The Impact of Assistive Technology on Communication Quality Between Deaf and Hearing Individuals

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ABSTRACT
Deaf individuals often experience communication difficulties in face-to-face interactions with hearing people. In order to support deaf individuals in such situations, an active stream of assistive technology (AT) research focuses on real-time translation of sign language. We investigate the impact of real-time translation-based ATs on communication quality between deaf and hearing individuals. We conducted a focus group and a Wizard of Oz study in which deaf and hearing participants jointly interacted with different assistive technologies. We find that while ATs facilitate communication, communication quality is degraded by to breaks in the conversation. Using Co-Cultural Theory, we identify deaf people as a subordinate group inside a hearing society. Our results indicate that current ATs reinforce this subordination by emphasizing deficiency of mastering the dominant form of communication. Based on our findings, we propose a change in design perspective by enabling the hearing to sign rather than the deaf to "hear". We argue that ATs should not be seen as "just" a tool for the Deaf but rather as a collaborative technology.

ACM Classification Keywords
K.4.2. Social Issues: Assistive technologies for persons with disabilities.

Author Keywords
Assistive technology; social implications;
Deaf; co-cultural theory; developing assistive technology.

INTRODUCTION
Over 5% of the world population ($\approx$ 360 million people) have profound hearing loss [32]. The community of people who are deaf or hard of hearing has developed different strategies to communicate with hearing individuals [9, 13, 42]. Examples for such strategies include writing on paper, communicating with gestures and sign language, or relying on interpreters. Research and industry have proposed Assistive Technologies (ATs)[1] to support deaf people in face-to-face conversations. Such ATs come in different forms, ranging from intrusive technologies, such as cochlea implants, to real-time translation apps on smartphones, such as Ava [1] or UNI [29]. Creating real-time translation technologies is one prominent focus of AT research as they are considered a promising approach to improve communication quality. However, assistive technologies are abandoned at a high rate by the Deaf community [30, 36]. Currently, it is not well understood what impact AT's have on face-to-face conversations between hearing and deaf people, making it difficult to explain the high abandonment rate of ATs.

Our work strives to better understand the impact of real-time translation based ATs on the communication quality in face-to-face conversations between hearing and deaf people. We conducted a focus group and a Wizard of Oz study including both, hearing and deaf participants. In the focus group we explored challenges deaf people face using ATs in everyday situations, and developed a general understanding of demands and goals from both deaf and hearing individuals towards ATs. We further explored the potential for real-time translation-based ATs using novel technologies, such as mobile projection and head-mounted displays, with technology probes. Based on the initial findings, we conducted a Wizard of Oz study to investigate the impact of three technologies (pen and paper, smartphone and a mobile projection prototype) on communication quality in conversation settings involving both deaf and hearing participants.

Using Co-Cultural Theory [31], we identified the Deaf as a subordinate group in the hearing-dominated society. Our findings indicate that current ATs reinforce this subordinate position by emphasizing deaf people's deficiencies of mastering society's dominant (spoken) language. We find that ATs generate breaks in the conversation because social norms of both groups are disregarded or inhibited (e.g., eye contact). Our results suggest that these two factors – conversation breaks and an emphasis of deficiency – degrade communication quality and can lead to maladaptive behavior, such as abandonment of the AT or even avoidance of communication leading to separation, i.e., the maintenance of a separate group identity outside the dominant structure.

We propose a change in design perspective to better address the identified issues in the design and development of ATs. We

[b] F. Schaub conducted parts of this research while at Carnegie Mellon University.

[1] Please note, that our focus is on assistive technologies (ATs) for the deaf and hard of hearing that support real-time translation. For brevity's sake, we will speak of ATs in the following without specifying our focus each time.

argue that ATs should be viewed as collaborative technologies for inter-personal and inter-cultural communication instead of a mere tool for the Deaf to participate in the dominant form of communication. We propose that ATs should strive to enable the Hearing to sign rather than forcing the Deaf to ”hear” in order to balance power asymmetries during communication. Our findings further indicate the value and importance of designing and evaluating ATs holistically, involving both deaf and hearing users.

RELATED WORK

Developing ATs for Deaf and hard of hearing is an active research field within Human Computer Interaction. Examples for research in this context are analyzing alternatives for selecting content [39], developing visualizations for sounds [18], and showing notifications for certain sounds like door bells [28]. The main focus of related work lies on the development of ATs, while we focus on analyzing how the usage of such ATs influences both conversation partners' behavior during conversations.

Developing Assistive Systems for Deaf

Kipp et al. assess attitudes towards animated avatars [23]. Animated avatars could be used to render translations of spoken languages. The results of Kipp et al. show that while avatars are generally accepted by Deaf, the overall acceptance of ATs can be significantly increased by including the Deaf community in the design process. Balch and Mertens describe their lessons learned from five focus groups including deaf and hard of hearing participants, as well as communication difficulties arising in such scenarios [2]. They showed that mixed-participant focus groups can lead to results that differ from focus groups having only hearing participants. Those differences include increased importance of visibility of participants' faces to other participants and increased awareness of moderators of communication barriers and constant removal of those barriers. They also found that communication times were longer to ensure mutual understanding. Barnett et al. used participatory design with participants form a local Deaf community to develop an accessible online survey for assessing health status among Deaf [3]. Similar to those projects, we use qualitative studies and user-centered design elements to analyze how ATs are used and affect communication.

Translating to and from Sign Language

One promising approach to help deaf and hearing persons to communicate are ATs with the ability to translate spoken language to sign language and vice versa. With SCEPTRE, Paudyal et al. developed a mobile system for recognizing and translating sign language [33]. Signs are recognized using electromyography and machine learning. Other approaches for recognizing signs leverage depth cameras [19], or instrumented gloves [22].

Research on synthesizing sign language addresses various aspects, including the development of human-like avatars showing sign language [40]. The user perception of such avatars and their sign animations have been analyzed with focus groups and questionnaires [23], as well as eye tracking [20]. Kacorri et al. further explored the acceptance of sign language animations in relation to user's demographics and experiences [21]. While the aforementioned efforts focus primarily on recognizing or generating signs, we focus on how a translation system augmenting a conversation with signs can be used and how such a system affects communication behaviors of both Deaf and hearing conversation partners.

Communication between Deaf and Hearing

Being able to communicate with hearing persons is sometimes crucial for Deaf people, for example during an emergency or when visiting the doctor. Doctors and paramedics may not be able to sign, and interpreters may not be available. Buttussi et al. [7] analyzed typical communication patterns between deaf patients and emergency respondents. Based on interviews, they developed an application providing recorded video translations of questions typically asked in emergency situations. An evaluation showed that the application eased communication and fostered understanding. Piper et al. proposed an application running on a tabletop for supporting patient-doctor conversations for deaf and hard of hearing persons [34]. On the tabletop, information supporting the conversation such as information material, x-ray scans, translations and text entry results were shown. Typical patient-doctor conversations were analyzed with the tabletop and with an interpreter. The findings show that the tabletop supports conversations. They also highlight the importance of cultural factors when developing ATs for the Deaf. In contrast, we did not compare one AT with interpreter mediated conversations, but analyzed how different ATs influence conversations.

