Exploring the Design Space of AAC Awareness Displays

Kiley Sobel[1,2], Alexander Fiannaca[1,2], Jon Campbell[2], Harish Kulkarni[2], Ann Paradiso[2], Edward Cutrell[2], Meredith Ringel Morris[2]

[1]University of Washington, Seattle, WA, USA; [2]Microsoft Research, Redmond, WA, USA

ksobel@uw.edu, {alfianna, jon.campbell, harish.kulkarni, annpar, cutrell, merrie}@microsoft.com

ABSTRACT

Augmentative and alternative communication (AAC) devices are a critical technology for people with disabilities that affect their speech. One challenge with AAC systems is their inability to portray aspects of nonverbal communication that typically accent, complement, regulate, or substitute for verbal speech. In this paper, we explore the design space of awareness displays that can supplement AAC devices, considering their output features and their effects on the perceptions of interlocutors. Through designing prototypes and getting feedback on our designs from people with ALS, their primary caregivers, and other communication partners, we consider (1) the consistent tensions that arose between abstractness and clarity in meaning for these designs and (2) the ways in which these designs can further mark users as "other." Overall, we contribute a generative understanding of designing AAC awareness displays to augment and contextualize communication.

Author Keywords

AAC; accessibility; ALS; awareness displays; conversational awareness; conversational flow; emotion expression; nonverbal communication; disability.

ACM Classification Keywords

K.4.2. Social issues: Assistive technologies.

INTRODUCTION

Amyotrophic Lateral Sclerosis (ALS) is a neurodegenerative disease that progressively weakens individuals' muscles to the point where they are unable to walk, speak, eat, or breathe without the help of assistive technology [31]. As people with ALS (PALS) lose their ability to speak, they can use augmentative and alternative communication (AAC) systems to communicate. PALS typically input text into AAC devices using eye gaze, which is generally not impaired during the disease progression [3], and the device speaks aloud the words they have typed in a synthetic voice using text-to-speech (TTS) technology.

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One challenge with AAC systems is their inability to portray aspects of nonverbal communication that typically accent, complement, regulate, or substitute for verbal speech. This is particularly salient for people with ALS, who are not able to nonverbally communicate through movements like gesturing or making facial expressions. This lack of nonlinguistic information affects aspects of communication such as conversational flow, emotion expressivity, and personality representation [19,33]. Conversational flow is not only affected because of the slow speed of eye gaze input, but also because little information is given to conversation partners about PALS' conversation "status" (e.g., listening, typing, or resting) or social cueing (i.e., indications for turn-taking) [19]. The devices also do not allow much emotional expressivity, mostly due to minimal paralinguistic changes in speech output [19]; and AAC systems are not considered fashionable or reflective of speakers' personalities [19]. Consequently, AAC devices, while improving communication and quality of life for PALS beyond simple communication boards [7], could still be significantly improved in supporting more effective and expressive participation in conversations [19].

In this paper, we explore the design space of awareness displays for AAC devices, considering their output features and their effects on the perceptions of both speakers and listeners. The term "awareness display" mainly stems from work by Tran et al. [56,57], who focus on the importance of interlocutors' awareness of the subtle, social, and contextual cues that are necessary for people to naturally communicate in person. In our case, we focus on designing awareness displays for conversational flow and emotional information to augment and contextualize communication for AAC users and their conversation partners.

Using an integrative research approach, we documented our process as we designed various displays. This design process began by creating a taxonomy of the dimensions that are significant to AAC awareness displays. We then iteratively designed six different displays that varied along two key dimensions of this taxonomy, *resolution* and *abstractness*. The six designs incorporated the following components: text, emoticons, emoji, an avatar, skins (i.e., thematic animations), and colored LED clusters. Based on feedback from people's initial understandings and perceptions of the designs, we built three (text, emoji, colored LED clusters) into an eye gaze controlled AAC device. We used this integrated system as the basis of an exploratory user study that allowed us to better understand 24 communication partners' perceptions of the three designs in the context of one-on-one small talk. Finally, we presented the designs to seven people with ALS and their communication partners.

By reflecting on this design process, the artifacts, and people's perceptions, we discuss (1) the tensions that arose between peoples' preferences toward clarity over abstractness in the designs; and (2) the ways in which these designs can further mark people with ALS (or AAC users) as "other" [34,49], play into currently normative patterns of communication, and/or create new communication paradigms that might better reflect speakers' personalities. Overall, we contribute a generative understanding of designing AAC awareness displays to augment and improve conversational cueing and emotional expressivity during communication.

RELATED WORK

AAC Devices for People with ALS

People with ALS rely on AAC devices to communicate [5]. They often start by controlling these systems with touch, and later transition to eye gaze input as they progressively lose motor control [15]. A main area of research in AAC has focused on improving the speed of eye gaze input (e.g. [21,22,28,38,58]). Another area of work is on advancing text-to-speech (TTS) technology to improve the quality of synthetic speech [63]. This has included creating customized system voices (i.e., *voice fonts*) so that the output speech matches the speaker's voice to a greater degree [59,68]. Others have explored using natural language generation to improve aspects of communication, like storytelling [46] and joking [61], by suggesting relevant messages.

While AAC technologies are used by many people with ALS [5] and have improved communication in many ways [7], research has not fully addressed the needs of PALS in regard to AAC [4,19,63]. In their interview study with seven PALS and their close companions, Kane et al. [19] studied how PALS deal with changes in their ability to communicate and how AAC device use has impacted their self-expression. Their findings illuminated PALS' challenges related to (1) conversation pacing and flow (i.e., turn-taking) due to the lack of 'feedthrough' [2] when they are using the device; (2) conveying emotions, mostly due to the lack of voice modulation; (3) their decreased ability to argue, be humorous and sarcastic, and sound warm and less stern; and (4) shifting roles in their lives; for instance, those who were once extroverted became more passive, and those who cared about fashion no longer felt stylish. Kane et al. [19] urge researchers to think beyond AAC performance metrics (like wpm) to matters like users' ability to be emotionally expressive and participate equally, take turns in, and direct conversations. In our work, we begin to address these issues, which we conceptualize through the design of awareness technology.

