, interfaces, and applications available today it is often difficult to find suitable and accessible interfaces or devices for people with ID. Current research refers mainly to special applications and functions and special types of disabilities, not to the type of interface in relation to people with ID in general. To limit the digital divide, the use of natural interfaces, as discussed below, and their possible adaptation for people with ID is needed.

A. Touch User Interfaces

We refer to *touch user interfaces* to any type of computer-pointing input technology that requires to touch a surface with or without a display. In the last decade, touch interfaces have replaced other forms of interfaces and are now widely used on smartphones, tablets and are also getting more attention as an alternative input device on PCs [13].

While smartphones and touch interfaces are ubiquitous in society, people with ID still face problems in their use, such as small screen, text or button sizes, difficult error handling, not enough provided feedback and a large number of interaction methods (tap, flick, pinch etc.) [14], [15]. People with additional visual impairment in particular experience problems interacting with touch interfaces, although there are some touch interfaces with accessibility features [16]. Saenz de Urturi Breton et al. offer a set of guidelines that developers can consider when designing accessible touch interfaces to improve usability [15].

B. Voice User Interfaces

We refer to *voice user interfaces*—which are also known as *conversational user interfaces* and include *voice assistants*—to any type of interfaces that lets the user interact with a machine and perform tasks with voice input and can also include voice output [17]. Voice user interfaces can run on devices such as PCs and smartphones but are now more commonly used on specially designed devices such as Echo from Amazon (with Alexa) or Google Home (with Google Assistant).

According to Pradhan et al., voice assistants can unintentionally be accessible to people with disabilities and increase efficiency and independence when using a digital device. At the same time, people with speech impairments can face accessibility issues due to speech recognition of the device [18]. Even for people with ID, voice assistants can be a suitable interface for operating a device. Balasuriya et al. [19] observed people with ID using voice assistants to perform specific tasks and showed that most of the participants could easily use their voice to activate the interface at the first attempt. Some participants had difficulties pronouncing "Siri" or "Google", others needed several attempts to activate the interface, but then had problems consistently maintaining correct pronunciation. Participants appreciated voice assistants, as they can avoid spelling and typing problems. For this reason, Balasuriya et al. propose adjustable input settings to make voice interfaces accessible to speech-impaired users [19].

C. Touchless User Interfaces

We refer to *touchless user interfaces* to any type of interface which allows us to command the computer via body motion and gestures without physically touching a keyboard, mouse, or screen and also exclude the class of voice user interfaces. Touchless user interfaces have not yet entered the mainstream, but are widely used in special applications such as gaming (e.g. using the Microsoft Kinect), as an input modality in virtual reality (e.g. using a Leap Motion Controller), and head- or eye-tracking (i.e. Camera Mouse, Tobii Dynavox). In the field of assistive technologies, touchless approaches exist that enable the control of wheelchairs or other assistive devices. They can recognize specific movements of the hands, face or other parts of the body and thus are especially interesting for people who are restricted in motor control and cannot use buttons, joysticks or touch [20].

Currently there is not much research on touchless user interfaces and people with (intellectual) disabilities. Saenz-de-Urturi and Garcia-Zapirain Soto developed and tested a Kinect-based game to correct poor posture of elderly people that took into account cognitive and physical disabilities of their target group. They stated that those interfaces have much potential for specialized forms of (elderly) care applications that are low-cost and enjoyable [21].

D. Adjustability of User Interfaces

Current research indicates that commercial technologies have the potential to contribute to assistive or educational settings for people with ID. It also shows, however, that these technologies either need to be adapted or users with ID need to be guided by non-disabled persons in order to exploit the full potential of the respective device [19], [22], [23]. While simpler interfaces can be adjusted without much effort—e.g. extending a knob by clay or replacing one button with another one—interfaces that heavily rely on pattern recognition, such as the investigated interfaces, are much harder to be adapted.

