

“We Speak Visually”: User-Generated Icons for Better Video-Mediated Mixed-Group Communications Between Deaf and Hearing Participants

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ABSTRACT

Since the outbreak of the COVID-19 pandemic, videoconferencing technology has been widely adopted as a convenient, powerful, and fundamental tool that has simplified many day-to-day tasks. However, video communication is dependent on audible conversation and can be strenuous for those who are Hard of Hearing. Communication methods used by the Deaf and Hard of Hearing community differ significantly from those used by the hearing community, and a distinct language gap is evident in workspaces that accommodate workers from both groups. Therefore, we integrated users in both groups to explore ways to alleviate obstacles in mixed-group videoconferencing by implementing user-generated icons. A participatory design methodology was employed to investigate how the users overcome language differences. We observed that individuals utilized icons within video-mediated meetings as a universal language to reinforce comprehension. Herein, we present design implications from these findings, along with recommendations for future icon systems to enhance and support mixed-group conversations.

CCS CONCEPTS

• **Human-centered computing** → **Accessibility**.

KEYWORDS

Deaf and Hard of hearing, Accessibility, Videoconferencing

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1 INTRODUCTION

Since the outbreak of the COVID-19 pandemic, everyday activities have largely shifted to digital platforms, and videoconferencing has become the norm. Driven by technological advances in remote communication tools, videoconferencing has evolved into a powerful and convenient method to support communication between users with disabilities. For example, advantages of video-mediated communication commonly discussed in the Deaf and Hard of Hearing (DHH) community include automated live captions [60] for spoken conversations, instant messaging for text communication, and easy sharing of images [72]. These advances are capable of supporting communication for mixed-group conversation between DHH and hearing people, which makes social interactions more accessible.

In work-related contexts, these advances have demonstrated crucial possibilities of lifting barriers for DHH people who are currently working or wish to be employed in the future. Statistics indicate the importance of hearing ability for success in employment [57, 83] and the importance of successful small-group communication for the inclusion of DHH employees in the workplace [3, 56], in addition to the fact that physical barriers prevent DHH people from pursuing many jobs [10, 53]. Therefore, remote working environments mediated with proper technological adaptations can ultimately resolve the work limitations arising from mixed-group communication complications while also mitigating physical barriers.

Despite these advantages and the considerable demand for inclusive video-mediated work meetings, mainstream videoconferencing platforms are primarily designed with hearing users in mind [82]. Given their dependence on audible conversation, these tools are challenging or stressful to use and are often inaccessible for Hard of Hearing people [37, 46]. Such absence of consideration for DHH users can cause troubles when communicating with hearing coworkers [29], inducing distressing experiences or hindrances in completing work tasks [14, 30, 55]. DHH users have learned to adapt to the online conversation in different ways, such as interpreting lip movements or requesting sign-language interpreters [25, 80] prior to meetings. However, these approaches do not resolve the

fundamental constraints that DHH users face in video-mediated communication. DHH users find the screen size and quality of digital video services inadequate for lip-reading [59] and available information does not suffice for full comprehension even with the help of auto-captioning technology as a support. Moreover, eye contact and facial expressions, which are essential for inclusive communication with DHH users, can be lost in an online context [33, 52]. DHH users' efforts to gather fragmented data leave them with an excessive cognitive load [67], and such problems are not always solved with the inclusion of sign-language interpreters. Not all DHH people know sign-language, and even those who do may prefer to communicate with hearing people without an interpreter [38]. Most importantly, impromptu meetings are often held without time to arrange for an interpreter; thus, the mere inclusion of interpreters is inadequate to render video-mediated work environments suitable for mixed-group communication.

Furthermore, there is a distinct difference in language preferences between DHH and hearing individuals which results in complications during mixed-group communications. The DHH community is a diverse group composed of individuals with varying levels of language comprehension [61]; usage of feasible auditory cues, lip-reading skills, and literacy in written language differ among people within the DHH community [76]. Therefore, forms of performative language, such as non-manual signals (e.g., facial expressions, body language, eye contact) [40], hand gestures, and pictograms, are critical for communicating with members of the DHH community. In contrast, auditory and text-based communication methods of the hearing community [43] differ considerably from DHH users' visual-centered methods.

With these apparent differences in transmitting information, the usage of common visual tools can provide a foundation to support video communication for workplaces that accommodate both DHH and hearing employees. For example, visual elements such as icons (Fig. 1a) can convey users' intended emotions, attitudes, and attention more clearly in computer-mediated communication [20, 44]. Based on prior research emphasizing the efficiency of using icons to support communication [15, 35, 51], we believe visual communication using icons can be considered as a solution to close the language gap between DHH and hearing users. The usability of icons in existing versions of Zoom (Fig. 1b) leaves considerable room for improvement, because the shapes, sizes, and locations of the icons are static, and the icons do not always adequately reflect the dynamic nature of users' intentions [6]. Therefore, in this study, we focused on methods for enhancing the usefulness of icons and investigated their impact on mixed-group communication.

To provide an accessible videoconferencing environment for users from both the DHH and hearing communities, we integrated users from both groups to explore ways to alleviate existing obstacles in mixed-group videoconferencing. We focused on these two groups' use of videoconferencing tools in a work context to examine the underlying difficulties involved in mixed-group remote communication. Our research incorporates the focus group interview (FGI) methodology [65] and a participatory design methodology [5] to investigate how DHH and hearing users overcome language differences and communicate in online interactions. To further investigate the implicit needs of these users, we involved our users

in generating and using icons to assist with video-mediated discussions.

This study had two objectives. First, we aimed to understand both DHH and hearing users' difficulties and needs in mixed-group videoconferencing from both of their perspectives. Second, we aimed to investigate the potential of and provide design recommendations for icons as a visual aid to enhance mixed-group remote conversations. This paper contributes to the domains of the Human-Computer-Interaction (HCI) and accessibility by offering novel insights into the experience of mixed-group video-mediated communication between DHH and hearing individuals.

2 BACKGROUND AND RELATED WORKS

2.1 Deaf Culture and Mixed-Group Communication

The topic of facilitating inclusive communication for DHH individuals has attracted considerable attention in recent years [63, 72, 86]. Researchers have implemented various approaches to address the challenges faced by DHH individuals in communication, including the integration of automated speech recognition (ASR) systems in text-based conversations [70–72]. These systems are designed to aid communication between DHH and hearing individuals and have been applied in small group meetings [9] and workplaces [48] to provide valuable insights into the interactions of DHH individuals by using live captions.

However, it is important to recognize that the DHH community is a highly diverse group comprising individuals with a wide range of language comprehension skills [61], auditory cue usage, lip-reading abilities [76], and literacy in written language. Some DHH individuals may rely on auditory cues to communicate, while others may rely on nonverbal expressions and non-manual signals such as facial expressions and body language [40]. The DHH community often commits to nonverbal communication, and consideration on these methods is crucial for DHH inclusive communication.

