Degrees of Freedom: Designing Information and Communication Technologies to Support Enhanced Agency for Blind and Partially Sighted Individuals Through Cross-Sensory Information Representation

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ABSTRACT

A significant change in working and learning environments has taken place in recent years, since the beginning of the COVID-19 pandemic. The core of this shift is a steadily greater reliance on information and communication technologies (ICTs) to mediate representations of information. For blind and partially sighted individuals (BPSIs), this has been a difficult transition that has carried many inclusive and accessible design challenges along with it. This study is concerned with the limitations and compromises on BPSIs' agency when relying on ICTs for equitable access to information relative to their sighted peers, and how designers of ICTs could responsibly use design recommendations aimed at supporting equal agency for these users. Actively shaping ICTs to be highly cross-sensory, interactive and navigable without a reliance on vision would be a step towards equal agency for BPSIs and making ICTs more inclusive. A research process was conducted comprised of functional usability testing of conventional ICT platforms (i.e. Zoom, Microsoft Teams and Google Meets), semi-structured interviews focused on narrative exploration of BPSIs' lived experiences with ICT use in working and learning environments, and longitudinal co-design workshops aimed at collaboratively building, testing and iterating on low-fidelity prototype ICTs. Through these activities, a suite of relevant themes were found, including the effectiveness of interactive information foraging, filtering for relevance, using different granularities of information depending on context, and navigation of the diagrammatic representations of ICTs using sensory-grounded language. Preliminary design recommendations for inclusive design of ICTs were informed by these outcomes, such as ensuring large quantities of information are curated interactively, providing appropriate choice selection relative to relevance to users' goals and intentions, and holding organizations accountable for representation of BPSIs in decisions relating to ICT service provision. These outcomes suggest a promising future area of design research may have been articulated via these concerns for accessibility, management, navigation, and sensory-grounded representation of information.

1. INTRODUCTION

1.1 Background

Widespread use of information and communication technologies during the COVID-19 pandemic exposed barriers that contributed to the exclusion of blind and partially sighted individuals (BPSI) from numerous opportunities within working and learning contexts. BPSIs have a need for non-visual spatial information conveyed via ICTs that corresponds to what sighted individuals access through visual graphics on computer screens (Gorlewicz, Tennison, Palani and Giudice, 2018; Lee, Sukhai and Coppin, 2022). Cross-sensory techniques are an alternative for BPSI, but adoption in consumer products is rare. Here, "Cross-Sensory Techniques" refers to representing spatial cues that might otherwise be shown through graphics for sighted individuals through auditory or haptic displays for BPSI. To investigate this issue, this major research project involves a plan to co-design cross-sensory prototypes to alleviate difficulties by extending prior work on: sonification of visual information (Basset-Bouchard, Saltz, Tane, Marie Carroll and Prathipati, 2017; Shafer, Larson and diFalco, 2019), tangible interfaces (e.g., McGookin, Robertson and Brewster, 2010), and audio-tactile interfaces, such as Ghodke, Yusim, Somanath and Coppin's (2019) audio-tactile globe for BPSI, with the aim of establishing effective guidance on designing future ICTs that meet the needs of BPSI for accessing and interpreting information with as maximized a potential for enhanced agency (Mendoza-Collazos and Zlatev, 2022) as possible.

This study also investigates linkages between individual differences and preferred types of representations (text versus images or diagrams, for example) to minimize mismatches between individual differences and interface features, reducing difficulties and improving experiences. For example, sentences struggle to explain the content of concrete visual representations of data accurately or completely, such as financial charts that appear as "three mountains of varying height" (Coppin, Li and Carnevale, 2016). Finally, returning to the aforementioned issue of enhanced agency (Mendoza-Collazos and Zlatev, 2022), this study also investigates how experiences of agency for BPSI, who are predominantly provided with screen readable text descriptions of visual graphics, are enhanced or impeded. Text descriptions potentially limit the information that BPSIs are able to receive to the interpretation provided by the author of the text description (Coppin et al., 2016) rather than their own first-hand perception. This project emphasizes an approach to developing recommendations and guidelines for future ICTs that will foster equity with access to information via ICTs and equal support of individuals' capacity for the agency that is provided through such technologies. To do so, participants involved with the research activities will be treated as experts on their lived experiences of using ICTs prior to and during the COVID-19 pandemic, in order to inductively produce these results.

1.2 *Problem Statement*

Recognizing the need for a shift towards direct perceptual access to the spatial-topological properties of visual content, provided through other sensory means (Gorlewicz et al., 2018), this major research project aims to identify and explore the role that inclusive design of ICTs and information representations have on the agency of BPSI and offer these insights as recommendations with which the agency of BPSI may be supported as effectively as possible, and designers of ICTs of the future may use these insights as guidance to include BPSI more fully in society.

1.3 *Research Questions*

- What new and more effective recommendations for the design of accessible ICTs can be informed through the lived experiences of BPSI using ICTs in a working or learning context?
- How might accessible and inclusive virtual information representations be designed to support, rather than limit, BPSIs' potential enhanced agency (Mendoza-Collazos and Zlatev, 2022)?

This major research project aims to discover how designers of inclusive virtual ICTs might adopt approaches that support the enhanced agency that people normally gain through the design of artefacts, signs, and language (Mendoza-Collazos and Zlatev, 2022). The collaborative input of BPSIs in developing these new approaches is vital (Han, 2020; Han et al., 2020; Ghodke et al., 2019; Lundgard, Lee and Satyanarayan, 2019) and may not only lead to more effective results but generate further insights on opportunities for developing new accessibility standards specifically for inclusive ICTs that support their users' agency, which does not yet exist (Elavsky, Bennett and Moritz, 2022).

1.4 *Significance of Research*

This focus on agency in the context of ICT use reflects the importance and changing role of information in current society, which has become increasingly visual, complex and dynamic as a result of the need to "make meaning from and interpret patterns, trends, and correlations in visual representations of data" (Borner, Bueckle and Ginda, 2019, c.f. Borner, Maltese, Balliet and Heimlich, 2016) and has yet to sufficiently include BPSIs or provide the same capacity for agency via access to information (Gorlewicz et al., 2018; Kim, Joyner, Riegelhuth and Kim, 2021).

The importance of and supportive strategies for providing BPSIs with equal capacity for agency is a humans rights issue that represents significant risks (i.e. the lag in inclusive design and accessibility of new, more visual-focused ICT platforms such as augmented, mixed and virtual reality) faced by blind and partially sighted communities in the present and the near future (Gorlewicz et al., 2018). Synergizing the approach to designing ICTs with strategies for inclusion and designing cross-sensory interactive experiences using these new platforms can be expected to pre-emptively close the gap.

2. LITERATURE REVIEW

2.1 Digital information representation & accessibility for blind and partially sighted individuals (BPSI)

There have been very few instances of ICTs that fail to provide any accessibility to BPSIs, eventually at the very least. However, these mainstream options for ICT access raise questions about how they came to be, why, and by whom. Hersh and Johnson (2008) describe an account of technologies to aid BPSI in accessing information throughout recent history. For the latter, they note that such technologies are often overlooked. However, this category does include large print, screen magnifiers, CCTVs that magnify video feeds, and telescopic systems, all of which aim to maximize the use of individuals' usable vision (Hersh and Johnson, 2008), which, if successful, would provide firsthand perception of the information visually.