III. Methodology & Target Group

In order to find out how interfaces need to be adapted in the future, this study must first determine the current accessibility-status of various user interfaces when used by people with ID. For this first overview, touch, voice, and touchless interfaces have been considered. Since there is no standardized method or questionnaire to date that examines the use of different user interfaces by people with ID, an experimental approach using an observational study, a questionnaire and an accessibility analysis was chosen. Of course, such a study can never be comprehensive and depends on the use case. In our observation, we decided on a generic application for navigating and playing music that can be well designed for different interface types.

A. Questionnaire for Observing Communicative Skills

To find out what basic cognitive and motor skills the people with ID have, a questionnaire using modules of the *Questionnaire for Observing Communicative Skills - Revision* (OCS-R) was distributed to the participating institutions and filled out by carers or managers for the individuals involved. The OCS-R is a structured diagnostic observation instrument for assessing communicative abilities and forms of expression of children, adolescents, and adults with limitations in their communicative abilities or their communicative development [24]. The OCS-R is initially not designed for interfaces-related decisions and of course cannot take into account all parameters that would be required to define the fit to a particular interface, but the importance of this questionnaire lies in its availability as it is already present (filled in) in many institutions. This fact can speed up and simplify the process of selecting suitable interfaces enormously since the carers of people with ID do not have to fill out an additional questionnaire. In addition, institutions often employ people without a technical background. A questionnaire that is too interface-specific could be quite difficult to be filled out by people without technical background knowledge. This makes the OCS-R a potentially suitable tool to find out which interface types might be suitable for an individual or which interface may be used when adapted correctly.

To find out which categories or parameters of the OCS-R are relevant for the three interface types mentioned above, all items were later evaluated by experts in the field of human-machine interaction or interaction/interface design. This evaluation resulted in an adapted version of the OCS-R, which contains only the relevant items about interface-specific abilities.

B. Target Group

This study included individuals with a range of different forms and degrees of ID, some with additional motor impairments. All participants were recruited from three different institutions in southern Germany. The majority of the participants (76.9%) live in residential groups in these facilities. Individual, less restricted participants (23.1%) live in outpatient residential groups, which also belong to the respective facilities. Intellectual disabilities include a spectrum from persons with mild learning disabilities to persons with profound ID, e.g. without apparent intentionality. Since this study uses oral and visual tasks related to different interface technologies, the study includes an observation to find out if the participants are able to complete these tasks or not. Not all participants who took part in the observation filled out the questionnaire afterwards, for this reason the number of participants in the observation is higher than in the rest of the study. The aim of this study is to include "all" people with intellectual disabilities as far as possible, thus obtaining a cross-section of the target group.

Access to this target group is made particularly difficult by the fact that some individuals cannot give their consent to studies themselves. For people without this possibility, for example, parents or legal advisors must give their consent before the individuals participate in scientific studies. This process can be quite difficult and time-consuming. In order to represent the best possible interests of all parties involved, we have had an ethical application approved by the *German Society for Educational Science* (DGfE) and only use anonymized data.

IV. Study

In this section, we describe our user study which took place from February to March 2020. A total of 91 participants were observed using one of the three interfaces. Of those 91 people, 23.1% had prior technical experience (i.e. experience with a smartphone or tablet). 14.3% additionally—besides their ID—had some sort of visual impairment, 48.4% had language restrictions (such as unclear pronunciation, communication only through sounds or complete lack of speech), 4.4% had hearing impairments and 18.7% some other kind of physical limitation (like using a wheelchair). The age of the participants ranges from 31 to 79 years, with the average of 55 years.

A. Observation of Interface Use

In order to find out how the target group interacts with the different types of interfaces, the participants were observed and observations noted. The allocation of the respective interface was randomized. The task for the

- **touch user interface** was playing music on an iPad via touch gestures and tried out by 48.4% of the participants.
- **voice user interface** was playing music on an iPad via their voice (Siri) and tried out by 32.8% of the participants.
- **touchless user interface** was playing music on a laptop with gestures of their hands and tried out by 18.7% of the participants. We used an application with the Leap Motion controller where you have to stretch your index finger and swipe to trigger an action.

