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Aligned Co-Design: An Interdependent, Multi-Modal Method for People with Motor and Communication Disabilities

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ABSTRACT

Co-design is not merely a set of design activities, but is grounded in the belief of equitable access and input in design. However, a common assumption in co-design is that participants can use their hands, easily communicate, and are able to actively participate in a timeframe based on the researcher's agenda. These assumptions can exclude underserved populations, including participants with motor and communication disabilities. We present Aligned Co-Design (ACD), a multi-modal, temporally flexible method grounded in communication theory and interdependent relationships. ACD requires the researcher to address their assumptions, communication, and role in co-design. We provide a proof-of-concept of ACD in practice, demonstrating multi-modal communication techniques and how those techniques align understanding and an equitable partnership in co-design. ACD achieves co-design's theoretical commitment to establish an interdependent partnership with a currently under-represented population in co-design, adults who have motor or communication disabilities, thereby increasing equity and inclusion in co-design.

1. Introduction

How do we include individuals in co-design when they cannot use their hands? Imagine an individual who uses a wheelchair, is unable to use their hands, is immunocompromised so that they cannot readily access in-person events, and uses specialized technology to access the computer that is only compatible with specific applications. Additionally, this individual has a degenerative condition in which they are losing their ability to speak. This person would like to contribute to research and design, but how can they participate equitably in co-designing technologies that are intended to support their daily lives? What is the responsibility of the researcher to provide equitable access to participating in co-design research? What methods can we use to ensure that an individual not only has physical access to participate in co-design but also can share their ideas without the researcher misinterpreting them?

The ideals of participatory design and co-design are grounded in democratizing the design process through a partnership with potential users. While work has addressed how co-design may be used with a variety of underserved populations, co-design and participatory design approaches may cause unintentional harm to participants (Harrington et al., 2019). For instance, researchers may not have the background knowledge needed to address the power dynamics involved when partnering with marginalized populations. Researchers may also lack the knowledge required to craft equitable inclusion of participants who cannot engage in traditional co-design sessions, such as participants who are not able to use their hands during co-design sessions. Subsequently, design outcomes may reflect the researcher's agenda with limited population representation, rather than reflecting an interdependent and co-constructed design agenda with diverse end-users.

To address this problem, we examine co-design methods within the context of one specific population: adults who have motor or communication disabilities and who use assistive technologies (AT). Many traditional co-design activities, such as manipulating objects to express design ideas, require participants to use their hands. This prerequisite ability in co-design can exclude individuals with motor disabilities, such as individuals with spinal cord injuries or Multiple Sclerosis (MS). Moreover, individuals with communication disabilities can have difficulty fully expressing their ideas with the competing voices of others in group settings (ter Wal et al., 2023). Individuals who use ATs, such as wheelchairs, alternative computer access devices (like eye control), or Augmentative and Alternative Communication devices (AAC), are likely to have difficulty in sharing or representing their ideas fully within time constraints, particularly within group settings (Kane et al., 2017; Valencia et al., 2020). People with motor disabilities can also have communication disabilities, such as individuals with Cerebral Palsy or Motor Neuron Diseases (Caron & Light, 2016; Cooper et al., 2009; Doyle & Phillips, 2001; Peters et al., 2024). In addition, individuals with progressive

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conditions impacting both motor and communication abilities, such as Amyotrophic Lateral Sclerosis (ALS) or MS, experience fatigue and other social barriers to active participation in public settings (Baylor et al., 2010).

While a body of work has advocated for inclusion of people with disabilities in design (e.g., Bennett et al., 2018; Newell & Gregor, 2000; Pullin, 2009; Pullin & Newell, 2007; Shinohara et al., 2018; 2019; Wobbrock et al., 2018), researchers have also documented the challenges of engaging in formative research and design with adults who have communication and motor disabilities and use AT (Kane & Morris, 2017; Subrahmaniyan et al., 2018). As a result, the design and development of technologies for people with motor and communication disabilities who use AT frequently involve end users as expert consultants who inform design through interviews or evaluate prototypes, rather than as co-designers (e.g., Fiannaca et al., 2018; Ivanyi et al., 2023; Kane & Morris, 2017; Sobel et al., 2017). Given the particular challenges within formative research and design to engage individuals who use AT for motor and communication disabilities, we use a multi-disciplinary framing to inform the development of an equitable and accessible co-design method.

Building on principles from the fields of communication and learning sciences, we present the rationale behind the Aligned Co-Design (ACD) method. The ACD method was created, not merely as a set of design activities, but as a considered approach in which we curate our communication and design activities to leverage participants' strengths so they can best contribute their design ideas as co-designers. Using ACD, participants who are unable to use their hands to craft materials or draw within the typical timespan of a co-design session are still able to participate in co-design. We contribute to the field of HCI through a robust discussion of the conceptual framing which informs ACD with illustrative proof-of-concept examples of ACD in practice. Our methodological contribution provides co-design researchers with an accessible, formative co-design process in which participants who use AT for motor and communication can equitably engage in co-design on their own terms. The ACD method challenges co-design researchers to deeply consider the conceptual rationale behind each component of their co-design sessions. ACD addresses the power dynamics of co-design, including: accessibility, the pacing and timing of the co-design process, and researcher/designer assumptions.

In this paper, we introduce the ACD method, where we address several challenges with standard co-design sessions. First, we ground the design of the ACD method within the multi-disciplinary context which informs each component of ACD. We discuss the ways in which communication can influence design and we advocate for multi-modal communication methods to guard against misinterpretations of design ideas. Next, we outline the ACD process, discuss key conceptual concepts behind ACD, and provide proof-of-concept examples of what ACD looks like in practice with adults who have motor and communication disabilities. We discuss specific communication techniques, how the approach to scheduling reflects perceptions of hierarchy, and how visual summarizing, as a form of graphical listening, aligns design ideas.

Through a deep exploration of the rationale of the choices we make when creating a co-design study, we can better address inequities in design research. We believe that the ACD method addresses the documented challenges of engaging individuals with motor and communication disabilities in formative research, and that in using ACD, co-design is more equitable and accessible.

2. Related work

Designing with people who have disabilities can result in designs that are accessible to a wide variety of users (Pullin & Newell, 2007). A number of frameworks have advocated for the inclusion of people with disabilities in the design process, such as User Sensitive Inclusive Design (Newell & Gregor, 2000), Tenets for Social Accessibility (Shinohara et al., 2018), and Ability-Based Design (Wobbrock et al., 2018). The development of ACD is inspired by these frameworks, and we sought to create a framework for accessible, inclusive co-design.

In our review of related work, we first discuss the theoretical concepts which informed the design of ACD's multimodal communication approach. ACD was created with a strong grounding in communication theory, which then informs the design of activities. We then review the practical techniques used to adapt co-design activities to participants with diverse abilities, with a focus on related work involving people with motor and communication disabilities. We conclude the related work drawing on concepts of interdependence, hierarchy, and equity in design.

2.1. Applications of language and communication theory in HCI

Understanding peoples desires and needs for future technology is deeply rooted in the ability to engage in productive dialogue. Work in the fields of applied linguistics and multimodal communication have treated interpersonal communication as a collaborative, dynamic, and multimodal process (Goodwin, 2002; Jewitt et al., 2016; Loncke et al., 2006), where different parties gradually take turns to create shared meaning, noticing and building on each other's contributions (Harvey et al., 1978; Levinson, 2016; Schegloff, 2006). This social constructivist, dialogic conceptual grounding is reflected in a number of prominent HCI traditions, such as participatory design (Simonsen & Robertson, 2020), experience-centered design (Wright & McCarthy, 2022), and other ecological-grounded approaches (Rogers, 2004; Suchman, 1987).

In the context of designing alongside end users who have motor and speech disabilities, this collaborative, dynamic, and multi-modal view of communication becomes highly relevant, particularly when working to achieve mutual understanding and alignment of ideas in co-design. Constructing and aligning shared meaning requires a flexible, multimodal approach which is contextually accessible to

all communication partners. It is widely understood that language is a code in which we express our ideas through an accepted system of signals to communicate (Lahey, 1988). However, language and meaning making also requires access to multimodal vocabularies, which are socially constructed and can change across contexts (Lahey, 1988; Talja et al., 2005). Words can carry different meanings and connotations for each person based on their own experiences, culture, and belief systems (Holt, 2022; Lahey, 1988). Recent HCI studies with people who use Augmentative and Alternative Communication (AAC) have highlighted the importance of attending to multiple modes of communication (Beneteau, 2020; Ibrahim et al., 2018) as well as strategies which enable AAC users to contribute to conversations in a timely manner (Kane et al., 2017; Seale et al., 2020; Valencia et al., 2024).