2.1.1 Historical account of accessible ICTs

Textual information has a significant history of being represented for access to BPSIs via Braille, which was created in the 19th century (Hoffmann, 2008). Braille provides sequences of raised dot patterns embossed on thick sheets of paper, which users feel with their fingertips and is therefore constrained to static representations of linguistic information (Hoffmann, 2008). Another constraint is the physical space which Braille characters occupy in comparison to regular text, which is the reason for the Grade 2 Braille code, which includes 189 abbreviations for most long words (Hoffmann, 2008). As ICTs developed, and dynamically changing digital displays became possible, Braille literacy and use dropped dramatically since dynamic Braille displays were never readily available and too expensive to reliably reach BPSIs (Hoffmann, 2008). This is attributed to "the fact that the size of the potential market is considered too small and decreasing" (Hoffmann, 2008).

Many similar questions regarding the integration of standard forms of accessibility to the information described previously play a part in determining the historical and current uptake of real-time text-to-speech systems, including screen readers (Hersh and Johnson, 2008). As a natural outgrowth of audio transcription products and services that provided print accessibility prior to the dominance of digital text and documents, screen readers have also had the advantage of providing access to text through inexpensive enough software that they often come standard with operating systems or are otherwise affordable to purchase (Hersh and Johnson, 2008; Evans and Blenkhorn, 2008; Gorlewicz et al., 2018). While highly useful for digital accessibility, especially in the context of digital text and many simple visual UI features that can be replicated through the readers' navigation systems, screen readers unfortunately still rely on digital content creators providing screen-readable content, which is highly inconsistent (Evans and Blenkhorn, 2008).

Raised line (tactile) graphics are another tactile format for accessible visual information. However, there are serious flaws with this representation type, particularly for digital information. Jansson (2008) refers to "embossed pictures" and "tactile maps" as historical ways of providing access to pictures, diagrams and maps that have existed since the 18th century, despite issues with complex images being extremely difficult to get a "haptic glance" of, and with the inherent difficulty in representing three-dimensional visual properties in what is functionally a two-dimensional form. Tactile graphics are also prohibitively expensive to produce in sufficient quantities for reliable access, require large sizes for output due to the large granularity of information required to perceive through touch and become obsolete when needing to represent dynamically changing digital information (Jansson (2008); Marriot, Lee, Butler, Cutrell, Ellis, Goncu, Hearst, McCoy and Szafir (2021)).

2.1.2 WCAG principles & limitations

As access to information has become progressively more dominant in society and day-to-day life, Web accessibility emerged as a major concern for BPSIs (Hersh and Johnson, 2008). Scacca (2022) notes that after first entering into general use in 1994, the World Wide Web Consortium (W3C) was formed to address how accessible the Internet needed to be and consisted of a "group of experts" who collaborated on the "Web Accessibility Initiative" (WAI). The result was a set of domains (architecture, user interface, technology, and society) and key areas (tools, education and outreach, research and development) for which guidelines were produced to ensure web content accessibility to all users (Hersh and Johnson, 2008).

The first set of guidelines was published in 1999, while the next major update arrived in 2008, introducing the four principal categories of accessible design for the Web (Scacca, 2022). These categories are Perceivable (i.e. captioning / alt-text), Operable (i.e. keyboard navigation), Understandable (i.e. predictability of UI functionality), and Robust (i.e. web content readable by any device) (Scacca, 2022). Three levels of compliance were also introduced (A, AA, AAA), which were intended to act as a measure of quality for web content on the basis of accessibility, but never a legal mandate or obligation for web content creators to follow (Scacca, 2022). 2018 saw a significant update (WCAG 2.1) that introduced a slew of accessibility standards for mobile devices, which are vital for blind and partially sighted users, who have had significant uptake of mobile devices since the introduction of the iPhone's screen reader in 2009 (Gorlewicz et al., 2018; Scacca, 2022). The new standards covered areas such as mobile keyboard access, screen orientation, target sizes, and interactivity of content on "hover" or focus (Scacca, 2022). Still, the status quo of accountability for web accessibility has remained the same, with several major legal pursuits of greater enforcement being stalled (specifically in the United States) as of today (Scacca, 2022).

2.2 Current "accessible data visualizations" & inclusive information communications technologies (ICTs) research

"Accessible data visualization" is a field of research and practice that primarily aims to make the benefits of visual representations of information accessible to BPSIs (Kim et al., 2021). By adhering to industry standards for image accessibility (WCAG, 2022), most designers of accessible data visualizations choose to use screen-readable text descriptions to achieve this (Elavsky, Le Gassick and Fossheim, 2021; Marriott et al., 2021). However, a critical limitation of text descriptions used for accessibility is that the diagrammatic properties (Larkin and Simon, 1987 - see section 2.3) of charts, graphs and other forms of visual information representation cannot be fully translated into text descriptions (Coppin, 2014; Coppin et al., 2016 – see section 2.4) without a significant loss of information. Furthermore, by restricting access to information representations to a description written by a single individual, BPSIs may be too dependent on these single interpretations, rather than their own, perceived firsthand. This raises questions regarding the impact on BPSIs' agency in the context of interactions with information representations. First-person interpretations in individuals' cycles of perception and action in their environments are frequently emphasized in the literature on ecological approaches to agency (Segundo-Ortin, 2020; Withagen, Araújo and De Poel, 2017; Mendoza-Collazos and Zlatev, 2022 – see section 2.5-2.6). So, are the standard approaches to making information representations accessible to BPSIs limiting their possibilities for acting intentionally (Mendoza-Collazos and Zlatev, 2022) in relation to their sighted peers?

Much of the literature reviewed during this study supports the use of text descriptions for accessibility to data visualizations, though none addressed concerns of user agency besides Elavsky et al. (2022) in the context of a "Flexible" heuristic for diverse and conflicting access needs, without elaborating further. Generally, this support makes use of the most low-cost and widely available access option (Elavsky et al., 2022; Kim et al., 2021; Potluri, Grindeland, Froehlich and Mankoff, 2021). Only raised line graphics offer comparable availability but are significantly higher in costs and cannot be made interactive (McGookin et al., 2010). However, text descriptions are also supported by some BPSIs as a preferred option for access, since they support diverse preferences (Lundgard and Satyanarayan, 2021) and can be delivered immediately as speech rather than tactile representations, which are often bulky. In some cases, text descriptions may effectively communicate abstract concepts (Coppin, 2014; Han, 2020; Han, Wnuczko and Coppin, 2020), and some BPSIs find that audio descriptions are useful in establishing a sense of presence and triggering multi-sensory experiences (Fryer, 2013). Despite these findings, problems such as the aforementioned lack of user agency and limitations such as the observed need to seek out trustworthy sources of text descriptions such as friends and teachers (Zebehazy and Wilton, 2014) severely limit the usefulness of text descriptions for accessibility. However, having trustworthy individuals provide descriptions of inaccessible information to BPSIs cannot be considered an alternative to making the information accessible, because it is not a solution which provides them with agency. Providing the information through multiple sensory modalities may be the only viable solution for BPSIs to have maximum capacity for agency.