Video calls, caption phones and teleconferences with interpreter services allow the Deaf to communicate not only when co-located, but also over a distance. Vogler et al. report on conducting teleconferences with groups including hearing, deaf and hard of hearing participants [44]. Based on their experiences with incorporating interpreters, they propose an accessible infrastructure setup and outline their lessons learned from several teleconferences, covering technical issues but also requirements for the communication, such as enforcing rules to ensure only one person speaks, positioning webcams so every signing person is fully captured, including sufficient interpreters, time delays caused by interpretation leading to confusions, as well as changing interpreters leading to disruptions. Concerning the comprehensibility of sign language when using video calls, Tran et al. showed that even with low frame rates communication partners could understand each other in free form-conversations [41]. We also rely on life interpretation in our study, yet we focus more on ad hoc every day conversations with co-located conversation partners.

Communication in classroom settings is also a topic of active research. Prietch and Filgueiras developed a technology acceptance model of ATs for deaf and hard of hearing persons in classroom settings [35]. Their model is based on both a literature review and questionnaires, whereas our observations are based on qualitative observations of everyday conversations. Focusing on lowering communication barriers and fostering understanding, Kushalnagar et al. analyzed how deaf students can be better supported in classroom settings [25, 26]. Regarding live captions of lessons, they found that deaf students preferred captions created by their classmates over automated speech recognition software [26]. Although we also evaluate the influence of live translation systems, communication in our scenarios is more bi-directional than in usual classroom settings, and also involves interpreting signs.

To foster the learning process of young sign language learners, Huenerfauth et al. analyzed how feedback in video-based sign language learning systems could help improve skills [16]. They conducted a Wizard of Oz study to evaluate several types of feedback, and showed that giving feedback both increased students' subjective rating and their sign language skills. While we also conducted a Wizard-of-Oz study, we rather focused on the effects ATs have on conversation partners using live interpretation. Focusing on parents of deaf children, Weaver et al. examined how sign language learning could be supported with mobile devices [46, 45]. They showed that sign language learners can successfully reproduce signs shown as videos on mobile devices. While we evaluate mobile interpretation systems, we focus more on ad hoc every day conversations than on learning of sign language.

In addition to academic research, ATs for the Deaf are also of interest for commercial software providers. Example applications include Ava [1] and UNI [29]. Ava is a real time captioning application leveraging the smartphones of each communication partner to locate and recognize their speech. Conversation is then transformed into a chat-like written protocol conversation partners with hearing problems can consult to follow the conversation. UNI recognizes signs and translates them into speech, and recognizes speech and transforms it into text. Those solutions aim to address a similar aspect as our research, though we also analyze how ATs influence communication behavior and communication quality.

COMMUNICATION QUALITY AND OPPORTUNITIES FOR FUTURE ASSITIVE TECHNOLOGIES

In this section, we define and discuss our understanding of communication quality for ATs and present a potential change in design perspective for future ATs.

Communication Quality for ATs

The range of possibilities for ATs to lower communication barriers is best described by the U.S. Assistive Technology Act of 1998 (amended 2004), which defines ATs as "any item, piece of equipment or product system whether acquired commercially off the shelf, modified, or customized that is used to increase, maintain or improve functional capabilities of individuals with disabilities." [8, p. 2]. Yet, as Shinohara et al [38] note, there is a strong emphasis on the functional capability of an AT in this definition. Focusing on the functionality communicates that the person using an AT has limited abilities and can lead to maladaptive behavior [13], as well as to the abandonment of the AT [30, 36]. For ATs that aim to lower the communication barrier, this definition means that any technology that enables people who are deaf or hard of hearing to better communicate with others functionally improves conversations. However, the problem here is that ATs, even if they are functioning perfectly well, might still influence the conversation negatively.

For example, when using real-time captioning, conversation partners who are following the written captions on their mobile phone might be led to focus more on the phone than on their conversation partners. This could be challenging for both: the conversation partner not reading captions might feel ignored, while the conversation partner reading captions might miss information on other communication channels like gestures and mimic. Similar problems arise when using instant messaging or paper and pen in a face-to-face conversation, both conversation partners are mainly engaged with the technology instead of each other. Cochlea implants, as well engineered and functioning as they are, lack acceptance in parts of the Deaf community due to forcing them to use communication channels they are uncomfortable with (spoken language) and making their preferred communication channel (sign language) obsolete. To address these aspects, research on ATs started to broaden its definition and focus [10] beyond mere functionality. Shinohara et al. [38] identified social perception as an important factor for the acceptance of ATs. Similarly, we propose to broaden usability considerations of ATs for the Deaf to encompass both deaf and hearing communication partners (conversation partners) in the design and evaluation of ATs.

Important for usability is achieving goals with "effectiveness, efficiency, and satisfaction" (ISO 9241-11) [17]. For a conversation, this means that information should be communicated so that the communication partner can understand it and that both conversation partners are satisfied with the communication outcome. Communication quality can be leveraged to assess satisfaction in conversation settings. A conversation with high communication quality should leave all conversation partners with the feeling that they achieved what they wanted in the form they wanted it in a most comfortable way. It also lets both conversation partners communicate with the same level of agency. Thus, communication quality is closely related to usability, as well as user experience, which takes a more holisitic view on users' interactions with technology, especially their perception of and reaction to systems. We argue accordingly that not only the effective and efficient achievement of goals, but also the quality of communication and its perception by the involved conversation partners should be considered when evaluating ATs for the Deaf and hard of hearing.

Considering the communication quality for *both* conversation partners poses certain challenges, especially when the preferred communication channels differ. Using different communication channels means to comply with certain norms and best practices these channels imply. For instance, proper lip reading is only possible if the conversation partners are facing each other and the mouth is clearly visible. Conversation partners who can hear might not be aware of this constraint, since it is not a requirement of their preferred communication channel. Similar issues occur when ATs are used in a conversational context. While a certain AT might be a useful and usable solution for one conversation partner (e.g., a deaf person can follow the conversation with real-time captions), it might not be equally well perceived by the other conversation partner (the conversation partner who can hear might be irritated because the conversation partner who is deaf only looks at their smartphone). Such irritations may negatively affect communication quality. To avoid this, both communication partners' perception of the communication has to be considered. However, the effects of ATs on the communication quality of both communication partners has rarely been studied in prior work. Most research focused on the functionality of a certain AT, or how one conversation partner could benefit from the AT. Due to the complexity of assessing communication quality and the lack of established metrics, we opted for qualitative analysis and focused on perceived communication quality (elicited through interviews) and observed communication quality (coding of interactions in conversations).