Moreover, in mixed-group settings, the highly visual communication methods used by DHH individuals can differ significantly from the auditory and text-oriented methods used by the hearing community, resulting in a language gap [43]. Previous research has indicated that hearing individuals tend to adjust their speaking patterns when communicating with DHH individuals or when speaking to speech recognition software [71]. For example, hearing individuals have been observed to speak more slowly, with more pauses and increased articulation, when speaking to ASR systems that can exhibit errors [69]. In summary, Deaf culture values performative language for communication and speaking with hearing colleagues may create a barrier to speaking in their preferred language, since it may not be considered as a standard communicative method for hearing users. At the same time, hearing individuals may also face challenges when adapting their speech patterns to communicate with DHH individuals. Mixed-group conversations can be complex and must consider all social, environmental, and technical factors [49].

In summary, disability and accessibility are dynamic, and the assistance required is not limited to specific technical support and services [27]. Instead, individuals with and without disabilities continually need to adapt their work routines and attend to each other's

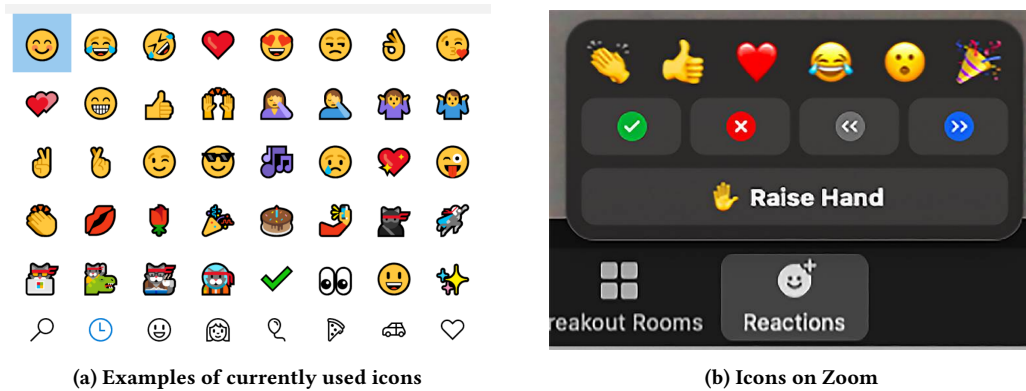


Figure 1: Currently used icons and application

needs [7] through “care work” to achieve accessibility [64]. Previous research has primarily focused on the perspective of DHH individuals, but gaining a deeper understanding of the fundamental and cultural differences in language between DHH and hearing individuals from both perspectives is important [47]. In this study, we aimed to facilitate the development of more effective and inclusive communication strategies by considering the experiences and perspectives of both DHH and hearing individuals.

2.2 Effectiveness of Visual Communication for DHH Users

Previous research has identified common difficulties that DHH individuals may encounter during videoconferencing, and has provided guidelines to address these challenges: offering live captions and transcripts [37] or providing visual and haptic feedback [68]. While these studies provide valuable insights assisting the DHH community, the methods discussed commit to live-captioning and sign-language interpretation as the primary means of communication. However, live-captioning technology and sign-language interpreters are not always available or legally required, and these periodic unprepared online sessions lead to DHH individuals missing important information during conversations and experiencing isolation, frustration, and reduced effectiveness and productivity in the workplace [71].

In addition, when users engage in communication in an online context, the use of critical visual languages such as non-manual signals, hand gestures, eye contact, and facial expressions, can be lost [33, 52]. This can be particularly challenging for individuals with disabilities who rely on multiple communication methods to fully understand conversations, including DHH individuals who may use a combination of techniques such as lip-reading, reading live captions, or analyzing facial expressions [79]. Such absence of nonverbal cues in computer-mediated communication can limit the scope and effectiveness of communicational exchanges, requiring more messages and more time to achieve the same level of understanding and connection as in-person interactions [84].

Respectively, in virtual settings, many users prepare visual materials in advance to support coworkers with disabilities [18]. However, these formerly prepared materials may only provide minimal

information on meeting content and are unable to fully support live conversations in virtual meetings. Previous research has suggested that DHH people prefer to receive information through visuals such as pictograms and motion graphics [31, 32, 62, 74, 75] because DHH individuals tend to communicate in a highly visual manner and often rely on their eyes to process information related to sound [85]. Therefore, in this research, we examined the use of visual materials in actual conversational dialogue in remote mixed-group meetings to understand how it can be utilized to improve communication. We considered that understanding the role of visual support in virtual communication may facilitate the development of more effective strategies and tools to assist the communication needs of DHH individuals in virtual settings.

2.3 Emojis and Icons for Personalized Communication

The use of visual elements such as emojis and icons has gained significant attention in the field of digital communication in recent years, with a focus on improving the user experience in various forms of computer-mediated and voice-mediated communication [35, 44, 52, 88]. Studies have indicated that emojis and icons are effective for conveying emotion, attitude, and attention, which can be important in videoconferencing settings where nonverbal cues are not easily conveyed [20, 44]. Additionally, prior research demonstrated that emojis and icons can be useful for clarifying or enhancing the intent of a message [17] and can be used to symbolize private jokes, create pictorial stories, and maintain or show interest in relationships [17, 66, 78, 87, 88].

Despite the benefits of emojis and icons for digital communication, there are notable challenges. One issue is that there can be cultural differences in the design and perception of emojis [34, 45, 50], as well as differences in individual preferences leading to varied applications of emojis [42]. Furthermore, different platforms have different designs for these visual elements, possibly leading to misunderstandings and miscommunications [78]. These issues can be particularly relevant for communication between DHH and hearing users, who may be reliant on visual aids for communication but demonstrate cultural differences.

Therefore, we investigated how cultural differences result in similar or different usage patterns when using icons to support mixed-group communication. By clarifying the challenges and benefits of using visual elements in communication, we hope to contribute to the development of effective and inclusive communication tools that can be used by a wide range of users. Herein, we discuss the potential of and make recommendations for future icon systems that can enhance computer-mediated communication between DHH and hearing users by supporting the nonverbal expressions of subtle meaning and nuances. By addressing the potential challenges and leveraging the benefits of emojis and icons for digital communication, we hope to improve the user experience for all individuals involved in mixed-group communication.

2.4 Participatory Design Workshops for Users with Hearing Disabilities

The participatory design workshop methodology is a highly effective approach to gaining a thorough understanding of the needs and experiences of end users [5]. It involves actively engaging stakeholders in the design process and has proven to be effective for creating integrated design solutions that meet the needs of users [15, 41]. In previous studies, participatory design workshops allowed researchers to identify the potential needs of users and create design solutions tailored to their unique needs and preferences [73].

However, research on the videoconferencing experiences of DHH individuals are often verbal interviews, which may not reveal the full range of experiences and needs of these users [11]. There is a lack of creative approaches for discovering the implicit needs of DHH users, which can be difficult to express because of the wide variation in their experiences [26, 36]. In this context, participatory design workshops can be useful, as they allow the active involvement of DHH stakeholders in the design process and can help to uncover their unique needs and preferences [63, 68].

