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► **To cite this version:**

Max Pascher, Annalies Baumeister, Stefan Schneegass, Barbara Klein, Jens Gerken. Recommendations for the Development of a Robotic Drinking and Eating Aid - An Ethnographic Study. 18th IFIP Conference on Human-Computer Interaction (INTERACT), Aug 2021, Bari, Italy. pp.331-351. hal-04345712

HAL Id: hal-04345712

<https://inria.hal.science/hal-04345712>

Submitted on 14 Dec 2023

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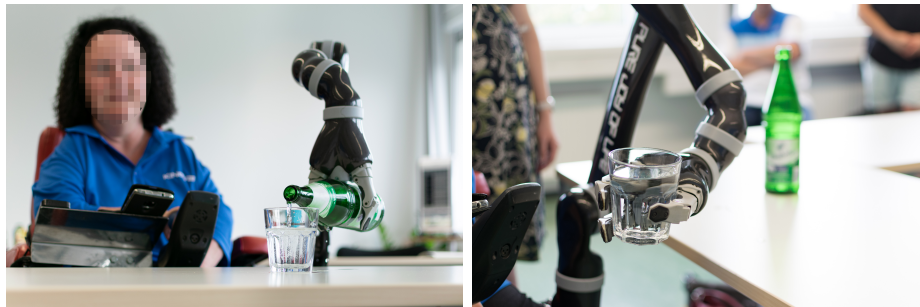
Recommendations for the Development of a Robotic Drinking and Eating Aid - An Ethnographic Study

Max Pascher^{1,2}[0000-0002-6847-0696], Annalies Baumeister³, Stefan Schneegass²[0000-0002-0132-4934], Barbara Klein³, and Jens Gerken¹

¹ Westphalian University of Applied Sciences

² University of Duisburg-Essen

³ Frankfurt University of Applied Sciences



(a) Filling a glass of water

(b) Grasping a glass to drink

Fig. 1: Robotic arms can support users with motor impairments in their everyday drinking and eating task. We explore how such systems should be designed to provide a benefit to the users and support them in living a self-determined life.

Abstract. Being able to live independently and self-determined in one's own home is a crucial factor for human dignity and preservation of self-worth. For people with severe physical impairments who cannot use their limbs for every day tasks, living in their own home is only possible with assistance from others. The inability to move arms and hands makes it hard to take care of oneself, e. g. drinking and eating independently. In this paper, we investigate how 15 participants with disabilities consume food and drinks. We report on interviews, participatory observations, and analyzed the aids they currently use. Based on our findings, we derive a set of recommendations that supports researchers and practitioners in designing future robotic drinking and eating aids for people with disabilities.

Keywords: Assisted Living Technologies · Human-Centered Computing · Meal Assistance · Participation Design · People with Disabilities · Robot Assistive Drinking · Robot Assistive Feeding · User Acceptance · User-Centered Design · User Participation.

1 Introduction

At the end of 2019, 7.9 million people classed as severely disabled were living in Germany [47]. With over 58% of these cases being attributed to physical disabilities, motor impairments affected an total of 4.6 million people; 11.2% of which are suffering from impaired functionality to a complete loss of motor control of their extremities. Additionally a further 10.4% were also affected by impairments in the spinal and torso region.

Functional loss of the use of extremities can be caused by upper spinal cord trauma and degenerative diseases. Those afflicted are struggling, or are simply unable, to perform every day tasks independently of others. One very prominent area is the one of nutrition. Being self-sufficient in terms of being in control of food and water intake is not only beneficial to ones health but also immensely important for ones self-worth [30].

Assistive technologies are increasingly becoming a vital factor in the field of assisted living; minimising the need for constant care and allowing people with motor impairments to regain some independence [35]. Initial studies by Klein [24] and Merkel & Kurcharski [34] indicated that assistive technology often meets non-acceptance and non-use and propose that devices need to focus more on the needs and preferences of the target group. Using a participatory approach integrating future users in the developing progress is recommended to promote a higher acceptance of the final product [50].

We conducted an ethnographic study in this work to shed light on how users envision future systems supporting them with everyday drinking and eating tasks. We interviewed 15 users with motor impairments, presented a robotic aid as a potential assistive system, and conducted in-situ observations of their drinking and eating behavior and used tools. We gained significant insight into user opinions and derived recommendations regarding structural, social, and collaborative concerns of future assistive systems like a robotic drinking aid (cf., Figure 1. These recommendations will help designers and engineers in a technology-focused domain to build systems that actually help people.

