Co-design Explorations of Expressive Objects to Support Conversational Agency in AAC

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ABSTRACT

Augmented communicators (ACs) who use augmentative and alternative communication (AAC) devices to speak often experience challenges in face-to-face conversations. Current AAC devices provide speech-based communication but do not provide nonverbal communication, although that is often a key resource for turn taking and for regulating conversational dynamics. We present a co-design study that explores nonverbal communication to support ACs in conversation using a "sidekick," a physical expressive object. We conducted a design workshop with ACs and motion experts to elicit ACs' goals for conversational support, prototype expressive objects and design motions and behaviors to achieve those goals. Following the workshop, ACs provided reflections on the generated prototypes and sidekick behaviors and on their participation in the workshop. We analyzed the results of the workshop and define the design space of possible tasks a sidekick could support and how it should do so. We also include guidelines and insights about conducting accessible co-design workshops.

Author Keywords

AAC; accessibility; augmented communicator; co-design; motion; sidekick; workshop

INTRODUCTION

People with severe speech and physical impairments may use augmentative and alternative communication devices (AAC) to speak by selecting letters, words or images from a board or tablet, which then get spoken aloud [6]. Compared to natural speakers, people using an AAC device who in addition have severe motor impairments may speak at significantly slower rates and use a smaller range of nonverbal behaviors (*e.g.*, gestures, body orientation) to communicate [17, 22].

Natural speakers, desiring efficient conversation and/or lacking familiarity with an augmented communicator's (AC's) communication style, often limit ACs' opportunities to participate in the conversation; for instance, by asking ACs yes/no questions, instead of open-ended ones, by dominating the conversation, or by failing to respond to ACs' communication attempts [12, 16, 45].

Figure 1. Workshop participants including a person using an AAC device to communicate, two close conversational partners (his mom and an aide) and a puppeteer co-designing a sidekick. A sidekick is a physical devices that uses movement to support AC participation.

Close conversation partners (CCPs) familiar to particular ACs (*e.g.*, parents or paid aids) can mitigate such social challenges to AC participation. CCPs translate ACs' verbalizations and gestures to unfamiliar speakers, and use nonverbal techniques (*e.g.*, gaze, body orientation) to orient the conversation towards the AC [45]. CCP's translation and use of nonverbal communication on behalf of the AC can help balance participation opportunities with other speakers who regularly use motion to pace conversation (*e.g.*, nodding) or negotiate turn taking (*e.g.*, raising hand) [46]. However, when a CCP is not present, or when the AC wishes to communicate spontaneously, using nonverbal communication to promote their own participation remains challenging.

Prior work outside of AAC indicates that physical devices can use *motion* to achieve communicative effects. For example, devices using motion can communicate nonverbal cues [25], and even influence the sentiment of an interaction [1]. Physical devices can use motion to draw attention only when needed and otherwise exist in the periphery of conversation [18, 28]. Because of these qualities, physical prototypes have been used to assist with conversations between people, for instance, during conflict [18, 21], or when mediating conversation between children with autism and their conversation partners [35]. Despite the advantages that motion provides in nonverbal communication, it remains an unexplored communication modality for AAC.

We explore the design of physical prototypes that use motion for the purpose of increasing AC's participation through a

co-design workshop. To encourage designs that support the AC, rather than function as an independent agent, we defined our workshop efforts towards designing an assistive *sidekick*. Previous work that used *sidekicks* as a metaphor for designing robots, found that sidekicks can help their user, create a sense of emotional connection, and suggest an alternative point of view, but they do not exist without their protagonist, who is the focus of attention [27]. We therefore followed this metaphor in our workshop, as it aligned with our goals and design problem.

In our co-design workshop, we included ACs and their CCPs along with puppeteers as domain experts in communicative nonverbal motion; puppeteers understand nuances of communicating with motion (how to use angles, speed, etc.) and using motion to elicit specific interactions or responses. Our inclusion of puppeteers is informed by previous work that successfully integrated movement experts as part of the design of a mechanical ottoman [41].Outcomes of the workshop include a list of potential tasks that physical sidekicks could support (*e.g.*, fill in a silence gap, draw attention to AC), physical prototypes produced by ACs and their teams, and 40 puppeteer-created motions to support sidekick tasks with 12 motions that received AC feedback.

As workshops are commonly inaccessible to people with disabilities [5, 24], we redesigned existing warm-ups and design exercises for inclusion of ACs with consultation from a speech language pathologist (SLP).

Our work makes three primary contributions. First, we identify design opportunities in which expressive physical prototypes may support ACs by helping them communicate more nuanced nonverbal cues, and increase their perceived agency with conversation partners. Second, we report the results of our initial exploration with puppeteers on specific motions and behaviors of sidekicks for identified needs. Third, we present the design of a co-design workshop with individuals who have severe motor and speech impairments. By reviewing our workshop observations and considering AC feedback, we discuss some of the tradeoffs of sidekick behaviors and the challenges that need to be addressed in this design space.

RELATED WORK

Our work builds on prior research on augmenting AAC conversations, considering embodied interactions and the implementation of accessible design workshops.

Augmenting AAC Technologies

Prior research on communicating with AAC devices has focused on improving device throughput, for example via text prediction [48], training [44] and vocabulary sorting [2, 22], and on improving device expressivity, via rendering speech with personal voices [30] and emotion [11, 33], as well as displaying device status information [42]. While most prior work focuses on the modalities of voice and screen-based communication, Sobel et al. also consider LED clusters for displaying device status (e.g., listening, typing, or resting) [42]. LED clusters can draw attention to help ACs communicate their status. However, for unfamiliar conversational partners, the status given by the LED may be difficult to interpret, and all existing modes (*e.g.*, voice, screen, LED) may fail to draw attention when conversational partners may be looking elsewhere or conversing with others. To address such conversational challenges, we consider motion as a new communication modality for ACs.