Kim et al. (2021) raised the issue of a lack of consensus in understanding tasks and motivations for data visualization use by BPSIs (using non-visual means). Additionally, the need to provide different granularities for the exploration of data visualizations (different levels of detail depending on intentions) is highlighted in Elavsky et al. (2021), Kim et al. (2021) and Sharif, Chintalapati, Wobbrock and Reinecke (2021). Each concluded that there is little agreement among practitioners of accessible data visualization design on how to structure the information in this way for BPSIs. Building upon this, a consultation of the Web Content and Accessibility Guidelines (WCAG, 2022; Web Accessibility in Mind (WebAIM), 2021) fails to produce any standards or guidelines specific to data visualizations or information representations presented on the Web (only images), confirmed by Elavsky et al. (2022) as a challenge for uniting accessibility practices in the data visualization field. While approaches to standardizing endeavours to make data visualizations accessible to BPSIs remain inconsistent (Kim et al., 2021; Sharif et al., 2021) and indistinct (Elavsky et al., 2022; WCAG, 2022; WebAIM, 2021), there have been many individual works that successfully designed accessible representations of visual information in a specific context. Among the findings that these works offer is the need for greater involvement of BPSIs in this field's research (Ghodke et al., 2019; Lundgard et al., 2021; Marriott et al., 2021), and evidence that multi-sensory and cross-sensory representations are of particular benefit to them. This is exemplified in the "Sensory Modality" category of Kim et al.'s (2021) problem space definition for accessible data visualizations and in the literature review of Shahira and Lijiya (2021).

2.3 Diagrammatic & sentential representations

Conventional ICTs afford a form of communication that, in a visual format, is distinct from text descriptions as a result of the "diagrammatic" properties found in pictures and diagrams (Lee et al., 2022). However, BPSIs experience text descriptions of diagrams in most cases (Elavsky et al., 2021; Jung Mehta, Kulkarni, Zhao and Kim, 2021; WCAG, 2022), since WCAG offers no technical way to distinguish diagrams relative to sentences without using sentences to do so, thus they are made accessible through screen-readable text descriptions (interpretations) of diagrams (Coppin, 2014; Coppin et al., 2016). There is a need for a technical understanding of the affordances, or constraints, of diagrams as opposed to text descriptions for accessibility experts (Barter and Coppin, 2022).

Several traditional theories of diagrammatic representations demonstrate that diagrams have distinct properties that provide information that text descriptions cannot (Barter and Coppin, 2022). These include the distinction between "diagrammatic and sentential representations" (Larkin and Simon, 1987, p. 66): the former is commonly defined as components being "indexed by location in a plane … [and] preserv[ing] explicitly the information about the topological and geometric relations among [them]", while the latter "[forms] a sequence corresponding, on a one-to-one basis, to the sentences in a natural language description[, and] … [preserves] other kinds of relations, for example, the temporal or logical sequence". The existence of diagrammatic representations implies that a complete translation into text or speech cannot be sufficient, as otherwise, it would and unnecessary to provide a diagram in the first place (Coppin, 2014).

2.4 Information losses in translation from pictures and diagrams to text descriptions

	Picture	**Diagram**	**Text - Sentence**
Relation	Pictorial	Pictorial	Symbolic
Object	Pictorial	Symbolic	Symbolic

Table 1: Theoretical model of relation / object representation in pictures, diagrams, text-sentences; adapted from Coppin (2014, pp. 10)

The contradiction in limiting the provision of pictures, diagrams, charts, graphs, and icons for accessibility to text descriptions is noted by Coppin (2014), reflecting the work of Shimojima (1996), who describes a "Constraint Hypothesis" that predicts that coding information into a two-dimensional plane with geometric and topological relations provides additional information without requiring additional inferences. This is a "free ride", a phenomenon that exemplifies how diagrams offer "consequential information with little inferential effort [that is] observable from [a diagram], not just inferable" (Stapleton, Jamnik and Shimojima, 2017). For this information to be observable from a representation, there must be an appropriate match of representational choices to goals or problems that necessitate the use of a diagram (Shimojima, 1996). A relationship of structural constraints of diagrams to target problem constraints (Shimojima, 1996) in the context of accessibility for BPSI must further consider the constraints of the sensory modalities available to this audience (Barter and Coppin, 2022).

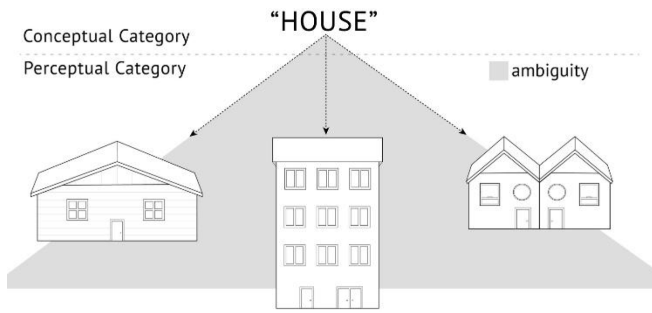


Fig. 1: Adapted from Coppin (2014, pp. 108), this demonstrates "perceptual ambiguity", as the abstract conceptual category "house" (top) produces many possible concrete perceptual categories (bottom) (Barter and Coppin, 2022).

Coppin (2014) adds that this relationship of constraints upon a structure of representation with its target problem also functions in the context of sentential representations, such as text. However, both diagrammatic and sentential representations have a drawback of conceptual (see Figure 3) and perceptual ambiguity (see Figure 2), respectively (Coppin, 2014). Consequently, these forms of representation are not equivalent in their information-providing capacities (Barter and Coppin, 2022). The free ride (Shimojima, 1996) may have a constraint of conceptual ambiguity (Coppin, 2014), however, understanding the constraint and options for complementing it in a representation may account for this issue (Barter and Coppin, 2022). For example, one may label a picture or diagram, and in doing so, use sentential representations in combination with pictorial and diagrammatic (Larkin and Simon, 1987; Coppin, 2014).

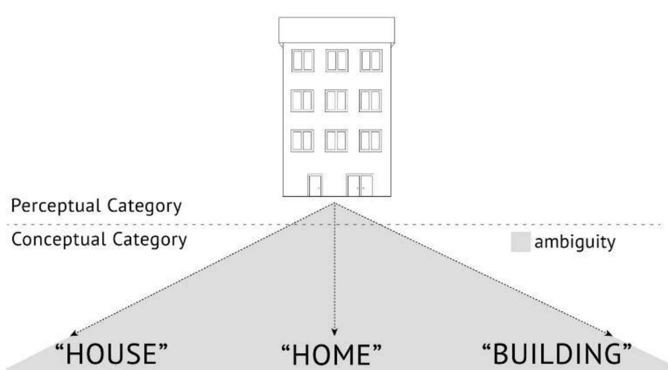


Fig. 2. Per Coppin (2014, pp.104), this demonstrates "conceptual ambiguity", as the concrete perceptual category of the image (top) produces many possible abstract conceptual categories (bottom) (Barter and Coppin, 2022).