2 Related Work

Traditionally the focus in the field of developing assistive technologies has been on functionality from an engineering point of view. Recent findings however highlight the need to include future users and their perceived needs in the design process [26]. In this section we first examine previous work done on concepts of user participation and collaborative approaches. In a second step, we present projects that already analysed the use of robotic devices to support people with disabilities and how these aids are valued by their users.

2.1 User needs

In recent years, there has been growing interest in the concept of user participation in the design of new assistive technologies. Groundwork laid by Thielke

et al. [48] and Merkel & Kucharski [34] expressed the need for this collaborated approach to maximize user acceptance. They indicated various methods for integrating the user group as well as family, caregivers and assistants into the innovation process. Focus groups, qualitative interviews, visits of the primary users' homes, and participant observation can provide significant insights into the needs and wants of the user group. The recommendation for this participatory approach that integrates the future users in the developing progress is also noted by Frennert & Östlund [17] and Efring & Frennert [13], confirming the findings by Klein and Merkel & Kurcharski.

During the development of a robotic therapy support system, Duckworth et al. used three different methods to include the future users preferences into their work [12]. Clinicians and patients were interviewed, given a questionnaire concerning the design of a robotic therapy support system and had the opportunity to use the developed robot during counselling sessions. They came to the conclusion that a participatory design provides essential information for the development of assistive technology and increases the chance of a positive user experience.

Using a similar approach, Mandy et al. conducted a qualitative study with users of the *Neater Eater* to gain an in-depth understanding of their user experience [29]. They report that self-feeding devices increase the life quality of people with disabilities significantly and support a more equal relationship between those who are in need of care and their carers. They stress the need of a positive approach towards assistive technologies for a wide general acceptance.

2.2 Human-Robot Collaboration in the Field of Supporting People with Disabilities

Robotic solutions can make a significant contribution to regaining independence and improving care by supporting and relieving caregivers, thus improving the quality of life of those in need of support [5].

A growing body of literature has examined the impact of assistive robotic systems in supporting people with motor disabilities. Work done by Chen et al. [9] for the *Robots for Humanity* project and Fattal et al. [14] looked into the feasibility and acceptance of robotic systems as assistive technologies. A common finding was that the robotic devices are often designed to assist with several activities of daily living. These devices are usually large; consisting of a robotic arm on a mobile module. They require a barrier-free environment and rooms with sufficient space to fit into and be able to move around safely. In contrast, Pascher et al. noted the potential of smaller, lightweight solutions designed for individual tasks [36], indicating that a specialized aid would be more accessible in terms of size and portability.

Research by Gallenberger et al. used camera and machine learning for an autonomous robotic feeding system to detect types of food items present and to plan the picking-up and transportation to the mouth of the user [18]. An alternative approach is presented by Canal et al. describing a learning-by-demonstration framework to feed the user [8]. Both projects ensure the ability of the robotic

arm to fulfill its autonomous tasks without any fine-control of the user focusing on the technical aspects of the development process of assistive technology.

A 2019 study by Beaudoin et al. focused on the long-term use of the robotic arm JACO [4], a recent advance in assistive technologies. They researched improvements of everyday task capabilities, satisfaction with JACO, psychological impact and the implications for users and their caregivers using a similar quantitative approach as employed in this study. Beaudoin et al. reported that almost all participants gained more autonomy in certain life aspects and experienced a number of positive psycho-social impacts. One such success was the increased capability of participants to drink independently of human support using JACO, thus reducing the amount of care and attention needed and increasing well-being and overall health by having a continuous access to beverages.

Interaction technologies such as gaze-based interaction and head movement have been explored to operate, e. g. a PC [11,38,40] and a robot [22,41,45]. Alternatively, brain-computer interfaces were used to control a robotic arm [1]. However, today's ubiquitous technology interaction scenarios are much more tightly integrated in everyday activities and require different interaction interfaces [28].

3 Study

The goal of this work is to understand users' requirements and demands of assistive technology that supports them with drinking and eating. For this, we conducted an ethnographic study consisting of an interview including a VR presentation of a robotic support system and in-situ participatory observations of their drinking and eating habits, with 15 participants afflicted by a varying degree of motor impairments.