Scandinavian co-design and participatory design research methods have also highlighted the importance of carefully considering language use (Ehn, 2017; Ehn, 1992). In their discussion of design research, Ehn [91:64] builds on the philosophical approach of Wittgenstein (Ludwig, 1998):

> To label our experiences is to act deliberately. To label deliberately, we have to be trained to do so. Hence, the activity of labeling has to be learned. Language is not private but social. The labels we create are part of a practice that constitutes social meaning.

Ehn builds on the concept of social language labels and discusses the role of "*language games*" in co-design, in which participants reconcile their different backgrounds and find a common language to collaborate and design together (Ehn, 2017; Ehn, 1992; Schuler & Namioka, 1993). Similarly, Schön describes conversation between people as a "*collective verbal improvisation*," in which participants are making something through the use of language (Schon, 1987, p. 30). As such, we must carefully consider how our use of language may be interpreted by others and how we interpret participants' language.

Prior work has highlighted that researchers' questions in co-design sessions with developmentally diverse children may be misaligned with participants' expectations, highlighting the importance of addressing researcher assumptions at the beginning of co-design sessions (Vasalou et al., 2021). A misunderstanding of language can be the cause of misinterpretations of data in research. Misunderstandings and mistaken assumptions can be easily made when communicating with people who use AAC (Morris et al., 2013). When working with individuals who have communication disabilities, researchers need to think deliberately about how to design interactions to accommodate communication abilities so that participants can fully express their ideas and to ensure that the research team does not misinterpret participants' communication. Therefore, when approaching the design of ACD, we explicitly consider the ways in which participants can easily and comfortably correct any misinterpretations of the data made by the researcher.

Design is a form of knowledge making (Oogjes & Wakkary, 2022). Participatory design methods with children have highlighted the ways in which identity shapes knowledge, influencing co-design and participatory design sessions (Brulé & Spiel, 2019). Based in the constructivist view that "*words of language do not carry meanings that remain stable*" (Talja et al., 2005), ACD incorporates the concept of member-checking, in which participants are encouraged to review their research data and to amend that data as appropriate (Beneteau, 2020; Ison, 2009).

In the development of the ACD method, we acknowledge that establishing shared meaning through language is emergent and collaborative. Therefore, we designed ACD to build shared understandings of language and we include member-checking in real time to force both the researcher and participant to confront their assumptions and correct researcher misinterpretations.

2.2. Utilizing visuals to enhance understanding

The field of AAC utilizes a variety of visual representations of language, including physical objects, drawings, icons, and photographs for individuals who are unable to use their voice to communicate (Beukelman et al., 2013; Beukelman & Mirenda, 1992; Johnson, 1996). Visual renderings of concepts can also enrich spoken communication. For example, the use of drawings and icons can support shared understanding for people with aphasia (Moffatt et al., 2004; Sacchett, 2002), dementia (Lazar et al., 2017; 2018), or other cognitive disabilities (Lazar et al., 2016). Lazar and colleagues discuss how art therapists use a "*third hand*" to assist and empower older adults to express themselves (Lazar et al., 2016). Piper and Lazar encourage researchers to use empathy, contextualize information, and empower individuals during art creation in co-design research, particularly with participants who have complex health needs (Piper & Lazar, 2018). Work from Gerling, et al. (Gerling et al., 2016) also demonstrates how the use of visuals encourages co-construction and shared meaning with people who have motor disabilities, even when the researcher creates visuals on behalf of the participant. For interaction design, the importance of establishing mutual understanding is crucial, yet for people who use AAC and their conversation partners, it is highly difficult to establish shared understanding without additional tools (Collins & Marková, 1999). Paying attention to visuals can help address the need to establish common ground and align mental models, even if visuals are abstract in nature (Ibrahim et al., 2024; Norén et al., 2013).

Summary sketching is more straightforward when designing visual systems, such as front-end user interfaces of apps and websites compared to less visual outputs, such as backend systems or algorithms, in which visuals may require more creativity and expertise to produce. Visual representation assists with learning and understanding complex concepts (Schwartz et al., 2016), including very abstract concepts such as density (Schwartz et al., 2011) and mathematical concepts (Cuturi et al., 2022). Refining best practices for generating visual summaries of abstract concepts is an exciting area of future work, which can draw on a robust foundation of prior work in visualization across disciplines (e.g., Kay et al., 2013; 2016; Ryu et al., 2023; Snyder et al., 2019).

Sketching and drawing in co-design is a common technique for capturing initial design ideas. Outside of co-design, Suchman and Trigg (Suchman & Trigg, 1986) have studied the role of whiteboards in facilitating work collaboration, and Rooksby and Ikeya have identified ways co-workers use visual representation of their work to share focus, mutually orient, agree and disagree (Rooksby & Ikeya, 2012). More universally, the use of drawing to capture information has been formalized through the use of *"sketchnotes"* (Buxton, 2007; Fernández-Fontecha et al., 2019; Rohde, 2012; Zheng et al., 2021). Like whiteboarding, sketchnotes are drawings of presented information, frequently created in real-time. Sketchnotes often include a mix of text and imagery. Proponents of sketchnoting indicate that the process of drawing helps with the acquisition and retention of knowledge (Dimeo, 2016; Fernández-Fontecha et al., 2019; Sturdee et al., 2018). Visual sketching in the context of participatory design can facilitate slowing down, becoming more self-aware, and foster interpersonal connections (Beck Tench, 2022). The use of sketching to process and synthesize information can not only benefit the person capturing the information, but also allows the synthesized information to be shared with others (Sturdee et al., 2018).

The use of sketchnotes is typically employed as a method for capturing information that is being taught or conveyed in a one-way information transfer process. However, in the ACD method we employ the concepts of sketchnotes, not in a one-way transfer process but rather, in a dynamic, interactive approach of drawing as a form of active graphical listening—in which we communicate our understanding and assumptions through language and visual mediums. Through using this multi-modal communication approach, we produce shared meaning and understanding together as interdependent co-designers.

2.3. Co-design approaches and activities

In addition to the concept of language games, Ehn describes the importance of including nonlinguistic artifacts as part of the co-design process. These non-linguistic artifacts supplement and complement the language games that occur during the design process. Ehn describes how "*design by doing*," in the form of creating mockups and prototypes, provides deeper understanding and sharing during the design process (Ehn, 2017). Methods might include: prototypes (Yip et al., 2013), layers of artifacts produced by other participants (Walsh et al., 2010), design *"non-proposals"* (i.e., lightweight concepts that reflect important values, politics, and ideas without prescribing a specific course of action) (Taylor et al., 2022), and the functional but incomplete designs of technology probes (Hutchinson et al., 2003). Within co-design methods, physical tools are prominent, including: crafts and household materials (Andersen & Wakkary, 2019; Beneteau et al., 2020), photographs (Wakkary et al., 2014), tokens (Yoo et al., 2013), drawing materials (Hiniker et al., 2017), and robots (Hunt et al., 2023).

The majority of these methods were designed with the expectations that co-designers use their voice to communicate and their hands to draw or physically manipulate objects to create low-fidelity prototypes. With the onset of the COVID-19 pandemic, researchers have recognized the benefits of online participation (Singh, 2020) and adapted co-design methods for remote settings (e.g., Fails et al., 2022; Lee et al., 2021; Peters et al., 2024; Woodward et al., 2022). However, many of these remote methods continue to assume that participants have use of their hands and voice to engage in the co-design activities.

2.3.1. Adapting co-design activities for diverse abilities

Researchers have increasingly addressed the need to include participants with diverse abilities in co-design methods (e.g., Frauenberger et al., 2017; Ibrahim et al., 2020; Lazar et al., 2018; Malinverni et al., 2014; Metatla et al., 2019). Recent works have also recognized the need for flexible co-design methods which can accommodate individuals with a variety of abilities (Adler et al., 2022). However, adaptations to include one population do not necessitate that the method is then accessible to all populations. For example, developing co-design methods to include participants who are blind or have vision disabilities has been an area of continuing work in the HCI community (e.g., Bandukda et al., 2022; Brewer, 2018; Winters et al., 2020). These adapted co-design methods often utilize spoken language, sounds, and tactile interactions as primary modalities for the co-design process. While the use of spoken language and sounds can also facilitate inclusion of individuals with motor disabilities, the use of tactile interactions with physical objects are barriers to inclusion. Similarly, co-design activities that rely on rapid verbal interactions within small groups might inadvertently exclude the opinions of participants with communication disabilities (Kane et al., 2017). Individuals who have communication disabilities might benefit from the use of visual representations whereas individuals who are blind or have visual disabilities may not.