While previous co-design workshops with DHH users have provided valuable insights, this approach has limitations, as common ability biases in co-design workshops can prejudice the feedback of end users and alter their authentic insights [4]. Therefore, conducting a participatory design workshop with DHH users is necessary when there is a lack of knowledge among designers and decision-makers about their interactions with digital technologies [58]. This is particularly important when the issues being addressed are driven by the disability of DHH users, as it is essential to align solutions with their actual needs to effectively address their challenges.

In summary, the participatory design workshop methodology is a highly effective approach to gaining a deep understanding of the needs and experiences of DHH users and is particularly valuable when there is a lack of knowledge about their interactions with digital technologies. We involved end users in the design process to facilitate the creation of design solutions that are aligned with their needs and preferences to address the real-life challenges that they face in their daily lives. By doing so, we can gain a deeper understanding of their lived experiences to discover practical insights that meet their preferences.

3 METHODS

We conducted a two-part study to investigate the mixed-group videoconferencing experiences of DHH and hearing users. The first part of the study comprised an FGI session to examine the real-life difficulties users face and discover essential areas for improvement. Participants were divided into groups according to their hearing abilities and then asked to identify the aspects of video-mediated services that needed improvement for mixed-group conversations. The second part of the study comprised a participatory design workshop using the paper prototyping method [39], where users were directly involved in creating icons to visually aid conversation. In this session, the users discovered ways of enhancing communication quality in a video-mediated meeting using the generated icons. We anticipated that these design decisions would uncover users' tacit needs and suggest design recommendations for visual aids as a potential tool to enhance mixed-group video conversations. The studies were structured to trigger users' memories from past videoconferencing experiences for a thorough investigation. Details regarding the study participants and procedures are presented in the following subsections.

3.1 Participants

Since the goal of our study was to improve video-mediated communication among coworkers in the workplace, we recruited the participants as groups within an organization that included both DHH and hearing employees. We recruited six DHH participants with severe to profound hearing loss [16] and six hearing participants (refer to Table 1 for details); all were currently working at the same Deaf welfare center in Seoul, Korea (the center is not named herein, by request). The users were colleagues who had been engaged in regular biweekly to monthly work meetings on Zoom [89] since the outbreak of the COVID-19 pandemic. Due to their frequent involvement with mixed-group videoconferencing for the past two and a half years, the participants identified themselves as being knowledgeable about using videoconferencing platforms such as Zoom or Google Meets [24] for group conversations. Communication experiences differ widely according to available communication support such as real-time captioning or sign-language interpretation. To examine the diverse variety of communication strategies possible in mixed-group discussions, we selected participants among the employees of the aforementioned welfare center according to the following criteria. The selected participants were required to have prior experience with video-mediated meetings in all three of the required contexts, i.e., 1) with neither live captions nor sign-language interpretation, 2) with live captions but without sign-language interpretation, and 3) with both live captions and sign-language interpretation. We recruited participants who were already acquainted with each other; thus, we anticipated that the study setup would provoke active and thorough discussions for high-quality group interviews [28] and provide a creative brainstorming environment for participatory design workshops [77]. Each participant was compensated 70,000 KRW (equivalent to approximately 50 US dollars) for spending a total of 3 hours completing the two-part user study (1 hour of FGI and 2 hours of design workshop).

Table 1: Participants in the user study

ID	Group	Hearing Loss Level: dB HL	Gender	Age	Affiliation	Previously Used V/C Tool
DHH Participants						
D1	FGI #1, PD#1	Profound: 90 dB or more	Male	25	Rehabilitator for people with disabilities	Zoom
D2	FGI #1, PD#3	Severe: 80 dB or more	Female	22	Accountant	Zoom
D3	FGI #1, PD#2	Profound: 90 dB or more	Male	33	Teacher for students with disabilities	Zoom, Google Meets, Skype
D4	FGI #4, PD#2	Profound: 90 dB or more	Male	27	Social worker	Zoom
D5	FGI #4, PD#1	Profound: 90 dB or more	Female	28	Teacher for students with disabilities	Zoom, Google Meets, Skype
D6	FGI #4, PD#3	Profound: 90 dB or more	Female	25	Video editor	Zoom, Skype
Hearing Participants						
H1	FGI #2, PD#3	Normal hearing: 25 dB or less	Male	51	Social worker	Zoom
H2	FGI #2, PD#1	Normal hearing: 25 dB or less	Male	31	Social worker	Zoom, Google Meets, Skype
H3	FGI #2, PD#3	Normal hearing: 25 dB or less	Male	27	Social worker	Zoom, Skype, Microsoft Teams
H4	FGI #3, PD#2	Normal hearing: 25 dB or less	Female	33	Social worker	Zoom, Skype
H5	FGI #3, PD#2	Normal hearing: 25 dB or less	Female	30	Social worker	Zoom
H6	FGI #3, PD#1	Normal hearing: 25 dB or less	Female	28	Social worker	Zoom

3.2 Part 1: Focus Group Interviews

Semi-structured FGIs were conducted via videoconferencing to naturally stimulate memories of past experiences with video-mediated meetings. We used Zoom as the videoconferencing platform because it was the most familiar videoconferencing tool to all the participants. For the interviews, the participants were divided into groups of three according to hearing ability; there were two groups of DHH participants and two groups of hearing participants (refer to Table 1 for the division of groups). Within the focus groups, users were encouraged to elaborate on their experiences with other users who had similar experiences. Although the DHH participants had experience with interviews without a sign-language interpreter, we invited an interpreter to support some participants who identified sign-language as their first language. We expected the interpreter to facilitate comfortable communication between the researchers and DHH participants. Each group interview lasted approximately 1 hour and progressed in the following order: 1) icebreaking: 10-15 min; 2) general discussion on mixed-group communication: 25 min; and 3) discussion on previous usage of visual aids: 25 min.

Before diving into a deeper discussion, we conducted an ice-breaking interview with offhand questions. Since the participants already knew each other, only a short period of time was necessary for them to familiarize themselves with the study environment. Our opening questions included self-introduction questions and general questions regarding videoconferencing experiences, such as *“In what context and with whom do you use videoconferencing tools?”* and *“Describe your first experience with videoconferencing.”*

The second session of the interview was structured to lead a general discussion on mixed-group communication. Our questions included 1) *“What are the similarities and differences between face-to-face and video-mediated mixed-group communication?”*, 2) *“What are some advantages and disadvantages of video-mediated mixed-group communication? What are some major difficulties?”*, and 3) *“What are*

some communication techniques you learned and adopted to better understand the other group in mixed-group video communication?”.

The third session of the interview was structured to ask about the previous usage of visual aids in mixed-group communication. In this interview session, we aimed to examine the uses of visual aids in mixed-group communication as a whole and investigate the possibility of existing offline techniques being applied to an online environment. Thus, we did not confine the discussion to an online context but instead covered both online and offline mixed-group communication experiences. The usage of visuals was examined for three conversational occasions following prior research on DHH communication conducted by Jazz Ang et al. [68]: 1) expressing and articulating ideas, 2) consuming and understanding information, and 3) performing a shared group task with the other group. Considering these three defined occasions, the participants were asked to share previous moments where limitations of text-based or audio-based conversation demanded visual materials such as drawings, pictures, or props for an adequate understanding.