3.1 Participants

In preparation for the main study, we opted to evaluate our methods with a pilot participant allowing us to adapt the study design before approaching the remaining participants. Participants were chosen in collaboration with the *Center for Paraplegic Patients Hamburg*, the *Locked-in-Syndrom e.V. Berlin*, and the *State Association of the German Society for Multiple Sclerosis Hessen e.V.* We recruited 15 participants with a permanent and significant degree of compromised mobility of the extremities and the reliance on support for the consumption of food and drinks. Table 1 presents the participants split by gender, age, and diagnosis. 4 female and 11 male participants took part in the main study; the mean age was 42.07 years (SD=16.68) and all were categorized as severely disabled.

3.2 Procedure

Each session took place in the participants' homes which allowed us to conduct the interview, observation of drinking and eating habits as well as analysis of commonly used aids in a natural setting. In most of the cases a caregiver or assistant was present.

ID	Gender	Age	Diagnosis
Pilot	female	60	Multiple sclerosis
P1	male	18	Spinal cord injury; incomplete at level C3
P2	male	46	Spinal cord injury; complete at level C4 & some rudimentary mobility until level C5
P3	male	41	Spinal cord injury; incomplete at level C3 (right body-side has some mobility until level C5)
P4	male	30	Spinal cord injury; incomplete at level C3
P5	female	62	Locked-in syndrom
P6	male	50	Spinal cord injury; incomplete at level C4
P7	male	38	Spinal cord injury; incomplete at level C3 & complete at level C5
P8	male	30	Spinal cord injury; complete at level C3
P9	male	22	Spinal cord injury; complete from level C3 to C7
P10	male	48	Spinal cord injury; complete at level C4 & C5
P11	female	60	Multiple sclerosis
P12	male	50	Inclusion body myositis
P13	female	51	Locked-in syndrom
P14	male	34	Spinal cord injury; complete at level C5 & C6
P15	female	51	Arthrogyriposis

Table 1: Overview of the pilot and main study participants

Interview Due to the nature of the physical impairments faced by the participants, obtaining their consent had to be adapted to their particular capabilities. After reading or listening to a researcher reading the consent form, participants signed the form by themselves or had their spoken agreement recorded. In other cases, an authorized caregiver signed the form on behalf of the participant.

The interview part was structured in four sections; each focusing on a different aspect detailing their living situation, attitudes regarding drinking and eating, level of assistance needed as well as wishes towards an ideal robotic aid. In the first part we aimed to understand their current living situation by establishing how many hours they spend in their wheelchair, where they spend most of the time, and where they eat and drink at home.

Next, we were interested in their value propositions and preferences regarding drinking and eating. The participants were asked to describe a typical meal-time routine, what they generally consume, and which preparations are needed. Further, we wanted to know if drinking and eating is seen as a necessary task or can also convey enjoyment. Participants were also asked if they consume food and drinks if they are not at home (at work, in a restaurant).

The third step focused on the process of drinking and eating in an assistive setting including the communication with their caregivers/assistants and any improvised aids used.

In the final step of the session, we focused on the use of a proposed robotic arm as a drinking and eating aid. To familiarize participants with the concept they were shown images of different eating support systems and wheelchair-extension-type robotic arms that are already on the market, e. g. iEat [3], Obi [10], JACO [23], and iArm [2]. To simulate the situation of sitting in front of an actual robotic arm performing tasks in a close-contact environment we used Google Cardboard [20] and a stereoscopic video of our in-lab robot setting. Conducting the interviews in the participants' homes made this lightweight solution necessary. Figure 2 shows the robotic arm bringing a glass of water to the user's face (in this case simulated by the camera lens). To further the realism of the situation, participants were able to experience the actual sounds of the robotic aid by simultaneously listening to an audio recording.