Awareness Technology

Awareness technology refers to systems that make onlookers or partners more aware of a user's identity, status in a conversation, or emotional state [56,57]. A good example of this is online messaging systems. Users of these systems may have a handle and icon that make other users aware of their identity. Typing indicators (e.g., "…"), away messages, and idle times make users more aware of conversational flow. Emoticons, emoji, GIFs, stickers, and other related ideograms plus stylized text (like ALL CAPS or *asterisks*) add emotional awareness to conversations.

Few AAC researchers have utilized the concept of awareness in their work. One example is Feuston [11], who developed *Expressiv*, a system that projects facial expressions onto a person with ALS to augment her ability to emote; this design, while provocative, was not validated with actual AAC users [11]. Directly building on this work, Vujic et al. [60] developed MoodLens, which shows emoticons in an 8x8 pixel display on a wearer's eyeglasses. Through evaluation with 20 participants who watched videos of someone using MoodLens, the authors found that the system improved expressivity and was considered socially acceptable to these viewers (who did not have or know anyone with ALS). We develop this work further by exploring multiple design options and by considering the perspectives of actual AAC users and interlocutors in a natural conversation.

Moreover, Toby Churchill Ltd. developed the Lightwriter®, a TTS device that has a text display facing conversation partners [8]; the display shows the letters as the speaker types or otherwise inputs them. Similarly, AACrobat connects AAC devices to a conversation partner's mobile phone app; the app displays text as it is typed or shows a status message ("typing…"), depending on the AAC user's privacy preferences [12]. Pullin [42] speculated how designers might design systems to present text being composed via AAC devices in unconventional, artistic forms.

Researchers have also investigated how technology can make individuals with certain disabilities more aware of their communication partners' nonverbal behaviors (e.g., [6,20,24,30,43,48,62]). For example, *EmoAssist* is a smartphone-based system for people with visual impairments, which translates nonverbal communicative behaviors like yawns and smiles to audio output [44].

In other areas of design research (not specific to disability), there has been more work done that has specifically addressed conversational, emotional, and identity awareness during communication. Schierer and Picard [47] developed a theory for building objects that communicate emotions and offer a framework to map affect to light, sound, color, and movement. Many researchers have used this theory to create wearables that make co-located and remote viewers more aware of the wearer's emotional state (e.g., [1,9,27,32,64,65]). Likewise, researchers have created shape-changing interfaces to communicate emotion during interpersonal remote communication (e.g., [37,53]). Researchers in remote communication have also designed and studied awareness for robotic telepresence [25,45,51], video chat [54], and text and online instant messaging [10,16]. Finally, Leung et al. [24] designed a system that projects a visualization of a person's real-time online social identity to the public, above a person onto the ceiling, connecting her virtual and physical selves. We drew on all of this research and design for our AAC awareness display work.

Social Acceptability & Identity in Accessibility Research

In his book *Design Meets Disability,* design researcher Graham Pullin [42] discusses the various tensions that arise when we "design for disability" (p. 2). These include conflicts between designing for people's diverse individual identities vs. their clinically shared abilities; for fashion (which usually has the purpose of standing out) vs. discretion; and for pure information exchange vs. aesthetic expression (particularly in the development of AAC).

Relatedly, Kane et al. [18] and Shinohara et al. [50] found that assistive technology (AT) being too conspicuous in public may cause some individuals to stop using the devices that would otherwise help them. Shinohara et al. [50] conceptualize an approach connected to these issues called design for *social acceptance*. Because AT often looks extremely different than mainstream devices and draws unwanted attention, these authors argue that we should not only consider functionality and usability when designing AT but also take into account (mis)perceptions and aesthetics that might stigmatize users or maximize socially acceptability [50]. However, Profita et al. [41] found that public observers may consider a conspicuous (or commonly negatively perceived) device as more socially acceptable if the device is AT. We draw on these tensions and the notion of *social acceptability* in our study of awareness displays.

DESIGN PROCESS

While there is often friction about whether accessibility research is a "problem solving" endeavor (from a medical or engineering perspective) or a more open-ended and/or creative effort (from a design perspective) [42], we agree with Pullin [42] that "design for disability would benefit from a better balance of these complementary approaches" (p. 45). Following other significant HCI work in accessibility that incorporates exploratory research methods and follows a holistic process that considers a person more fully, we took a more integrative exploratory approach to our research. We designed, considered the experiences of multiple actors, and engaged in constant reflection in this multi-faceted and complex communication situation. We began our research by iteratively designing while documenting and reflecting on the process. Later, we carried out lab studies with users with and without disabilities since our design must address the needs of both conversation partners (i.e., what Pullin [42] calls "resonant design"). Ultimately, using an integrative methodology prompted us to think beyond one perspective [13,42] and explore awareness displays from complementary angles.

Awareness Display Taxonomy

At the beginning of our design process, we created a taxonomy of the dimensions that one could explore when designing AAC awareness displays. We began by brainstorming as many factors as possible without judgment, based on the related literature and our expertise in design, HCI, accessibility, AAC devices, and doing research with people with ALS. We iterated on this list over three brainstorm sessions, continually expanding and narrowing down the factors until we reached consensus [36]. We then iteratively grouped the factors according to five broad themes (Table 1): *input features, output features, practicality, scenario,* and *user perception*. *Input features* denote ways in which the awareness display will be controlled, and *output features* include the ways it will be presented toward communication partners. *Practicality* includes engineering-focused considerations for the design. Within *scenario* are factors that relate to when, where, and why the display will be used. *User perception* refers to the ways the person controlling the awareness display or his communication partners perceive the experience with and qualities of the display.

While extensive, our taxonomy is not necessarily exhaustive, and the dimensions are not all mutually exclusive, nor are they completely orthogonal (i.e., many influence each other – e.g., resolution may influence cost). It is also important to note that the factors may differ depending on which "user" we are considering: the person speaking through the AAC device or her communication partner. This encapsulation of the design space works as an exploratory tool to think with, which we used to narrow down and examine our designs.