B. Questionnaire (OCS-R)

In our adapted questionnaire we used the OCS-R modules “basic communication skills” containing questions about signal production, signal perception, and interaction, “perception” containing questions about general perception and specific perceptual competencies and “motor skills”. In detail:

- **Signal production** questions the abilities in vocalizations and spoken language as well as gestures and manual signs. It consists of 17 items, e.g.: ”can speak single words intelligibly”, ”uses conventional terms”, ”can speak simple sentences intelligibly”, can point to objects purposefully”, or ”uses conventional gestures/manual signs” [24].
- **Signal perception** includes questions about the abilities in speech comprehension and ways of perceiving information. It consists of 11 items, e.g.: ”can gather information from pictorial symbols”, ”can gather information from spoken language”, or ”understands simple prompts” [24].
- **Interaction** includes 14 items that determine whether the individual has difficulties in conversation or different situations when interacting with people, e.g.: ”can focus their attention on a person or object”, ”can start a conversation with someone of their own initiative”, or ”can maintain a conversation” [24].
- **Perception** first asks about general perception (is the individual able to see/hear correctly) and then questions specific perceptual competencies. It consists of 11 items, e.g.: ”can hear with no impairments”, ”can see with no impairments”, ”can recognize shapes”, or ”can recognize pictorial symbols” [24].
- **Motor skills** asks about the individuals’ motor abilities. It consists of 14 items, e.g.: ”can press a switch”, ”can purposefully look in a direction”, ”can purposefully grasp an object”, ”can hold an object”, or ”can point accurately [24].

The answers range from 1 = never, 2 = rarely, 3 = frequently and 4 = always [24]. The questionnaire was filled out by caregivers for 51 of the 91 persons that also participated in the observations.

C. Interface Accessibility

In order to find out whether the examined interfaces can currently be used by the participants, we asked seven experts working in the field of human-machine interaction or interaction/interface design to give their opinion on the importance of the statements of the OCS-R for the three interface types surveyed. The expert survey used a scale from 4 = very important to 1 = not important for each statement. With these results, the existing skills of the 51 participants—collected from the questionnaire (OCS-R)—can be compared with the relevant skills for each interface to find out how many of the participants can currently use the respective interfaces.

V. Findings

In this section, we analyze the collected data and present our findings.

A. Observation of Interface Use

Table I gives a summary of the interface usage, task understanding, and task completion. In discussions with the participants and their carers it became clear that many of the participants would like to use more technology in their daily life to help them with various everyday tasks. Most participants were very interested and had fun using the devices. However, difficulties currently exist in this regard, for instance in the procurement and financing of technology such as smartphones or tablets and the availability of Internet access in German institutions. It is especially difficult to find out what kind of technology or interfaces and applications are available for an individual person and to teach the person how to use this technology. Furthermore, some care

Table I
OBSERVATION OF INTERFACE USE

User Interface	In Total	Task Understood			Task Completed		
		understood	*partially understood*	*not understood*	*completed*	*partially completed*	*not completed*
Touch	44	37 (84.1%)	6 (13.6%)	1 (2.3%)	25 (56.8%)	12 (27.3%)	7 (15.9%)
Voice	30	15 (50.0%)	6 (20.0%)	9 (30.0%)	8 (26.7%)	2 (6.7%)	20 (66.7%)
Touchless	17	12 (70.6%)	3 (17.7%)	2 (11.8%)	9 (52.9%)	2 (11.8%)	6 (35.3%)

workers expressed concerns regarding data privacy and security, when people with ID would use such devices without knowing privacy settings.