3.3 Part 2: Participatory Design Workshops

The participatory design session lasted 2 hours, including break time between sessions, and progressed in the following order: 1) introductory session on the design workshop: 15 min; 2) observational study of real-life videoconferencing use: 20 min; 3) generating icons: 20 min; 4) observational study of icon application: 20 min; and 5) user reflection: 30 min.

The design workshops were conducted at the Deaf welfare center, where all the participants worked. The two observation sessions (sessions 2 and 4) required the replication of a realistic video-mediated mixed-group environment, and it was necessary to provide a comfortable and natural videoconferencing environment. The participants were accustomed to attending video meetings at their desks in the workplace. Therefore, we prepared two study



Figure 2: Settings for the participatory design workshop

settings at the welfare center: 1) a conference room for group discussions and 2) working desks of participants for attending two observational study sessions over Zoom (Fig. 2).

We held three workshops with groups of four participants. The number of participants was selected according to the statistic that most work-related meetings consist of 4-6 members [79]. Two DHH participants were paired with two hearing participants for the group discussions and participatory design workshops (refer to Table 1 for the division of groups).

The study procedure was largely taken from previous research conducted by Cho et al. [15] on the use of icons by hearing users of videoconferencing. Considering the methodology in a DHH-inclusive context, two major changes were made for our mixed-group setting: 1) a prior observational session was added for a clear comparison of communication with and without generated icons and 2) the acrylic panel was omitted to reduce the barrier to accessing the computer keyboard for typing — a common communication tool for mixed-group remote communication.

The participatory design workshop began with a short introductory session describing the study procedures and icebreakers. Users introduced themselves and briefly shared their views on videoconferencing for a short recap of the user discussions from the FGIs.

Before the participants began prototyping [39], they carried out discussions as they normally would. The participants positioned themselves at their own work desks to access the prepared Zoom environment for the observational study of real-life videoconferencing use (Fig. 2a). This observational session served three purposes. First, we observed the existing communication strategies for mixed-group videoconferencing. Second, this approach acted as a mechanism that reminded our users of their past experiences and difficulties with mixed-group videoconferencing. Third, it provided a clear comparison of mixed-group video meetings with and without the user-generated icons as visual tools to assist conversation.

The discussion in the first observation session began with choosing on a topic of interest. To administer natural online discussion sessions similar to real-life work meetings for the participants, we selected and offered two topics for discussion that were related to their real meetings. Additionally, for facilitating fluent online sessions, their first task was to select a discussion moderator. After assigning the moderator, the participants initiated the meeting by agreeing on a topic of interest from two given options. Two presented topics were as follows:

- (1) The Seoul City Center is arranging a Thanksgiving Field Day for families with DHH members for the upcoming Thanksgiving in Korea. What type of sports should be included in this event, and what prizes should be provided for the winning families? Let's plan a sports day together! Think about when, where, how, what, and why while planning the event.
- (2) On October 31st, the Deaf welfare center would like to host a Halloween event for families with Deaf children or kids of Deaf adults (KODA). Plan a special event day that children and adults can enjoy together. Think about when, where, how, what, and why while planning the event.

After the first observation session, users gathered in the conference room to generate icons. They were encouraged to recall difficulties in communication from the previous session to individually generate icons that they needed or wished to use for better comprehension. We provided them with commonly used emojis (Fig. 3b) and icons that incorporated sign-language (Fig. 3c). These prepared icon sets were used to initiate the creative thinking process for this session. The users were allowed to select and use the emoticons from the toolkit to use as they were, add drawings or text to provided icons to create an iteration on the existing emoticon, and create their own original icons. We used the paper prototyping method [39] to allow the participants to express their ideas simply and intuitively.

With the constructed icons from the previous session, the users moved back to their desks and resumed the paused discussion from the first observation session. They were permitted to use all their typical communication techniques as usual, such as typing and using hand gestures, and were advised to use the generated icons as an additional tool to aid online communication (Fig. 2c). While engaging in the conversation using the previously generated icons, users freely made iterations on the icons or created new icons on Post-It paper notes as necessary.

After the second observation session with the applied usage of icons, the users reflected on the usability of icons for mixed-group communication. A semi-structured group interview strategy and a post-questionnaire were used for qualitative analysis. In the group interview, the users were asked to explain the purpose and meaning of each of their icons, if and when they used the icons, and whether their intentions were successfully communicated to other participants. Furthermore, the users discussed how these icons could or could not replace real body language or nonverbal gestures and shared their opinions on the potential of icons for

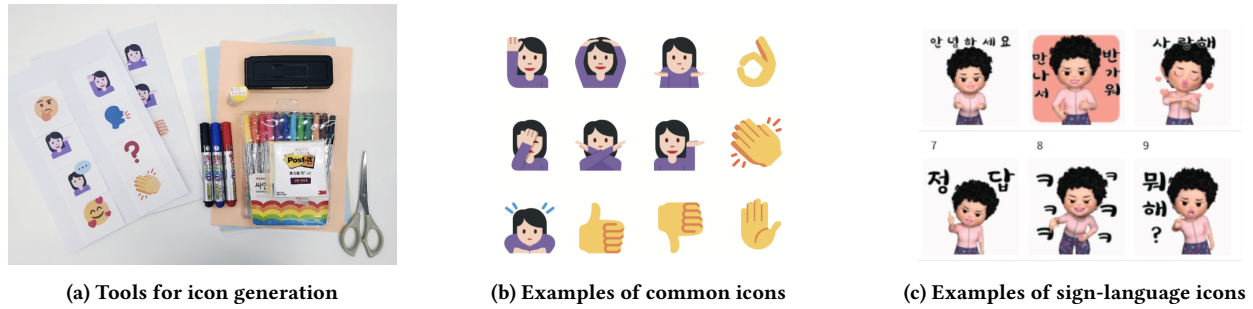


Figure 3: Provided toolkit for the generative workshop

future applications. For post-evaluations, the users were asked to evaluate the second online session in comparison with the first online session. The evaluations involved five categories.

- (1) Effectiveness: Were generated icons used effectively in the video meeting?
- (2) Efficiency: Did using generated icons increase the efficiency of the video meeting?
- (3) Interaction: How did the usage of generated icons affect interactions between DHH and hearing participants?
- (4) Content: Did usage of generated icons affect the meeting content?
- (5) Application: Are the generated icons applicable as visual tools for videoconferencing platforms?

3.4 Data Analysis

The obtained data comprised dialogues from the interviews and observations from the observational studies. All parts of the user studies were first transcribed professionally for review; sign-language instances were coded by interpretations in spoken Korean. Additionally, users' behaviors from observational sessions and generated icons were coded by thoroughly reviewing the recorded videos. We performed an open-coding thematic analysis [12, 13, 22] on our data. For the first review pass, the first author performed a qualitative analysis using the data from the studies; recorded videos were reviewed in this process if clarification was needed. Then, the second review pass was performed by researchers in a sequential manner. For this process, we included a researcher who had not attended the user study for an unbiased judgment. Lastly, according to the results of the data analysis, we divided the generated icons into five categories on the basis of their functions to create a framework for icon usage in mixed-group videoconferencing.