A Change in Design Perspective for ATs

As defined by Harre et al. [14], a conversation is an interaction sequence with a defined beginning and end, turn taking, and some sort of purpose or set of goals. An AT that aims to support communication between deaf and hearing people has to integrate itself into these phases of a conversation. However, we argue that the goals or purpose of the conversation should not be influenced by the AT, i.e., using the AT should not require the communication partners to adjust their goals or outcome expectations for the conversation. ATs should primarily modulate between communication modalities in a conversation, which matters in particular in turn taking and at the beginning and end of the conversation. Despite these goals, some ATs may lead to maladaptive behavior such as a change of the goals and purpose of the conversation or even avoidance of the conversation [13].

Most existing ATs act as a tool that is only operated by the deaf communication partner, emphasizing their dependence on the AT and their deficiency to communicate otherwise. This clashes with the dominant self-perception and identity of the Deaf community, who do not see their condition as a disability but rather identify themselves as a "visual community" [43]. Therefore, we asked the question how ATs could be designed to enable the Hearing to sign rather than forcing the Deaf to "hear." An AT should act as an interpreter but without emphasizing deficiencies.

One way to achieve this goal could be to actively involve the hearing person in the translation process. Augmented reality with head-mounted displays or mobile projection could enable such interactions. Augmenting the hearing person with a visualization of computer-generated arms that translate the spoken word of the hearing person into sign language could create the impression that the hearing person is able to communicate using sign language. Similarly, the signs of the deaf person could also be captured, interpreted and translated into spoken language which is then played back through a speaker. This would allow each communication partner to use their preferred modality. Progress in the field of real-time translation of sign language would allow for this approach to be implemented in future ATs. In order to assess and compare its impact on communication quality, we developed prototypes of this concept, which we call BodySign. Note that we were primarily interested in studying the effects of the respective change in design perspective with regard to communication quality.

STUDY ONE: FOCUS GROUP

We conducted a focus group to gain a deeper understanding of challenges deaf people experience with assistive technologies. We further elicited perceptions, reactions and feedback regarding future real-time translation-based ATs.

For this purpose, we implemented two mockup prototypes of BodySign and used them as technology probes in the focus group. One prototype was implemented using a projector, projecting recorded arms of a signing person onto the body of the hearing participant. The concept of augmenting a person with projected arms is depicted in Figure 1. The second prototype used Google Glass to show the signs translating the currently spoken text. We decided to use those technologies since they both are capable of realizing the concept of BodySign and are both becoming more prevalent in upcoming consumer technology [5, 37]. Both prototypes were implemented as mockups with predefined sentences to say. Participants were asked to stand in front of each other and two of the authors held up posters with the sentences they should say (see Figure 2). We choose this approach to better understand the implications of changing the design perspective for AT and involve individuals from both communities (Hearing and Deaf) in the design before fully implementing it.

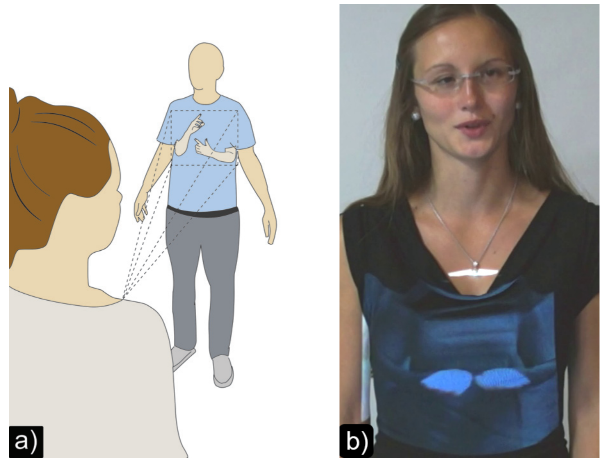

Figure 1. The BodySign concept. Hearing communication partners are augmented with signing arms, either by projection or by HMDs. Both communication partners can communicate using their usual communication channel (a). A prototype of the projection variant of BodySign (b).

Figure 2. Image taken during the focus group. Two persons (one Deaf wearing a blue shirt, one hearing wearing a white shirt) testing the projection variant of BodySign. Due to the prototype being a mock up, two researchers standing behind the conversing participants are holding up posters with the sentences participants should communicate.

Procedure

The focus group consisted of three phases: the introduction, the practical task and an open discussion. During the whole session a sign language interpreter was present to translate into both directions to facilitate understanding by both hearing and deaf participants. We recruited participants from three groups: deaf and hearing impaired, hearing with knowledge of sign language, and hearing without pre-knowledge.

During the *introduction* we explained to the participants that the goal of this study was to learn about their experience and challenges with current ATs and gain feedback on the design of potential future ATs. They were asked to introduce themselves to the rest of the group by stating their name and their favorite food (as an ice breaker). Each participant was asked to do this introduction in their preferred modality (e.g. sign language). The interpreter translated as necessary. This helped the group to get acquainted with the communication style of each individual. Then the concept and both technical realizations of BodySign were presented and explained. In the *practical part* each of the deaf participants was asked to try both technical props (projection and smart glasses) to communicate with a hearing participant. All other participants were asked to watch the conversation. Their communication and interaction, as well as the conversations of the bystanders were recorded using a 360 degree camera. Afterwards all participants had to fill out a questionnaire about their impression with the presented technology and their general experience with ATs in their daily life. The final part consisted of an open discussion about the presented concept and ATs in general, and how they influence participants' daily lives. The focus group session lasted approx. 2 hours and was video recorded with a 360 degree camera and a standard camera.

Participants

We recruited 13 participants (5 deaf and hard of hearing, 3 with knowledge of sign language, 5 without any pre-knowledge). The hearing participants were recruited randomly using hangouts, while the deaf participants were recruited through the local Deaf association. The average age of the deaf participants was 48 (range: 41 to 54). All had at least graduated high school and had diverse occupations in different fields (e.g. technical assistant, media designer, or electrical engineer). One of the deaf participants wore a hearing aid, while the others mostly relied on their lip reading and speaking ability. The average age of the hearing participants was 29 (range: 21 to 41) being mostly students at our university studying various subjects (e.g., psychology, computer science). Each participant received €15.

Findings

The video footage of the focus group was transcribed by colleagues with sign language knowledge. All transcripts and video data (interaction and group discussion) were coded independently by three researchers using open and axial coding. Afterwards, they re-watched several sessions together in order to arrive at a consistent interpretation consisting of categories and general themes. Conflicts were resolved by discussing each individual coding.