While the majority of prior work in AAC devices considers the device itself, we work on technologies designed to increase augmented communicator's (AC's) agency with respect to social challenges when speaking with others. Other work has also considered communication partners in AAC communication through making an AC's status visible to others through a mobile companion app [12] and a partner-facing display [42]. However, such work explores displays primarily with a close conversational partner, whereas our work considers possibilities for using motion for nonverbal communication when others are not already familiar with the AC's conversational style.

Embodied Interaction

Prior work in human-robot interaction has explored the benefits of embodied interaction – the way our perception of physical and social phenomena develops in interplay with our space and surroundings [10, 13]. Embodied interaction leverages people's ability to interpret nonverbal behavior to communicate a range of ideas and emotions through motion [1, 41]. Embodied interaction objects have been designed to stay in the periphery of people's attention, and move to the foreground only when needed [20, 28]. Prior work has explored how embodied technologies can act as communication supporters in a range of domains. Researchers have explored a peripheral robotic device to draw attention when the conversation between a romantic couple becomes aggressive [18], and to shape conversational dynamics in conversation in a small group [43].

Peripheral embodied interaction devices have also been suggested as assistive devices. For example, minimally expressive anthropomorphic robots have been used to assist autistic children to communicate with others [35] and to facilitate interaction between a dementia patient and their care-giver [31]. We extend the work in the design of peripheral embodied interactive objects to consider a peripheral object framed as a sidekick that aims at increasing augmented communicators' agency in conversation.

Accessible Design Workshops

Creating accessible design workshops has been a growing interest for researchers working with people with disabilities motivated by increasing the usability of assistive technology products [38, 47] and increasing agency for people with disabilities in the design process [15, 34].

Prior work has identified barriers to including people with disabilites in the design process such as a lack of training in user-centered design [47], lack of awareness on behalf of engineers and developers about the importance of including disabled co-designer's perspectives [39] and the inaccessibility of design workshops themselves, which heavily really on set visual [9], verbal [24] and cognitive [15] tasks.

For augmented communicators with severe motor impairments, current design activities such as brainstorming or ideation may be inaccessible given that they heavily rely on the ability of participants to verbally express their ideas in a timely manner and to physically produce sketches or prototypes. To successfully include augmented communicator's ideas in a design workshop, certain accessibility considerations need to be put in to practice. We draw inspiration from Lazar *et al.* on using affirmations that establish everyone as a collaborator, creating a shared language and using making as a way to express ideas [24]. In addition, during the workshop we allowed participants to explain their preferred ways of communicating. We wrote down key ideas that emerged on the board to form a shared representation of concepts [9] labelling them with numbers for easy reference. We also provided a variety of prototyping material, as using diverse materials was useful to provide more opportunities for people with disabilities to participate during other ideation sessions [5].

DESIGN GOALS & APPROACH

To preserve the agency of ACs in conversation, we framed the design of our physical prototypes that move as *assistive sidekicks* for the AC rather than primary participants. We began our process with the following design goals for assistive sidekicks, building on the success of embodied interactions that are peripheral to conversation in prior work [18]: (1) assistive sidekicks should act on behalf of ACs interests, rather than the interests of other speakers; (2) assistive sidekicks should play a supportive role and never act as a primary participant; (3) assistive sidekicks should be able to selectively draw attention or fade into the background as needed; (4) assistive sidekicks should be nonverbal, as ACs already have and use verbal communication. To explore the use of motion for sidekick interactions, we took a co-design approach [36] to integrate the expertise of ACs, their close conversational partners, and puppeteers (experts in nonverbal motion). In particular, we designed the workshop to answer two key research questions: (1) *what are ACs' needs in conversation that would benefit from sidekick support?* and (2) *how can an assistive sidekick support these goals and tasks through motion?*

To explore these questions with co-design, we employed prototyping and movement improvisation techniques. Prototyping lets co-designers explore options for a sidekick's form and can enable people with disabilities to reveal more about their personal challenges and stories [24, 4]. The stories embedded in the form will later shape the behavior exploration as well. Movement improvisation and *bodystorming* lets co-designers explore ideas physically, generate knowledge through doing, and explore options for sidekick motion to support a range of tasks [14, 40, 41].

While co-design workshops provide benefits for aggregating perspectives and expertise in design [36], some design activities can be inaccessible to ACs who have speech and motor impairments. To accommodate the range of speaking rates, styles and preferences of our participants, we followed a series of access commitments generated with feedback from a speech language pathologist and based on prior work [5, 9, 24]: (1) allow enough time during the workshop for everyone to communicate, (2) send question prompts in advance, (3) establish preferred modes of communication, (4) make shared content easy to reference, (5) assure that visuals and materials are physically accessible to users.

Participant	Role	Team
Tammy	Augmented Communicator	Tammy
Jim	Father to Tammy (CCP)	Tammy
Matt	Augmented Communicator	Matt
Linda	Mother to Matt (CCP)	Matt
Tyler	Aide to Matt (CCP)	Matt
Kathy	Puppeteer	Matt
Doug	Puppeteer	Tammy
Nancy	Puppeteer	Tammy

Table 1. Participants included two augmented communicators (ACs), their close conversational partners (CCPs) and three puppeteers. We include participant pseudonyms (Participant), the role of each participant (Role), and their AC team for the first part of the workshop (Team).

METHODS

Before the co-design workshop, we conducted pre-workshop activites including a review of previous work to formalize a set of tasks that a sidekick could do(*e.g*, securing the AC enough time to type) [45] and consulting with a speech language pathologist (SLP) on these tasks. Formative work also included getting the SLP's feedback on the in-person co-design workshop schedule and generating the accessibility commitments for our workshop. We then carried out a two-part co-design workshop over one day that lasted for a total of 6 hours. The first part of the workshop involved all participants to refine tasks and generate initial prototypes. Workshop part two, involved only puppeteer participants to generate potential motions that would carry out sidekick tasks. Post-workshop, we provided ACs with a subset of motions generated with puppeteers in a survey for feedback.