4 RESULTS

During our user study, few participants mentioned benefits of being online, such as a reduction in the commuting burden, which can be a significant barrier for workers with disabilities. However, most of the participants focused on negative aspects and their real-life difficulties. This may be because Korean live-captions are currently not directly supported on any videoconferencing platforms; therefore, Korean-speaking DHH users must arrange real-time human captioners or rely on external live-captioning software (e.g., Google

Docs, Naver Clova Note), which can be more cumbersome than using built-in plugins. However, such technical concerns were rarely mentioned as critical barriers in mixed-group videoconferencing. Most of the users focused on difficulties due to intrinsic cultural and linguistic differences.

We analyzed the results of our interviews and observational study to identify overarching concerns within mixed-group conversations in general and defined difficulties that are specific to the online environment (Table 2). The observed difficulties in video-mediated mixed communication between DHH and hearing users are summarized in Table 3. Then, we analyzed the users' usage patterns of icons by interpreting the generated icons. We categorized the icons by function and usage, as shown in Table 4 and Fig. 4, referring to a similar study involving hearing audiences [15]. The analyzed data were used to define current problems and the corresponding approaches developed by the users. We focused our findings on issues considered distinctive in a mixed-group context.

We observed that crucial aspects of mixed-group communication are limited in remote contexts, causing difficulties in mixed-group videoconferencing. We analyzed the challenges in mixed-group videoconferencing and divided them into four major categories (Table 3): 1) building mutual consensus on disability, 2) understanding the extent of idea comprehension, 3) grasping overall discussion status, and 4) asking for additional support. The first two difficulties were commonly observed for both the DHH and hearing user groups, and the remaining two difficulties were specific to the DHH group. In the following subsections, we define important aspects of mixed-group communication, clarify the challenges related to these aspects in a videoconferencing context, and describe corresponding approaches found from observed usage patterns of user-generated icons. There were limitations of icons regarding their usability; we present the observed limitations at the end of this section.

4.1 Building Mutual Consensus on Disability

When DHH and hearing users participate in the same meeting environment, they are aware of the existing cultural gap but are often unsure of the exact underlying differences. Difficulties in communication for DHH users are not limited to sound-related problems. Some DHH individuals may have linguistic concerns due to temperamental or environmental factors, which can ultimately lead to barriers in text-heavy communication [1]. These semantic challenges can have psychological effects such as a lack of confidence and anxiety when speaking [2], leading to a general

Table 2: Major concerns regarding the communication methods in mixed-group videoconferencing

	DHH users	Hearing users
Written language: typing in chatbox	Difficult to correlate typed text with the deliverer	Typing is inconvenient compared with speaking
Spoken language: live-captioning	Loss of nuance or jokes in communication, burdens for understanding depending on one's literacy level	Hesitation on choosing vocabulary due to uncertainty of literacy level or skepticism of live-captioning accuracy
Non-verbal language: body gestures, expressions, and manual signals	Limited view of non-verbal signals depending on screen and internet quality	Grasping ideas with excessive non-verbal language not normalized
Sign-language: interpretation from a sign-language translator	Latency in communication due to time taken for interpretation	
	Incomplete transmission of sign-language depending on screen and internet quality	Concerns on miscommunication due to misinterpretation

discomfort with engaging in hearing-oriented small group discussions [31]. In the present study, the DHH participants expressed the importance of explaining the extent of an individual's contrasting experiences and unique preferences beforehand to create a more comfortable environment ready for communication. In remote meeting environments, DHH users are often frustrated when they cannot thoroughly explain their disability to hearing users prior to discussions owing to the distant nature of videoconferencing.

"I think it is difficult for most of the audience to know my position. I have to explain why it's hard for me to understand on many occasions." (D2)

"I can easily talk about my disability face-to-face...however, it is difficult when remote." (D2)

Challenges: Uncertainty of language gap interrupts communication.

It is important to understand the intrinsic communication concerns of not only DHH users but also the hearing user group. Hearing individuals often vary their way of speaking with DHH colleagues [70], and knowing the possible preferences in communication is a crucial factor in adjusting communication patterns in mixed-group communication [71]. For example, in this study, hearing users described their encounters with the DHH group as needing careful consideration. They were mindful of their word choice when talking to DHH coworkers — particularly if they knew the DHH colleagues' levels of literacy or linguistic preferences. However, building consensus on the degree of disability is difficult for distant meetings, and most of the time, hearing users hesitate with their speech.

"I think you need to be more careful in additional data preparation...such as whether the vocabulary can be easily understood by the DHH person." (H4)

"Sometimes DHH users need more time to read text...there were times when they had trouble interpreting." (H3)

"Sometimes I hesitate in my speech because I am unsure whether [the DHH coworker] knows such terminology." (H6)

Icons used as a total communication strategy for fluent communication.

To reduce the vague language gap, our users employed icons as a total communication strategy, a method of using a combination of communication methods to support information exchanges [19, 51]. Many of the user-generated icons included both a pictogram and text and were often used with hand gestures to convey the meaning clearly. By using a combination of multiple communication channels, such as text, drawings, and nonverbal expressions, users participated in the discussion with reduced language restriction, which enhanced the communication quality. Compared with the observational study without icons, there were fewer instances of participants signing or speaking — users were able to carry on the conversation via simple delivery of ideas through visually aided total communication.

4.2 Understanding Extent of Idea Comprehension

Our users expressed frustration about not knowing the extent of comprehension due to indirect communication. Communications between the DHH and hearing users are often indirect; for example, a vocalized idea from a hearing person is transcribed to text and then delivered to a DHH user, and sign-language from a DHH user is interpreted and delivered to the hearing user. Both the DHH and hearing user groups reported past experiences of reiterating or clarifying ideas because of misinterpretation and miscommunication. Therefore, our users needed frequent verification of level of comprehension during communication.

"I think it is inconvenient for [DHH users] because they have to understand from the transcribed version of what we say." (H5)

"I usually express my opinion in [spoken] words, so there were cases where the interpreter sometimes misunderstood...so it was a little difficult to know if they (the interpreter and the other person in the discussion) correctly understood." (H5)

Challenges: Loss of nonverbal signals hinders complete understanding.