Minimizing perceptual ambiguity means utilizing the spatial and topological relations among marks (a diagram, as per Larkin and Simon, 1987) to represent the spatial and topological properties of an item (Barter and Coppin, 2022). To minimize conceptual ambiguity, one should rely on conventions that refer to abstract meanings that are familiar to a target audience (Coppin, 2014). The perceptual certainty of a diagrammatically represented item recruits capabilities to perceive and act in the physical world (Gibson, 1986). For example, the choice of what route to take after inspecting a map, which varies significantly as a result of one's goals and intentions, such as *desiring to remain near the coastline*, or *save as much time as possible by taking the best compromise between shortest and least complex path to the destination*. These options can be conveyed visually or through the physical properties that characterize the boundary of the coastline (e.g. the sound of water crashing against a shore) in the former example, and the combinations of path options as *short* or *comple* in the latter. This demonstrates that this understanding of diagrammatic properties can be expanded to other sensory modalities, such as through 3D models and binaural audio (Coppin and Windeyer, 2018). The possibilities for action are therefore also a result of a relationship of constraints between the structural constraints (properties of the environment) and the target problem's constraints (an organism perceiving and acting in their environment) (Coppin, 2014; Gibson, 1986; Warren, 2005). With an understanding of this idea, we may view diagrams as possessing affordances and producing possibilities for action (Gibson, 1986; Barter and Coppin, 2022). However, are the geometric and topological properties of diagrams (and their "free rides") afforded consistently to BPSIs (Barter and Coppin, 2022)? Do BPSIs have sufficient access to the quantity and certainty of information in diagrams to possess equal potential for choices and actions by interpreting them (Barter and Coppin, 2022)?

2.5 *Accessibility issues caused by diagrammatic representations of conventional ICTs*

BPSI have historically been limited mainly to sentential representations, such as alternative text and Braille, rather than diagrammatic representations (e.g. raised line diagrams, which have disadvantages discussed in Han, 2020; Han et al., 2020; Jansson, 2008). High costs and a lack of guidelines for multi-sensory representations (Han, 2020; Han et al, 2020; Dragicevic, Jansen and Vande Moere, 2020; Hogan and Hornecker, 2017) limited the use of these alternatives in the past, however, the barriers to making the necessary representational choices have been reduced (Barter and Coppin, 2022). The possibilities for providing cross-sensory correlates for diagrammatic properties has only increased in options and decreased in cost over time (Dragicevic et al., 2020; Basset-Bouchard et al., 2017; Goncu and Marriott, 2011).

In conjunction with this issue, note that a majority of practitioners and researchers in the accessible ICTs field prioritize sentential representations for the information access needs of BPSIs (Elavsky et al., 2021; Fryer, 2013; Lundgard and Satyanarayan, 2021). Examples of this approach include: a presentation delivered at the data visualizations conference "Outlier 2021", which demonstrated a standard approach used for graphics accessibility at Microsoft (Elavsky et al., 2021). It overviews graphics delivered in speech through a screen reader, including descriptions of the meaning that a user should acquire from the visual properties (produced by mapping large quantities of data to a chart). Second, perceptual and linguistic processing in BPSI were shown to be linked in Fryer (2013). Linguistic audio descriptions were demonstrated to be capable of producing an equivalent to multi-sensory experiences for them (Fryer, 2013). Finally, Lundgard and Satyanarayan (2021) only argue for better informed accessibility standards for using natural language to describe complex images. The authors did not address whether this complexity makes representation solely through language appropriate in the first place (Lundgard and Satyanarayan, 2021). Text descriptions for accessibility support a multitude of information perception and interpretation tasks (Jung et al., 2021) and uphold accessibility standards that minimize costs and barriers to availability (WCAG, 2022). However, considering how limited and perceptually ambiguous (see Figure 2) strictly sentential forms of representation of diagrams are (Coppin et al., 2016), representational choices and related standards should be reconsidered to provide greater equity in information provision for BPSIs.

These limitations persist in practice despite some examples that represent diagrammatic properties non-visually and show promise for more effective and beneficial outcomes for accessibility (Barter and Coppin, 2022). In Bassett-Bouchard et al. (2017), a web application provides a sonification of financial charts that translate diagrammatic properties into non-linguistic sounds. Pitch and tempo convey positive or negative relationships between chart values and a mean over time, or the change rate of data values at any set of points on the chart (Bassett-Bouchard et al., 2017). Biggs et al. (2021) explored binaural audio labeling via an augmented reality application for a 3D scale model map of a playground. The project leveraged the constraints of spatial audio and cross-sensory tangible interactions that assist BPSI with way finding and orientation relative to the features of the playground without needing visual representation (Biggs et al., 2021). Finally, an audio-tactile globe (Ghodke et al., 2019) provided cross-sensory interactions through spatial-topological properties of the Earth's land masses and bodies of water combined with auditory labels. It augments the perceptual specificity (see Figure 3) of the shapes of continents with the conceptual specificity of the continents' and oceans' names (see Figure 2) to communicate geographical insights to BPSIs in an alternative format to the diagrammatic representations of visual maps (Ghodke et al., 2019).

In each case, effective representations are constructed for BPSIs by recognizing what is afforded by the relationship of constraints between representation options and their abilities (Barter and Coppin, 2022). This builds upon the Constraint Hypothesis (Shimojima, 1996), since using and combining different sensory modalities have inherent constraints that may guide design decisions. For example, whereas visual perception effectively processes a visual diagram composed of items indexed to different elevations of a rectangle (Larkin and Simon, 1987), audio perception has been shown to be effective for detecting items at different directions on a virtual ground plane (Biggs et al., 2021; Coppin and Windeyer, 2018). An audio diagram should translate visual relations to auditory relations of this kind. Doing so would provide additional possibilities for action (Gibson, 1986) compared to text descriptions alone and could conceivably foster equivalent access to information for BPSIs as users with sight. With only text descriptions for accessibility, however, their available action-possibilities (Gibson, 1986) would be comparatively limited, considering that their sole resource for action would be a conceptually specific interpretation (Coppin, 2014 - see Figure 2) provided for them (Barter and Coppin, 2022).

The examples above demonstrate scenarios in which BPSIs possess an equal potential for "enhanced agency" by virtue of having the same available resources for making choices and taking action in pursuit of what they consider relevant via their intentionality (Mendoza-Collazos and Zlatev, 2022; Withagen et al., 2017) as their sighted peers. Without these resources, they have limited potential enhanced agency (Mendoza-Collazos and Zlatev, 2022) in comparison, making said restriction a possible issue of human rights that should be explored in addition to the challenges of accessibility (Barter and Coppin, 2022).

2.6 *The significance of human rights of autonomy & agency*

Philosophies of human rights (Seabright, Stieglitz and Van der Straeten, 2021) relate strongly to the perception-action cycle and the behaviour of organisms in an environment (Barter and Coppin, 2022; Gibson, 1986; Warren, 2005). An organism's available choices for action are built upon the relationship between themselves and the environment that they occupy (Gibson, 1986), establishing them as an agent that "competently inhabit[s their surroundings]" (Warren, 2005). A relationship of constraints emerges, including those of perceptual affordances (Gibson, 1986), perception of information, and the representation-structure-to-target-problem constraints theorized to provide “free rides” (Shimojima, 1996).

In this context of human rights, consider the relationship of constraints that yields a “social contract” (Seabright et al., 2021). This theory explains that without a society, humans and their status as agents give them “natural rights” that would cause conflict (over resources, territory, etc… - see Seabright et al., 2021). However, humans are not known to have existed in such a “state of nature”, rather than form societies (Seabright et al., 2021). A “social contract” implies that all members of a society agree to cede an equal aggregate of their “natural rights” to achieve peace and security, and minimize the threat of individuals’ agency causing conflict (Seabright et al., 2021).