Pre-workshop: Formative work

Before the workshop, we collected a set of potential tasks for an assistive sidekick (*e.g.*, "indicate the AC needs more time to type", "indicate the AC wants to participate") and drafted our workshop design based on prior work [45]. We sent the potential sidekick goals and workshop design to a speech language pathologist to gain feedback on (1) the importance and practicality of our selected tasks and, (2) the accessibility of our workshop for adults with severe speech and motor impairments. We used the received feedback to improve our workshop design. Some of the changes we made include allowing ACs more time to share experiences, including a discussion of communication expectations and ground rules at the beginning of the workshop, and iterating our list of sidekick tasks.

Workshop part I: Sidekick tasks and prototypes

The first part of the workshop aimed to discover AC's needs and challenges in conversation that would benefit from sidekick support. We carried out brainstorming and prototyping activities to uncover existing values and tensions related to communication. This first workshop included Participants then

shared stories of prior successful and/or challenging communication experiences to identify potential goals for an assistive sidekick. Drawing from reported values and goals, participants prototyped assistive sidekicks on two AC-led teams.Below, AC participants and their family's names were altered to protect their anonymity.

Participants

Workshop participants included two augmented communicators (ACs), three close conversation partners (CCPs) and three puppeteers (Table 1). Augmented communicators, Tammy and Matt, (23 and 38 years old respectively) both have cerebral palsy and have used AAC devices for over 18 years. Tammy and Matt are also wheelchair users. Tammy uses a joystick to point to words or letters and pauses, or dwells, over her target to make a selection. Tammy also sometimes uses her hands to make pointing gestures and other signs she has come up with with her family. Matt's device constantly scans through each option on the display (*e.g.*, word, letter, shortcut) until he presses his head switch to select his desired option. Matt needs more time to use his device than Tammy due to the scanning input mode. Matt uses arm restraints.

Tammy participated with her dad (Jim), and Matt participated with his mother (Linda) and his aide (Tyler). Jim teaches arts and crafts and has gained extensive hardware expertise from working with Tammy on her device and setup. Linda has a background arts management and public relations along with extensive experience with AAC devices and users. Tyler is a recent graduate in physical therapy and professionally works with Matt as a communication aide. We invited artists with prior experience in puppetry, art and puppet design. In addition, two puppeteers (Doug and Kathy) had previous experience teaching art to people with disabilities (Kathy was also a former art teacher for Tammy). Nancy was new to communicating with augmented communicators.

Introduction

To familiarize participants with each other and the workshop's goals, we asked them to introduce themselves (*e.g.*, name, communication preferences of ACs, and interests. Then we introduced co-design and assistive sidekicks; we explained co-design (*e.g.*, designing with people of differing expertise) and discussed strategies to design with each other successfully (*e.g.*, use your expertise, share examples, describe ideal future states). We were inspired by prior work that highlighted the importance of introducing design concepts to AC co-designers [47]. We also introduced the goal of the workshop: exploring devices that move with the goal of improving ACs experience in face-to-face conversations. We used MicBot, a microphone that moves to facilitate turn-taking, as an illustrative example of a device to support conversation [43].

Brainstorming: What does communicating mean to me?

As a warm-up, we asked participants to write their answers to the question: "What does communicating mean to me?". To generate deeper reflections on participant's communication values, we used metaphors as a prompt to discuss what is communication. Metaphors have been suggests as an ideation tool that encourages people to think about abstract ideas from new perspectives through concrete illustrations [26]. We therefore used "New Metaphor" cards that represented potential metaphors for communication (*e.g.*, bridges, a balancing act, roots) on a white board (Figure 2). We asked each participant to select a metaphor card that best expressed what communication meant to them, and to share their selection with the group.

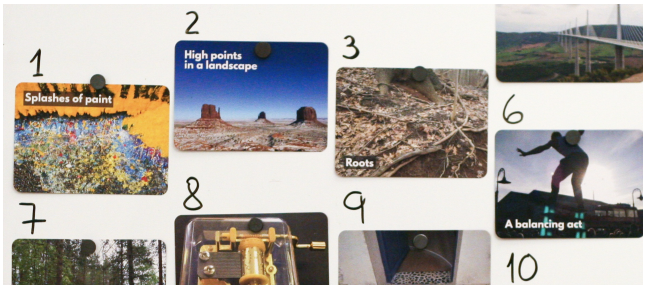

Figure 2. A selection of metaphor cards as a warm-up brainstorming activity. Metaphors can help people think about abstract ideas in concrete terms and gain new perspectives [26]. We gave participants the prompt "select a metaphor for communication and explain why the metaphor applies.", and encouraged them to select a metaphor using text or the number.

Sharing stories

To explore and dicuss AC needs in conversation with the group, we asked ACs to share stories about their face-to-face conversations and highlight any challenging, successful or humorous moments. We provided ACs with our prompts in advance so that they could prepare answers ahead of time.

Prototyping activity

After our in-depth discussions, we facilitated a sidekick prototyping session. The goal was to explore how to address the needs and values identified during the discussion, and to think-through-making by rapidly prototyping ideas in a group [32]. For this task, we separated participants into two AC-led teams: Team Tammy and Team Matt. Each ACs' team included their close conversational partners (CCPs) and one or two pupeteer(s) (Table 1). We asked participants to select one challenge or story that came up from previous exercises that resonated with them, and to use a range of craft materials we provided to create an assistive sidekick for that purpose. Teams then presented the concept and behaviors for their assistive sidekick prototypes they came up with. Finally, we asked a participants to share their closing thoughts in a debrief discussion.