In in-person settings, users can easily tell if the other person is confused or has questions by interpreting their facial expressions. However, in an online context, nonverbal expressions are often lost owing to the limited screen size or quality [33, 52]. Without these

Table 3: Difficulties of mixed-group videoconferencing compared with face-to-face communication

	Offline meetings	Video-mediated meetings
<i>Common difficulties for both DHH and hearing user groups</i>		
Building mutual consensus on disability	Easier to share their level of disability prior to discussion to excuse for related complications	Feels distant to build mutual understanding of their disability and difficult to maintain a comfortable discussion environment
Understanding the extent of comprehension	Easier to understand if the idea is sufficiently delivered through detailed facial expressions	Harder to confirm the level of idea comprehension, uncertain if the idea is fully delivered to others
<i>Difficulties specific to DHH user group</i>		
Grasping the overall discussion status	Easier to grasp the overall status of discussion like the current speaker or order of presentation with physical ambiance	Impossible to grasp the overall ambiance when physically absent; cannot keep up with meeting content and speaker change
Asking for additional help	Easier to quietly raise hand or ask the person sitting next to them for additional support	Refrain from asking questions during the meeting to avoid unneeded attention

nonverbal signals, misinterpretations during conversations are difficult to pinpoint and are missed most of the time. To make matters worse, our users found the videoconferencing tool unsuitable for quick exchanges between users, as it can disrupt the meeting.

“There is a difference between face-to-face and remote communication in terms of knowing whether the [DHH user] understood 100% or not.” (H4)

“When it comes to videoconferencing, it’s harder for me to communicate. You can see [the face] more closely and other gestures in person for better understanding.” (H6)

“When I attend a videoconference, I feel that it is difficult to understand smoothly because it has a limited framework and does not look three-dimensional.” (D5)

“I used to ask questions when I was confused before; however, I stopped (asking questions) because I didn’t like the feeling of everyone looking at me.” (D3)

Icons used for convenient expression to enhance communication quality.

Our users repeatedly used the icons to confirm comprehension of their ideas. When discussing, the users frequently expressed their understanding with reaction icons (Fig. 4c) before continuing the discussion. In many instances, users did not move on to the next discussion topic unless all participants expressed agreement. Using icons as an expressive tool had another advantage: it allowed painless articulation of jokes during communication. Reaction icons were used not only to confirm users’ understanding but also to lighten the atmosphere. For example, D3 constantly raised the “NO” icon (even when he agreed) with a smile on his face to tease other participants. Furthermore, H4 and H5 stated that introduction of visual materials acted as a mechanism to refresh the communication atmosphere, saying that “video communication can be fatiguing, especially when [participants] are overly focused...but using these icons refreshed the mood in positive ways”.

4.3 Grasping Overall Discussion Status

For mixed-group conversations, physical presence is critical for understanding discussion statuses, such as the start/end of the discussion, pauses, or changes in the speaker. Physical presence in face-to-face meetings allows participants to understand nuances and the ambiance to sense the overall tone of communication at a glance to keep up with the meeting. However, in virtual situations, mixed-group conversations are often based on audible communication; unfit for DHH users to conveniently grasp the meeting status.

“There are situations where multiple people talk simultaneously. It is difficult to understand the situation on these occasions. In in-person meetings, [DHH group] can focus and understand the situation with ambiance, but not the same for virtual meetings.” (D4)

“(The Zoom system itself) is a bit complicated. If I were to face [another person] in real-life, I would be able to grasp the situation, but this is harder for video communications.” (D6)

Challenges: Lack of surrounding awareness leads to passive participation.

In videoconferencing, the nuance and ambiance of a meeting are lost due to the absence of physical presence. Correspondingly, turn-taking has been constantly discussed as one of the major challenges present in video-mediated meetings, regardless of whether the participants are able-bodied [15] or have a varying degree of disabilities [18]. In mixed-group meetings with DHH participants, the lack of awareness of the surroundings tends to intensify the challenges of turn-taking; thus, DHH users often find themselves isolated from a meeting, not knowing when to speak. Our DHH users were often unsure of the start and end points of utterances, leading to passive participation.

“During our work meetings, there are times when we have to do presentations. After a while, I find myself only looking at the presentation material. I can’t figure out the presentation order, so I have to look at the comments to find out that it’s my turn” (D1)

Table 4: Functions of generated icons by category

Icon Function	Generated Icons	Icon Function	Generated Icons
<i>Indicating discussion status - refer to Fig. 4a</i>			
Indicating start of the discussion	Hello	Reaction - negative	Awkward
	Start		I don't like it
Indicating end of discussion	Wrap-up	Reaction - positive	Haha
	Thank you for today		Yes
Indicating progress of discussion	Next	Participation - self	Okay / I agree
	Hurry up		Good
Indicating pause in discussion	Wait	Participation - others	Correct / Great
	Contemplating		I love it
	Breaktime		Thank you
<i>Requesting action - refer to Fig. 4b</i>			
Requesting further comprehension	Why?	Direct delivery of idea	I don't want to talk
	Why / I don't know		I have an idea
	I don't understand		I want to talk
	Please repeat		Please be quiet
Requesting attention	I have a question	Direct representation of object	Please speak
	Attention		Do you have something to say?
Requesting language change	Help (SOS)		
	Please interpret		
	Please type		

“There are times when I can't ask questions because it's hard to figure out if the time is appropriate” (D2)

Icons used to distinguish meeting status and encourage participation.

The users actively utilized icons related to clarifying meeting status. They were committed to defining the start and end of their sentences with ‘indicating discussion status’ icons (Fig. 4a). Consequently, the users straightforwardly captured the meeting status and understood the current progress in the meeting, facilitating their participation. If any of the DHH participants appeared lost or left out of the conversation, other participants attempted to balance out the meeting presence by using icons requesting participation, such as “Please speak” (Fig. 4d). Here, we examined the relationship between power dynamics of DHH and hearing colleagues and meeting participation. In the first observational study, hearing participants were noticeably dominant in the discussion, primarily leading the overall discussion. On the contrary, the participation and meeting presence were more balanced between DHH and hearing users in the second observation session.

“In the first discussion, I spoke a lot even though I knew (D4) was the moderator for our discussion. This may be because of my personality because I am impatient.” (H5)

“I couldn't lead the discussion during the first session because (H5) was doing my job. However, I felt it was easier to participate and lead the discussion in the second

session by using the icons, so I engaged in the meeting more actively.” (D4)

4.4 Asking for Additional Support

For DHH users, an accessible window to ask for help is important to handle their dynamic and unexpected obstacles in communication. Asking for help is simple in real-life situations; for example, our DHH participants noted painless techniques of asking for help such as tapping the shoulder of the person sitting next to them.

“The advantage of face-to-face communication is that when I don't know what's going on, I can ask questions directly to the person next to me or understand through the exchange of notes.” (D5)

Challenges: Absence of supportive window due to physical alienation.

The experiences of asking for help differed significantly in virtual communication. The DHH users stated that the distant nature of videoconferencing resulted in a feeling of alienation, making it more difficult to ask for help. As our DHH participants did not prefer vocalizing when communicating, losing physical contact removed their window to ask for help. Some of our users attempted to attract attention by waving at screens in the past; however, hand gestures are often hard to see and easy to miss – particularly when the other user is not accustomed to focusing on nonverbal language for communication.