Current Situation and Relevant Scenarios: The deaf participants described scenarios in which short inquiries were necessary as situations in which they had a high need for ATs. Such scenarios included ordering food in a restaurant or buying a ticket at a counter (e.g., for the train or a movie). The participants explained that these scenarios typically do not require deep conversation but a particular goal has to be achieved (e.g. purchasing the correct train ticket). These short interaction scenarios often arise spontaneously when no interpreter is available. Participants reported that they typically have to resort to lip reading and writing or speaking. Even though participants found none of these solutions ideal, they have no other option to communicate in such face-to-face scenarios. P1 commented on writing in face-to-face conversations: "It is unpleasant in stress situations but I don't have another choice." One participant also reported that she could only read lips for about one hour before it becomes too exhausting. Speaking is an option that some deaf participants have, but it was often reported as uncomfortable. P4 (a deaf teacher for sign language) reported that she was forced as a child to speak and has a negative association using her voice.

Desire for Joint High Quality Communication: Deaf participants emphasized the desire and need for ATs that provide high communication quality in face-to-face conversations. Our presented prototypes (projection and Google Glass) were perceived positively since they allowed to maintain eye contact during the conversation and allowed to read the facial expression. Both prototypes simulated real-time sign translation, which was seen as an essential feature for future ATs since it would enable AT support in short and spontaneous face-to-face conversations. Subsequently, participants started to discuss general technical challenges for the development of such ATs. An interesting aspect was that deaf participants were quite concerned about the perception and comfort of the hearing communication partner during the conversation. Multiple deaf participants mentioned that an unpleasant experience for the hearing partner would probably result in a rejection of the AT.

Technology Comparison All deaf participants used both prototypes (projection and glasses) to communicate with a hearing participant (see Figure 2). In a comparison between both technologies, deaf participants tended to prefer the projection over the glasses (3 out of 5). Participants valued the possibility of having a group conversation where the projection would allow several deaf people to participate. Furthermore, the projection was considered self-explanatory to the hearing participant and potential bystanders. Using Google Glass, deaf participants noted that the small display prompted a hearing person to want to know what exactly the other is seeing. Based on these insights and feedback we decided to focus on projection as an incarnation for our collaborative AT for the second study. An interesting side effect of the projection is that it literally puts the hearing participant into the spotlight. We decided to investigate this aspect further in our second study.

Overall, the focus group provided insights on what current ATs deaf people use for face-to-face conversation. Participants reported to use translation services such as TeleSign[2] or ask a hearing family member to help with conversations which are scheduled in advanced (e.g. doctors appointment). In spontaneous and short face-to-face conversations none of our participants relied on technology but used gestures, speech (if possible) or pen and paper (if necessary). Participants positively mentioned the ability to keep the focus on the facial expression and mouthing of the conversation partners which both technologies supported.

STUDY TWO: COMPARATIVE EVALUATION

Based on the insights gained in the focus group, we designed and conducted a subsequent lab study to investigate the impact of different ATs on communication quality in a more controlled manner.

Study Design

The major goal of the study was to evaluate the overall impact of real-time translation-based ATs on the communication quality in conversations between deaf and hearing individuals. Since we were primarily interested in the implications of future real-time

[2] www.telesign.de

Figure 3. The setup of the second study. The sign language interpreters translations were either streamed to a mobile phone (a), which the Deaf participants could hold as they pleased while communicating with the hearing participants, or streamed and projected onto the hearing participant (b). The setting involved one hearing participant standing behind a counter (c), left most person), one hearing participant acting as a bystander (c), person in the middle), and a deaf participant standing in front of the counter (c), right most person). Props were provided for each scenario (e.g., posters of movies and tickets).

Figure 4. Sign language interpreter (left, standing) and experimenter (right, sitting) in the separate room. The interpreter interprets, while standing in front of a camera. The camera (encircled) is adjusted so that only the upper body is recorded.

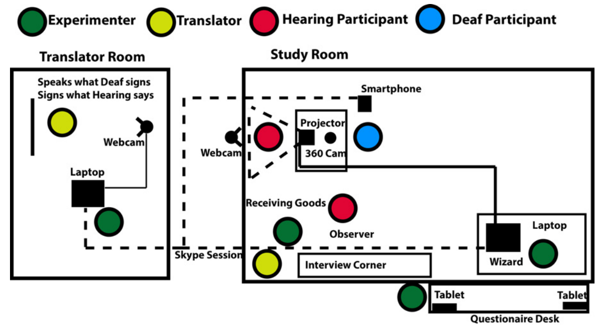

Figure 5. Schematic overview of the second study's setting. Green circles represent the experimenters, beige the interpreters. The red circles resemble two hearing participants (one as communication partner, one as bystander), and the blue circle represents the deaf participants' position. One interpreter and one experimenter were always present in a separate room (participants were naive to there being a second interpreter), where the interpreter performed life interpretations. Audio and video signals of the interpretations were streamed to the main room. The second interpreter and the other examiners were present in the actual room where the study took place, as were all participants.

translation-based ATs, we used a Wizard of Oz experiment that simulated fully functional systems able to translate from and into sign language. We hired two graduate students of German Sign Language (GSL) to act as the "wizards" over a period of one week in which we conducted the whole study. This approach allowed our participants to freely communicate using each of the ATs we asked them to interact with, and it allowed us to study the impact a fully functional system would have on communication quality. We compared three different types of ATs and assessed their individual impact on communication quality. The three ATs are shown in Figure 3 and described below.

Projection: This condition corresponded to our proposal to change the design perspective of ATs towards collaborative technology. The system in this condition corresponded to the projection-based prototype of BodySign from the focus group. The words spoken by the hearing person were translated live by the wizard into signs, which were then projected onto the upper body of the hearing participant. This created the impression that the hearing person was able to sign. The deaf participant could respond in sign language, which was then translated into spoken language and played on speakers attached to the projector.

Smartphone: This condition was motivated by emerging smartphone apps that aim to provide real-time translation, e.g., Ava [1] and UNI [29]. Focus group participants also reported to already use smartphones for other forms of communication (e.g., online chat). We simulated a fully functional translation app with the same capabilities as the projection system. Words spoken by the hearing person are live-translated into sign language, which is shown on the smartphone. The deaf participant could also sign as a response, which was then translated into spoken language and played by the phone. Participants where instructed that they could freely sign without having to face the smartphone's camera. The translation for the projection and the smartphone was done live by our interpreters which observed the full scene through a webcam from a second room (see Figure 5).

Pen and paper: This condition served as a baseline. Participants were asked to solve a daily task using only pen and paper for support. This simulated a scenario frequently faced by deaf people in their daily lives, as reported in our focus group. While manual, we consider pen and paper an AT because it is frequently used as such by the Deaf community.

Apparatus

In our Wizard of Oz setup, our interpreters translated live between speech and sign language, and vice versa. The schematic setup of the study is shown in Figure 5. The study was conducted in two different rooms. In one room the interpreter (wizard) was placed in front of a laptop and a webcam, allowing the interpreter to follow the conversation inside the second room and live translate as needed. The webcam stream was displayed by the AT (smartphone or projection). The wizard was instructed to wear black cloths and white gloves to ensure high contrast between hands and body. The webcam was focused on the interpreter's upper body of the interpreter (see Figure 3) so that the interpreter's head was not shown. We actively decided not to include the head to avoid conflicts in mouthing and facial expressions between the wizard and the participant projected onto. To ensure that the projection was properly positioned and sized even when the hearing participant moved, one of the experimenters continuously re-adjusted the projection via a laptop.