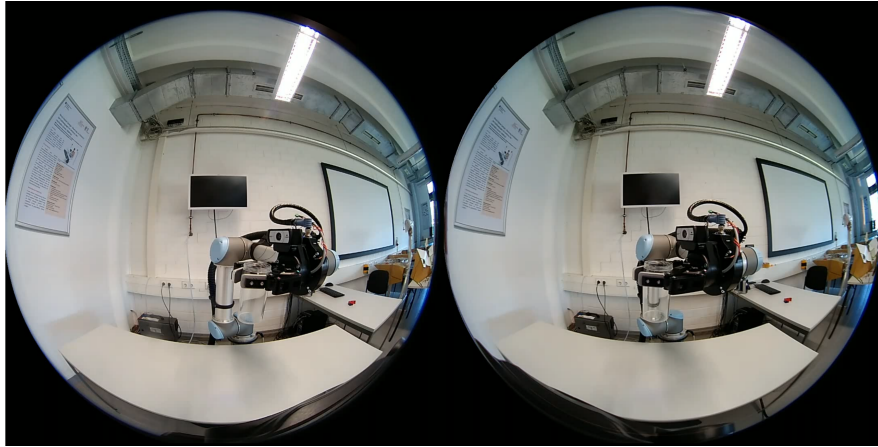


Fig. 2: Stereoscopic video in a first-person perspective of sitting in front of a robotic arm performing tasks in a close-contact environment

Following this experience we inquired about the participants' perception of the robotic aid including their likes and dislikes of the simulation and any changes they would appreciate from an end-user perspective. We encouraged them to express wishful thinking without worrying about current technological capabilities. We were also interested in how the participants would like to interact and collaborate with the robot. Special interest concerned the preferred location of attachment (e. g. table, wheelchair or self-mobile) and which additional functions should ideally be available.

Any additional thoughts, wishes, and suggestions of the participants were recorded for use in future research.

Participatory Observations This part of the study focused on observing participants consume food and drinks (cf., Figure 3) with the assistance of their caregiver. Observations of the relative location of the assistant, the methods used, and the communication between both parties were recorded. Depending on the specific type of impairment participants were either laying in their beds or sitting in their wheelchairs. Filming these interactions allowed for easy access during data analysis.



Fig. 3: Observation of eating drinking habits together with their caregiver

Analysis of Commonly Used Aids During the qualitative interviews we found that every study participant uses some kind of aid to facilitate food and drink consumption (cf., Figure 4). In order to consume the necessary amount of fluids, tea and water are provided in teapots (cf., Figure 4b) or in large dispensers (cf., Figure 4c). Large dispensers contain enough beverages for all day without the

need for re-filling by an assistant. We recorded images of these aids to increase our understanding of the help people need and want when confronted with tasks they cannot independently do anymore.