“(Unlike face-to-face communication,) there is no one next to me online. I feel alone in online situations, and it's hard to ask someone for help. So in the end, I don't

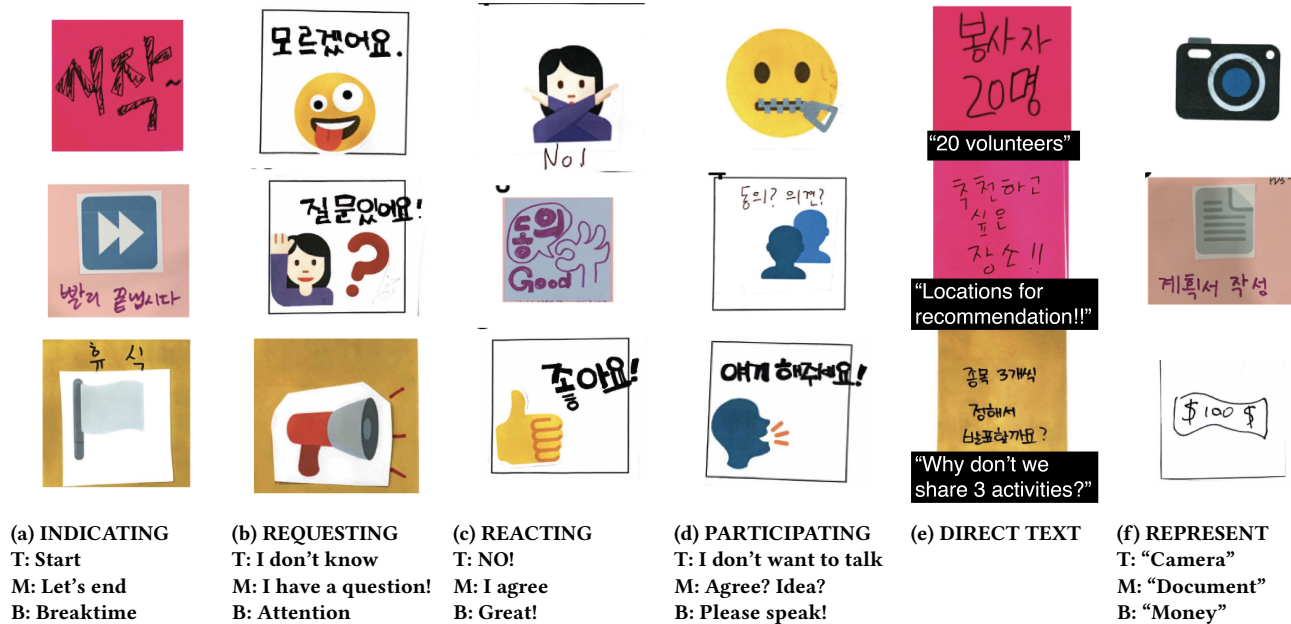


Figure 4: Examples of generated icons (T = top, M = middle, B = bottom)

say anything and I just stay still. There were experiences where I didn't know what was going on but just had to let it go." (D5)

Icons used as a common communication channel to attract attention.

With the active use of icons, asking questions and asking for help became more flexible. Users freely requested attention from other users by using icons such as "attention" or "help" (Fig. 4b). Users were often limited with regard to the type of communication channel; for example, hearing users depended on auditory communication, whereas DHH users were more accustomed to visual communication. DHH users were confined to hearing user-oriented communication techniques and expressed the need for a common communication channel that is easy to use for both DHH and hearing meeting participants. Icons not only visually grab attention, but the building of a common communication channel using the icons also encourages a feeling of togetherness, leading to a more comfortable environment to ask for help.

"(Using icons as a shared language) brought us a basic sense of trust in each other and helped form a supportive and positive atmosphere." (D5)

4.5 Observed Limitations of Icon Usability

Despite the significant advantages of icon usage in communication, icons had limitations when applied to the real meeting context. Three major limitations of icon usage were 1) challenges in the expression of long or complex ideas, 2) barriers in identifying the desired icons, and 3) limited usage of icons depending on the meeting context.

First, icons convey simple and short messages. This makes it difficult to express long or complex expressions of ideas. Users generated quick written bullet points of ideas on Post-It notes to deliver their ideas (Fig. 4e); however, they had a tendency to type in the chat box for longer explanations, e.g., "Most Halloween events have a dark and scary atmosphere; I hope our event can be like that. I think kids would like for us to dress up in scary costumes" (D5). H5 explained that "although simple answers and communication were possible using icons, there was a limit to communication beyond that". Similarly, D1 claimed that the "icon allows simple delivery, so maybe a little difficult for long content". Videoconferencing interfaces have a limited screen size, which is insufficient for long phrases of text. However, all of our users unanimously mentioned that instant messaging is inconvenient because of the difficulty in correlating typed text with the deliverer and that using icons to represent direct text (Fig. 4e) was more useful in this sense.

Second, participants reported challenges related to finding the desired icon in a fast-paced conversation. For H5, her "concentration was sometimes dispersed during the meeting because [she] was looking for icons". DHH-inclusive communication is largely visual; therefore, looking away from the screen can present problems [21]. On the other hand, D2 reported a lack of proficiency in icon usage as a barrier to selecting the correct icon. He mentioned that he "was not used to using icons mainly for conversation, so it was difficult to pick and use the right icon within the context instantly". Nonetheless, our participants added that these issues can be temporary, and probably will be resolved as users become more accustomed to icon usage.

Lastly, the participants discussed the importance of the meeting context when the icons are used for communication. Participants mentioned that they could actively and comfortably use the icons

because they were close to each other and the meeting topic was casual, whereas it may be difficult to use the icons with strangers or in a serious context. H4 and H5 both commented, “I don’t think I can use these icons when the meeting topic is serious or when we are arguing on a topic”. Interestingly, this concern was only discussed among hearing users. DHH users appeared to be more well-adjusted to active usage of icons during the conversation, which may be due to the fact that DHH users already regularly use visual elements to exchange information.

5 DISCUSSIONS ON DESIGN IMPLICATIONS AND RECOMMENDATIONS

In our user study, we used paper prototypes for users to express demands deliberately by using hands-on toolkits. Through our user engagement, we discovered implicit user needs regarding the use of icons as visual aid. We observed and analyzed hearing and DHH users’ reflections and experiences of using icons as visual material to support conversation. These perspectives provided valuable insights regarding the usage of future icon systems in videoconferencing platforms in a mixed-group context. In this section, we discuss key implications of our findings and make recommendations for designing and developing an icon system as a semantic tool to enhance mixed-group communication.

5.1 Differences in Icon Perception

A distinct difference in perceiving icons was observed between the DHH and hearing users. The DHH users perceived the icons as language, whereas the hearing users perceived them as tool that provides support. Such differences in icon perception can lead to differences in usage patterns; for example, the DHH group was already accustomed to using performative communication, but the hearing group may not have been accustomed to such frequent use of visuals, creating a barrier to the dynamic use of icons.