The puppeteers made five additional prototypes that were informed by the discussions with ACs at the end of the co-design session. These prototypes allowed broader exploration of function given more options for form. These prototypes, along with the ones made in the co-design process, were used as props for the improvisation part of the workshop (Figure 4).

Workshop part II: Sidekick behaviors

The second part of the workshop aimed to use improvisation as a form of bodystorming [37] to explore how the identified needs would play out in motion and behavior. We guided puppeteers through a physical warm-up activity to create short

skits, followed by a behavior improvisation session. This method has been previous used in the field of human-robot interaction as a way of exploring motion for robotic prototypes with domain experts [37, 41].

Physical warm-ups

As a warm-up activity, puppeteers created short skits, also known as "Compositions", where they acted out scenes based on a set of constraints given for each composition [8]. To make compositions that would encourage puppeteers to think about the context and topic of the workshop, we selected related constraints for the improvisations. Each skit was required to include two characters and a sidekick, and 3 additional constraints: (1) One of the metaphor for communication that was selected by participants in the discussion bit of the workshop; (2) a relationship type between non-sidekick characters (*e.g.*, "two friends", "a hierarchical relationship", "two strangers"), and (3) an environment in which the scene (*e.g.*, occurs"loud").

Behaviors improvisation

We used improvisation as a form of bodystorming [37] ideas of how sidekicks may behave and move in physical space. The researchers selected four tasks from the first part of the workshop based on their prominence in discussion and their diversity: (1) Filling the silence gap while the AC types, (2) Showing others the AC is ready to participate, (3) Softening an AAC device message, and (4) Inviting others to look at the AC's screen.

One task at a time, we instructed puppeteers to generate as many behaviors as they could for that particular task. Puppeteers rotated between them in acting out the AC's role, the sidekick or the conversational partner in the improvisation sessions. After exploring the possible motion for each task, We held a brief discussion to talk about what worked, what did not, and what they notice in the process of brainstorming and improvising motion. The behaviors that were explored were documented in order to circle back to ACs and ask for their feedback about the tasks and how they might play out in motion.

Post-workshop: Follow-up survey

To gather feedback from ACs on the candidate movements and the workshop itself, we created an online survey with videos of selected sidekick behaviors generated by the puppeteers. We selected three behavior examples from each task, and included short clips of them in the survey. We asked for AC's impressions on the usefulness, appropriateness and how supportive is each behavior for the goals of enabling ACs more agency. In addition, we asked questions about the workshop's accessibility to learn whether the ACs felt included in the design process.

Data Collection and Analysis

We video recorded, audio recorded and photographed both workshop stages. Three paper authors additionally took observational notes during the workshop including participant quotes and paraphrasing of events with timestamps. To determine a list of sidekick tasks, we noted tasks that emerged from the first part of the workshop and added them to a list of sidekick tasks determined in formative work. To determine emergent behavior themes of the sidekick design, we segmented the video recording of the puppeteer workshop into demonstrated behaviors. Then, two authors wrote notes to record the goal of the behavior (*e.g.*, soften a message "no") and the content of the behavior (*e.g.*, softly shakes head "no" such that the hair of the puppet moves back and forth). Two authors conducted a thematic coding [29] of the behaviors to reach behavior themes. To determine accessibility of our workshop, we reviewed the transcript to report on AC team collaboration procedures. We also reviewed our notes including quotes with respect to our access commitments.

#	Stage	Sidekick Tasks
1	O	Show others there is an AAC device problem
2	O	Show others the AC needs more time
3	S	Fill the silence gap while the AC types
4	I	Show others the AC is ready to communicate
5	I	Tell others to remember what they're talking about
6	P	Soften an AAC device message
7	S	Show others that the AC is typing
8	S	Invite others to look at the AC's screen
9	S/P	Show others the AC disagrees
10	P	Add humor to an AAC device message
11	P	Convey emotion quickly

Table 2. The sidekick tasks along with their corresponding numbers and the stage in the workshop at which they were introduced: original task from formative work (O), task mentioned in introduction (I), task mentioned in sharing stories (S), task mentioned in prototyping (P).

FINDINGS: SIDEKICK TASKS AND PROTOTYPES

In our co-design through formative work, a workshop, and post-workshop feedback, participants generated the following components related to sidekick design: (1) a refined set of AC conversational goals that a sidekick could support (Table 2), (2) a set of physical prototypes to represent potential sidekick forms (Figure 3), and (3) a set of behaviors that the sidekick could use (Table 3).

Sidekick tasks

Throughout all phases of the workshop, researchers added to the list of tasks that an expressive sidekick could help the AC with as relevant stories and prototype considerations emerged (Table 2). During the first part of the workshop, ACs and close conversational partners mentioned tasks that ACs found challenging in their daily lives. For example, typing and retrieving messages from their device in a timely manner, showing others that they are ready to speak, and using signs effectively with new communication partners. As Matt's mother (Linda) reported:

> *Matt has so much stuff pre-programmed in there [AAC device], but the problem is that he can't get to it very quickly so it doesn't work even though it is already there, because of the access problem he can't get there fast enough* - Linda

To address the challenge of quickly communicating in a way that is not dependent on his access mode (scanning), Matt's family created a light that is placed on his wheelchair close to

his head. Eric (Matt's aide) explained that Matt turns on the light with a separate head switch when he's ready to speak. In Matt's college classes, when the professor asks a question he can work on the answer while other students contribute, then turn on his light when he's ready to participate.