“Natural rights” meaning to be ceded equally in a society (Seabright et al., 2021) emphasizes why agency is an important criterion for developing diagrammatic representation practices for inclusive ICTs. Understanding what actions are available, which are taken, and why they are taken is critical for supporting agency for BPSIs (Barter and Coppin, 2022). For a human being in an environment, in a society, and in engagement with a problem concerning information that possesses topological and geometric relations, the provision of more or less information to users solely on the basis of differing abilities causes unequal, limited agency potential (Barter and Coppin, 2022).

2.7 The ecological and cognitive-semiotics perspective on agency in technology design & use

The ability of computer screens to represent information in multiple dimensions enables viewers to infer information from its spatial arrangement. These inferences become unavailable when the information is presented sententially, such as in a text description or a list, due to the loss of the spatial arrangement of the informations (Larkin and Simon, 1987; Shimojima, 1996). This is a critical piece of theoretical background necessary to understand why text descriptions on their own cannot fully translate a diagram (or ICT interface) for accessibility to BPSI individuals, as there is missing inferential potential, and a perceptual ambiguity that arises with that loss (see Fig. 1- Coppin, 2014; Coppin et al., 2016).

Perceptual ambiguity also implies that this approach to inclusive virtual ICT design lacks appropriate affordances (Gibson, 1986), which exist as a coupling between organisms and their environment that fosters “opportunities for action” (Segundo-Ortin, 2020). Affordances embody a state in which perception of one’s environment is not mediated by internal representations of one’s mind, but through direct information detection (Gaver, 1991; Segundo-Ortin, 2020). Being capable of altering the environment, and its affordances with it, places humans in a strong position to design for inclusion and diversity, since "interactions with the environment are configured by the people and technology within it" (Thieme, Bennett, Morrison, Cutrell and Taylor, 2018). Yet, the standards and guidelines for non-visual access to diagrammatic information representations persistently uses representation choices that result in minimized opportunities for action for those who seek access (Elavsky et al., 2022; Marriott et al., 2021; Segundo-Ortin, 2020; WCAG, 2022).

The opportunities referenced above relate to the concept of *agency*, defined broadly in Segundo-Ortin (2020) as the "capacity to act with intentionality". This cognitive semiotics-oriented theory for agency accounts for how affordances do not regulate actions entirely on their own. Rather, multiple affordances normally exist simultaneously and offer a suite of perception-action cycles that an agent (organism in their environment) is able to choose between (Segundo-Ortin, 2020). When stronger couplings of affordances to an agent's intentions are presented, an affordance may also "invite" actions, while still retaining agency in the form of the ability to modulate this strength depending on its relation to the agent's intentions (Withagen et al., 2017).

This mediation of possibilities for action by agency is analyzed further in Mendoza-Collazos and Zlatev (2022), who propose an agency hierarchy that distinguishes a form of agency that is gained specifically by being capable of designing. In this "enhanced agency", artefact-mediated, sign-mediated, and language-mediated agency each provide essential possibilities for intentional action, and so losing any combination of them would constitute a limitation of "enhanced agency" (Mendoza-Collazos, 2022). Hence, a representation of information limited to language (a text description) may not support the mediation of agency in comparison to visual information representations for sighted individuals or multi-sensory information representations for BPSIs. Each of the examples from section 2.5 support all three forms of "enhanced agency" through their pictorial, diagrammatic and sentential representations (Coppin, 2014; Coppin et al., 2016; Larkin and Simon, 1987; Mendoza-Collazos and Zlatev, 2022).

2.8 Shared Intentionality

A previous study of inclusion and accessibility issues for BPSIs who used ICTs in the virtual-dominated COVID-19 pandemic era revealed insights related to the concept of how *shared intentionality* (Tomasello, Carpenter, Call, Behne, and Moll, 2005; Lee, Sukhai and Coppin, 2022) can be fostered between individuals with varying degrees of sight. As ICTs are fundamentally about communication and collaboration, an individual's capacity to participate in collaborative activities with shared goals and intentions, mediated through ICTs, is of paramount importance for establishing joint agency with ICTs (Mendoza-Collazos and Zlatev, 2022). Many ICT platforms of the past and present struggle to provide shared intentionality for all users, BPSIs in particular, due to the limitations with communicating via *spatial-topological synchrony*, *temporal feedback loops*, and *mutual (symbolic) knowledge creation* in digitally mediated settings (Lee et al., 2022). Each of these dimensions of shared intentionality are poorly understood in non-visual terms (Lee et al., 2022): for example, while conventional ICTs such as Zoom cannot easily provide body language cues visually, the information and the technological means to do so are relatively clear (widening the camera angle of one's video, using a pan-tilt unit to follow body movement, use of expressive digital avatars, etc…) Meanwhile, for blind and partially sighted users, one must rely on auditory and tactile body language to enhance shared goals and intentions, which present more of a technical and user experience design challenge (How do you "feel" other people in a video call? What is "auditory body language"?)

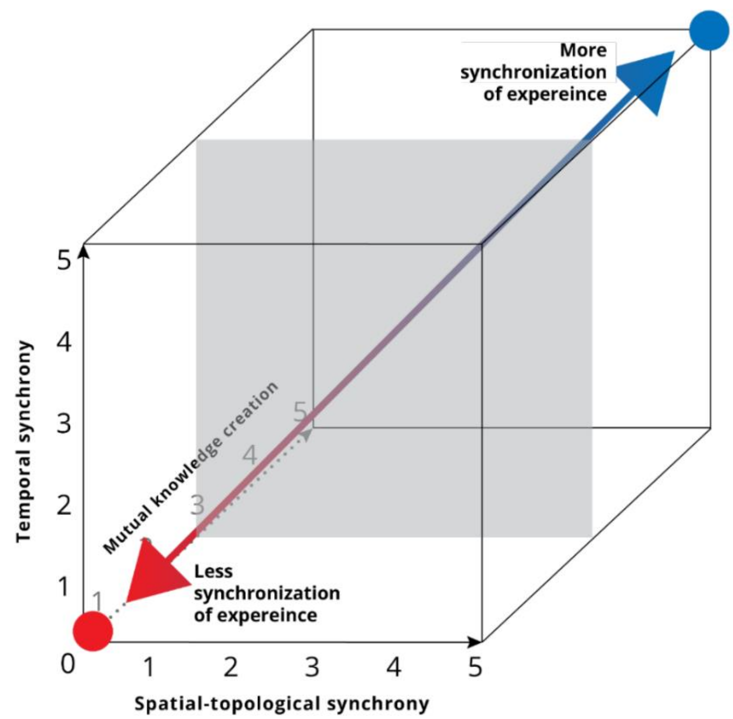


Fig. 3: Per Lee et al. (2022), the cube model for shared intentionality, with a scale of 0-5 marking the x-axis (spatial-topological synchrony), the y-axis (temporal synchrony) and the z-axis (mutual knowledge creation), referring to the degree to which each dimension is supported in a user experience with ICTs; pictured are the two end points marking the full range of experiences (0, 0, 0 and 5, 5, 5; the latter is the bottom-left-front of the cube, the former is the top-right-back)

2.8.1 *Spatial-topological synchrony*

This first dimension establishes the degree to which ICTs convey perceptual cues such as gesture, body location and visual-spatial representations (Lee et al., 2022). These cues are restricted by what the interface (ICTs in this case) can facilitate to infer the intentions of others (Lee et al., 2022). Contrast with the scenario of a physical meeting space in an office, as opposed to a virtual meeting space such as Zoom: the information that can be perceived in the former, even non-visually for a BPSI, is significantly greater, as a result of environmental auditory and tactile cues (binaural sounds made by people and objects around the individual, reverberations of peoples' footsteps and movements while seated, etc...) (Lee et al., 2022). Even for sighted participants, virtual meetings provide only a limited view of the environments, gestures, and body language of other participants. For BPSIs the experience of virtual meetings is further restricted to monaural audio from all attendees at once, and auditory feedback is "curated" through the use of the microphone muting feature (often used out of temporal synchrony and only when attendees have something to say, thus limiting the feedback of sound and movement made at all other times) (Lee et al., 2022).