At the end of the study, all participants were asked how they thought the technology works. None of them realized that it was a Wizard of Oz study with a human interpreter. Two interpreters and three experimenters participated in each session.

Procedure

To gain a holistic assessment of the communication quality of each AT, we recruited a triad of participants consisting of a deaf participant, a hearing participant and a hearing bystander. This was motivated by the fact that, during the focus group, deaf participants were concerned about the perception and comfort of the hearing communication partner during a face-to-face conversation. Thus, we interviewed the hearing conversation partner to gain insights on their perception of the used AT. Furthermore, we added a bystander to simulate a public environment and create a certain pressure as often experienced in public scenarios, according to our focus group participants. We also interviewed the bystander, following the suggestion of Shinohara et al. stating the relevance of public perception for the acceptance of AT [38].

Communication Roles: Each of these roles received specific instructions. The deaf communication partner was instructed to complete a specific inquiry task using one of the ATs. The tasks and the AT were counterbalanced using a Latin square. The hearing communication partner was instructed to play a "sales person" with specifics based on the actual scenario, but otherwise behave like they would in their daily life. The bystander was instructed to act as an observer in a public scenario (e.g., waiting in the queue behind the deaf participant).

Communication Scenarios: Each communication scenario was derived from everyday scenarios reported in the focus group. The three communication scenarios that were mentioned the most in the focus group were buying a train ticket, buying a movie ticket, and buying coffee in a cafe. To contextualize the scenarios, each scenario was supported with props such as posters, which were placed behind the hearing participant (see Figure 3), or schedules and price lists placed in front of the hearing participant. The participants were allowed to use all the props provided. We carefully crafted the scenarios to be comparable in terms of communication difficulty. In the cafe scenario, the deaf participant had to buy a specific type of coffee and cake; in the train station scenario a train ticket to a specified city at a specified time; and in the cinema scenario a ticket for a movie showing at a specific time and with subtitles.

Each session involved three participants, one deaf person, one hearing communication partner and one hearing observer. After an introduction, each participant received instructions regarding their specific role and that the focus of them was to test three different ATs for communication between deaf people and hearing people. During a session, one of the two interpreters translated all instructions for the deaf communication partner and was available in case of questions. After the introduction, the deaf participant was given a specific task (e.g. buy a ticket to Berlin leaving at around 10pm) and one of the ATs (based on the Latin square) was introduced to all participants in the session. Both, the hearing and deaf communication partner were given time to familiarize themselves with the AT and ask questions, until they felt comfortable using it. Then they were asked to start their conversation and they tried to fulfill the given task. Afterwards, the participants were interviewed separately about the conversation. One of the two interpreters translated for the deaf communication partner. After the interview, the next AT was introduced and used in a different scenario. After all three ATs were tested, participants filled out a final comparison questionnaire and were again interviewed individually to compare the ATs. Overall, a study session took 1.5-2 hours to complete. Our studies received IRB approval.

Methodology

All interviews and the interactions themselves were video recorded (approximately 6.5 hours of interview and interaction footage) and transcribed verbatim. Every transcript and interaction video was coded by two of the authors in several joint coding sessions using open and axial coding. Conflicts were resolved by discussing each of the coding decisions. In an iterative process categories and themes were extracted and placed in relation to each other.

In addition to interview and survey responses, we collected several quantitative metrics. In our analysis we will focus on emotional state (SAM [4]) and number of interaction cycles (an interaction cycle consists of a question and the respective answer of the communication partner). The number of interaction cycles indicates a metric for the efficency of the conversation, i.e., how long it took to reach the desired goal. A high number represents more inquiries and indicates the need for additional clarification. An ideal technology task would result in a low amount of interaction cycles. The SAM questionnaire consists of three subscales (dominance, arousal and pleasure) ranked on a nine point scale. It enabled us to assess participants' emotional state after the use of an AT.

Participants

We conducted six sessions with 18 participants (6 deaf, 6 hearing active, 6 hearing bystander) recruited through posters and mailing lists. We scheduled every session to consist of one deaf participant and two hearing participants. At the start of the session, the roles for the active and passive hearing participants were randomly assigned. The deaf participants were mainly recruited through the local Deaf association, though none of them had participated in the focus group. The hearing participants were on average 26 years old (range: 18 to 35) and had mostly an academic background, being students at the university. The deaf participants were on average 39 years old (range: 22 to 49) and had a more diverse background (see Table 1). Deaf participants who used a hearing aid removed it for the study. Each participant received €15.

Findings

We organized the identified themes in a model of the communication process, as shown in Figure 6. In the following, we will discuss each of those themes individually, in particular how they impact the communication process.

UserID	Sex	Age	Employment	Hearing Aids	How do you communicate with hearing people in your daily life
D1	F	49	Technical Drawer	None	Difficult ! Slow and focus on enunciation
D2	F	43	Cleaning Lady	None	Sign language Interpreter
D3	F	47	Cleaning Lady	Behind the Ear Aids	Using the voice and writing
D4	M	49	Carpenter	Behind the Ear Aids	Mostly lip reading
D5	F	22	Medical Assistant	Cochlea Implant	Lip reading (Viseme)
D6	M	23	Student	Behind the Ear Aids	Smartphone and slow speaking using the voice

Table 1. A detailed overview of the deaf participants in the second user study.

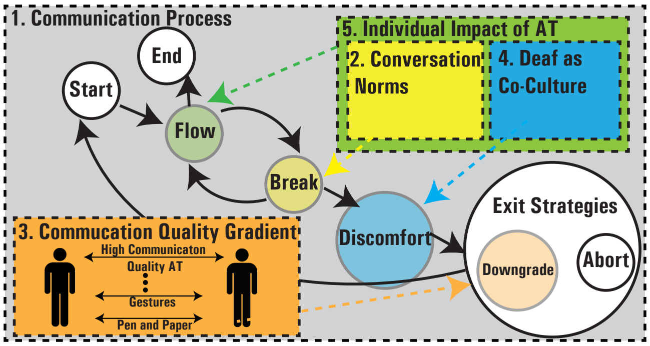

Figure 6. The model of the communication process (from the perspective of the Deaf participant).