Our augmented co-designers also shared how they currently deal with their conversational agency challenges (*e.g.*, securing a turn to speak) by using their own nonverbal gestures with their close conversational partners. Matt uses eye blinks as a shortcut to communicate with others: one blink is no, two blinks is yes, and three blinks means I don't know. Tammy also has established her own nonverbal gestures with her family members. She shared how using her signs could create confusion if a person did not know the sign's meaning:

> *One day my mom taught me to point to my throat when I was thirsty. I was thirsty so I tried my new sign on dad and he got a funny look on his face. He rubbed [ointment] all over my neck it was a while before I got a drink.* - Tammy

Close conversation partners (CCPs), specifically the parents (Jim and Linda), expressed challenges they faced when communicating with ACs such as feeling messages sound abrupt, forgetting the topic being discussed, and knowing if they can look at a partner's screen. Matt's mother (Linda) explained how even though she is familiar with AAC devices she felt some words sound harsh:

> *"I was with an AAC user and we were having a talk. We were doing something and she said "I have got to go now. Goodbye." I found myself feeling hurt when she said it. There is an aspect of the computer that made it abrupt. I think a light-hearted and playful approach can be good"* - Linda

Tammy's dad (Jim) mentioned that it is hard to remember what they were talking about when Tammy says something. He explained that Tammy's head movement was a useful cue to know when he had to remember what they were talking about:

> *"I tell others to watch when Tammy looks down, that means she is typing and we need to remember this is what we are currently talking about."*

Both parents also discussed how the AAC device was like a barrier, Linda commented: *"the person over here is like, can I come over to the other side and look? you have to come all the way over here (moves behind Matt's screen) to look."*

Prototypes

We wanted to include the ACs and their caregivers in prototyping potential form factors for the sidekick, as form will determine some of the function. We asked each team to choose one challenge or task from the discussions that resonated with them, and create the sidekick for that purpose. The final prototypes created by each team are shown in Figure 3. Puppeteers also created their own sidekicks informed by the conversation, to have a variety of props for an improvisation session in the second part of the workshop (Figure 4).

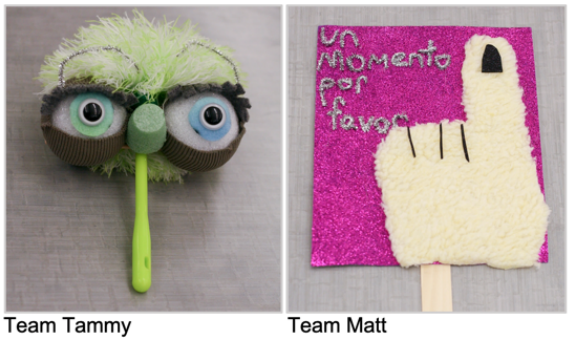

Figure 3. Prototypes created by Team Tammy (left) and Team Matt (right). Team Tammy's prototype featured a large set of eyes, customized to match Tammy's eye color and to express humor. Team Matt's prototype read "one moment please" to communicate that he disagrees with someone.

Figure 4. After meeting with the ACs, puppeteers created additional prototypes, informed by the discussion and needs ACs expressed. These were used in the second half of the workshop.

Team Tammy: Tammy's team addressed the need to convey emotions quickly in settings where it would be hard to use the AAC device, like public transportation that is noisy and crowded. They especially emphasized the humorous part of the sidekick, inspired by Tammy's sense of humor. Tammy's team attempted to make the sidekick visible from different angles, and matched the prototype eye color to Tammy's eyes. With instruction from Tammy, the puppeteers chose to focus on making the face of the sidekick expressive (Figure 3). As the team discussed the ideas, Tammy used an adjustable table to draw while her team asked her feedback on different ideas, and later helped Doug (puppeteer) with the prototype.

They considered gaze and eyebrows as legible ways to quickly convey emotion. Tammy's dad (Jim) and Nancy (puppeteer) outlined different gestures that centered around the eyes and eyebrows while Doug and Tammy worked on refining the prototype. Jim mentioned how the eyes could be short-cuts for expressions (*e.g.*, rolling eyes could mean "really! are you kidding me?", or eyes drooped could show "I am bored"). The puppeteers also explained how the eyes could move to react to comments people said during dinner at home. To that comment Jim told Tammy: *"you would love that right? You are always teasing"*. Tammy typed on her device that she

wanted to use her sidekick to express "you are pissing me off" too. The team laughed and added that to the possible expressions they were outlining for the sidekick to do.

Tammy's team spent time customizing the form of Tammy's prototype to represent Tammy (*e.g.*, sense of humor, eye color) and later proposed further customization (hair color). Jim expressed a lot of interest in animating the sidekick's eyes with electronics and shared all the possibilities: *"we could add expressions and she could control it, she could customize it or pre-program expressions. You could do anything. That is pretty neat."*. As puppeteers glued the final touches on their prototype, Tammy commented: *"I have a very interesting bug"*.

Team Matt: Matt wanted a way to say he disagreed and needed a moment to share his point of view. The team imagined a scenario in which people are talking very fast, and Matt wants to indicate that he has something to say. The team's prototype was a sign that read "un momento por favor" (Spanish for "one moment please") and had a magenta glitter background and a furry hand with one finger pointing upwards with black nail polish (Figure 3).

The team focused on showing disagreement while also acknowledging the opposite point of view respectfully and drawing attention towards Matt. To show respect while also disagreeing, they decided on using a magenta-glitter background instead of a strong color such as red. The use of a different language (*i.e.*, Spanish) also served to add playfulness. Matt's team took into account the content of the prototype sign (*e.g.*, one finger pointing up) and the material (thick and furry fabric) to indicate friendliness. To achieve drawing attention towards Matt, the team considered the prototype's range of motion which at the peak would rest close to Matt's face. the team also envisioned adding a spring that would make the sign pop-up, to show others Matt has something to say. After finishing the prototype, Matt told one of the researchers: *"This was helpful"*.