While there are some examples of techniques to adapt activities for individuals with communication disabilities, these adaptations typically involve including co-participants who do not have communication disabilities to assist with informing the design process (e.g., Curtis et al., 2023; Valencia et al., 2021; Wilson et al., 2019). Other common adaptations are to limit participant sizes, conduct the study over a period of time, and use a variety of methods of data collection in co-design studies. In an example of using all of these adaptations, Valencia et al. engaged in a 12-month case study co-design process which incorporated diary studies, interviews, prototyping sessions, and surveys with an AAC user and their family members (Valencia et al., 2021). In their multi-phased, co-design approach with primary school age autistic children, Wilson et al. (2019) observed interactions with the children's physical objects to convey meaning and interviewed the children's teachers and therapists. Other examples include the use of technology probes and prototypes to inform iterations of those prototypes. For example, Curtis et al. first engaged with speech-language therapists and specialists in the user-design process, eliciting feedback and iterating on prototypes, and later conducted

co-design focus groups with adults with aphasia with the high-fidelity prototypes (Curtis et al., 2023; Curtis & Neate, 2024). O'Connor and colleagues also created exploratory prototypes as technology probes for an adult with complex physical and communication disabilities in a single case study (Cian et al., 2006). These studies show how co-design adaptations have typically included co-participants without disabilities and pre-made technology probes and prototypes.

While the inclusion of non-disabled co-participants with knowledge related to the end-user group is helpful, we seek to understand how we can include the end-user as the primary co-design partner in the formative stages of co-design, rather than using ready-made probes and additional participants outside of the targeted end-user group. An example of the complexity of engaging in co-design with the end-user as primary co-design partners is from Kane et al. (2012). Kane et al. conducted a co-design study with five adults with aphasia, utilizing interviews, observations, focus groups, in addition to both low and high-fidelity prototypes over a period of six weeks. The sessions were conducted at an aphasia center, in which the research team initially presented a series of scenarios to the end-users, refining their prototype based on participants' reactions to the scenarios. When working with adults with aphasia, language, communication, and cognition may be impacted (Luck & Rose, 2007), which can limit the ability of participants to generate design ideas in the earliest, formative stages. Therefore, Kane et al. (2012) used ready-made scenarios and technology probes as tools to engage participants. In contrast to prior co-design work with people who have aphasia, our focus is on co-design with adults who have communication disabilities or motor disabilities, and who do not have diagnosed conditions which can impact cognition or understanding of language. Rather, we seek to develop a method in which we must understand how to engage participants who use AT both for computer access and for communication, in the earliest stages of formative co-design.

In an example of early stage formative co-design activities that were adapted for people with motor and mobility disabilities, Gerling and colleagues (2016) used a multi-stage co-design process with nine early teens and young adults. The multi-stage process limited the potential for participant fatigue. The researchers used "*guiding questions*" to encourage participants to share their interests regarding the research topic (gaming) and to ensure that the next iterations of the co-design sessions were tailored towards the participants' interests. As a result, the co-design sessions became increasingly more relevant and meaningful to participants throughout the co-design process. As part of the co-design process, participants were asked to dictate drawings to the researchers. The researchers drew sketches based on the participants' descriptions and directions. In this way, the researchers gave power and control to the participants over the drawings, while the research team merely executed the physical drawing task itself.

In designing ACD, we build upon Gerling et al.'s work, in which we expand upon the concepts of guiding questions and dictated drawings and broaden the user population to include participants with communication disabilities in addition to participants with motor and mobility disabilities. We also further expand to include participations who use assistive technologies for computer access and/or communication. In the development of ACD, we broaden prior work by incorporating the theoretical concepts of multi-modal communication, active graphical listening, and explicitly address relationships in research.

2.4. Addressing relationships in co-design

In co-design, researchers must not only focus on adapting activities for accessibility, but also address how the design and implementation of our research impacts the relationship we build with participants. Bennett et al. emphasize the importance of considering the relationships within the contexts discussed in Ability-Based Design when designing for people who use AT (Bennett et al., 2018). Using an interdependent framing, Bennett et al. advocate that designers should consider relationships and interactions to be mutually reliant. Thus, using the framing of interdependence in design, the hierarchical nature of designer and user is rejected. The designer and the user are equally dependent on each other. Accessibility is not strictly about obtaining a linear goal but about creating a context in which everyone and everything contributes to create access.

Prior work has highlighted unintentional hierarchical practices within participatory design research, in which the researcher's agenda can dominate over participants' needs and expectations (Harrington et al., 2019). A hierarchical agenda can be communicated in a variety of ways, including through the timing and modality of the co-design sessions in which the researcher's schedule can dictate participation. Prior work has shown that flexible research approaches, such as those which include asynchronous components, can provide participants with greater agency to participate and communicate (Caron & Light, 2016; MacLeod et al., 2016). In fact, asynchronous research participation can outperform synchronous participation in research (Alhadreti, 2022). An example of a language-based, remote, co-design study with people with physical disabilities is from Fortune et al. (2022), who used a design thinking approach with four young people with cerebral palsy and four parents. In contrast to the population we address in ACD, Fortune et al. (2022) did not explicitly work with participants who required AT for computer or communication access which enabled participants to convey design ideas and feedback through both verbal and written communication methods using online post-it notes on a Miro Board.

Approaches which address psychosocial factors and context when working with AAC users are critical (Light & McNaughton, 2015). Consideration of all contexts throughout the end-to-end research process can foster equitable inclusion for people with a variety of disabilities and health conditions, as shown with Dewing's work with participants with dementia (Dewing, 2007), in which multiple, deliberate, approaches were used for participant-driven informed consent.

ACD builds on the concepts of interdependence and contextual accessibility while deeply exploring how communication informs relationships and design. In the development of ACD, we created a method that is flexible for a number of different research and design agendas, and is accessible to a specific population: adults with complex communication and/or motor disabilities who use AT. The population of focus in this paper also may have concomitant health conditions, such as ALS, which requires a co-design method that is not only accessible but accommodates health needs, including fatigue.

3. Method

ACD was developed based on the related works described earlier. In this section, we provide a high-level overview of the method, highlight the key constructs which inform ACD, and follow with examples of the ACD process in a proof-of-concept application.

3.1.1. Aligned co-design method summary

ACD is carried out through three distinct design phases, including: two synchronous co-design sessions and one asynchronous reflection session in between them. The processes used in ACD consist of: (1) creating shared understanding, (2) visual summarizing, (3) asynchronous reflection, and (4) reconciliation and revision (Figure 1). In ACD, the researcher is learning and re-learning the rationale for discrete design elements in addition to the purpose of the overall design. The processes of ACD occur with an initial, synchronous session in which the participant and researcher engage in creating shared understanding and the researcher uses visual summarizing. At the conclusion of the first session, the researcher and participant engage in asynchronous reflection, and have the option to continue visual summarizing to perpetuate shared understanding. The second and final synchronous co-design session is when both co-designers reconcile any misinterpretations, amend the design based on additional reflection, and revise the design collaboratively. The final synchronous session concludes with an agreed upon final design, with the rationale of the design developed and expressed throughout the ACD process.

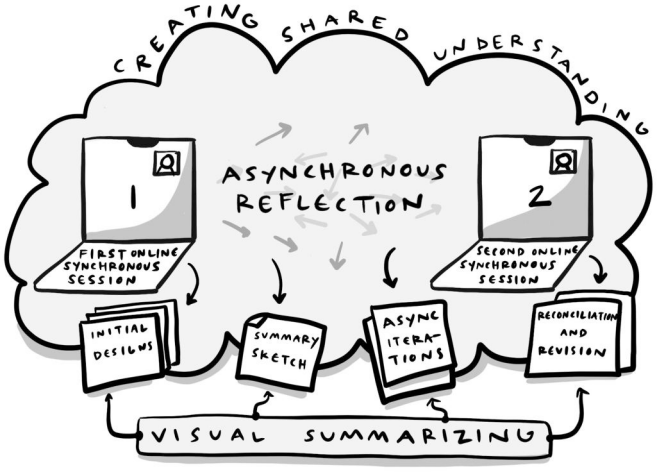

Figure 1. Sketchnote of ACD method, which is held across two synchronous, remote sessions and one asynchronous session.