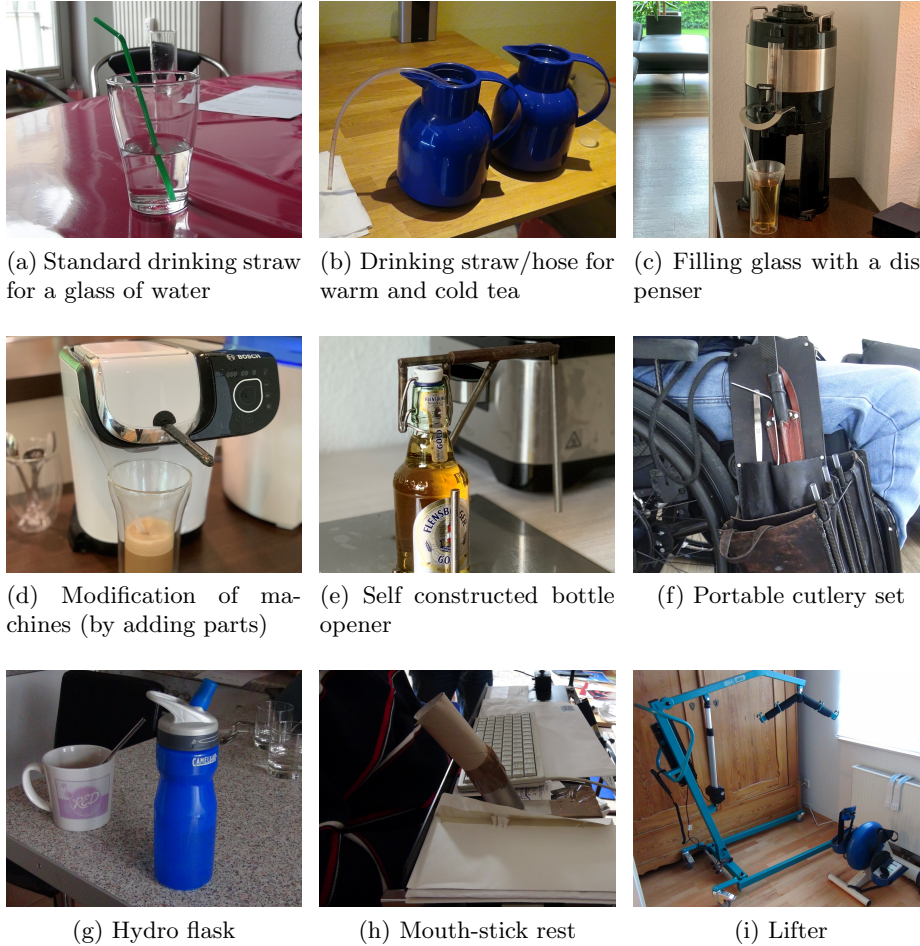


Fig. 4: Analyzed aids in the participants' homes which are currently used

3.3 Limitation of our study

The main target group of our study were people with quadriplegia caused by spinal cord injury. The noticeable skewed ratio of more male than female participants reflects statistic by the WHO [51] and German Federal Statistical Office

(Destatis) [47] of a 2:1 male-to-female ratio for overall recorded spinal cord injuries worldwide [33]. Additionally, a higher number of women refused to take part in our study as they felt uncomfortable with the study design (e. g. getting filmed while eating and drinking).

Use of a Robotic Arm during the Study One participant (P15) has rudimentary mobility functions in her lower right arm which allows her to use a joystick-controlled robotic arm for nearly every activity of daily living including consuming food and drinks, manipulating objects and basic hygiene. Figure 5 illustrates how she handles the tasks with her robotic arm.



Fig. 5: Observation on the use of a robotic arm (JACO) for the consumption of food and drinks

4 Results and Recommendations

Based on the analysis of interviews, observations, and images we devised a set of user-centered design recommendations for a robotic drinking aid. Recommendations are split into three sections referring to structural, social and collaborative concerns respectively. All materials were transcribed, coded, and categorized independently by two researchers. We focus on processes related to drinking and eating, interactions between participants and caregivers, and additional topics of interest. All participants were interviewed as experts in their own right, as they can accurately describe and explain their situation, their abilities, limitations and needs. Therefore, our analysis method for the interviews and questionnaires followed the qualitative content analysis approach from Mayring [32]. Based on a predetermined interview guide established by the research team, questions

belonging into different categories were discussed with study participants. Descriptive and normative statements concerning housing and living situation, individual wishes and needs regarding food and drink intake and attitude towards robotic aids were analysed [7]. The analysis of videos and images was based on the qualitative hermeneutical approach from social sciences by Reichertz & Englert [39] and the photo analysis by Pilarczyk & Mietzner [37]. In a first step, the videos and photos were cataloged according to content (e. g. drinking aid) and subject (e. g. drinking with a straw). Next, the videos were viewed, transcribed and coded. In a last step the photos were viewed again and theme-oriented photo series formed, e. g. photos showing self-made aids. Overall we conclude that photos provide additional information to the videos and interviews or can be used to better describe findings but do not provide much value as standalone objects.

4.1 Structural Concerns

Any design process starts with a structural framework defining size, weight and materials to be used. Whilst the choices might make sense from a purely technical point of view the preferences of the end-user should still be considered. Nobody benefits from the development of an assistive technologies that ends up too big in size to be used in the home of the typical end-user. With the aim being the widespread usage of the new device, taking wishes, where technically possible, regarding size and design into considerations can only be beneficial to future acceptance.

Dimensions of the Robotic Arm Although all but one of the participants reported living in accessible housing, barriers including narrow hallways remain. During the in-home session we found several of the participants housings to be either too small for current robotic aids or lacking in space due to other large assistive devices present. Care beds and tables, lifters and wheelchairs are essential to support people with disabilities living in their own homes. Adding another large-size device taking up space can be problematic and in some cases impossible.

P10: “There is a second wheelchair somewhere, then maybe there is a bed-side table somewhere, and there is a lifter somewhere and the shower chair somewhere. (...) At some point, many run out of space.”

Recommendation 1

A robotic drinking aid should be primarily designed for saving space. The arm has to have the ability to fold itself during waiting/suspended-mode. And include the possibility of space-saving storage when not in use.

Physical Attachment Types of suitable attachment methods vary depending on individual preferences, type of wheelchair used, and space availability in the

participants' homes. Frequent changes between user location (bedroom/living room and bed/wheelchair) is a further factor to consider. Some participants use a chin-controlled electronic wheelchair. This poses an additional challenge for possible attachment methods and hinders both control and movement of the robot during the drinking and eating process because the joystick is in this case directly in front of the mouth.