Prototyping activity closing comments: After hearing each team's presentation, the group shared different ideas and concerns regarding the sidekicks created. Doug (puppeteer) asked Matt and Tammy if they found this approach of having very expressive sidekicks too "juvenile". While Tammy and Matt typed, Jim answered Doug's question: *"Well, I think it goes on a person to person basis. Tammy is very expressive for example so I think she doesn't mind"*. One of the puppeteers from Tammy's team mentioned how having the sign stand close to Matt and close to the range of vision of somebody standing, instinctively drew his eyes to Matt's face. People brought up other benefits and considerations for the prototypes including expressing emotion quickly when your movement is limited, the appropriateness of a particular sidekick given the situation (*e.g.*, no green hair in a board meeting), and methods that the sidekick could use to mitigate the sound of the AAC device's voice (*e.g.*, having form factors that are light-hearted and playful).

Goal	Behavior Title	Behavior Description
Fill silence gap	Tapper	Taps fingers to show typing
	Dancer	Dances and sings
	Boomerang	Moves cyclically out from the AC and back to original position
Let AC participate	Up Up Up	Moves up for attention, then opens mouth when partners look at the AC
	Attention Sign	Springs up sign from flat to upright
	Outward Reach	Moves forward for attention, gazes at partners who are still speaking
Soften a message	Gentle "No"	Spins to soften "no"
	It's Time	Looks at watch patiently to soften "I have to go"
	Bye-bye Wave	Waves to soften "I have to go"
Invite partner to look at screen	Imitate Me	Demonstrates looking at screen
	Inviting Arm	Gestures with an arm to invite partner to look at screen
	Swirly Look	Spins then looks at screen

Table 3. Puppeteers generated a series of 10 movements for each sidekick goal, using puppets of their choice. The follow-up survey included videos of three representative movements for each goal, selected to cover a range of activities.

FINDINGS: SIDEKICK BEHAVIORS

All motions performed by the puppeteers consisted of three main types of motions in sequence: (1) motions to call for the other speaker's attention and then motions that either (2) mirrored an AC action or (3) made a demonstration about what the partner should do (*e.g.* looking at screen to show they should look too) (Table 4).

Motions to draw the attention of speaking partners included moving out towards them, spinning, dancing or moving upwards. After calling their attention, the puppeteers either performed a motion that mirrored an AC action or demonstrated something for their partner. Tasks that aimed at communicating a specific message that could further the AC's conversational agency (*i.e.*, showing they want to participate or directing their partner to look at their screen) conveyed their message by mirroring an AC action (*e.g.*, typing, looking at watch). Tasks that aimed at supporting the not-adjusted expectations of conversational partners, such as not knowing how long to wait for an answer, conveyed their message by performing motions that demonstrated the partner what to do (*e.g.*, "come close", "look here") (Table 4).

Throughout all tasks explored, the puppeteers placed the sidekick next to the AC's face. This was the "home" position. They explained that a sidekick should be a friend to the AC and should be placed close to them to indicate this and to help orient other's attention to the AC.

Filling the silence gap

Puppeteers explored how to carry out the task of filling the silence gap while an AC is typing and their partner is waiting for a response. While ACs compose their message, other people often think the AC is not engaged in conversation [23] or people are not sure what is going on [42]. The behaviors explored for this goal included showing a person was working on a message by making a typing motion and making the sidekick move constantly in a "dance" or "boomerang" motion

Call attention	Convey Message
Moves close	**AC action**
Moves upwards	Types
Goes from hidden to seen	Dances
Rotates whole body	Strokes partner
Lifts head	Shakes head and nods
Turns towards partner	Looks at watch
Directs gaze to partner	**Demonstration**
Swirls	Moves close to partner
Grabs partner's hand	Moves close to screen
Blinks	Points at screen
Opens and closes body part	Looks at screen

Table 4. Motion themes for the behaviors created through the improvisation session.

to show something was happening. The behaviors progressed from generating cyclical repeating motions to generating more playful ideas such as having the sidekick give the partner a massage while they waited for a response and comforting the waiting partner by stroking them with the sidekick's feathers.

We selected three behaviors to gather feedback from AC users through the survey (Figure 5): (1) sidekick tapping on the typer's shoulder to show that typing is happening, 2) a sidekick dancer floating over the AC's space and a 3) Boomerang, a sidekick that moved outwards from the AC and towards their conversation partner and back. (Table 3).

Showing others the AC is ready to participate

As the puppeteers improvised different ways to show that the AC would like to participate, it was clear that finding an effective way to interrupt the group was an essential, and often most effective way to do so.The behaviors that worked to call the groups attention consisted on moving the sidekick upwards so that everyone could see it, raising a sign that was hidden before in a sudden manner, and moving outwards and close to the group (Table 3. Sometimes puppeteers used sound to get the group's attention, like clearing throat or hissing. After getting the other actors attention, the sidekick puppeteer tried to communicate the intent to participate by pointing at the AC (played by puppeteer), gently poking the partner, nodding upon being asked if the AC had something to say and using gaze to look at the partners and then the user.

Softening a message

To soften a message, puppeteers explored telling another person they had to go and in one iteration explored declining an invitation. The idea to explore how to soften the message "I have to go" came from the story shared by Matt's mother. The puppeteers explored behaviors such as blowing kisses, rotating their fingers to symbolize "wrap it up" and looking at a watch on a wrist. To soften declining an invitation, the puppeteers acted out saying no to someone verbally and then having their sidekick slightly twirl towards the speaker to make the decline more humorous.

There were some improvisations that instead of softening a message made the message even harsher (*e.g.*, one puppeteer brought the sign close to the partners face and said "back off" to show they were done with the conversation). Different iterations of this task included adding some type of emotion to the message. The puppeteers commented on how it would be great if ACs could have a "sacarsm drip" that could add sarcasm to their sidekicks expressions as they said it.

Figure 5. Example movements Tapper, Dancer and Boomerang for the sidekick goal of filling a silence gap. The Tapper taps fingers on the typer's shoulder, the Dancer moves over the typer's shoulder following a semi-circular path, and the Boomerang cyclically moves in a circle out from the typer's shoulder and back to its original position.