3.2. Key constructs in the development of ACD

ACD was designed for the inclusion of participants who had motor and/or communication disabilities and who use assistive technologies (AT) in co-design. ACD was also designed to address the health needs of participants who have concomitant health conditions, such as Amyotrophic Lateral Sclerosis (ALS). We build on theoretical constructs and practical applications from speech-language therapy, neuroscience, communication theory, co-design, and visual thinking to inform the key constructs of ACD. These constructs should always be in the mind of the researcher during the ACD process, and by keeping these constructs in mind, the researcher and participant form an interdependent partnership in co-design that is mutually beneficial.

3.2.1. Power dynamics

As discussed in the related works, participatory research can be unintentionally hierarchical and have the potential to cause harm (Harrington et al., 2019). When designing with individuals who have communication disabilities, power dynamics can manifest in the speed and nature of communication interactions, inhibiting participant's abilities to fully express their ideas (Kane et al., 2017; Valencia et al., 2020; 2024; Vasalou et al., 2021). Therefore, ACD was designed to intentionally follow the participant's communication pacing. By designing for individuals with communication disabilities, ACD also accommodates the needs of individuals who may need extra time due to health needs.

We address power dynamics in ACD through the underlying structure of the method. First, ACD is held in one-to-one co-design sessions with the researcher and participant as co-designers. Using a dyadic format gives the researcher the ability to follow the participant's lead in the pacing of the co-design session. Second, ACD uses both synchronous and asynchronous sessions, which also creates an opportunity for the researcher to follow the participant's lead with the timing and pacing of the co-design process.

Finally, ACD was developed so that participants could leave the co-design research study at any time throughout the process, while still providing the researcher with useable data. Theoretically, all research studies should provide opportunities for participants to discontinue the research process at any time. ACD embeds that theoretical principle into the formation of the method, in which the researcher and participant both engage in the process as they are able. Because data collection is taken during each step of the ACD process, and participants are given explicit opportunities throughout the process to continue to engage or disengage from the co-design research, participants have less pressure to keep up their participation if the research process is not benefitting them or causing unintentional harm. The extended asynchronous time between the two

synchronous sessions, determined by the participant, not the researcher, not only provides an accessible time for the participant to engage in co-design but also provides the participant with an opportunity to take ownership of their involvement in the research study with low-cost barriers to discontinuation.

3.2.2. Accessibility

ACD was designed to be accessible for a specific participant population: adults with communication and/or motor disabilities. Accessibility in this context includes a variety of factors which could impede participants' abilities to fully engage in co-design. First, ACD is designed to be physically accessible. Sessions are held remotely so participants do not need to spend time, money, or physical effort to transport themselves to a physical location, which can inhibit participation (Beneteau et al., 2022). Due to the variability of AT systems which potential participants might use; it was critical for the method to rely on existing software solutions that could be compatible with various AT systems. Participants who use AT for computer access may be limited to one particular video conferencing software platform that is compatible with their technology, so it was important to ensure that the technical aspects of ACD could be used across various platforms. Therefore, the tools of ACD are unremarkable, everyday tools used for remote communication. The researcher uses video conferencing, screensharing, a slide deck, and sketching tools. The participant uses whatever forms of computer access that they typically use.

A second form of accessibility is timing. As described earlier, the pacing of the synchronous sessions are designed to follow the participant's lead. The dyadic format of ACD aids in cooperative communication turn-taking between participants with communication disabilities, particularly those who use AAC, and the researcher without extraneous time pressure (Savolainen et al., 2020). The asynchronous timeframe is dictated by the participant, who chooses when they want to schedule the second synchronous session, based on their needs and priorities.

ACD uses spoken language, visual communication, and written communication forms in deliberate ways throughout the co-design process to stimulate different regions of the brain and to foster shared understanding between co-designers. This form of accessibility benefits both researcher and participant to increase their collaboration and understanding as they co-design.

3.2.3. Multi-Modal communication

ACD is based on the concept that language is a socially constructed system to create shared understanding (Ludwig, 1998; Lahey, 1988; Talja et al., 2005). Thus, the focus of ACD is an iterative, recurring process of generating a shared understanding between co-designers which are enabled through spoken language, non-verbal communication, visual representations of concepts, and textual communication. Non-verbal forms of communication are often essential for individuals with communication disabilities who experience fatigue or who use AAC systems (Beneteau, 2020; Beukelman et al., 2013). Therefore, the use of synchronous online sessions provides critical opportunities for observing non-verbal forms of communication. Synchronous sessions also provide the researcher with the ability to notice any signs of participant fatigue or hesitation during the co-design process which may not be expressed verbally.

During ACD, the use of iterative sketches reflects the collaborative idea generation between co-designers, facilitating easy and accessible ideation. ACD blends the use of drawing with a focused effort on developing a shared understanding of language, resulting in a form of visual summarizing, in which the researcher sketches in real-time during design ideation. By employing the use of drawing as a form of participatory, collaborative information transfer and co-creation ACD uses methods that are accessible to participants with motor and communication disabilities who use AT, establishing an interdependent partnership in design. In addition, the researcher collects a variety of artifacts during the co-design process, spoken, written, and visual, which provide a data trail of the rationale and iterations of the design.

4. ACD method in-practice

Here we present an example of ACD in practice, with descriptions of the four processes involved in ACD with an illustrative example of each process. ACD consists of three sessions: (1) synchronous, online session, (2) asynchronous reflection, and (3) synchronous, online session. During these sessions, the researcher and participant engage in four processes which build on the key constructs described earlier. These four processes are: (1) creating shared understanding, (2) visual summarizing, (3) asynchronous reflection, and (4) reflection and revision.

4.1. Context

In our examples, we draw on data from a prototype pilot of ACD, in which the co-design prompt for participants was "how can you improve access to creativity in your daily life?". In this paper, we discuss how the method enabled participants to engage in co-design. Because the purpose of this paper is to describe the method rather than the results of the study, we do not match participant identifiers with demographic details to protect anonymity. This prototype study was conducted to provide descriptive examples of the ACD method in action.

4.2. Participants

Participants were adults with communication and/or motor disabilities who used assistive technologies, which included: wheelchairs, voice recognition software, eye control, adapted mice, head mouse, and speech-generating devices. None of the participants were able to quickly and easily engage in drawing, therefore, the researcher employed the ACD method, in which the researcher translates the participant's ideas into visual sketches in real-time.

We recruited a total of six participants, using convenience sampling, with the primary criteria that participants used AT for computer access, which is the target population for the ACD method. One participant used AAC for communication, and AT for computer access and mobility. The remaining five participants used AT for mobility and computer access. All participants were literate, spoke English, and did not report any diagnosed cognitive disabilities. Three of the six participants engaged in a meta-reflection of the ACD method after the co-design process concluded. This study was reviewed and approved by our institution's ethical review board and all participants consented to be part of the study.

All participants had motor disabilities which made real-time physical engagement with co-design materials challenging or impossible. Participants also had limited abilities to engage with on-screen tools that could be incompatible with their specialized assistive technologies. Therefore, we chose to pilot the ACD method with these individuals, in which the researcher draws in real-time during co-design to represent the participant co-designer's ideas. The use of ACD limits technological barriers which could inhibit participants from fully engaging in the co-design process. The researcher takes responsibility for ensuring that participants can communicate their ideas without physical barriers, consequently, the researcher is responsible for the visual representation of co-design prototypes.

4.3. Method and tools

The tools used by the researcher were an iPad tablet and pencil, with Notability software (Notability, n.d) for drawing. Notability is a notetaking app which can be used in lieu of an onscreen whiteboard, allowing the researcher/co-designer to make notes and sketch in real time, so the participant/co-designer can see how their words are being interpreted into visuals. At the time of the study, this configuration was compatible with various video conferencing software solutions, allowing the researcher to share real-time sketching easily while simultaneously seeing the participant on-screen. The video conferencing software for each co-design session was chosen by the participant, based on the compatibility of the software with their AT system. The two video conferencing software options that were used with best result in compatibility with participants AT systems were Zoom and Skype.