2.8.2 Temporal feedback loops

Originally defined by Lee et al. (2022) as "temporal synchrony", this dimension refers to the information and communication-providing qualities of feedback loops, which may be synchronous (during a live meeting through an ICT such as Zoom, for example) or asynchronous (such as text messages, or a chain of e-mails (Lee et al., 2022). A feedback loop scores high on this dimension if it is more suitable for communication tasks at hand, such as in the scenario of driving a car. When one activates a turn signal it provides "body language" of the car, such that it is predictable when a turn will be made and what direction it will be in. However, this relies on a degree of temporal synchrony: too much time passing prior to taking the action causes the intention to be lost) (Lee et al., 2022).

2.8.3 Mutual (symbolic) knowledge creation

Finally, mutual knowledge is created when representations originating from the diverse perspectives and experiences of more than one individual establish a baseline for meaning-making that becomes a resource for sharing goals and intentions (Lee et al., 2022, c.f. Tomasello et al., 2005). This includes sign use, or "signitive intentionality"; bodily mimesis (the embodied performance of actions recruited to symbolize specific meanings in sign-based communication, such as pantomime); and "symbolic intentionality", which consists of highly articulated semiotic systems such as spoken and written language (Mendoza-Collazos and Zlatev, 2022). An example of low mutual knowledge creation from Lee et al. (2022) is the case study of "Skype Stalking", in which an employer was observed to use remote employees' status on Skype as indicative of whether or not they were currently working, which fails on the level of mutual knowledge as a result of the employer basing their judgments of how hard an employee is working on an inaccurate and asynchronous information display, rather than becoming familiar with employees' working styles relative to the employer's expectations. High mutual knowledge was observed in the "Hand over Hand" case study, involving an instructor who was teaching life skills to a BPSI through direct guidance of their hands to complete tasks such as cooking or use of a smartphone (Lee et al., 2022). Here, bodily mimesis (Mendoza-Collazos and Zlatev, 2022) was used to convey the spatial, topological, and geometric properties of the action while communicating with the student to verify the connection between the action and shared goal (Lee et al., 2022).

2.8.4 Shared intentionality black holes & white holes

A logical extension of the concept of shared intentionality is to consider situations in which it is necessary to collaborate with someone whose goals and intentions are impossible to gauge. Crasto (in press) describes a model for many such possibilities specifically in the context of ICT use in virtual working and learning environments. A "shared intentionality black hole" describes the phenomenon of being unable to receive information or communicate with one or more individuals in a collaborative setting, such as being in an online meeting with a participant who chooses to be completely unresponsive (i.e. camera turned off, microphone muted, no sign of presence or attention in other forms, such as text messages in a chat – described in Crasto (2023) as a "digital shell"). The circumstances under which a "black hole" occurs, rather than shared intentionality, are much more common for BPSIs due to the absence of visual perception as an option for gaining information and for communicating (Coppin, Ingino, Syed, Barter, Crasto, Lee, Mejia, Murgaski and Puvanesasingham, 2023). Similarly, a "shared intentionality white hole" is the phenomenon of information being available and communication being possible without any mediation or interaction for relevance to the individual who needs to receive the information (Crasto, 2023). The significance of these phenomena for accessible information representation is foreshadowed here for insights found in Sections 4.1.3, 4.2.2, and 4.2.3.

3. METHODOLOGY

3.1 Recruitment methods

Participants for this study were primarily recruited via a collaboration with the Canadian National Institute for the Blind (CNIB). Recruitment was procured utilizing email scripts (see Appendix D) and responses were followed up on an individual basis for the first two phases of the study (see section 3.2). For the third phase (Co-Design Workshops), a significant recruitment effort on the part of the CNIB, OCAD University and Ontario Tech University resulted in a conference, titled "Co-Designing Accessible Futures", which was held on February 23rd and 24th, 2023 at Ontario Tech University. At this venue, four co-design workshops were held, and recruitment for the three follow-up co-design workshops (see section 3.5.2) began via connections with participants who attended these four workshops.

3.2 Participants

The total number of participants was thirty-three. All participants were over the age of eighteen, self-identify as blind or partially sighted, and some identify as having additional disabilities (e.g., deaf, hard of hearing or neurodivergent). There was a wide diversity of demographics represented in this participant sample, including gender, ethnicity, cultural background, and professional expertise, including fields such as graphic design, computer science, fine arts, teaching, law, and business development.

In our three main research activities during this period (see sections 3.3-3.5), many of these participants attended two or more of the activities, resulting in the following breakdown of participant numbers per activity:

- ICT Functional Testing: 19 participants
- Semi-Structured Interviews (Retrospective Narrative Inquiry): 10 participants
- Co-Design Workshops: 13 participants

When interacting with ICT platforms, BPSIs generally need to use specialized assistive technology to accomplish tasks such as muting and unmuting the computer's microphone, participating in text-based chats, and utilizing the many other features that these platforms offer. These assistive technologies include software such as screen readers, which read the contents of the screen aloud in a synthetic voice, as well as screen magnification software, which may be preferred by those with partial vision. The use of these programs often adds complexity to using more standard software, which may not be designed to work well with assistive devices. Participants' lived experiences with the operability of ICTs and software through assistive technologies was a significant contributing factor to the findings of the research activities.

3.3 Functional usability testing of conventional virtual ICT platforms

Virtual meeting platforms such as Google Meet, Zoom and Microsoft Teams score generally well on widely used technical standards that are used to measure accessibility. For example, Microsoft and Zoom claim that both Teams and Zoom meet the AA standard under the Web Content Accessibility Guidelines, indicating achievement of both the basic level (A) and the mid-level accessibility requirements frequently cited as standard (WCAG, 2022; Microsoft Accessibility Conformance Reports, 2023; Zoom Accessibility FAQs, 2023). However, it is clear from interviews of people with lived experience that conformance to accessibility guidelines does not necessarily indicate that software is sufficiently usable for everyday purposes (Coppin et al., 2023).