For the purpose of getting feedback from ACs we only selected example behaviors that softened a message. These behaviors included (1) gently shaking the head to say no, (2) having the sidekick look at the watch to say the AC had to go and (3) waving good-bye (Table 3).

Inviting others to look at the AC's screen

To explore how a sidekick could let others know that the AC wanted them to look at their screen, puppeteers tried to first catch the speakers attention and then made a motion towards the screen, such as glancing at it or moving close to it. The puppeteers varied the ways in which they tried to catch the partner's attention (spinning the sidekick, appearing from behind the screen and moving upwards) but they, in 7 times out of 10 ended the movements by pointing towards the screen with the prototypes' eyes (4 times) or by using another sidekick's body feature (*e.g.*, whole body, head or light effect) to point at it (3 times). Another behavior included having an arm and hand (played by the puppeteer) that slowly invited the other speaker to come close. Once close, the hand would point to the screen.

We selected three behaviors that used distinct strategies to share with our AC co-designers (Table 3): (1) demonstrating looking at the screen, (2) gesturing with an arm to invite the partner to look, and (3) spinning to call attention and then looking at the screen.

Follow-up survey outcomes

We received survey feedback from one of two AC participants, Matt, who evaluated all videos included in Table 3. The survey is not intended to be an evaluation of the prototypes or the main contribution of this work, but to be additional input from the ACs throughout this co-design process.

Filling the silence gap: Matt rated the task of filling the silence gap as an extremely useful task. Matt reported liking all three behaviors but found the *Tapper* and *Boomerang* behaviors to be the most useful ideas. Matt explained the Boomerang was "straightforward" and selected it as probably being the

best at supporting his agency in conversation. Matt thought having the sidekick dance and sing was too distracting. He indicated the *Tapper* behavior was the best at giving attention to the AC without being too distracting to the conversation.

Showing others the AC is ready to participate: Matt rated the task of showing others that he is ready to participate as being extremely useful and indicated he liked the *Attention Sign* behavior the best but did not dislike any of the other behaviors. He indicated the *Up Up UP* behavior gave the most attention to the AC without being too distracting to the conversation and the *Attention Sign* gave the AC the most agency.

Softening a message: Matt rated the task of softening a message as being very useful and stated he didn't have any preference for any behavior or any behavior he disliked in particular. He selected the *It's Time* behavior as the one that could provide more agency and the *gentle "No"* as the least distracting.

Inviting others to look at the AC's screen: Matt rated the task of inviting others to look at his screen extremely useful and indicated he liked the *Swirly Look* behavior the best and being the less distracting. Matt found the *Inviting Arm* to be the behavior that could provide the most agency.

FINDINGS: WORKSHOP ACCESSIBILITY

To evaluate how accessible our workshop was we analyzed how much Tammy and Matt participated in the co-design activities and asked them directly about their workshop experience and suggestions. During the closing debrief at the end of the prototyping activity, both Matt and Tammy reported positive impressions about the workshop and the prototypes. Tammy commented: *"it was really fun, I would like to do it again with more people"* and Matt mentioned re-prototype: *"I'd keep it"*. Tammy's dad and Kathy brought up how to better integrate AAC users in the workshop by having adaptive art tools (*e.g*, head pointers that can be used to draw) and other materials such as clay. We report on the successes and challenges of our access commitments and the team collaboration.

Access commitments

Allowing enough time for communication: In each workshop activity, all participants including Matt and Tammy took at least one turn. To provide more time for AC answers, one strategy that emerged during the workshop was asking Matt and Tammy the question first, but then letting other participants take their turns until Matt and Tammy prepared an answer.

Sending question prompts in advance: Both Matt and Tammy shared prerecorded messages suggesting that our AC participants took advantage of the prompts provided in advance. Matt shared a prerecorded message during introductions and Tammy shared prerecorded messages during introductions and sharing stories.

Establishing preferred modes of communication: Matt's mom explained that Matt uses blinks to communicate "yes", "no" and "I don't know". During the prototyping phase, his team used these cues when asking Matt to answer questions about the prototype. Matt's mom also explained that Matt gives 1-2 word answers and asks others to elaborate on his behalf. Matt used this strategy in the workshop to ask his mother to elaborate for him. Knowing that Tammy puts her head down to indicate that she wants to type,as her father explained, helped Nancy, the puppeteer unfamiliar with AAC, understand Tammy was busy typing and that she should wait before asking the next question.

Making shared content easy to reference: While Tammy did not make use of the numbers we included for quickly referencing metaphors, Matt used a number to indicate what metaphor he selected.

Making visuals and materials physically accessible to users: As themes, challenges, and goals emerged during the workshop the researchers wrote brief references to these ideas in large font on the board. In each team, the puppeteers used the list to start the discussion of what to build or eliminate options. For instance, Kathy mentioned to Matt about an idea on the board *"showing you're ready, you already nailed it"* in reference to the light he already uses for this function. This list on the board was also used for the second part of the workshop for the puppeteers to reference earlier discussions.

AC team collaboration

Matt's team started the prototyping activity by asking a series of questions to Matt and narrowing down ideas through Matt's feedback. For instance, after Matt mentioned *"I want to use what we were talking about"*, Matt's mom (Linda) and Kathy, with Matt's blinking to answer yes or no questions, narrowed the topic down until Kathy asks *"So do you want to show another person that you have a different opinion?"* and Matt said *"yes"*. For the form factor of Matt's prototype, the team gave suggestions (*e.g.*, Tyler suggested avoiding red, Linda suggested a different language) that were each confirmed or denied by Matt before implementation. Tammy's team started the prototyping activity with Tammy rallying the team by asking *"so what are we making?"*. Tammy drew using paper and marker while her team consulted with her on key decisions such as Nancy asking *"Do you think we should focus on the whole body? Or just the face?"*. Jim (Tammy's dad) contributed facial expressions for the sidekick, but Tammy's drawing did not share a clear connection to the prototype. The puppeteers and Jim selected features for the sidekick based on Tammy's humor and eye-color.