Unlike traditional co-design methods which are often held in pairs or groups, in which participants might not be able to keep up with the pace set by the group, ACD is conducted in a 1:1, online, setting. Holding the sessions in 1:1 settings accommodates individuals who have mobility and communication disabilities by eliminating competing time-pressure from other participants. By holding ACD in a 1:1 setting, the researcher is able to follow the participant's lead at the participant's pace, ensuring equitable inclusion in the co-design process.

5. Implementation of ACD

The co-design prompt in our pilot study asked participants to design tools to improve access to creativity. Participants designed both physical objects as well as computer interfaces to improve accessible creativity in their daily lives. We provide examples of using the ACD method both for the design of physical objects and of computer applications. No matter the project being designed, ACD requires that the researcher and participant engage in co-design through computer-mediated technologies in an online, 1:1 setting.

5.1. Creating shared understanding

The process of creating shared understanding starts during recruitment. Potential participants are directed to an accessible webpage that provides information about the scope of the co-design study and the elements involved in participation, including the time involved in active participation in the study. The use of a webpage allows participants to take as much time as they need to access and absorb information about the study at their own pace. The inclusion of time estimates for participation is used to foster mutual understanding of the research process and dissemination process of results, which may take more time than participants might expect. This early discussion about time creates a shared understanding between researcher and participant of both the researcher's and participant's constraints, and establishes a precedent of following the participant's lead for pacing.

The initial synchronous session between the participant and researcher begins with explicitly checking on the communication tools and methods used for the session. The researcher closely observes and actively listens to the participant throughout these initial activities to learn the participant's communication style, language use and to begin creating a shared understanding.

> Researcher: *So now I'm sharing [screen], has that messed up* [AT software]?
>
> Participant: [indicates 'no' non-verbally]
>
> Researcher: *I'm so glad. Good. Alright, so I'm going to move forward then*….[pause and observes participant on screen]. *Unfortunately, it made your video a bit smaller. But I'm assuming you're typing or resizing the screen.* [long pause].
>
> Participant: *It took some adjusting but I am good now.*

In this excerpt the researcher starts by checking on accessibility when they share their screen. First, the researcher checks to ensure that screen sharing has not interfered with the on-screen AT software the participant uses, a common problem for individuals using AT for communication and screen sharing. Through this questioning, the researcher also reinforces their understanding of the participant's communication use: using non-verbal signals to indicate yes and no. The researcher continues to stay actively engaged in attending to the participant's non-verbal communication by observing the participant's actions. In this case, the participant appeared to be focused on an aspect of their screen

rather than the screen sharing window or the researcher's speech, so the researcher paused and checked in with the participant as a means of explicitly checking their assumptions that the participant was occupied with a task. The participant verifies that they were engaged in figuring out how to use their AT software with screen sharing. This interaction, though short, is critical to establishing a shared understanding of both non-verbal and verbal communication. Establishing a shared understanding of communication is essential for any collaboration but particularly essential for collaborating with individuals who use AT for communication and computer access. Because of the limited view the researcher has of the participant during the online session, participants are encouraged to express their needs throughout the entire synchronous session, such as needing to take a break.

Next, the researcher shares a slide with a visual timeline of the research process. This timeline has the same information as the recruitment website, and provides an opportunity for dialog about the research process and expectations (example of timeline used in pilot study in Figure 2). Throughout the session, the researcher uses slides with visual text as well as spoken language to ensure that the participant had opportunities to engage in the manner most suited to their communication style. Each slide was limited to *one* question or concept, to assist with processing time and to provide focus to each concept. After the timeline slide, the researcher shares slides defining key concepts/jargon used in the research study, utilizing visuals, text-based communication, and verbal communication. These slides assist in creating shared understanding, in which the researcher and participant are able to align their vocabulary for the co-design session.

Creating shared understanding continues throughout the synchronous session in a deliberate manner, in which the researcher intentionally prompts the participant with questions designed to inform the researcher of the participant's interests and the participant's use of language to describe those interests. In this example, the researcher and participant had previously discussed gardening, which provided the researcher with context.

> Researcher: *That's good. So as far as gardening goes, that's an interesting one to me. Because it's a different form of creativity than most people think about. But you and I had talked about it a lot [during a previous study]. How is it inaccessible to you right now? What are the barriers with gardening?*
>
> Participant: *Well, you extend what you want. I would like to deadhead more easily.*

When the participant uses the phrase "*extend what you want*" and "*deadhead more easily,*" the researcher infers that the participant is referring to a tool used to cut off wilted flowers. However, this is an assumption on the part of the researcher which the researcher will be able to confirm or amend as they enter the next process: visual summarizing.

5.2. Visual summarizing

The visual summarizing process evolves naturally as a byproduct of creating shared understanding, in which the researcher begins to visualize design ideas as the participant expresses them through real-time sketching. During the process, the researcher actively listens to participants and begins prompting participants for details through drawings that the researcher creates and shares in real-time as the participant is speaking. Because each participant's physical abilities can vary significantly, the researcher takes the lead on initial sketching based on the participant's discourse. Participants who are physically able to draw in real-time are encouraged to draw their own sketches during the ideation process as a companion to the researcher's drawings.

During the initial process of visual summarizing, the first sketches are based on the participant's answers to guided questions. Then, as the focus shifts from spoken language to a combination of spoken language and visual representations, the participant and researcher discuss and refine the concepts further. During the process of refinement, the researcher creates new sketches based on the discussion. The participant may agree or disagree with elements represented in the sketches or they might make additional suggestions. This time of co-creation and ideation is when the researcher and participant use their shared language to build on each other's ideas. At this time, a deep conversation regarding the rationale of design elements occurs, providing rich data for the researcher to analyze at a later time.

We continue sharing the example from earlier, in which the researcher made an assumption in response to the participant's statement that they would like to "*deadhead more easily.*" The researcher changed screen sharing to share the image of a blank Notability canvas (Notability, n.d), and the researcher began to sketch based on the participant's response using an iPad and Apple Pencil. Through this technique, the researcher and participant use language established during the shared understanding process to discuss the nuances of the design concept more easily.

Figure 2. Timeline slide of ACD process shared with participants/co-designers in pilot study.

Researcher: *Ok, so here are the scissors and I assume you need a handle, do you want fingerholes?*

Participant: *yeah, I don't even think you need that because they would do it themselves.*

Researcher: *Oh! Ok, so maybe you would just have one handle.* [starts new drawing of blades of scissors only]

Researcher: *Ok, they open and shut themselves so these are the scissors, but they need a handle, do you have a straight handle?*

Participant: *Yeah, a straight handle.*

Researcher. *Ok. Awesome. So then you just have a handle here. Does it matter to you, like the grip, if it's thicker or…* [draws straight line out from blades]

Participant: *Yeah, something quite large and with maybe a silicon handle that is grip-able. I mean, you don't want to accidentally drop this on your toes.*

Researcher: *Does it matter or does it help you to have some sort of texture?*

Participant: *I think for knives and things I just use a silicon handle…*

Researcher: *Nice. Nice. Ok, so ….* [creates larger handle and writes notes by design]

Participant: *The other thing that is an important aspect of any design is that you want it to look nice.*

The researcher used a combination of written words and visual sketches to capture the ideas shared by the participant/co-designer. Together, the words and visuals helped the researcher and participant see any discrepancies between their understanding in real-time and could use language to refine ideas and come to a common understanding. In this excerpt, we see that the word "scissors" created different images for both the researcher and participant. This discrepancy was visualized in the real-time drawing created by the researcher (Figure 3). For the researcher, the term scissors referenced hand-held instruments used in cutting paper or fabric, whereas for the participant, scissors denoted garden shears. In this example, we see how the word scissors holds different conceptual meanings for both co-designers, highlighting how active visual summarizing enhanced shared understanding of the vocabulary being used. Through ongoing questioning regarding the design's elements, the participant corrected the researcher's misinterpretation (Figure 4). With visual summarizing as well as written text and drawings, participant and researcher form a shared understanding of the design.