Initial Designs & Reflection

After developing our taxonomy, we decided to focus on two main dimensions of AAC awareness displays: *output features* and their effect on *user perception*. Within output features, we varied (1) the *display resolution* and (2) the *abstractness* of the display's meaning. *Display resolution* is interesting mainly due to issues of practicality (e.g., a lower resolution display could be less expensive, use less energy, and be smaller/less obtrusive). *Abstractness* of meaning is interesting because this has implications for user perception and usability. For instance, while less abstract designs may be easier to learn, more abstract designs may be subtler and provide ambiguity typical in communication.

We iteratively brainstormed and designed different types of outputs that varied along these two dimensions, as well as a variety of other output constraints. For instance, we began with prototypes for both audio and visual output, but later scoped to only visual designs. For the sake of space in this paper, we will present the six visual designs on which we most consistently iterated: **text** (low res, low abstractness); **emoticons** (low res, medium abstractness); **emoji** (high res, medium abstractness); **avatar** (high res, medium abstractness); **skins**, in our case, animated nature scenes (high res, high abstractness); and a **colored LED cluster** similar to the design concept proposed (but never evaluated) by Kane et al. [19] (low res, high abstractness).

For each of these six displays, we implemented a set of five conversational cues and six emotions. The five conversational cues were based on work by Kane et al. [19], describing important concepts that PALS often wish to express in conversation: *listening*, *talking*, *typing*, saying "*Hold on*," and asking "*Pardon me?*" We choose the six emotions based on models of universal emotions [35,39,40] and Kane et al.'s work [19]: *happy*, *sad*, *angry*, *sarcastic*, *laughing*, and *caring*. Examples of each of the designs with detailed descriptions are in Table 2; please see the Appendix and Video Figure to view all of the designs' contents.

The process of designing the six types of displays along two awareness dimensions brought up two themes that consistently emerged throughout the study. The first theme was ***discomfort with abstractness in meaning***. For highly abstract designs and the cues and emotions that could be represented multiple ways, the choices that we made (although based on prior work and theory of affective objects [47]) sometimes felt too indiscriminate and too ambiguous, depending on the context. For example, for **skins**, choosing what nature scene would represent *listening* felt personal and at the same time disconnected from its meaning; could waves washing ashore perhaps associate with the movement of a slow head nod? Would a pink sunset feel *caring* to communication partners, or would it evoke calmness?

For the **colored LED cluster**, we had to make choices about whether we wanted to play into normative paradigms of representation that might be more familiar (e.g., animated audio signal processing waves to signify *listening*; a smiley-looking face for *happy*) or create more abstract color animations (e.g., slow blinking green lights as a sign of being engaged, nodding, and *listening*; fast moving, blinking bright yellow lights for *happy*). This idea leads to the second theme that arose throughout the design process: tensions between designing "socially acceptable" or normative displays (e.g., **emoticons** and **emoji** are already used in text and online messaging) vs. digital artifacts that might further ***mark speakers as "other"*** because they are uncommon in current forms of communication. For our initial designs, especially those that were more abstract, we positioned our designs as artifacts that indicate '*what might be*' as opposed to *'what is'* [14]. In this process, we realized that this decision might come into conflict with the experiences of PALS, their caregivers, and communication partners *now*, marking these abstract designs as "different," and the common designs as preferable, especially without long-term in situ use. However, in this exploration, we became interested in what types of feelings and perceptions the designs evoked in people, which served to create generative understandings of this design space.

Communication Partner Interpretation

The initial process of design and reflection led to our first mixed-methods exploration into how people with little or no experience communicating with AAC users with ALS might interpret and perceive the different types of displays. While such users are not representative of frequent communication partners of PALS (e.g., spouses, friends, professional caregivers, etc.), they do provide a reasonable facsimile of the kinds of casual conversation partners PALS encounter (e.g., employees in a store, an infrequent visitor, etc.). These people would not have time to learn how to interpret an AAC awareness display and would have to quickly interpret its meaning.

Input Features	Always on vs. sometimes on
	Amount of customizability vs. static input
	Amount of user input
	Continuous vs. discrete
	Explicit/manual vs. implicit/automatic
	Location (e.g., from body, in device)
	Prediction
	Scaffolding for user
	Sensing/aware of context
	Transformation of input
	Type (e.g. GSR, sentiment analysis, etc.)
Output Features	Abstract vs. clear (meaning)
	Always on vs. sometimes on
	Amount of output/time scale
	Augmentative vs. replacement vs. separate
	Continuous vs. discrete
	Dynamic vs. static
	Embodiment
	Form factor (virtual, physical, 2D, 3D, etc.)
	Location (on person, chair, etc.)
	Low vs. high tech
	Modality (audio, visual, multi, etc.)
	Recognizable features (e.g., street signs, symbols)
	Resolution
Practicality	Cost
	Battery life/power
	Efficacy
	Maintenance (setup, over time)
	Materials
	Noticeability/visibility
	Optimized for ability
	Portability/size
	Reliability
	Training
Scenario	Location (co-located vs. remote)
	Private vs. public communication
	Purpose (type of awareness)
	Scalability (dyads, small or large groups)
	Target audience demographic
	Target user demographic (age, ability)
	Type of design (universal, accessibility, etc.)
User Perceptions	Aesthetically pleasing/beauty
	Burden/complexity
	Comfort
	Disruptiveness
	Dys-appearance [23]
	Habituation
	Impact on autonomy
	Learnability (how to interpret meaning)
	Learnability (how to use)
	Privacy
	Related to personality/personal style
	Social acceptability [50]
	Subtlety

Table 1. Taxonomy of dimensions to consider when designing AAC awareness displays (in alphabetical order).