FINDINGS: SIDEKICK VALUES

Our affinity diagramming revealed three values that were recurrent in conversations throughout the workshop and the improvisation sessions: Attention, Precision and Agency. We included these three values in the feedback survey to let ACs assess how well final puppeteer behavior examples adhered to each value.

Workshop participants expressed excitement about the prototype's ability to call *attention* for the purpose of communication (*e.g.*, Tammy's dad envisioned quick expression of emotions), and also initial concern about the prototype calling attention away from the conversation (e.g., Matt mentioned "wouldn't it be too distracting?"). AC-led teams and individual puppeteers managed this challenge by using motion to attract attention when needed, and leaving prototypes static

when not in use. Workshop participants also discussed the importance of *precision* of AC nonverbal communication. In particular, participants mentioned that AC nonverbal communication can be fast, but also ambiguous making it harder for ACs to participate effectively. For instance, Tammy cited a scenario in which she used a quick gesture to her throat to indicate that she was thirsty, but her dad (Jim) misinterpreted her communication, attributing the gesture to a sore throat. Finally, the participants cited the importance of seizing the moment to provide new input to the conversation, or *agency*. In particular, Matt pursued the ability to express disagreement to the conversation by a quick motion.

LIMITATIONS

While we included several stakeholders in the co-design workshop, we could have included additional input from experts, and plan to do so in future work. For example, we consulted a speech language pathologist (SLP) in our formative work, but they did not participate in our in-person co-design session. An SLP could have brought a wider perspective of AC experiences potentially resulting in additional tasks or prototype considerations. In addition, we explored 4 of the 11 possible tasks in our puppeteer improvisation session as an initial examination of this complex design space. We prioritized a smaller set of tasks to explore a broad range of possible behaviors per task. It is possible we may discover new and interesting sidekick behaviors in exploring the remaining tasks. Finally, while we used adjustable tables to assist ACs in prototyping, we lacked other useful adaptive tools (e.g., a head-mounted pointer device for painting) to make AC prototyping easier. The ACs collaborated with their partners to do the physical work of prototyping, but the prototypes may have had different properties if the AC physically participated in the crafting.

DISCUSSION AND FUTURE WORK

Interpretability of sidekick motion

Prior work has highlighted the importance of interpretability for augmenting AC communication when adding partner-facing text, emojis, or LEDs [42]. Immediately recognizable, or interpretable, augmentations let the AC communicate easily with partners outside of their most immediate circle [7] who may not be familiar with AAC or the particular AC's communication style. Although we did not set interpretability of sidekicks to be an explicit aim of our workshop, the prototypes and motions generated by our participants were often easy to recognize. In particular, the form factor of the puppet prototypes were largely anthropomorphic with highly visible features (e.g., eyes, mouth, hand). Most behaviors produced by puppeteers also leveraged common motions including opening eyes, orienting the head, pointing, looking at a watch, and typing. During our debrief our puppeteers mentioned that leveraging "universal symbols" is helpful for fast communication and to "speak to" different audiences. The consistent use of common visual features and behaviors for the sidekick prototypes suggests that future sidekicks should use common appearance features and motions to be as interpretable as possible.

Phases of sidekick behaviors

Our thematic analysis of puppeteer improvised behaviors revealed that behaviors were composed of specific "stages." All behaviors first started with a motion to *call attention* (*e.g.*, swirling, looking at partner) and then took some *communicative action* which either amplified an AC's own actions (*e.g.*, shake head) or performed a movement to communicate information (*e.g.*, pointing). This two-stage process is reminiscent of how people achieve joint attention, the shared visual focus of attention on a common object in space [3]. Joint attention is typically broken down into three stages: initiating, referring and monitoring [19]. In our case, initiating involved the motion for calling attention, and referring involved taking a communicative action. We did not observe the third stage, monitoring, which tracks whether the other person is still engaged in the shared activity. The behaviors generated by puppeteers in our workshop considered single isolated tasks rather than long term interactions that might require monitoring. Future work can consider designs that include monitoring to ensure that the listener has understood the sidekick's intended communication.

Sidekicks that use multiple modalities

In designing the workshop task, we initially limited our exploration of sidekick expressivity to motion, because speech is already enabled in AAC devices. Despite that, puppeteers used both speech and non-speech sound to accompany sidekick motion. Puppeteers typically employed speech for the purpose of calling attention or directing the partner. For instance, one sidekick opened its mouth and said *"psst"*. Future work could consider how sidekick speech may complement or conflict with AAC device speech produced by the AC. Additionally, adding sidekick speech may elevate the expressive object to a more social agent, because a sidekick that talks might be interpreted by others as having a "mind of its own." While puppeteers most frequently used sound as an augmentation to motion, one puppeteer used light to direct attention. The use of light presents an opportunity for the sidekick to interact through a non-anthropomorphic modality. Future work may investigate the benefits of new modalities for sidekicks supporting AC participation.

CONCLUSION

Our findings offer design opportunities for physical prototypes with the goal of enhancing augmented communicator's (ACs) face-to-face conversations. In a co-design workshop with ACs, their close conversational partners, and puppeteers, we explored the metaphor of a "sidekick"— a physical device that supports ACs in conversation through movement. We provide evidence of the usefulness of motion to bring attention to the AC, convey precise messages, and enable the AC to seize the moment in conversation. We have characterized the design space of conversational sidekicks for AAC, while also identifying accessible co-design commitments needed to ensure the participation of ACs with severe speech and motor impairments in similar workshops.

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