To better understand the limitations of ICTs for use by BPSIs, in-person functional usability testing of Zoom, Microsoft Teams and Google Meet was conducted over a three-month period (Coppin et al., 2023). Nineteen participants were tasked with interacting with two of the aforementioned three ICT platforms (decided based on a pre-screening survey of ICT platform and device preferences – see Appendix F) using a desktop Operating System (OS) (e.g., Windows or Mac) and mobile operating system (Android or iOS) of their choice with their preferred assistive technologies (e.g., NVDA, Voiceover, etc…) (Interim Report, 2023). The devices used for testing were:

- A Windows 10 laptop computer connected to an external monitor with a Keys-you-see keyboard.
- MacBook Pro 13 inches (M1 processor)
- Samsung Galaxy Tab S7 FE
- iPad Pro (M1 processor)

To prepare for the in-person testing, a recruitment email was sent out along with a pre-screening survey (see Appendix F) that helped understand the users' preferences, including personal devices, prior experiences with ICT platforms, assistive technologies that were utilized when accessing ICTs and other accessibility settings (e.g., font size, colour correction, etc…) (Coppin et al., 2023). The test was tailored to how they would interact with ICTs on their own personal device (Coppin et al., 2023). Originally, it was intended that participants would be tested on ICT platforms that users had (i) the most experience with and (ii) the least experience with. However, after testing with the first thirteen participants, it was clear that there would not be enough tests of Microsoft Teams, due to the lack of participants indicating that this platform was their choice for (i) or (ii). Thus, this approach was abandoned for the final six testing sessions (Coppin et al., 2023).

In these sessions, participants were presented with tasks needing to be completed in a reasonable amount of time (maximum five minutes). If it was clear that the task was proving to be very difficult, such that the participant was becoming frustrated, the task was marked as incomplete. The thirteen tasks were as follows:

Task number	Task (identical between all platforms)	Description/ success requirement
1	Create a chat room/ instant meeting	Start an instant meeting and enter the call

2	Schedule meeting	Schedule a meeting for any time and describe what date/time the meeting was set to
3	Generate a shareable link	Copy a meeting link to the clipboard
4	Invite participants through email	Find the interface where you can send the invite link to a contact. (Email does not need to be sent, as this is another program outside of the ICT)
5	Setup audio output	Find the User Interface (UI) menu that lists all available audio devices and determine which is the currently selected device
6	Setup video output	Find the UI menu which lists all video devices and describe which is the currently selected device
7	Toggle mic or video	Toggle either the mic or video and describe if it is on or off
8	Screen share	Share your screen and describe what is being shared (entire desktop or a specific window)

9	Send text message	Send any message in the chat
10	Raise hand	Raise your hand and determine if it is raised or unraised
11	Blur background with any effect	Blur background with any effect
12	Record session (if possible)	Start and stop recording a meeting session (not available on mobile OS without a premium account)
13	Access program settings	Access the main program or app settings

Table 2: ICT Functional Usability Testing tasks and descriptions of success requirements.

After completion of each task, participants were asked to reply to the questions in the heuristic evaluation questionnaire that is adapted from National Aeronautics and Space Administration (NASA)'s Task Load Index (TLX) scale (Hernandez, Roll, Jin, Schneider and Pyatak, 2021). These questions are documented in Appendix G: ICT Function Usability Testing Data Collection Questionnaire. The full sessions were ninety minutes per participant (approximately forty-five minutes per ICT platform), with a total of thirty-eight tests conducted (Interim Report, 2023). If the participants' test exceeded ninety minutes, all remaining tasks that were not completed were left blank (no data) and the test was concluded (Interim Report, 2023). The data collected was both qualitative and quantitative, and included (i) the most commonly used ICT platforms (between Zoom, Microsoft Teams and Google Meet), (ii) the assistive technologies that are most commonly utilized when accessing ICT platforms (which depend on the user's needs and degree of sight), (iii) issues experienced between specific assistive technologies and an ICT platform on a specific device; and (iv) the tasks within ICTs that have the highest perceived mental workload that was collected in the heuristic evaluation questionnaire (see Appendix G).

3.4 Retrospective narrative inquiries (RNIs) into BPSIs' lived experience with ICT use

In order to generate insights for developing a co-design methodology, a series of one-on-one, semi-structured retrospective narrative inquiry (RNI; Clandinin, 2000) interviews were held with the intention of examining the lived experiences, adaptations and pain points associated with ICT use on the part of BPSIs. These interviews treated the participants as experts with ICT use and accessibility challenges in a working and learning context. Participants were guided to share and reflect on past experiences, and discuss topics such as: which ICT platforms they use in these contexts most and least frequently; whether it is by choice, due to a mandate, or from a lack of other options; how and why the ICTs support or impede their activities; and how they would change ICTs to better support their needs and why. The results highlighted pain points, particular scenarios of concern, and potentially beneficial design interventions that were carried forward into the forthcoming longitudinal co-design workshops.

3.5 Longitudinal co-design workshops

3.5.1 "Co-designing accessible futures" festival

The longitudinal co-design workshops brought together our research and induction from the interviews and usability testing with participants' lived experience and knowledge. The co-design methodology involved guiding and empowering the participants to generate and explore ideas informed by the research team's findings and participants' own experiences (Hagen et al., 2012). The co-design workshops were a part of the broader Co-designing Accessible Futures Festival hosted at Ontario Tech University on February 23rd and 24th, 2023. The festival was a joint effort between the CNIB, Ontario Tech University and the Perceptual Artifacts Lab at OCAD University, with the goal of addressing the current realities of the role and impact that ICTs had on the blind and partially sighted community, and what insights could be produced to inform the design of future ICTs.

3.5.1.1 Summary of Session 1: Virtual Distractions

The introductory session began with a discussion of the technologies used by participants for virtual meetings and working collaboratively. Its main objective was to identify challenges with regard to how BPSIs are increasingly being exposed to distractions (for example, unnecessary speech from screen readers, environmental noise, phone notifications) via working and learning environments that involve ICTs. Alternatives that avoid the information overload that is common when using accessibility features, for example, was explored by prototyping in a variety of materials and platforms. Those who joined used their lived experiences with distractions and accessibility challenges in working and learning environments to guide what was created. The goal was to collaboratively design better versions of ICTs used in these settings that distract less and provide greater accessibility, with the help of facilitators. Following this, a facilitated discussion and feedback session on those ideas concluded the workshop.

Prototype	Description	Image
Audio avatars of virtual meeting attendees	Circular/rotary pieces each represent a virtual meeting attendee and the affordance of turning the piece either way, increases/decreases the respective participants' audio output for the user.	
Clay Microsoft Teams	Clay 3D representation of Teams Graphical User Interface (GUI), to understand diagrammatic properties of teams made in preparation for co-design.	

Table 3: Prototype outcomes from Workshop 1 (Coppin et al., 2023)

3.5.1.2 Summary of Session 2: Virtual Meetings

In this session, we delved more deeply into specific accessibility challenges in virtual meetings. We demonstrated a prototype: a commercially available device called an "XP Pen AC19 Shortcut Remote" (2023), which the research team who facilitated this session had modified to increase its accessibility to BPSIs. Its purpose is to provide a set of keyboard shortcuts in a chosen software program that is mapped by the user. It provides nine keys, each of which provide a shortcut command with a single depression or hold of the keys, as well as a rotating dial that can be mapped to a magnitude (such as volume) and directional keys. The facilitators collected feedback about the device from the participants, and introduced hardware technologies, such as the Makey Makey (2023) and BBC Micro:bit (2023) microcontrollers, which were options for participants to create their own devices, once they have clarified their ideas through prototyping. These activities introduced participants to the idea that their feedback for more accessible solutions can be actualized, for example, by modifying existing devices, or building future virtual meeting platforms to operate in a variety of materials and platforms based on insights from their lived experiences of using virtual meetings in working and learning environments as a guide.

Prototype	Description	Image

XP-Pen	Modification of a product for designers who need extra control over shortcuts keys on various software. Performs shortcuts for Microsoft Teams, found that BPSIs tend to rely on shortcuts for non-linear (screen-reader) navigation of the software.	