We deployed two online questionnaires (one for conversational flow and one for emotion) that involved three parts each. The first part presented unlabeled non-text designs for each intended meaning (i.e., *talking*, *typing*, etc.) in random order. We asked an open-ended question about what participants thought each meant, in one word, regarding communication. We did not include **skins** in the conversational flow questionnaire because pilot-testing within our research team indicated they were largely uninterpretable. **Text** was not shown in this first part or the second because the **text** display already presents an unambiguous meaning. Second, after respondents indicated what they thought the designs meant, they ranked them according to how accurately they felt that the designs depicted our intended meaning (i.e., "depiction accuracy"). For example, in the emotion survey, participants were shown the **emoticon**, **emoji**, **avatar**, **skins**, and **colored LED cluster** designs for *happy*. Then, participants ranked them from most to least accurate in depicting *happiness*. In the third part of the questionnaire, we showed all of the displays, including **text**, and asked the participants to rank them from their most to least favorite designs overall. We also asked them to describe why they chose this ranking. The goal of the two questionnaires was to help us narrow down which design concepts to include in more thorough user testing, by eliminating designs that would be difficult for casual or new communication partners to interpret without training, and by including designs that would help us further unpack users' perceptions.

Participants

We recruited a total of 81 participants from a large technology company by randomly sampling employees in technical and non-technical positions. Forty participants completed the emotion questionnaire (*Q1-Q40*), and 41 (*Q41-Q81*) completed the conversational flow questionnaire. Ages ranged from 19 to 64 (mean = 37.9 years; SD = 11.2). Thirty-seven (45.7%) identified as female, and 44 as male. Only five participants (6.2%) did not use any form of pictures or symbols (e.g., emoji, emoticon, stickers) in online or text communication. Three participants (3.7%) reported having spoken with someone who uses an AAC device.

Analysis & Findings

Using a joint inductive-deductive approach to qualitative analysis [52], one researcher coded each one-word design interpretation response per its dictionary meaning. She then grouped the responses according to synonymous meanings. For example, "sad," "gloomy," "melancholy," "upset," and "somber" fit into a general theme of *sadness*. Two to three researchers met to review the codes and thematic groupings and to discuss and clarify disagreements. We then calculated the percentage of thematic responses that correctly corresponded to the intended meaning for each design. Table 3 shows these percentages aggregated for each design.

We also calculated aggregate weighted scores for each design in terms of (1) depiction accuracy and (2) preference by adding all participant rankings for a particular design for each of these measures (items ranked first have a higher value or "weight"). Table 4 shows the weights for depiction accuracy averaged across all content for each type of awareness display. For conversational flow, the designs from most to least favorite were **text** (weight of 190), **emoji** (160), **avatar** (105), and **emoticon**, tied with **colored LED clusters** (80). For emotion, the most to least favorite designs were **emoji** (218), **avatar**, tied with **text** (160), **emoticon** (154), **skins** (75), and **colored LED clusters** (73).

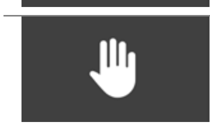
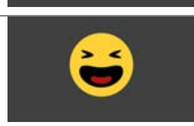
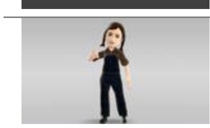
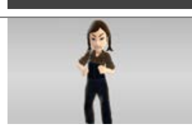
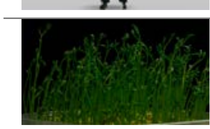
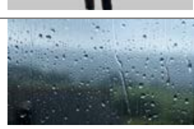
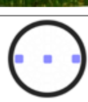
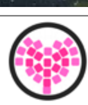
Conversational flow	*Emotion*	*Awareness display type*
I'm listening.	sarcastic	**Text (left: *listening*; right: *sarcastic*):** The exact meanings in plain text. For conversational flow, they are presented in sentences. The emotions are individual words.
(^o^)<<<	:)	**Emoticon (left: *talking*; right: *happy*):** Pictorial representations using ASCII punctuation marks, numbers, and letters (i.e., emoticons). For emoticons that did not have Western style representations (e.g., *happy*), we used or created Japanese style emoticons (e.g., *talking*).
		**Emoji (left: *hold on*; right: *laughing*):** Static expressive symbols, currently popularly used in text and online communication. Here, the emoji are from Windows 10. The majority of emotions are face-based, while the conversational cues are other types of ideograms.
		**Avatar (left: *Pardon me?*; right: *angry*):** An animated Xbox Live Avatar, available through Windows. Animations last from anywhere between 1-15 seconds. The animations repeat until the corresponding key is released or the action (i.e., *typing*) stops.
		**Skins (left: *talking*; right: *sad*):** Animated thematic videos; in our case, nature scenes retrieved from Creative Commons. Animations lasted from between 1-12 seconds and repeated as necessary. (Left by Always Shooting / CC BY 2.0; right by Frank Vincentz / CC BY-SA 3.0.)
		**Colored LED cluster (left: *typing*; right: *caring*):** Brightly colored LEDs animate within a circle, and repeat as necessary. Some emotions are modeled after faces/emoticons, while conversational cues are abstract symbols and movement.

Table 2. Examples of each type of awareness display for various conversational cues and emotions. Please see the Appendix and the Video Figure for all of the displays' contents.

Finally, following our prior qualitative analysis process [52], we open coded participants' qualitative explanations for their favorite ranking order, which resulted in six consistent themes: (1) **Text** is most precise, which is preferable for conversation flow. (2) The abstract displays (**colored LED cluster** and **skins**) are "too" individually interpretable. (3) Interpretation should be "direct" and "quick." (4) **Emoji** are common and "universal." (5) The **avatar** is more expressive and better for conveying affective information. (6) The **skins** are more beautiful and interesting.