Visual summarizing can be used for co-designing physical objects (e.g., Figures 3 and 4) as well as for user interface design, including intelligent interfaces (e.g., Figures 5 and 6). One participant described the need for dictation software to learn how to visually represent their tone of voice through text, as a way to save them from having to format text manually. The researcher used both written text and a stick figure to reflect the participant's initial idea (Figure 5). Upon seeing the researcher's visual representation of their idea, the participant and researcher were able to specify features for specific inputs. Figure 6 shows how the researcher and participant collaboratively designed the feature of using a loud voice to trigger text written in all capitals, and a sarcastic voice to trigger text written in italics. The use of visual summarizing establishes common ground between the participant/co-designer and the researcher/co-designer through the use of both visuals and text, providing an opportunity to probe into specific features of the design. In this case, the researcher probed how the dictation software would be trained to learn to detect different voice inputs for automated formatting (Figure 7).

As the ideation process continues, the researcher and participant come to a mutual understanding of the design concept. At the conclusion of the first synchronous session, the researcher returns to the timeline slide to summarize what they had accomplished and what the next steps are for the co-design process. The researcher asks the participant for their preferences regarding logistics and timing for the upcoming processes of the co-design study, including what file types are most accessible for the participant for a final visual summary. The session concludes with an agreement for the next steps based on the participant's preferences, and with the researcher committing to sharing the final visual summary from their synchronous design session with the participant in the asynchronous manner of the participant's choice (via email or a shared folder/drive).

After the conclusion of the synchronous ACD session, the researcher reviews the iterative drawings and creates a visual summary of the final design concept. The researcher includes written text to support the sketches, highlighting key concepts generated in the synchronous session (Figures 8 and 9). By taking time after the synchronous portion of ACD to reflect on the design, the researcher can deliberately highlight the concepts they interpreted as important, using colors, visuals, and text. The exercise of creating the summary is a means for the researcher to synthesize the information and engage in reflexivity. The summary also documents the research data and provides a form of

Figure 3. Initial sketch of scissors based on researcher's interpretation of the word "scissors".

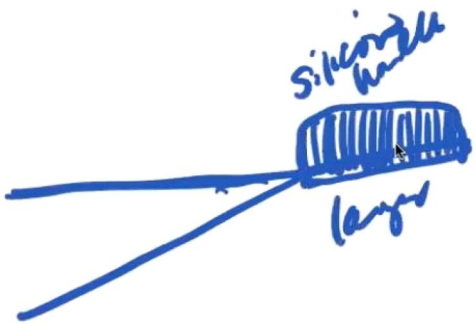

Figure 4. Revised sketch of scissors after re-establishing shared understanding.

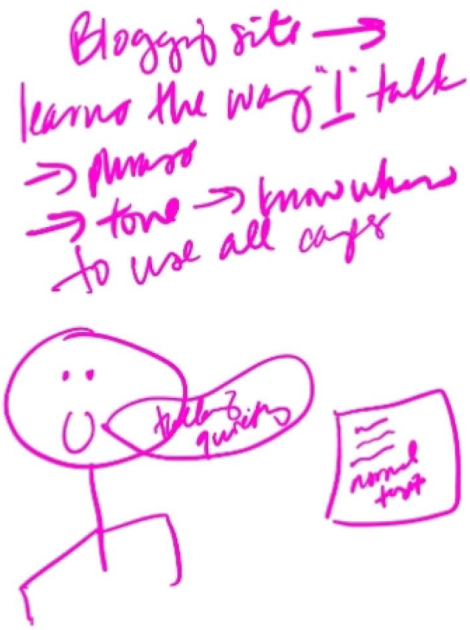

Figure 5. Initial sketch of dictation automated text formatting.

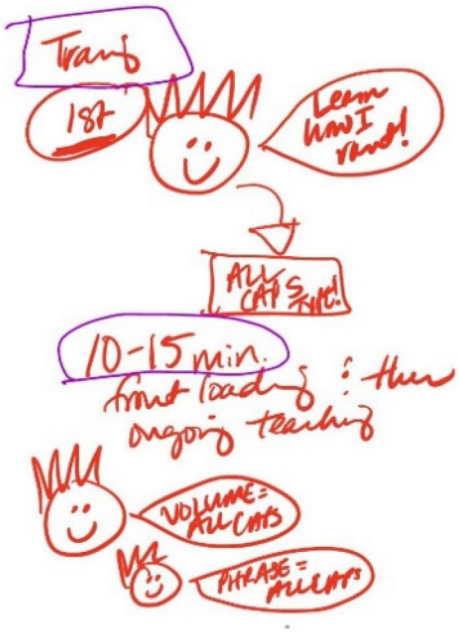

Figure 7. Sketch of training dictation software for automated text formatting.

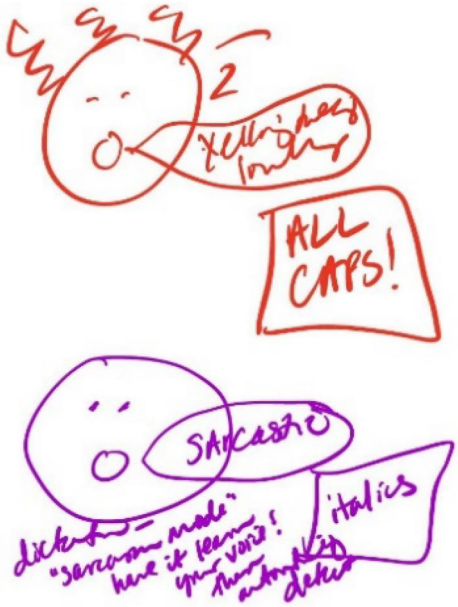

Figure 6. Revised sketch of dictation automated text formatting.

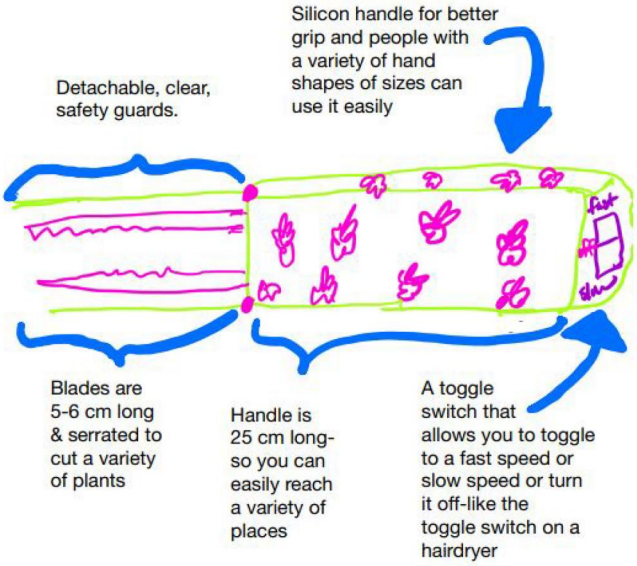

Figure 8. Summary sketch of garden scissors after first synchronous session.

member-checking with the participant for the next process of ACD.

5.3. Asynchronous reflection

The focus of the asynchronous reflection is to allow participants to reflect and iterate on the design process in the way that is most accessible and easiest for them. The researcher shares concept sketches and brief, written summaries of the designs created with the participant within three days of the synchronous session, while the session is fresh in the co-designers' minds. Participants are asked to reflect on the sketches and to send the researcher any further ideas they have on the design concept. Participants are encouraged to use a variety of digital formats to provide feedback: their own sketches, images, videos, and/or written text. This reflection process incorporates member-checking (Beneteau, 2020; Ison, 2009) mid-way through the co-design process in a way that allows both the participant and researcher to take time to reflect on the design.

During asynchronous reflection, participants are also able to reflect on their participation in the research process itself. Providing this time for reflection can serve as an additional check for participants who might have extenuating circumstances that make ongoing participation a challenge. Near the conclusion of the asynchronous reflection process, the researcher contacts the participant to confirm that the participant would like to meet again for the second and final synchronous session. At this time, the researcher

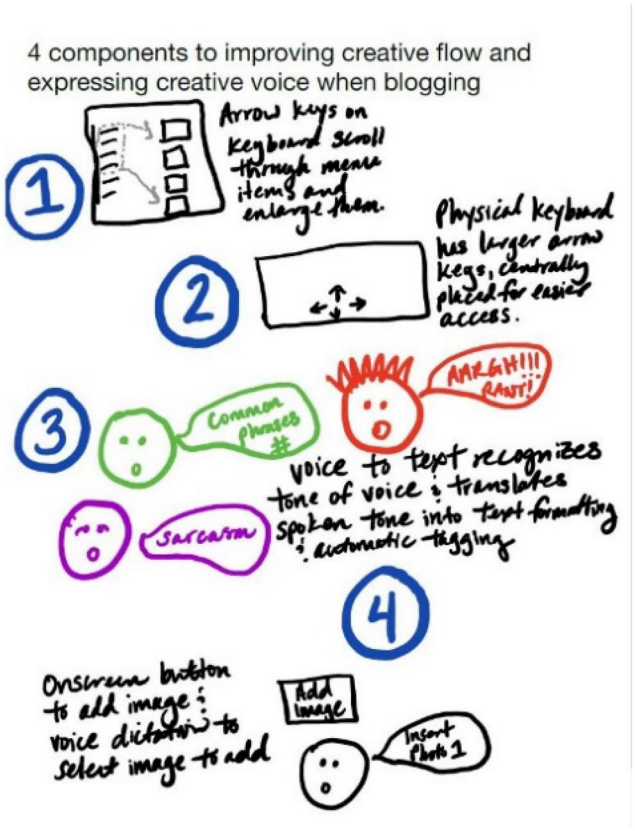

Figure 9. Summary sketch of dictation automatic text formatting after first synchronous session.