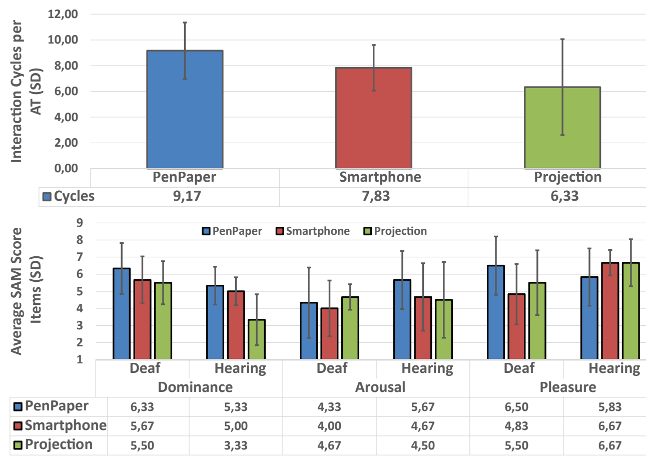

Figure 7. Distribution of the quantitative data: (top) interaction cycles for each AT and (bottom) the three subscales of the SAM questionnaire for each AT.

1. The Communication Process based on Discomfort, Wellbeing and Exit Strategies: Due to the nature of our tasks, all 18 conversations followed a similar process (see Figure 6). The deaf participants tried to achieve a goal and initiated a conversation. The conversation had a certain flow until a communication break occurred. During the flow, participants reported feeling well and comfortable, which often coincided with a high perceived communication quality. We asked participants to describe the conversation using three adjectives. Conversations which had few to no breaks were most frequently described as "natural," "easy," and "comfortable." This often occurred in scenarios where each conversation partner could use a modality they felt comfortable with (e.g., speaking for the hearing). In accordance with Communication Accommodation Theory [11], this wellbeing was enhanced if the communication partner adjusted to accommodate the other's modality, e.g., deaf participants using their voice (D5, D6), or hearing participants using signs for numbers. This is described in the Communication Accommodation Theory as *convergence* – where someone from a different group will adapt their communication behavior to reduce social differences. However, the difference between our participant groups is not created through active behavior but is inherent due to different capabilities. Almost every hearing participant started this adjustment by using signs for numbers and speaking slowly, which is consistent with Piper et al.'s findings [34].

During the communication flow, the AT effectively facilitated the communication, having little noticeable influence on the conversation. A perfectly functional AT would disappear into the background and remain unnoticed by both communication partners, keeping them in a state of communication flow until both achieved a positive outcome and the conversation ends (see Figure 6). However, the AT became noticeable when communication breaks occurred (e.g. misunderstanding). In case of a break, all deaf communication partners picked between one of two exit strategies depending on their level of discomfort: (1) In case of a high level of discomfort, the deaf participants tried to end the conversation even if it meant accepting a suboptimal solution (e.g., wrong time for the train ticket). For instance, participant D3 had to quit the task using the smarthphone since the conversation resulted in a situation in which both communication partners did not understand each other. D3 then apologized and aborted the task. (2) In case the deaf participant still felt sufficiently comfortable, he or she either continued with the same modality (6 x phone condition, 6 x projection condition) or "reset" the conversation. The "reset" was done by switching the interaction modality (2 x projection) to a modality with lower communication quality but higher transparency (see theme transparency) and more likely to lead to a successful outcome (e.g., starting to speak and point).

D1 after a communication break occured with the projection: "I would have used pen and paper now if that would have been an option. I mean if it would have been a possibility I would have carried pen and paper with me."

In several conversations (8 x pen and paper, 1 x smartphone, 3 x projection) participants did not fully switch to a lower interaction modality but instead added a modality, such as gestures (6 x pen and paper, 1 x smartphone, 3 x projection) or using props in the surrounding (2 x pen and paper, 1 x projection).

2. The Roll of Conversation Norms: We were particularly interested in why communication breaks occurred and what role the AT had in those breaks. We defined a break as an interruption in the conversation flow (e.g., misunderstanding, addressing the experimenter, conversation stop, visual discomfort). Every session exhibited some kind of communication break. We conducted a deeper analysis and identified two main types of breaks in the communication: content-related or norm-related. The content-related breaks occurred when one of the participants did not understand a statement of their communication partner. Content-related breaks may not be related to the AT but could happen for several reasons (e.g. misheard, misunderstood). The norm-related breaks happened with every AT (8 x pen and paper, 7 x smartphone, 1 x projection). All of them occurred when certain conversation norms from one culture were not respected by the other communication partner (e.g., hearing participant not facing the deaf participant while talking). This aligns with Burgoon et al.'s Expectancy Violations Theory [6], which states that unanticipated violations of social norms in a conversation can lead to a negative perception of the violator. In case of a violation, the level of arousal (i.e., stress) of the other communication partner will raise and he or she will focus more on the person who committed the violation then on the message. Based on our data from the SAM questionnaire (see Figure 7), pen and paper resulted in the highest level of arousal for the hearing participants indicating a high level of norm violations/communication breaks. In the post interviews, both deaf and hearing participants reported negatively when such a break occurred.

D1: "Well if they speak too fast for instance, or when they mumble and don't enunciate properly or if it is a small mouthing that's also difficult. It is important that I can see their face, that we are face-to-face and the other does not look away." H8: "Yeah, that [using the smartphone] resulted in her not facing me during the conversation and in those awkward breaks. That's why it was weird to me."

Our findings suggest, that ATs can have a large influence on whether those breaks occur by implicitly supporting or ignoring norms. All the norm-related violations we found were related to the visual focus (probably because the visual focus was one of the major differences between our ATs). Deaf participants mostly (1 x pen and paper, 4 x smartphone) created breaks by constantly focusing on the AT instead of the hearing participant and thereby missing visual cues (e.g., nodding, pointing). Hearing participants mostly (7 x pen and paper, 3 x smartphone, 1 x projection) violated the rule of "facing the conversation partner while speaking," which resulted again in the deaf participant missing visual cues. For example, the pen and paper condition did not support simple norms from both cultures, but supported negative behavior such as writing and talking at the same time. In our study, this went so far that D1 paused the conversation with H1 to explain certain ground rules on how he should behave in order for her to be able to understand him. The projection, on the other hand, implicitly enforced some norms of the Deaf community, such as not turning away and talking, since turning away would lead to the deaf communication partner not being able to see the projection. This lead implicitly to the deaf participants being able to read lips during the conversation.

Furthermore, in almost every session deaf participants violated the norm of keeping eye contact during a conversation. Even if this is not necessary for the conversation to work, it is relevant for the communication quality as it was frequently mentioned negatively by the hearing participants.

H9: "[...] I expect if someone is not talking and cannot hear that they focus permanently on the piece of paper and keep less eye contact. That is why I liked the [projection]. I had the feeling it was all happening on the side and you keep eye contact. But if you have this piece of paper you only focus on it."