To increase its interpretability, one participant (*Q70*) suggested combining **text** with the **avatar**. Similarly, another (*Q58*) indicated the **colored LED cluster** needs a key. Only one participant (*Q33*) noted how abstract and multiple interpretations might be more realistic to the communication of emotion: *"I like the abstraction of the [**skins**], how it leaves room for interpretation and doesn't attempt to oversimplify something as complex as emotion and feeling."*

Reflections & Implications for our Design Process

The quantitative answers and qualitative themes that emerged from this study paralleled some of the initial threads of our design process. The notion that communication should be straightforward, "leav[ing] no room for interpretation" (*Q56*), plays into the ***discomfort with abstract meanings*** we had while designing. From the perspective of potential casual interpreters of AAC awareness displays, less abstract designs were favored for both conversational flow and emotion awareness. This was despite the fact that, even without any contextual communication clues, participants guessed the meanings almost equally on average across all of the displays (with the exception of **emoji** and **skins** being on opposite extremes) (see Table 3).

Furthermore, the continual reference to **emoji** as common and universal relates to the concept that other types of displays might further ***mark AAC device users as "other."*** By choosing to incorporate currently conventional forms of communication into our designs, we may increase not only their understandability but also their social acceptability [50] and, in turn, decrease stigma. However, this comes into conflict with the idea of designing for *'what might be'* [14].

Using these results and reflections, we chose three designs to integrate into a working system for further evaluation: **text**, **emoji**, and the **colored LED cluster**. We chose **text** because of its straightforward nature; **emoji** because it is normative and performed well in terms of interpretability and preference in our questionnaire; and the **colored LED cluster** because, while some people were uncomfortable with it, its inclusion in the next step of our process allowed us to further investigate a design that landed on different parts of the *resolution* and *abstractness* spectra. Because lower resolution displays have some *practical* advantages, it was important to include this design in later evaluations.

	emoticon	emoji	avatar	skins	LEDs
convo	32%	72%	49%	N/A	45%
emotion	58%	76%	58%	30%	55%

Table 3. Percent of responses overall in which reported design meanings were similar to their intended meanings.

	emoticon	emoji	avatar	skins	LEDs
convo	89	144	90	N/A	87
emotion	122	179	144	64	91

Table 4. Average weight of depiction accuracy for each display design (higher numbers indicate better accuracy).

ONE-ON-ONE CONVERSATIONS

To extend our exploration, we wanted to see how these three display designs might affect conversation partners' perceptions during a one-on-one chat with a person using an AAC device. Supplementing the interpretation questionnaire, this lab study allowed us to probe more deeply into how conversation partners interpret and perceive the displays in a more realistic context that did not ignore the challenges of communicating when dialogue is mediated by an AAC system.

Participants

We recruited 24 participants (*S1-S24*) with a variety of job roles (e.g., human resources assistants, legal specialists, software engineers) from our organization. The participants were randomly assigned to one of the three display types such that there were eight participants per type. One participant identified as non-binary, 12 as female, and 11 as male. Three participants were in the 46-55 age range; 10 were 26-35; and 11 were 18-25. Only one reported not using any form of pictures or symbols (e.g., emoji, emoticons) in digital communication. All participants were fluent in English, although three were non-native English speakers. None of the participants had previously spoken to someone who uses an AAC device.

Materials

We integrated the awareness display into a fully operational eye gaze controlled AAC device, implemented in C# on a Microsoft Surface Pro 4. The display could be set to show **text**, **emoji**, or an animated image simulating a **colored LED cluster**. The content appeared on an Adafruit Qualia 9.7" DisplayPort Monitor (2048x1536) on a vertical desk stand, facing the conversation partner (Figure 1).

We modified the AAC device's keyboard by adding keys for all six emotions (*happy, sad, angry, sarcastic, laughing*, and *caring*) and for three conversational cues (*listening, hold on*, and *pardon me?*). The system could already detect when the

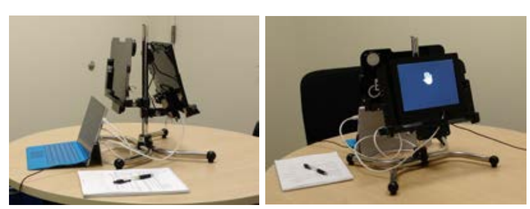


Figure 1. Lab study setup. Interlocutors sat on either side of AAC device and stand (left). The awareness display faced the conversation partner (right).

user was *typing* or playing text as speech (i.e., *talking*). Typing on the device, speaking through the device, or clicking the added keys (via mouse, touch, or eye gaze) showed the corresponding cue on the awareness display.

Setting & Procedure

We ran the sessions in a room with two ceiling-mounted cameras recording each interlocutor's face and the awareness display. The lead researcher acted as the study facilitator and AAC device user. Rather than controlling the system with her eye gaze, she used the trackpad while looking directly at the AAC keyboard to type on the device; however, she typed at a slow pace that was comparable to the speed of typing with eye gaze (~20 wpm [28]). This is because gaze typing is very fatiguing, so the researcher would have been unable to conduct several study sessions in succession if using gaze input. Gaze input is also extremely error prone, and we did not want errors in speech output to confound the already complex communication dynamics we were attempting to isolate in this study.

After a participant signed a consent form, the researcher explained to him what they would be doing during the session, including describing what an AAC device is, showing a video clip of a person with ALS using an eye gaze controlled AAC device, and making clear that AAC system typing is very slow. Then, the researcher (i.e., the AAC device user) and her conversation partner sat on opposite sides of a round table with the AAC device between them (Figure 1); from this point onward, the researcher did not speak verbally, and relied only on the AAC device to communicate. The researcher usually began the conversation by asking the participant where he was from originally. The rest of the conversation continued as it would naturally in any situation between two people meeting or getting to know each other. Occasionally, when the researcher seemed to be dominating the conversation, she reminded the participant that he could ask her questions so that the chat would be more balanced, as opposed to an interview.

For the first five minutes of talking, they spoke without the awareness display monitor connected to the AAC device. The purpose of this time was for the participant to get used to chatting with a device mediating the conversation. After these five minutes, the lead researcher told the participant that she would be connecting the display to give him more information about the conversation. They spoke with the awareness display connected for 15 minutes (a typical amount of time in AAC research [17]).