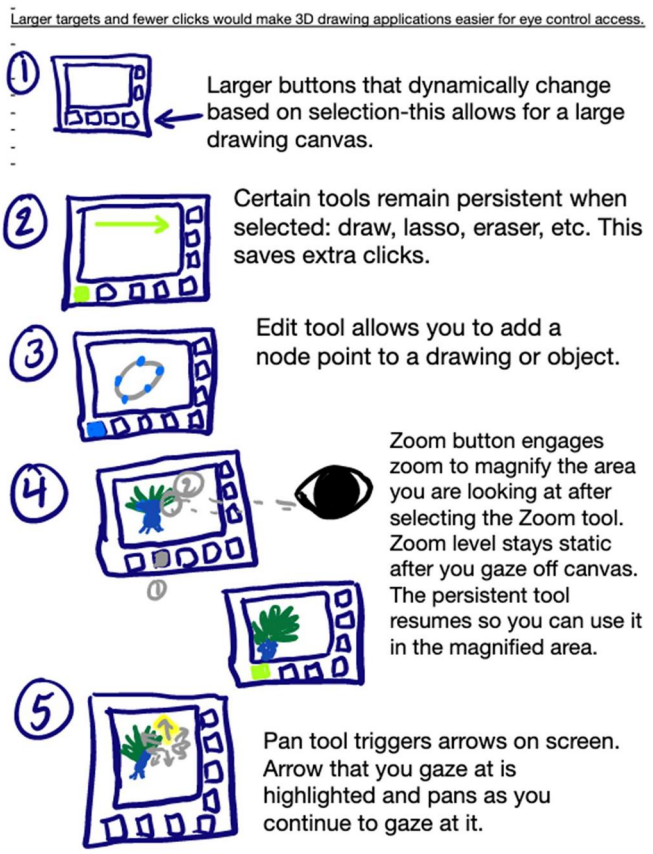

Figure 10. Visualization summary sent to participant at start of asynchronous process.

intentionally provides an opportunity for the participant to opt-out of continuing in the study, without any penalty to the participant. By providing this time for reflection, participants have the option to discontinue the study without feeling pressure from the research team.

In one example, a participant opted not to continue with the study during the asynchronous reflection process based on their health. The energy required for the participant to continue with the ACD study was energy that the participant wanted to put towards engaging with their family instead. By having the asynchronous reflection time built into the co-design process, the participant was able to reflect and make their choice to discontinue their participation in the study without the pressure of being online, or in-person, with the power dynamics of a researcher present.

Even with the participant discontinuing the co-design process, the participant's contribution to the research in the first synchronous session was acknowledged and utilized by the researcher. The participant was able to discontinue the study based on their needs, while still having made a notable contribution to the data set for the study.

In another example of the asynchronous reflection process, which highlights the importance of checking with participants on file types that are accessible with their AT, a different participant had the ability to directly open and edit a PDF. The researcher sent the co-design summary from the first synchronous session in PDF format. The participant edited the PDF and emailed it back to the researcher, adding both written comments and copied/pasted images. In this way, the participant was able to build on the initial co-design work and clarify concepts that they felt were important directly in a shared document. Importantly, the participant did not have a tight time constraint in which they needed to share their ideas. The flexible asynchronous reflection process provided enough time for the participant to use their AT system to access the PDF and make the changes they wanted.

The summary visualization and asynchronous reflection process served both as a form of member-checking as well as a platform for further design development. Figure 10 shows the original summary generated by the researcher after the synchronous co-design session, which was shared at the beginning of the asynchronous reflection process. Figures 11 shows a page of the edited summary generated by the participant during the asynchronous reflection process that was shared back to the researcher before the start of the final synchronous session.

5.4. Process 4: Reconciliation and revision

The final process of ACD revises and reconciles the asynchronous reflection with the initial visual summaries. A second online, synchronous session is held with participants in which the researcher and participant review the initial design concept, the problem it was trying to solve, and the asynchronous reflections. This final process incorporates

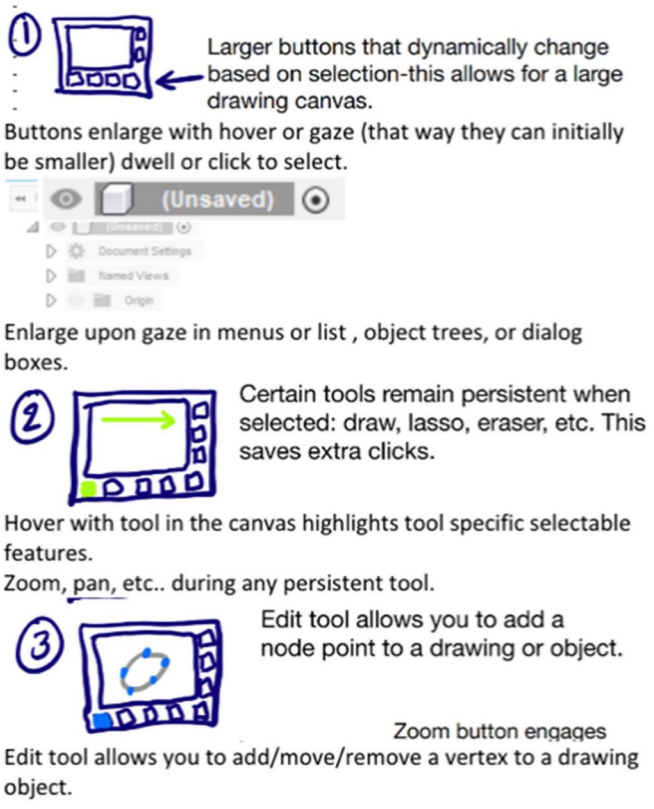

Figure 11. First page of summary edited by participant during asynchronous phase with pasted image.

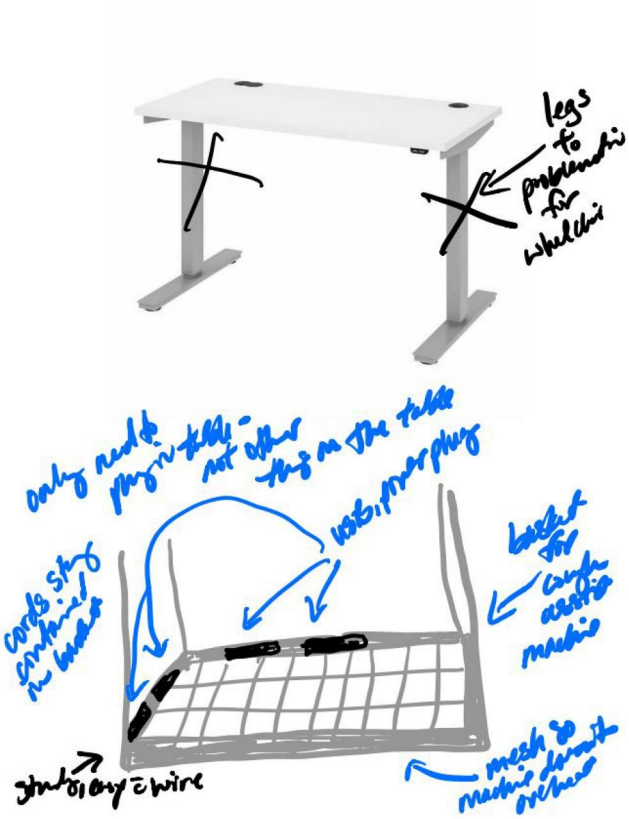

Figure 12. Reconciled design features incorporating screenshot and visual summary with textual notations.

principles of positive design in which we address the subjective well-being of people who might use the design (Desmet et al., 2013). The focus of the session is for the researcher to understand the participant's perspective on how the design might impact them, and others, and how this impact is reflected in specific elements of the design concept.