P13: "It would be great to be able to fix the arm to the table with a small screw clamp. (...) Adding it to the wheelchair might be good too. But in any case it must be easy to dismantle."

Recommendation 2

Different mounting options for the robotic arm have to be available to allow attachment to different surfaces and care devices including mobility aides, resting chairs or overbed / side tables. Special consideration has to be given to the restrictions imposed by types of wheelchairs used.

4.2 Social Concerns

The advantage of an interdisciplinary approach as outlined in this study is the combination between technical necessities and preferences of the end-user. During our analysis we found that the majority of respondents were much more worried about 'social concerns' than technical aspects.

Taking Design Seriously Stigmatization of people with disabilities is an ongoing problem highlighted in a number of studies and literature e.g. [31]. All participants have reported that they worry about unwanted attention and further stigmatisation by using too-conspicuous aids. Almost all asked for the robotic arm to be unobtrusive and designed with a positive public image in mind.

P14: "I can imagine that design is relatively important, because it is likely the crucial factor whether people accept it and whether they want to integrate it into their environment, right?"

Recommendation 3

The design should range between something plain and unobtrusive to a chic lifestyle product. The arm should be recognizable as a technical tool and not mimic a human arm by using skin-colored coloration or skin-like material.

The Care Situation and Social Aspects All participants relied on care from in-home relatives for their daily needs. Additionally all but one also employed professional personal care assistants. Due to the limited possibilities of outside interactions the bond with family members and other regular caregivers was

observed as particularly strong and important for the mental well-being of the participants.

Interviewer: “Would you describe the exchange between you and your assistant during mealtime as formal or informal?” P4: “Very informal, just about everyday life. Not just about mine. They tell me about themselves. And then you just sit together and talk about everything that is going on. Daily events, personal matters, politics, experiences, about everything really.”

Recommendation 4

Disruptions of conversations and social interactions by the drinking aid have to be minimized. The robotic arm should be placed without obstructing the line of sight between user and assistant. Sound and noises have to be kept to an absolute minimum to avoid distractions.

Safety Safe use must be guaranteed for primary and secondary users from the onset. Teething problems must be avoided at all costs; therefore strict adherence to safety protocols for direct physical proximity is vital. People within the target group are already faced with numerous health concerns [6,46] and many participants expressed worries about additional injury risks posed by the robot. Worries surrounded their inability / decreased ability to move out of the way if the robotic arm does not stop at a certain distance from their face. A frequently suggested solution would be an adjustment to have the robot bringing a cup with a straw close to the mouth - but not directly touching it; thus enabling the user to cover the last few centimeters on their own accord.

Solutions include the aid of a straw to avoid the drinking cup being delivered directly to the mouth. Allowing users the final approach increases their feeling of autonomy, control and safety.

Interviewer: “What could prevent you from using the robotic arm?” P2: “Teething troubles, something every device has at the beginning. If problems with the programming come up and the whole weight of the robot would fall on me.”

Recommendation 5

Apply the principle of *safety first* and design for scenarios of use avoiding body-contact.

Privacy All participants require 24/7 assistance with results in very limited privacy. They all stated that they have to drink a lot during the day for health reasons. Particularly in the case of paraplegia, it is necessary to consume up to three liters of fluid a day to support digestion and temperature regulation [21]. Being able to regulate fluid intake independently and not having to ask for assistance every time they want to drink would allow users to spend several

hours at a time without a caregiver. A frequently recorded hope concerns the increase of time being alone gained by integrating the drinking aid into the users' lives.

P4: "And you really sometimes want to be all alone. And even if I send my assistants to go shopping and have an hour alone here or there, that's not comparable to really being alone."

Recommendation 6

Users have to be able to use the device, once set up, independently or with minimal assistance. Once operational, assistants and caregivers should not need to interact with the device at all. Potential components worn by the user need to fit securely to prevent a constant need of re-adjustments (cf., guidelines for wearability [19]).

Data Privacy and Security Only a small number of participants were concerned about data protection. Some however expressed concerns about the type of data collected, storage options, as well as access to it.

P6: "If there is a camera then I do not know where these images are going. Especially if the robot is connected to the internet."

Recommendation 7

Transparency about collected and stored data have to be maintained to reduce uncertainty and skepticism about modern technology. Storage of personal data, including camera images, should be avoided and frameworks for voice commands should work offline as much as possible. If data have to be stored, it has to be stored securely.