Afterward, the participant filled out a computer-based questionnaire about their time talking with the awareness display turned on. The questionnaire asked a set of Likert-scale questions based on scales in AAC research by Wisenburn and Higginbotham [66] and Todman [55]. It also asked 5-point Likert-scale questions specifically about the awareness display content as it related to our *user perception* taxonomy dimension (e.g., how *distracting, familiar, subtle, complex, understandable, helpful,* and *abstract* the display was, where 1 = not at all, and 5 = extremely). For participants who viewed the **emoji** and **colored LED cluster** displays, we asked them if they understood what the display's content related to conversation flow indicated and how well they thought it represented that meaning. Finally, we asked for open-ended comments about their experience and the awareness display. Participants received a US$10 Amazon gift card for their 30-minute participation.

Data Analysis

For the quantitative post-conversation questionnaire, we performed an Aligned Rank Transform [67] on the Likert-scale data to run multivariate analysis of variance tests; based on these results, we then performed pairwise comparison t-tests to check for individual significant differences between the three displays. For clarity, in the findings, we report untransformed means of Likert data. Using a grounded theory approach [52], the lead researcher open coded participants' comments and her own brief reflexive notes from the study sessions; she grouped the codes thematically and then iteratively refined them. Subsequently, two to three researchers met to review the codes and themes. They discussed disagreements, clarified misunderstandings, and refined the themes. For study sessions for which there were pertinent participant responses or notes, we reviewed the recordings to support overall data analysis. We did not code the conversations themselves because we were interested in participants' *perceptions*, as opposed to actual effects on the dialogue.

Findings

The conversation partners who viewed the **colored LED cluster** design had issues with its ambiguity. Some qualitative responses mentioned how the conversation flow animations were "confusing" and "too abstract." Participant *S19* even suggested using more concrete representations instead: *"Using icons such as an Ear [sic] for listening… may be clearer to understand what the other person was doing."* Quantitative differences in conversation partners' perceptions complemented these notions. Participants perceived the **colored LED cluster** to be significantly less helpful for conversational flow (M=2.8; SD=0.89) than both **text** (M=3.9; SD=1.3) and **emoji** (M=4.5; SD=0.76) ($p<0.05$, $\eta^2=0.38$, $1-\beta=0.86$), and significantly less understandable (M=2.9; SD=1.1) than both **text** (M=4.5; SD=1.1) and **emoji** (M=4.5; SD=0.54) ($p<0.05$, $\eta^2=0.43$, $1-\beta=0.92$). Moreover, the **colored LED cluster** was perceived as being significantly worse at depicting *listening* ($\eta^2=0.68$, $1-\beta=1.0$), *typing* ($\eta^2=0.42$, $1-\beta=0.84$), and *hold on* ($\eta^2=0.32$, $1-\beta=0.66$) (all on average "neutral") compared to **emoji** (on average "very well") (all $p<0.05$).

Participants who only saw **text** made comments related to it being precise. One participant who saw **text** (*S5*) wanted there to be even more precision. She said, *"The information on the screen was helpful, but the emotions displayed could've been a little bit more nuanced ([e.g.,] annoyed/frustrated vs. angry)."* Because of how precise **text** is, there might need to be more distinct emotions displayed on the screen to match the granularity of expression that people know text can allow.

The **text** display also prompted two participants to make comments about wanting to see what the lead researcher was typing as she typed it, whereas no conversation partners who saw the **emoji** or **colored LED cluster** designs made such comments. *S3* said, *"[It would be] helpful if it showed some of the text being input, ahead of the text-to-speech, to help me understand what's coming, and potentially steer the conversation ahead of the other person completing a thought/sentence."*

In terms of emotions, the **emoji** design was perceived by many participants as being particularly expressive. *S14* who saw the **emoji** said, *"The emojis [sic] were very helpful, especially when I'd tell a joke in the middle of what I'm saying [and the researcher would respond with a laughing emoji]. The emojis [sic] allowed much more emotional and real time interaction with things like smiles and laughs or sympathy in real-time with what I'm saying..."* Moreover, two participants who saw the **emoji** display mentioned how the communication was "like texting," while no participants who saw the **text** and **colored LED cluster** displays mentioned something similar.

Finally, one issue around eye contact came up for participants in this user study. Because participants who saw the **text**, **emoji**, and **colored LED cluster** displays all brought up a challenge with eye contact, we believe that this has more to do with personality and the awareness display in general, rather than a particular design. During some conversations, the lead researcher noticed how conversation partners seemed to try very hard to keep eye contact with her while they were talking during the study, and this resulted in them not looking down at the awareness display. Although others seemed to glance up and down from her face to the screen, she also observed some participants staring at the screen instead of looking at her face. Pointedly, *S2* who saw the **text** design noted, *"I think the screen helped me understand what the other person was doing, but it felt like a tradeoff, of making eye contact vs. looking at the screen. It might make me less aware of the person's face, and lose a bit of the humanity of the dialog."*

PALS & THEIR CLOSE CONVERSATION PARTNERS

The last stage in our exploration involved getting direct feedback about the three types of awareness displays from seven people with ALS (*P1-P7*) and their close conversation partners (e.g., family members, significant others, and/or professional caregivers) (*C1-C10*). PALS' ages ranged from their 40's to 60's, and they had lived with ALS for three to five years. One of the seven was female (ALS is more common in men [29]). Four of the PALS use gaze- or head-mouse-based AAC for all communications, and three (*P1*, *P4*, and *P7*) retained some dysarthric speech ability, and did not yet use an AAC device regularly; however, they owned or planned to obtain AAC devices for anticipated future use.

To be sensitive of their limited availability and tendency to fatigue easily, and to ensure they focused on the *output* as opposed to the *input* mechanisms, we had the PALS and their conversation partners watch a five-minute video describing the awareness display. Similar to our Video Figure, this video showed the **text**, **emoji**, and the **colored LED cluster** designs and included recordings of two people using the three display types during short conversations. This allowed the PALS and their conversation partners to see how the displays work both in and out of context.