Touch User Interface: The task of playing music on a touch interface was understood by 37 out of 44 (84.1%) participants and completed by 25 (56.8%) participants. In this study group, only 4 participants (9.1%) had previous experience with technology. Of these 4 people, 3 could complete the task without problems. Due to impaired vision, one of the four people could not complete the task but claimed to have experience with voice commands on an iPhone. It should be noted that of the remaining 40 participants with no previous technical experience, 22 (55.0%) were able to complete the task. A lot of people who did not complete the task fully had problems with small play button size, letting go of the button (pressing too long and using it as a physical button), keeping their whole hand on the screen and not being able to only use one finger of their hand to touch.

Voice User Interface: In the observation of voice interface use, 15 out of 30 (50.0%) participants understood the task and only 8 (26.7%) did complete the task. A lot of participants had some sort of speech restriction and background noises caused additional errors. This study group consisted of only 6 people (20.0%) with previous technical experience. Of these 6 people, 4 were able to complete the task. One person did not want to use voice and used touch instead and another was not able to stay concentrated during the task.

Touchless User Interface: Trying out the touchless user interface, 12 out of 17 (70.6%) participants understood what they had to do and 9 (52.9%) completed the task. The task was particularly difficult for those with problems in the fine motor skills of their hands, as they were unable to stretch a finger in isolation. In addition, many participants did not understand the concept of gesture recognition, which was shown by the fact that they touched the controller and wanted to use it as a button. In this study group, 11 participants (64.7%) had previous technical experiences. 7 of those people could complete the task without problems, one did not want to try. Although the other three understood the task and tried to complete it, they could not operate the interface properly due to motor limitations of their hands. Among the remaining participants with no previous technical knowledge, only two were able to complete the task.

B. Questionnaire (OCS-R)

Here we present the results of the respective categories of the OCS-R.

Signal Production: Looking at all 51 participants, the mean value in this category is 2.5 (rarely to frequently). Looking at the distribution in Table II, it is becoming clear that 47.1% of all participants have scores below 2.4, meaning they rarely to never have these abilities. Only 25.5% of all participants always have these abilities. This shows that, overall, the target group shows large gaps in skills in this category.

Signal Perception: The mean value in this category is 2.9 (frequently). The majority of participants have these abilities frequently (52.9%) or always (21.6%). 25.5% rarely or never have these abilities (Table II).

Interaction: The mean value is 2.3 (rarely). Looking at the percentage values in Table II, it is obvious that the majority of the participants have problems in this category. 54.9% rarely or never have these abilities.

Perception: The mean value in this category 2.8 (frequently). 31.4% rarely or never have the abilities in this category, but the majority (68.6%) of participants have scored over 2.4 (frequently or always).

Motor skills: The participants have an average score of 3.4 (frequently) in this category. Only a few have larger problems here, with scores of 2.4 or lower (7.8%). The majority frequently or always has all motor skills queried (Table II). As our target group is people with ID, these results were predictable. Not all people with an ID have additional problems with motor skills, but there are still participants who lack some of these skills.

C. Interface Accessibility

This section examines the results of the expert survey and identifies the relevant skills of the OCS-R for each interface. The important skills are then compared to the actual skills the participants have. This helps to find out how many of the participants can currently use the respective interfaces. In the following accessibility analyses, only those items of the OCS-R that were considered important by the experts were looked at.

Touch User Interface: As seen in Table III, 18 different skills from all five categories are important for touch interface use. In the category ”signal production” 1 of 17 skills is important, in ”signal perception” 2 of 11 skills are important, in ”interaction” 2 of 14 skills are important, in

Table II
QUESTIONNAIRE CATEGORIES

Range	Signal production	Signal perception	Interaction	Perception	Motor skills
always (>3.5))	25.5%	21.6%	11.8%	17.6%	60.8%
frequently (2.5..3.5)	27.5%	52,9%	33.3%	51.0%	31.4%
rarely (1.5..2.5)	21.6%	19.6%	31.4%	27.5%	7.8%
never (<1.5)	25.5%	5.9%	23.5%	3.9%	0.0%