Just as with the first synchronous session, both visual, textual, and verbal information is conveyed to accommodate a variety of abilities. At the beginning of the session, the researcher shares an outline of what to expect during the session, using visuals and text, following the principles of creating shared understanding. During this second synchronous session, participants who reviewed the design summary but who were unable to submit any feedback during the asynchronous reflection process (either due to accessibility issues, time constraints, or other barriers) are able to continue iterating on the design, with the researcher responding to the participant's feedback in real-time through screensharing and sketching.

During reconciliation and revision, the researcher uses the following guiding questions to understand the participant's perspective on the design: (1) what benefits will this design provide, (2) what are the essential features of the design, and (3) who might use this? The final output from ACD reflects the answers to these questions. The researcher and participant continue to iterate on the design, as appropriate, based on the responses to the questions. The design iterations conclude when the participant feels satisfied with the final concept sketch after responding to the guided questions.

In one example, a participant emailed the researcher their feedback on the design of an accessible desk through email, the most accessible form of communication for the participant. In preparation for the final synchronous session, the researcher took the participant's textual feedback from the asynchronous process, and used a screenshot of an existing desk to visualize the participant's text-based reflections on the design. This provided both co-designers with a visual medium to reconcile any misinterpretations the researcher might have and to revise the final design features (Figure 12). In this way, the reconciliation and revision process incorporate earlier processes: creating shared understanding, visual summarizing, and asynchronous reflection.

The reconciliation and revision process concludes by revisiting the timeline that was shared in the first synchronous session. The researcher discusses the anticipated timeline for sharing the results of the co-design research and provides any updates to the timeline that may have occurred since the first session with the participant. In this way, the researcher is transparent with participants about their contribution to the research study and aligns expectations for when the results of their co-design work might be shared. The timeline provides another opportunity for the participant to ask about the research and also provides the researcher with an opportunity to explicitly recognize and celebrate the participant's contribution to the research process.

6. Discussion

Prior work has shown that people with disabilities and degenerative conditions want to be actively engaged but need temporal flexibility to minimize fatigue (Baylor et al., 2010; Beneteau et al., 2024). People with communication disabilities can feel undue pressure to communicate within set periods of time, particularly in group settings, resulting in conversational constraints (Valencia et al., 2020). Ensuring that participants feel comfortable in continuing with their participation is particularly important for marginalized populations so that they do not feel they are being used to promote the researcher's agenda (Baldwin et al., 2019; Harrington et al., 2019). ACD provides an opportunity for participants with diverse abilities to engage in co-design. ACD is a temporally flexible method, expanding on Friedman and Yoo's concept of *"pause"* (Friedman & Yoo, 2017) by introducing explicit participant-led pausing. The incorporation of the timeline, the explicit invitations to take breaks as needed during the synchronous session, the asynchronous reflection, and the participant-led timing of the second synchronous session are designed to equalize the power-balance between researcher and participant. By eliminating the time-constraints for real-time participation, the asynchronous reflection period accommodates participants' abilities, thereby reducing additional stress which researchers may inadvertently cause by adhering to a strict co-design timeframe. The reflection period of ACD also allows participants to choose if they want to continue with the co-design process without any undue pressure from the researcher.

The resulting ACD method is not only accessible to the target population, but as a method, it provides extremely rich data. Through ACD, the rationale for each element of a design is discussed at length throughout the process of co-design, leaving a trail of design rationale as the co-design process evolves. Through the interdependent partnership and the four processes of ACD, the researcher has intimate knowledge of the motivations behind each element of the design. We provide a reference guide for researchers who are interested in using ACD, in which we break down the steps of ACD (supplementary materials).

6.1. Discussing next steps and anticipated outcomes of research as interdependent co-designers

Prior work has highlighted the potential for a mismatch between researcher expectations and participant expectations for the outcomes of the research process (Baldwin et al., 2019; Harrington et al., 2019; Newell & Gregor, 2000). Participants' understanding of the co-design process is influenced at the start of the co-design session. Researchers employing the ACD method should explicitly address the expectations and constraints (or lack of constraints) in the co-design process. Drawing on Sanders and Stappers' concept of the co-design process, the researcher includes a visual of the process at the start of the first synchronous session and positions the study within that process (Sanders & Stappers, 2008). In the case of the study described in this paper, the first author positioned their study entirely within the *"fuzzy front end"*, as an exploratory study (Sanders & Stappers, 2008).

The graphic from Sanders and Stappers' [87:6] provides dedicated time to discuss the research study, thereby incorporating visuals, text, and words to enhance shared understanding of expectations. After the proof-of-concept study, the ACD method now incorporates the timeline slide after introducing the co-design process graphic and at the end of the co-design sessions. These slides provide a platform for the researcher and participant to have a frank conversation about anticipated outcomes and the time and processes involved in dissemination of research, increasing transparency of the larger research design process.

6.2. Towards expanding the use of Aligned Co-design

With the development of ACD, we build on creating new domains of collective creativity by expanding the diversity of participants who *can* participate in co-design. The participant population who took part in the study were comprised of people who had diverse motor, speech, and accessibility profiles, all of whom used AT. We propose that ACD could be extended further to be used with an even broader participant population. The design of ACD, with the use of visual summarizing and emphasis on creating a shared understanding, as well as the flexibility of participant-controlled scheduling of sessions, lends itself towards other populations who may not otherwise be able to attend in-person or group co-design sessions. The flexible use of tools and multi-modal communication incorporated into ACD may also address previously documented challenges with remote co-design in which participants experienced challenges with communication and preferred the use of familiar tools rather than bespoke tools created for online co-design sessions (Walsh et al., 2012). ACD's dyadic format may also make co-design session more accessible to populations who have difficulty in group settings either because of abilities, sensory stimulation, logistical feasibility, or health concerns.

The development of ACD connects to a broader, ongoing discussion across HCI that is considering how to develop and sustain longer term relationships for co-designing which mutually benefit both researchers and participants, as in the case of designing with children (Druin, 2002; Hourcade, 2022; Yip et al., 2017) and people who have disabilities (Frauenberger et al., 2017; Holone & Herstad, 2013; Waller et al., 2011). With the ACD method, we offer a first step towards finding workable ways for negotiating time commitments that are flexible and participant-led to ensure that technologies can be respectfully designed with diverse populations.

6.2.1. Limitations

There are a number of limitations to the ACD method. ACD was designed for a specific participant population: adults with motor and communication disabilities. ACD, as currently designed, might not be appropriate for some participants. One limitation is that the ACD process requires

that co-designers are able to read and are sighted. Alternatives need to be explored to include participants who are blind or have low-vision. Further iterations of the ACD method could be designed to include participants who are not able to easily read by increasing the use of drawing and visual representations of concepts during the ACD process, which might also be a viable option for including young children as participants. Another limitation of ACD is that participants must have access to technology (computer and internet access). Potential accommodations for outreach to populations who might not typically have access to reliable internet could include partnerships with public libraries to reserve computer stations for ACD sessions, but this needs to be investigated further.

7. Conclusion

We introduce Aligned Co-Design (ACD). Building on an interdependence framework, ACD seeks to balance the inherent hierarchy of researcher and participant starting with participant-driven timing of co-design sessions. With a focus on creating shared understanding, the researcher learns the language of their co-designer/participant and develops a shared design vocabulary through the processes of visual summarizing, asynchronous reflection, and reconciliation and revision. The design of ACD inherently uses member-checking in real-time and serves to check misinterpretations of data over multiple sessions. The synchronous and asynchronous sessions of ACD are participant driven. As a result, participants in ACD can opt-out during the research process while the researcher is able to obtain useable data. ACD was created to include participants with motor and communication disabilities in distributed locations, however, we suggest that the method can be used with many populations who might not otherwise engage in traditional co-design research. The ACD method provides an opportunity for more inclusive and equitable co-design while also establishing a positive and collaborative co-design experience for the researcher and participant in a setting of the participant's choice.

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The authors report there are no competing interests to declare.

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