3. Transparency and Communication Quality Gradient: Based on the observed interactions and participant interviews, the three technologies we evaluated can be arranged based on their level of communication quality and transparency. A technology with high communication quality leaves all conversation partners with the feeling that they achieved what they wanted in a most convenient way. This perspective is also supported by the number of required interaction cycles (see Figure 7) where the projection required the fewest cycles (M=6.33, SD=3.72), pen and paper the most (M=9.17, SD=2.19), and the smartphone the second most (M=7.83, SD=1.77). This suggests that both parties would prefer the projection initially, since it demands the least effort (least cycles). However, based on our analysis of the communication process, we found that in case of a break, participants often add or even switch to a technology with a higher level of transparency (with transparency we mean the ability to be more in control of the functionality and reduce ambiguity). This kind of technology offers the user a higher level of control and understanding of the functionality. Participants (Deaf and Hearing) reported the highest level of transparency when not relying on a technology at all but using pen and paper or gestures. Participant D3 started the pen and paper condition trying to communicate using gestures and speaking but after the first break fully switched to a turn by turn writing "conversation." This allowed both participants to fully understand each other but was perceived negatively by the hearing participant.

H5: "Yes, it took very long. Well it is complicated if I want to say something. I have to write it down first and this takes a while. Then she has to read it and respond by writing and this just takes ages and does not really progress."

The observed interactions suggest that transparency and communication quality are inversely related. This also implies that there will likely not be a perfect technology for every scenario but that an interplay of different technologies may lead to the best outcome (e.g., use of projection but also carrying pen and paper as a backup).

4. Deaf as Co-Culture: Based on our analysis, we found strong analogies to Orbe's co-cultural communication theory [31]. The Deaf community can be understood as a subordinate group in the dominant hearing society. Orbe's theory focuses on communications between individuals from underrepresented groups and representatives of the dominant society. Orbe's theory builds upon the muted group theory by Kramarae [24] and the standpoint theory by Hartsock [15]. The standpoint theory emphasizes how the dominant society has their "limited" social knowledge since the viewpoint of the co-culture is "invisible" to them. In our scenario, the hearing community is often not aware of their dominance and does not know behavioral norms or even superficial facts of the Deaf community (e.g., the fact that there is not a single sign language but 138 different ones [27]). The muted group theory states that dominant groups determine and control the dominant communication system and thereby mute the subordinate group. In current society, the Deaf community is forced to express itself by adapting to the dominant (spoken) language.

Orbe further explains what communication strategies co-cultures apply (non-assertive, assertive and aggressive) to achieve a preferred outcome when interacting with the dominant group (assimilation, accommodation and separation). In our study, deaf participants followed a non-assertive communication strategy ("putting the needs of others before one's own" according to Orbe) striving for separation ("rejecting the notion of forming a common bond with the dominant group and seeking to maintain separate group identities outside the dominant structure" according to Orbe). In case of a communication break during the conversation, deaf participants were mostly looking for mistakes they made since they felt they were not able to master the dominant language (non-assertive). This struggle led to frustration and could potentially lead to an abandonment of the AT (separation). Participant D1 reported about her overall struggle during those communication breaks: *"Well, it's always a fight for me if I have to say that something with the conversation is not working out [...]."* In the pen and paper condition, the AT faded into the background as both conversation partners relied on their basic communication capabilities. This exposed the struggle of the deaf participants to communicate in the dominant language and ended in them blaming themselves for the communication breaks that occurred.

D3: "So without my hearing aid it was difficult for me to understand the speaker. This I have to ... This I have to learn."
D2: "Well there were parts which I really could not understand. Like when she was speaking, and that is my personal problem, I cannot read lips. It would have been better if we would have written or she would have written it down."

One hearing participant unconsciously (standpoint theory) encouraged this behavior by emphasizing that he already said a certain fact and the communication break was not his fault since he provided the information already. *"As already mentioned, there are three trains going to [...]."* During the smartphone condition the focus of the deaf participant was mostly on the technology. The technology became a third agent in the communication (almost like an interpreter). This resulted in a scenario where the blame for communication breaks was directed towards the AT. *H5: "I had the impression that she signed something and the system did not translate it. So you wait, nothing happends and you wait and still nothing happens, that was a little difficult [...]."* An interesting effect could be observed with the projection-based AT. Similar to the pen and paper condition, the AT faded more into the background and actually blended with the hearing conversation partner. This led to situations where the hearing participant felt responsible for communication breaks, since they fused with the technology and "became" one agent. These findings correspond with the dominance scale results from the SAM questionnaire (see Figure 7), where hearing participants reported the lowest level of dominance in the projector condition (projection: M=3.33, SD=1.49; smartphone: M=5.00, SD=0.82; pen and paper: M=5.33, SD=1.10).

H7: "I always had to pay attention if it is good on my belly, is it clearly visible."
D1: "[...] otherwise I would have asked if she could speak slower so I could also read lips. That's why I wanted to tell her to try a little harder."

After the study, one hearing participant mentioned that he preferred when the deaf participant used the smartphone since he was not responsible for anything in this conversation. Note that both participants are from different cultural groups. According to the anxiety-uncertainty management theory by Gudykunst a high level of anxiety and great level of uncertainty exists in a first encounter [12]. The theory describes that if the level of uncertainty in a communication goes over the acceptable threshold for the conversation partner, the level of anxiety grows as well. In a communication between a deaf and a hearing person both parties will have a high level of uncertainty if this is their first encounter. None of our hearing participants ever had a face-to-face conversation with a deaf person. Therefore, the participants preferred when the deaf participants focused on the phone. In case of a communication break, the technology was responsible instead of them feeling responsibility for it. In contrast, the projection created the impression that in case of a break the hearing participant being projected on was a fault.

5. The Impact of each individual AT: Each of the evaluated ATs had different implications for communication quality. Pen and paper were mostly perceived as a fall back technology resulting in some participants even forgetting that they could use it. As an AT, pen and paper does not facilitate high communication quality in conversations since it does not fulfill any communication norms but even encourages breaks of these norms. However, it is an ideal fall back AT since it gives the participants full transparency over its functionality (as discussed in the transparency theme). Between all ATs used in our study, deaf participants reported the highest level of pleasure using pen and paper (M=6.50, SD=1.71) and hearing participants the lowest (M=5.83, SD=1.67). This indicates that deaf participants were more familiar communicating without any technology and hearing participants preferred having technology to support them during the conversation. Hearing participants also reported the highest level of arousal (M=5.67, SD=1.69) using pen and paper. This further indicates that they were anxious communicating without any technical support. *H3: "... well if you can't rely on anything, like no one is projecting information on my belly then you constantly have the feeling of being up a creek without a paddle."*

The smartphone allowed both conversation partners to use their preferred modality to communicate. Because of that, participants preferred it over pen and paper in terms of communication quality. However, it breaks several communication norms such as the focus of the deaf participant which is mostly on the device itself and not on the communication partner. It creates a third agent which becomes part of the conversation similar to an interpreter. In case of communication breaks, participants were more likely to blame the device instead of one of the communication partners. A conceptual downside of the technology is the fact that the deaf person has to hold the device in one hand whilst signing. Participant D5 directly addressed this downside and placed the smartphone on the table to be able to freely sign with both hands.