4.3 Collaborative Concerns

Effective assistive technologies only work if they can be used by the target group without major effort. End-users know best what they are capable of and how they feel most comfortable interacting with the robotic device. Therefore it is important to consider the way they want to collaborate with their robotic aid.

Ease of Use The aim of using assistive technologies is increased independence of the end-user; something that is only possible if the devices are easy and straightforward to use. Especially in the case of changing caregivers, it is exhausting for users to repeatedly train others in the use of their robotic aid.

P1: "That means that I might not need a nurse anymore, but a technician. Because I already struggle to instruct the carers; and that is just to trigger three commands on my computer."

Recommendation 8

Ease of use, preferably as *ready-to-use* design, should be the aim of the assistive technology. Given the potential of frequently changing assistants, intuitive design and an obvious command structure are required to ensure a short - if at all necessary - familiarization periods. No prior knowledge or training by secondary users can or should be expected and if anything a short introduction guided by the primary user has to be sufficient. The robotic arm should be - once adjusted to a mounting spot - ready to use and easily used.

Interaction Design and Interaction Technology Participants in the study indicated various desires regarding the interaction with the robotic aid. Due to the frequent changes in position during the day, it is important that the robotic arm is usable in a lying and in a sitting position either from a bed and from a wheelchair.

The majority of the participants already use voice controlled components in their homes, e.g. telephone, door opener, and lighting fixture. However, these components generally cannot be compared with modern smart devices as they do not connect to the internet. Only one participant used a smart speaker for smart home solutions. Other participants refrained from using devices with internet based voice control due to unreliable internet connections or - more often - out of concerns towards data security.

P14: “So I think it would be great if it was using voice control. (...) I think using a joystick or something similar is also very complex. But if I only have to say: ‘Give me a glass of water’, and that would work, that would be great.”

Recommendation 9

Whilst voice control is preferred for control and interaction, speech impairments must be taken into account with the extra requirements they pose. Additionally, data security has been identified as a concern when usage of internet based voice control is suggested. Offline solutions are preferable to address these worries. Alternatively, eye-tracking devices and data glasses can be viable options. Participants preferred the former two options compared to head gestures and headsets. Participants preferred eye-tracking control via gaze-dwelling on either real world components or virtual objects in combination with the data glass’s user interface.

For users with residual hand and arm functions, a switch among semi-autonomous mode and manual mode via direct joystick control is interesting as it allows greater flexibility and adaptation to daily needs, due to the fact that in a semi-autonomous mode scenarios have to be learnt by the robot. The current mode has to be communicated to the users and

assistants, e. g. by a ring of two-colored LEDs around the robot's flange like a bracelet.

Robotic Arm as Combined Drinking and Eating Aid All Participants are excited about the prospect of a functional drinking aid, allowing them to independently regulate their fluid intake. In contrast, few participants can imagine regularly using a robotic arm for food consumption. Those who can still eat independently due to residual functionality in their upper extremities would like to use and maintain this ability. A robotic arm as an eating aid is only interesting for this group if food can be cut into small pieces with the help of the arm. A cutting function would further increase their autonomy and enable participation in meal preparation; in their eyes another step towards social integration. Participants who have their food served to them expressed satisfaction with the assistance they receive from other people. They would like to continue in this way because they value this social interaction and note that people can be more flexible and spontaneous in responding to all eventualities. This includes emergency situations such as choking or spillages, a worry of a number of participants from our focus group voiced.

P5: "I would prefer [the aid] of my husband, because we do communicate a little throughout lunch. I think when the robotic arm feeds you, there is just silence."

Recommendation 10

When prioritising the development of robotic assistance the first focus should be on fluid intake. The scenario of eating with a robotic arm is influenced by various complex aspects, such as social interactions, which need further exploration.

Robotic Arm as a General Aid Participants frequently expressed a desire for a robotic arm with a distinct grasping function beyond a mere drinking aid. Desired functions include manipulating objects, such as picking something up, taking something out of a cabinet, or being able to lift things. Fine motor tasks such as turning the pages of a book or grasping easily breakable items were also desired. In addition, particularly the younger participants would like to be able to operate a game console. Furthermore, some of the participants would also like to use a robotic arm for aspects of basic care, such as combing hair or brushing teeth.