Table III
EXPERT SURVEY: IMPORTANT ABILITIES

User Interface	Signal Production	Signal Perception	Interaction	Perception	Motor Skills
Touch	1/17 (5.9%)	2/11 (18.2%)	2/14 (14.3%)	6/11 (54.6%)	7/14 (50.0%)
Voice	6/17 (35.3%)	8/11 (72.7%)	10/14 (71.4%)	1/11 (9.1%)	0/14 (0.0%)
Touchless	3/17 (17.7%)	3/11 (27.3%)	2/14 (14.3%)	1/11 (9.1%)	2/14 (14.3%)

”perception” 6 of 11 are important and in ”motor skills” 7 of 14 skills are important for touch interface use. The mean values for importance range from 4.0 (very important) to 1.0 (unimportant). Only values above 2.5 were classified as important.

Comparing the important skills with the actual skills of the individuals (Table IV), 19.6% of the participants would be able to use a touch interface without any problems. The majority (51.0%) would still have the important abilities most of the time, maybe facing some minor problems while using. For 29.5% there would be major problems because they lack the abilities that are essential for the use of touch interfaces.

Voice User Interface: As seen in Table III, there have been examined 25 relevant abilities for voice interface use belonging to the categories “signal production” (6 of 17), ”signal perception” (8 of 17), “interaction” (10 of 14) and “perception” (1 of 11).

Looking at the important abilities for voice interfaces, 25.5% would be able to use this interface type without any problems, as they have a score of 3.5 or higher (Table IV). 39.2% would still be able to use the interface, possibly facing some issues while using. 35.3% would most likely not be able to use voice interfaces without any adjustments.

Touchless User Interface: According to the experts, 11 skills from all five categories are important for the efficient use of touchless interfaces (Table III). In the category ”signal production” 3 of 17 skills have been rated important, in ”signal perception” 3 of 11 skills, in ”interaction” 2 of 14, in ”perception” 1 of 11 and in ”motor skills” 2 of 14.

19.6% of the participants would be able to use touchless user interfaces, as they have a score of 3.5 or higher in the important skills (Table IV). 47.1% maybe would face some problems, most likely still being able to use the interface. 33.3% would not be able to use touchless user interfaces or face major problems while using them.

Comparisment between the User Interfaces: Looking at the individual participants and their scores in all three interfaces, it is interesting to note that only 13.7% can always use all of the three (Table V). For these people today’s interfaces are most likely usable and accessible, and they do not experience a digital divide when dealing with them. 19.6% can always use at least two of the interfaces and 31.4% can always use at least one of the interfaces. 54.9% can use all three, 64.9% can use two, and 76.5% can use at least one of the interfaces frequently. For this group it would still be possible to use all or some of the interfaces, maybe facing smaller problems. It is promising to note that 90.2% can at least rarely use all three, two (94.1%) or one (98.1%) of the interfaces. For people with scores below 2.5 (can rarely use...), it would make sense to work out adaptations to enable them to participate in digital technologies.

Table IV
MEAN VALUE OF IMPORTANT ABILITIES AND INTERFACE TYPES

Range	Touch	Voice	Touchless
always (>3.5))	19.6%	25.5%	19.6%
frequently (2.5..3.5)	51.0%	39.2%	47.1%
rarely (1.5..2.5)	27.5%	29.4%	29.4%
never (<1.5)	2.0%	5.9%	3.9%

Table V
NUMBER OF USABLE INTERFACES

Range	can use at least ... interface(s)		
	three	*two*	*one*
always (>3.5)	13.7%	19.6%	31.4%
at least frequently (>2.5)	54.9%	64.7%	76.5%
at least rarely (>1.5)	90.2%	94.1%	98.0%

To investigate the correlation between the interface possible usage we used Spearman’s rank. Touch and voice interfaces show a moderate positive relationship of 0.56, touch and touchless interfaces show a strong positive relationship of 0.91, and voice and touchless interfaces show a positive relationship of 0.78. This shows, not surprisingly, that a person who is able to operate a touch interface could most likely also operate a touchless interface and vice versa. It is interesting to observe that voice and touchless interfaces seem to have more in common than voice and touch interfaces.