The projection had an interesting effect on the communication quality. In contrast to the smartphone, it did not create a third instance in the conversation but became part of the hearing communication partner. Even if the deaf participant did not actively start to blame the hearing person for communication breaks, the perception of responsibility for the success of the conversation changed drastically for the hearing participants (lowest level of dominance M=3.33, SD=1.49). They felt more responsible for breaks and made an effort to fulfill their expectations. Participants reported that they did not feel uncomfortable being projected on but struggled more with the fact that they were restricted in movement. *H7: "You are more restricted and cannot do anything besides standing still like an advertisement board while he tries to read."* Even if perceived negatively by the hearing participants, it enforced the communication norm of always facing the deaf partner when talking. With the other technologies, hearing participants sometimes enforced their communication norms as they could point at the object of interest, turn towards it, and talk about it.

The bystanders reported mostly the same feeling and perception of the conversation as the active hearing participants. They acted mainly as a multiplier for the two active communicators by creating the feeling of being watched. The only opposite perception between bystander and hearing conversation partner was the impact of the projection on the body. Bystanders often reported that they would expect to feel more self-conscious if they would be projected on. However, all the hearing communication partners unanimously reported that they did not mind being projected on. H5 when asked about the projection on his body said: *"During the conversation I actually did not notice it. Well only if I intentionally looked down on me but otherwise I did not notice it when I focused on my conversation partner."*

DISCUSSION

Using ATs empowers deaf people in their daily lives and offers them a high level of autonomy, especially in chance encounters and targeted inquiries involving hearing persons. Current research in the field of real-time sign translation will lead to future ATs that will likely be able to translate in real-time during face-to-face conversations between hearing and deaf individuals. In our study, we investigated the impact such real-time translation-based ATs would have on the communication. We identified the Deaf community as a subordinate group (Orbes co-cultural theory) inside the speaking dominated society and further use Co-Cultural theory to explain certain behavior.

In our analysis, we firstly identified the communication process that such short inquiries follow. We show that ATs can lead to breaks in this process and furthermore generate discomfort for the deaf user with every break by emphasizing their disability to master the dominant language of society and being dependent on technology to communicate. This discomfort leads to different "exit strategies" either (1) aborting the communication or (2) trading the currently used AT for something that will more likely lead to a successful outcome (e.g. pen and paper) at the cost of communication quality. We further investigated the type of breaks that occur during the communication process and show that they are mostly related to the AT breaking with social norms (mainly focus related).

Using the Co-Cultural Framework we identify the communication approach of the deaf participants in our study being mainly non-assertive (non-confrontational, e.g., self blame) and often leading to separation (e.g., identity outside the dominant structure). This is in line with the current view of the Deaf community as a "visual community" which often rejects ATs such as Cochlea implants. Deaf people do not perceive their inability of hearing as something "broken" and therefore do not need to be "fixed." Since the dominant culture is often not aware of their dominant position (standpoint theory) we propose two design considerations which can be embedded into future ATs to challenge this status quo:

Firstly, we propose the approach of "change in design perspective" which changes the goal of an AT for the deaf user. Instead of enabling the deaf user to hear we suggest enabling the hearing user to sign. This subtle change can lead to situations after communication breaks where the deaf user will not see the reason for the break in his or her inability of hearing (self blame) but in the inability of the hearing communication partner to in their modality (signing). This levels the power relation during the conversation since it reduces the level of dominance the hearing participants experience, and can potentially lead to accommodation ("insisting that the dominant culture reinvent or change the rules of society so it can incorporate the life experiences of each co-culture group" according to Orbe). However, further research is necessary to show this implication.

Secondly, based on our analysis we demonstrated how ATs impact both conversation partners (hearing and deaf) and bystanders, proposing a holistic evaluation of these stakeholders. This shifts the focus of ATs towards a more collaborative use in a social environment and away from a basic tool only operated by the deaf person. Enhancing the overall collaboration (e.g., including the social norms of both communities) with an AT will lead to an overall higher communication quality for each stakeholder and hopefully to less abandonment. This further highlights how ATs for communication should be understood as a collaborative tool and should be researched more in the field of CSCW.

These two suggestions can be used in future real-time translation based ATs for the Deaf community and would implicitly (per design) help the Deaf community (co-cultural members) to negotiate their cultural identities.

Limitations

Potential limitations of our study are the small sample size and homogeneous group of hearing participants (mostly students). However, our sample size is fitting for a qualitative study. We carefully considered the homogeneous background of our hearing participants in our analysis and paid close attention to its potential influence for each concept that arose from the interviews and interactions.

Our implementation of BodySign using a projector limited the interpreters to use only signs in front of their bodies. However, for several signs in the GSL (and throughout all our scenarios) there exist synonyms that can be signed in front of the body instead of around the body. None of the deaf participants noted the use of in-front-of-body signing as a limitation during the study sessions or in interviews. However, a relevant direction for future work is to improve the support for signing around the body. For instance, it may be worthwhile to explore the incorporation of augmented reality glasses for this purpose.

We investigated the impact of real-time translation based assistive technologies on communication quality with three example ATs. While we acknowledge the variety of existing and future ATs, our goal was to study exemplar technologies that represent currently existing (pen and paper) and possibly future (smartphone app, augmented reality glasses) assistive concepts. Conducting a Wizard of Oz study involving two live interpreters behind the scenes allowed us to convincingly simulate fully functional future assistive technologies, while reducing the potential for recognition or classification errors. At the same time, the use of live interpreters limited the scenarios we were able to consider. We chose three scenarios that emerged from the focus group in order to allow the interpreters to prepare for each scenario (rehearse specific vocabularies). To the best of our knowledge we are the first to conduct studies on assistive technologies with a live interpretation Wizard of Oz setup and involving both deaf and hearing participants. Despite the outlined limitations, our approach provided novel and deep insights on the impact of ATs on communication quality.

CONCLUSION

In this work, we explored the impact of real-time translation based ATs on face-to-face conversations between deaf and hearing people. To be able to understand the impact of AT on the quality of communication we conducted a focus group and a Wizard of Oz study including both, hearing and deaf participants. The focus group (n=13) gave insights on current challenges deaf people face using ATs and helped us to gain a good understanding of demands and goals from both perspectives. We collected several face-to-face scenarios in which deaf participants reported the need for ATs and compared two future technologies (projection and smart glasses) using technology probes. Based on these findings, we used three technologies (pen and paper, smartphone, and a mobile projection prototype) and studied their impact on communication quality in conversation settings. We conducted a Wizard-of-Oz study involving both deaf and hearing participants in conversation scenarios. Our analysis identified the underlying communication process between deaf and hearing participants and show where it is influenced by ATs. Our findings suggest that a shift in design perspective which strives to enable the hearing to sign instead the deaf to hear can balance power relations during communication. Furthermore, we propose to view ATs not only as a tool for the Deaf but as a technology for collaboration between the Deaf and the Hearing, and thereby assess its usability in a holistic way, including both stakeholders.

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