“I think the icon system is a shared language between Deaf and hearing people” (D6)

“Communication using icons was more comfortable and easier to understand because we (DHH and hearing people) used the same language for communication.” (D2)

Currently, many videoconferencing platforms offer icons merely for simple expression and do not consider the existing gap in perceiving icons, creating barriers to icon usability. For instance, current icons such as simple reactions and smiley faces are not adequate to serve as a communication language that facilitates the exchange of ideas.

Design recommendation: Straightforward controls for maximized usability to normalize icons as a communication channel.

To effectively use icons and give the sense of *universal language* the DHH users anticipated, all participants must be actively involved with icon usage to build a sense of togetherness. When the users discussed their experiences with videoconferencing tools, many expressed difficulty becoming accustomed to the videoconferencing platform.

“I think the first video conference experience I had was a little awkward. I wasn’t used to video conferencing,

and it was natural for me to have face-to-face meetings with [DHH coworkers].” (H2)

“I got used to [the platform] naturally as time went by. I lacked experience at first but got used to it with regular use, and now most of us (DHH and hearing team members) are using it familiarly.” (D4)

Especially, when an apparent language gap is present, e.g., in mixed-group conversations between DHH and hearing people, users are unsure of possible technological mechanisms that they can benefit from when first introduced to a feature. When these icons are applied to videoconferencing software as visual aids for communication, users need an introduction to the system to understand its benefits fully. Currently, the icons can be used for simple occasions, but the feature is not suited for using them continuously during communication. Additionally, choosing from an abundance of icons creates a barrier, and the icons placed in the corner of the screen are too small to convey ideas at a conversational level. For users to use icons in an easier and faster manner, we recommend providing shortcuts according to the context of the conversation, which can be captured from the live captions or chat messaging, categorizing the icons according to their purposes, and providing an icon set according to the theme or content of the meeting.

The simple application of icons in conversation can be encouraged with the use of speech recognition technology [23], for example, by suggesting fitting icons according to the spoken content for convenient utilization. Utilizing icons as a visual language in mixed-group conversations is critical. The DHH users reported a sense of equality from speaking a common language by conversing through icons, which led to more active and comfortable participation of DHH users.

5.2 Clarification of Icon Meaning

Because of differences in the preferred language, icon interpretation differed among users. Accordingly, when user-generated icons were applied in videoconferencing, users sometimes could not infer the meanings of other users’ generated icons. For example, D5 used the “clap” icon to indicate “start” because “start” in Korean sign-language is expressed by holding the palms of both hands together (Fig. 5a). Likewise, icons representing non-manual marks [54, 81] that are specific to Deaf culture may be difficult to understand for hearing users. Therefore, our user reflections indicated the necessity of creating a set of rules for using icons in real-life contexts.

“If you set a certain range and social rules with icons, you can easily express your feelings and communicate with each other.” (D2)

Given the cultural differences among the users — particularly considering users with disabilities — icons consisting only of simple pictograms did not convey sufficient meaning. Therefore, we observed our users specifying icons’ meanings using text and facial expressions. The icons currently included in the video conference platforms are generic, leading users to assume their meaning. However, owing to the cultural gap between the DHH and the hearing, icons may carry different messages depending on the situation and prior experiences.



Figure 5: Icons used with Deaf culture

Design recommendation: Icons constructed to build common ground and bridge the language and cultural gap on visual interpretation. Due to the cultural differences between DHH and hearing users, icons used in mixed-group contexts must be introduced with a clear definition. Icons with a set of rules can be used in videoconferencing to build common ground for minimizing the cultural gap between DHH and hearing users. With the gradual application of icons, a mutual icon system representative of both Deaf and hearing cultures can provide the groundwork for closing the cultural gap, enhancing smoother communication experiences.

5.3 Icons Usage in Deaf Culture

DHH users frequently used icons in combination with non-manual signals specific to Deaf culture. For example, we observed ‘face-names’ [8] being used with icons when requesting directly to a specific meeting participant (Fig. 5b). Also, DHH users often used icons representing specific objects along with sign-language, and we observed hearing users intuitively reiterating the movement to show mutual understanding. Consequently, total communication using icons and sign-language naturally endorsed teaching or learning opportunities for sign-language. According to our users, if the prior understanding of Deaf culture suffices among meeting participants, icons have the potential to be a more powerful tool when used in combination with sign-language.

“I think understanding words through icons and sign-language can also help me memorize some sign words.” (H2)

“If the icons with both languages (e.g., “Thank you” in sign-language + “Thanks” in Korean) are applied to the non-face-to-face communication system, they can bring smoother interaction.” (H3)

Design recommendation: Expressive icons with range of motion for expressive and direct communication.

For the icons to assist conversations with such a performative characteristic, they must be more articulative. To accomplish this, motion or sound can be used along with texts and pictograms for detailed expression. Current static and image-based icons on videoconferencing systems are not fully suitable for DHH users because of the dynamic nature of sign-language. However, although expressive, icons must be carefully designed considering the requirements of the DHH community. Icon systems must consider that many

problems in DHH communication arise from split visual attention [21]; thus the design should not distress, distract, or fatigue users’ visual attention.

6 LIMITATIONS AND FUTURE WORKS

One limitation of this study was that the recruited hearing participants had been working with DHH colleagues for a long time and therefore had considerable prior knowledge of Deaf culture. Different individuals have differing levels of understanding Deafness and accessibility; therefore, experiences of mixed-group videoconferencing may be different for other workplaces. For example, video-mediated meetings with an employee who has never encountered a DHH person would differ considerably from those of our user group. Moreover, the DHH community consists of a diverse group of users with varying levels of disability and communication preferences. Our study included DHH users with severe to profound deafness and therefore is not representative of DHH users with different degrees of hearing loss, such as moderate hearing loss. To investigate such a diverse user group, studies involving DHH users with different levels of disability and hearing users with different levels of Deaf culture awareness should be conducted.

Furthermore, we specifically considered a work-related meeting context, and users’ usage patterns of icons may differ in other contexts, such as educational interactions or casual family gatherings on videoconference. Additionally, the number of participants engaged in the meeting may affect the usage pattern. For example, our workshops had only four participants, and it was fairly easy to see the generated icons; however, this would not be the case for conferences with large group participation. Moreover, our observational sessions were short; therefore, we may have missed user needs that would only be observed in longer meetings. In future research, the analysis of icon usage in real work meetings rather than as a part of a study setup is necessary.

Lastly, our study sessions did not include large numbers of DHH or hearing participants; therefore, our findings suggest a novel starting point rather than a representation of the DHH or hearing community as a whole. Future work with a larger group of DHH and hearing users is necessary to gain a better understanding of these users for generalization to a larger population.

7 CONCLUSION

In the user study, we aimed to understand the DHH and hearing user groups' perspectives on mixed-group videoconferencing. Through the users' perspectives, we obtained critical insights that must be considered to resolve the current issues arising in mixed-group videoconferencing with both DHH and hearing users. This study addresses an unexplored perspective of using icons as a visual aid to support mixed-group video-mediated conversation. Our findings provide insights into existing difficulties and interpret these insights to offer design recommendations for making videoconferencing interfaces more accessible.

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