VI. Conclusion

This study examined the current state of accessibility and the need for adaptation of present natural user interfaces when used by people with intellectual disabilities. It focused on the three interface types *touch, voice* and *touchless* and consisted of three parts: an on-site observation, a questionnaire and an accessibility analysis. In conclusion, in the on-site observation, most of the test persons understood the operation of touch interfaces, but only slightly more than half of the participants were able to complete the task. Problems exist especially when people with ID have additional visual difficulties or limited fine motor skills. Moreover, a large number of test persons found it difficult to operate a virtual button. Observing the voice interface use, it is noticeable that many of the participants had some sort of speech restriction, which made it difficult for them to use the interface or complete the task they were given. The touchless interface was particularly difficult for those having problems with motor skills. In our observation, most of the participants trying the touchless interface were quite technology-conscious with rather mild ID. This could bias the results in this regard.

The expert survey revealed important skills for the respective interface types. For touch user interfaces this resulted in 18 important skills from all five categories of the questionnaire, for voice user interfaces 25 important skills from the categories “signal production”, “interaction” and “signal perception” and for touchless user interfaces 11 skills from all five categories were identified. In the future, it might be possible to extend the questionnaire with further skills that are important for the respective interface types in order to make it even more detailed and accurate.

The analysis of the accessibility status of the current interface types touch, voice, and touchless showed that there still exist large gaps in this area, but also that there is great potential for improvement. People with ID currently face major problems in accessing, selecting, or using different types of interfaces. In our study, 29.5% would most likely not be able to use a touch interface, 35.3% would not be able to use a voice interface and 33.3% would not be able to use a touchless interface. 51.0% with touch, 39.2% with voice, and 47.1% with touchless interfaces would still face minor problems in daily use, having mean scores between 2.5 and 3.4 (only frequently and not always having the important abilities). The comparison showed the strongest correlation between touch and touchless interfaces, meaning that people who are or aren’t able to use touch interfaces are most likely able or not able to also use touchless interfaces. For our target group—people with intellectual disabilities—we share the statement of Pradhan et al. that accessibility issues can occur in voice interfaces due to speech recognition problems [18].

This analysis and the prior observation in the participating institutions once again highlighted the existing digital divide. At the moment, there are major obstacles in the use of technology for people with ID. It is noticeable that the technical infrastructure in german institutions is little or non-existent in terms of technology. Only a few of the participants in the observation had technical equipment available themselves or were able to use the Internet. The caregivers are usually not technically competent and do not know which technical devices might be suitable for an individual. Moreover, the acquisition of technical equipment is often a problem from a financial point of view. Nevertheless, the participants in the observation and the staff and managers of the institutions were very interested in changing the current status and integrating more technology into the everyday life of people with ID. Some even had more or less precise ideas about the areas of life in which technology could be of particular help the participants.

This study had some limitations, since there is no standardized method or questionnaire to date that examines the use of different interface types by people with ID. We had to choose an experimental approach using parts of the OCS-R, which is initially not designed for interface-related decisions. In addition, fewer participants were able to try out the touchless interface because the Leap Motion Controller was not available for testing at first. However, the results show that the three interfaces types are accessible to some people with ID, but the majority faces major problems while using. In order to make current interface types usable for people with any level of knowledge or ability, accessibility or universal design decisions can be made in the development process. Because the abilities of users are very diverse, it is almost impossible to take everything into account when designing technologies [11]. While some mistakes can be avoided by those decisions, people with ID have to be trained in interface use and existing interfaces must be adapted or modified so that the individual can use them in the best possible way. In addition, the best fitting interface based on the abilities of the person in question must be selected, for which this study should provide a first indication. Further studies will be necessary to investigate other types of interfaces and abilities and how exactly they have to be adapted to fit the needs of people with ID.

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