Participants who still eat independently also showed interest in the topic of cooking. A robotic arm that can cut food, handle cooking utensils, and assist with setting the table would increase autonomy and lead to more participation in the entire process of eating. Participants expressed the wish to handle even fragile objects like raw eggs or eat small but delicate snacks like crisps. Although

fears of possible stigmatization due to the use of the robotic arm exist, overall the hope that a robotic arm with various functions could promote independent and self-determined living whilst also giving relieve to caregivers was expressed.

P4: “Having such an arm fulfill different functions such as gripping, I think that makes more sense because it would then be more versatile.”

Recommendation 11

Apart from functioning as a drinking and eating aid, a robotic arm should be developed to fulfill other everyday tasks. Since participants fear stigmatization over having too many tools, a robotic aid with various functions would meet greater acceptance.

5 Discussion

Our ethnographic study provides recommendations for future research and development as well as hypotheses that should be tested for further validation. In the context of our target user group, implementing a solution based on our recommendations will still require adaptation to fit individuals with their specific physical abilities, along with further research to verify that a designed assistive system does indeed support the user. Recommendations regarding “Taking Design Seriously” and “Privacy” concern interaction devices that might lead to further stigmatization by drawing unwanted attention and require asking for assistance for wearing or re-calibration - both aspects the target group wants to avoid.

5.1 End-User Involvement in Assistive Technology

Assistive technologies are on the rise, with a number of different robotic aids already on the market or in various stages of development [15,25]. Studies by Scherer[43] and Verza[49] have shown that these devices, albeit useful in an assistive setting, can have a high rate of non-acceptance and non-usage. There is a growing body of literature indicating that this is due to the exclusion of the end-user from the design process [16]. In recent years the field of collaborative work between developers and end-users (or their advocates) has grown but is still in its infancy as discussed by Lee et al.[27] and Simonsen [44]. Our work represents such a collaborative approach investigating the needs and wants of the end-user in regards to a robotic drinking and eating aid. In fact, participants particularly valued the inclusion in the design process of a device developed specifically for them.

5.2 Potential Autonomy

One important finding is that participants want the possibility of spending time without their assistants. Specifically drinking as continuous hydration throughout the day is vital for people with disabilities which results in a near-constant

need of care when drinking independently is not possible [21]. Thus, the most important capability of the robotic system should be to support the users with drinking. On the other hand, however, the participants also noted that the number of assistive systems should be limited and, thus, the system should provide multiple tasks. This trade off will be a core challenge for future developers.

5.3 Importance of Structural Concerns

Our results confirm findings by Fattal et al. [14] and others [34,48] as similar structural concerns are also expressed by our participants. Thus, our results also highlight the need for recommendations related to the physical characteristics of the robotic arm and attachment site.

5.4 In-Home Methodology

In this study we recorded the preferences people with severe motor disabilities have towards a robotic drinking and eating aid in terms of functionality and design. We used in-home sessions to interview our participants and record their everyday behaviours in a familiar setting. We opted for this particular approach to increase authenticity of our observation in accordance with Sakowska [42]. Combining all findings from our conversations and observations allowed us to gain significant insight in the actual living situation and challenges faced by the target group. We believe the in-home methods used in this study to represent a much more accurate picture than studies conducted in artificial laboratory or workshop environments. One downside of this approach, however, is the limitation to a small geographical area, potentially limiting the generalizability.

6 Conclusion

People with motor disabilities face a number of obstacles when confronted with everyday tasks such as drinking and eating. Assistive technologies have the potential to greatly improve the quality of life of the target group; however their user acceptance has been challenged by previous work. In this paper we investigated how drinking and eating aids are perceived by conducting interviews and participatory observations. By analyzing the relationship with food and drink intake as well as analyzing the wishes for future assistive technologies we were able to better understand the needs and wants of the target group.

Our research has highlighted the importance of acknowledging structural, social, and collaborative concerns in respect to the design of a robotic arm, defining a set of recommendations for the designs of robotic drinking aids. These recommendations represent an important step in bridging the gap between technological design and the preferences of the target group, thus increasing the likelihood of acceptance of any further assistive technology.

Acknowledgement

We would like to thank all study participants and their assistants for their valuable opinions and time. The authors are also grateful for the support of the *Center for Paraplegic Patients Hamburg*, the *Locked-in-Syndrom e.V. Berlin*, and the *State Association of the German Society for Multiple Sclerosis Hessen e.V.*. This research is supported by the German Federal Ministry of Education and Research (BMBF, FKZ: 16SV7866K and 16SV7868).

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