After watching the video, conversation partners filled out a questionnaire that asked them how much they liked each type of display (separately for conversational flow and emotions), and asked them to describe a situation (if any) in which they felt this type of display might be helpful and why. While the conversation partner(s) filled out the questionnaire, a researcher asked an equivalent set of quantitative questions to the PALS. Because communication for PALS can be slow and fatiguing, we focused mostly on multiple-choice questions rather than open-ended comments; the researcher would read the question and the set of possible answers, and then would say each answer aloud until the PAL gave an agreed-upon signal (e.g., blinking, grunting, typing via AAC) to indicate their answer choice. To those who were able to speak or type a longer response, the researcher also asked for any qualitative feedback on each of the displays, including suggestions or justifications for their multiple-choice responses. Again, we followed our prior qualitative analysis processes [52] of individual open coding and thematic grouping, and discussions with two to three researchers to discuss, clarify, and refine codes and themes.

Findings

On average, across all of the participants for both conversational flow and emotions, the **colored LED cluster** was rated the lowest in terms of how much they would want the display (i.e., all "neutral," rather than toward "very much") and was ranked on average as least favorite. For most of the PALS, **text** was ranked as most favorite for conversational flow and second favorite for emotions. On average, PALS ranked **emoji** as their second favorite for conversational flow and most favorite for emotions. These findings held overall for their close conversation partners too. Table 5 shows the average favorite rankings for the designs.

Qualitative feedback about the displays from PALS and their close conversation partners expanded on theses quantitative answer choices. Many conversation partners noted how the **colored LED cluster** is ambiguous and **text** is more straightforward. *P3*'s brother (*C6*) noted it would be necessary *"to train people as to what some of the different abstract lights [i.e., the **colored LED cluster**] represent - text is easier."* Similarly, *P7*'s wife (*C10*) said the **colored LED cluster** would *"not [be] easily understood by [casual] visitors, so I wouldn't want to have to explain what he is saying through the lights."* *P1* explained that if we could get the **colored LED cluster** to look more descriptive, he would like it more.

He then suggested putting a key next to the **colored LED cluster** to make the meanings clearer. Likewise, *P1*'s nephew and caregiver (*C2*) remarked for emotions, *"[Text is] to the point, but less fun than emoji."*

A few participants suggested combining **text** and **emoji** designs to make their meanings more obvious or more expressive. *P3*'s brother (*C6*) thought that **emoji** could be added to **text** to stress its meaning. *P1* requested the opposite so that if someone does not understand the **emoji**, it will be clearer: *"If it's not a big deal, make an **emoji** with a little **text** on them." P6*'s husband (*C9*) suggested combining all three designs to be more interesting, or stylizing the text to make it more expressive.

However, some recognized unique benefits of the **colored LED cluster** that the lab study participants, who were unfamiliar with AAC devices and people who use them, did not. Specifically, *P5*'s wife (*C8*) recognized, *"I could see the [**colored LED cluster] display** easily if I weren't in the immediate vicinity."* She also called it *"an attention grabber."* Likewise, *P1*'s nephew and caregiver (*C2*) called the **colored LED cluster** *"accessible"* and *"attention grabbing." P1* said the **colored LED cluster** was *"more fun."*

A few of the PALS' close conversation partners noted how **emoji** and **text** are normative, and, thus, more "normal." For instance, *P3*'s significant other (*C5*) said, *"[**Emoji**] are most similar to what others use (texting) so nice that it is more 'normal.'"* Correspondingly, *P2*'s wife (*C*3) explained that **text** and **emoji** for conversation flow are *"[m]ore like normal conversation."*

The conversation partner participants also liked how **emoji** are, as their name denotes, more emotional as well. *P2*'s wife (*C3*) specified that *"**emoji** communicate feelings better,"* while *P5*'s wife (*C8*) indicated, *"**Emojis** [sic] would provide immediate insight."*

In regard to issues of personality, a few PALS conveyed how they would want to be able to add other types of emotions and customize what is shown on the display. For instance, *P4*, who really liked the **emoji** design, mentioned that "shocked" is another emotion he would want for the awareness display. *P7* said he might also like to have "concerned," "frightened," and "upset." *P1* expressed how, when he was able to move more, he would smile and nod a lot when other people were talking to him. He lamented that now *"they [conversation partners] think I'm bored."* Therefore, he wanted to be able to better show "enthusiastic listening" on the awareness display. As a type of suggestion, he told us when he communicates online with a group currently, he likes to use a GIF of a bag of movie popcorn being eaten to indicate he is paying attention and to portray this "enthusiastic listening" feeling.

Finally, all of the PALS and their conversation partners were receptive to and liked the general idea of an awareness display. The PALS said things like the following: *"It's a great idea"* (*P1*); *"That would be useful"* (*P2*); *"I like the general concept"* (*P3*); and *"I think it's a good concept"* (*P7*). Their close conversation partners gave more detail for why this type of display might be important to them personally or for communication overall. *P3*'s significant other (*C5*) explained, *"I think it would be most helpful for people that aren't around very often. People that get uncomfortable waiting for a response from [him] (so 'typing' would help); or that don't get his sense of humor/way of speaking."* On a more personal note, *P2*'s wife (*C3*) said, *"I miss [my husband]'s voice, and our conversations. Anything that can help restore some of that would be so wonderful."*

		text	*emoji*	*LEDs*
PALS	***convo***	1 (0.5)	2 (0.7)	3 (0.5)
	emotion	2 (0.0)	1 (0.8)	3 (0.8)
CPs	***convo***	2 (0.7)	2 (0.7)	3 (0.5)
	emotion	2 (0.7)	1 (0.3)	3 (0.5)

Table 5. Average ranking, rounded to one significant digit, (with SD) for favorite displays of PALS and conversation partners (CPs) (1: most favorite; 3: least favorite).

DISCUSSION

From the beginning to the end of our study, matters related to ***abstractness in meaning*** and further ***marking AAC device users as "other"*** persisted in our reflections and findings. These issues were entangled with other dimensions of our taxonomy, as well (which we indicate with *italics*).

In both the questionnaire and lab studies, participants recognized the difficulty in interpreting more ambiguous awareness indicators. Thus, they perceived them to be *less learnable*. Despite it being more *practical*, especially in terms of *cost, power, maintenance*, and *reliability* due to it being a *low resolution* display, the **colored LED cluster** might not be appropriate for most forms of conversation. The PALS and their close conversation partners brought up similar concerns, but also identified situations in which such a *low resolution*, *highly abstract* display might be appropriate (i.e., to grab attention or flag an emergency).

At the same time, the least abstract of the displays, **text**, was favored by participants because of its precision, especially for conversation flow. Clarity seemed to be key in this context. However, this was at the expense of "fun" (*C2*), *beauty,* and ambiguity common in typical conversations. In addition, lab study participants who saw the **text** design brought up matters that could affect the display's *efficacy* or perceived *complexity* and challenge a speaker's *privacy*. Specifically, **text** for emotions may not be nuanced enough, causing more misinterpretations in conversations. Or, if we included more emotions (i.e., "frustrated" and "annoyed" instead of "angry," like *S5* wanted), we may increase the *burden* on the speaker to pick from more options. At the same time, the fact that only lab study participants who saw the **text** display commented on wanting to see the speaker's typed words as she typed them (like with [8,12,42]) points to possible issues with *privacy* that might arise with having such a display (if listeners assume the speaker can show their typed text). This is an important issue, as Fiannaca et al. [12] found that PALS are only willing to share text as it is being typed with very close conversation partners in certain scenarios; otherwise, they consider it rude or an invasion of *privacy*.

The **emoji** design seemed to be a nice middle ground, although the *highest resolution* of the displays, to be able to increase interpretability and be more emotional, yet capture and represent multiple feelings with one face. Subsequently, this was the design usually favored by the participants, particularly for emotion awareness. Following some of the PALS' and their close conversation partners' suggestions, combining **text** and **emoji** in one design might be most *effective* for conversations. Also, a *high resolution* display is flexible enough to show **text** for conversation flow and **emoji** for emotions, perhaps making it more *effective* too.

Next, as we experienced from the start, a continual conflict emerged between designing *socially acceptable,* normative display content as opposed to that which may further mark speakers as "other." While participants throughout our evaluations described the **emoji** displays as "universal" and even "normal," we argue that this is not a reason to choose such a display design for the long term. Designing for what is current and popular may not be *practical* or sustainable. However, using a *higher resolution* display that could show **emoji** now, and other types of designs now and later allows for both *customizability* and adaptability to changing *socially acceptable* trends. It is even more important to make the display flexible in this way, for people like *P4, P7,* and *P1* who wanted to add their own content, so that the designs can better *fit to the speaker's personality and style.* This makes any question or tension about if we are trying to model realistic conversation or designing for quickness and functionality at the expense of stylish designs more of a moot point. Again, *higher resolution* gives more flexibility to address both. The challenge is balancing this customization with *burden*. If this requires too much effort for *input* or caregiver support for *maintenance*, it might not be used. And, if a high-resolution display adds too much *cost*, *weight*, or *energy* use to a system, it may not be *practical*.

Finally, because it was most contextualized, one issue came up in the lab study that centered around eye contact. If we design an awareness display to be too *large*, *disruptive*, and *not subtle*, we may be taking away from, in the words of *S2,* "the humanity" of the communication. Removing "humanity" means further marking the speaker as "other," which is where more *abstract*, *subtle,* and *ambient* designs might be more appropriate. Rather than putting **text** or an **emoji** front and center, something more like the **colored LED cluster**, but less bright, *smaller*, and in a more *peripheral location* or closer to the eyes (like [60]) might better *augment* communication, keeping focus on the person, not on the device; however, displays near the eyes, while possibly drawing attention upward, risk interfering with gaze-operated AAC.

Limitations & Future Work

In this work, we took an integrative approach to evaluating our awareness display designs, as different methods offer different insights and help balance out each other's limitations. However, readers should bear in mind the limitations of each method when interpreting our findings. Participants in the questionnaire and in-lab conversation studies were not regular communication partners of people with ALS and cannot represent that perspective, but do give insight into the reactions of casual conversation partners and the walk-up-and-usability of a system. The purpose of the conversation study with the researcher simulating AAC use was to lend further realism and context to the interpretation of the awareness displays beyond what was possible in the online questionnaire; though, of course, this does not lend nearly as much realism as an organic conversation with an authentic AAC device user. Our evaluations with PALS and close conversation partners were, by necessity, shorter and less formal than the other studies, but add crucial perspectives of the most frequent, important stakeholders in such systems. Being aware of possible acquiescence bias for these evaluations with PALS is important; however, the fact that participants gave constructive criticisms to the colored LED cluster designs indicates that this bias was reduced.

An extremely important next step is a long-term deployment of awareness displays to true AAC device users. Future work should also be done to validate the number of cues and emotions needed for awareness displays and if this changes over time. Further exploration of resolution and abstractness, since our results may be tied to our representations and their fidelity, is necessary too. Finally, future work needs to unpack more factors within *output features, practicality, scenario,* and *user perceptions*, and the entirety of *input features*, which may have major implications that relate to *burden*, *comfort,* and *impact on autonomy*.

CONCLUSION

We explored the design space of awareness displays for augmentative and alternative communication. By reflecting on our design process and reporting on various interlocutors' perceptions of the display, we revealed key conflicts that arose in regard to (1) the designs being more abstract vs. straightforward and (2) the designs playing into normative paradigms of communication vs. further marking speakers as "other." As an important takeaway from our discussion, we considered how *higher resolution* displays give more flexibility to find the right mix of normativity, abstraction, ambience, and customizability. Our taxonomy provides more directions researchers can investigate in this space. Overall, we contribute a generative understanding of designing AAC awareness displays to augment and improve conversational cueing and emotional expressivity during communication. We hope researchers can use our work to better understand the tensions and potential effects of specific design choices on the perceptions of conversation partners and those who use eye-gaze controlled AAC devices.

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