Table 4: Prototype outcomes from Workshop 2 (Coppin et al., 2023)

3.5.1.3 *Summary of Session 3: 3D Audio Navigation*

To explore the issue of how to make use of 360-degree (binaural - Coppin and Windeyer, 2018) audio in navigation contexts, the facilitation team held discussions on how participants would, if given the option, move through a three-dimensional audio-digital space, select and interact with digital objects and documents, induce meaning for sounds, control a binaural audio interface, and materialize these ideas through collaborative prototyping. The focus was on identifying and developing concepts for auditory and cross-sensory ICT interface possibilities, starting from the participants' lived experiences with navigation in a variety of contexts that were freely discussed. The discussions led to ideas with not only contextual audio cues, but cross-sensory adaptations using unexpected modalities, such as olfaction. These lived experiences also guided the participants' prototyping outcomes and communicated scenarios in which 3D virtual navigation could be beneficial if the insights from their experiences were understood and applied.

Prototype	Description	Image
Tangible map of a grocery store	Physical scale model of a store (aisles, displays, etc.) for virtual use from home. Items and areas of a store can be explored through touch, and speech output for identification of areas and items.	
VR audio grocery-shopping interface	Objects in the VR Unity interface had audio of grocery items linked to them. When participants selected an item with the hand-held controller, it would announce the grocery item.	

Table 5: Prototype outcomes from Workshop 3 (Coppin et al., 2023)

3.5.1.4 *Summary of Session 4: Digital Collaboration and Creation Tools*

The final session began with a facilitated discussion to understand participants' current context of remote collaboration tools and digital content creation workflows (e.g., collaborative documents). The discussion also helped identify participants' current challenges with remote collaboration tools. Pain points and levels of solutions and interventions were further developed through audio and tactile activities (prototyping). Furthermore, an audio collaboration activity was conducted using audio messages on a recorder. The facilitation team found that asynchronous collaboration allows for more informed decisions (ability to research options and resources). It was also found that synchronous interaction trends toward immediate agreement with less cognitive processing time. The resulting concepts for cross-sensory tools to co-create digital content could revolutionize digital literacy, virtual and hybrid work and digital engagement with the wider community for BPSIs, so long as these integrate with the ICTs necessary to connect these environments and individuals who will take part.

Prototype	Description	Image
Modular 3D diagram	Form and process represented adaption, problem-solving, and add-on accessibility solutions. Participants in the group noted they would be able to come back, orient themselves (catch up/understand what is changed) and work on it asynchronously, because of the tactile nature and initial synchronous engagement.	

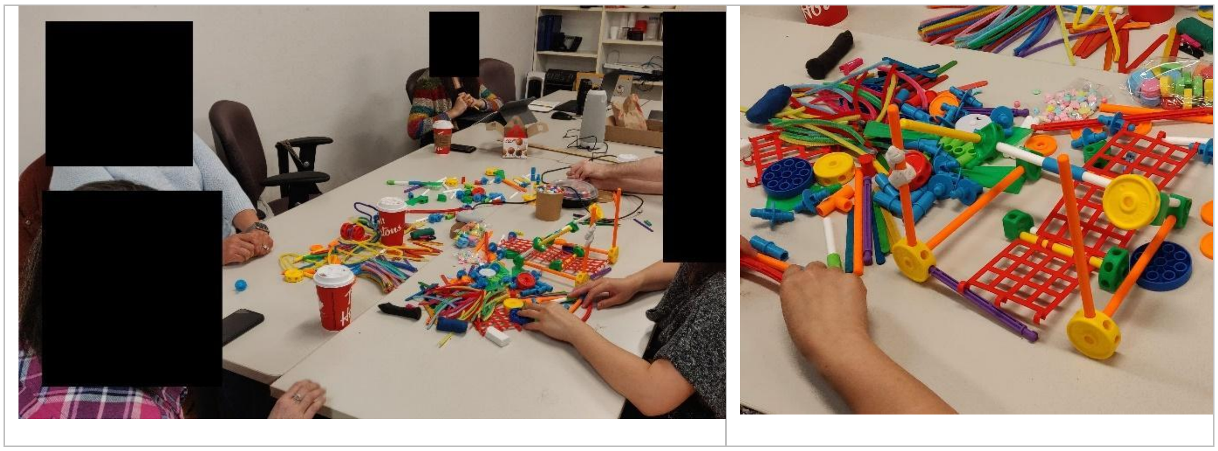
Table 6: Prototype outcomes from Workshop 4 (Coppin et al., 2023)

3.5.2 *Follow-up longitudinal co-design workshops*

After collaboratively developing numerous highly promising insights through the four aforementioned co-design workshops, a series of smaller, follow-up longitudinal co-design workshops were held to continue to iterate on the work. The objectives of these smaller workshops concentrated more on co-designing prototype outcomes for the design challenges that had previously emerged, discussions of the problem areas with individuals who have relevant lived experiences, and evaluating the prototypes through simulations of use whenever possible ("Wizard of Oz" techniques, such as making physical diagrams with a Tinkertoy (2023) and performing interactions as though it was a functional model created in a virtual reality environment).

3.5.2.1 *First workshop*

The first workshop, which hosted four participants who had each participated in at least two of the prior co-design workshops, focused on a lengthy discussion activity. The facilitators summarized the findings from the co-design festival that had been analyzed thus far and prompted the participants to think more deeply on the problem areas and possible solutions. Meanwhile, a variety of physical prototyping materials were placed in front of each participant, including clay, pipe cleaners, and the aforementioned Tinkertoy (2023) set, the latter of which was provided after inspiration from the "Modular 3D Diagram" that was autonomous constructed previously (see Table 6, p. 29). Once participants began to reach possible solutions, a prototyping activity using these materials began, and the participants worked as a group to represent the solutions that they had in mind. Following the prototyping, a wrap-up discussion was held, focused on what the outcome of the prototyping had been, and what next steps could be taken.



From Follow-up Workshop 1 – participants discussing and prototyping (left); closer view of grocery store Tinkertoy (2023)] model (right).

3.5.2.2 *Second workshop*

Following on the previous workshop, the second in the series involved much more discussion than physical prototyping. This was a natural step in the iterative design process since the previous prototyping sessions had already generated many ideas which needed to be defined more concretely. Thus these ideas continued to be explored in divergent thinking in response to the problem areas and a broadening beyond the initial ideas from the co-design festival workshops. A major theme emerged during these discussions, of several common burdens that BPSIs encounter in their lived experiences (of advance preparation and planning, as well as time and training to use ICT platforms – see Sections 4.2 and 4.4). Additionally, much focus was given to AI algorithms' potential to be used for effective voice assistant interfaces, prompted by basic and brief experimentations that the participants had with Chat GPT (2023) recently, and interest on their part in learning more about this tool.

3.5.2.3 *Third workshop*

Finally, the iterative design process enacted in these follow-up co-design workshops reached the most plausible conclusion of introducing a prototype designed in line with the early insights from the researchers' analysis of findings from the co-design festival workshops and the prior two follow-up workshops. We found that although the experience of our participants with ICTs varied widely, the problem of navigating through a grocery store was an experience they all shared. It presented many similar difficulties to those encountered during ICT use, such as quickly accessing information which is available visually but not through other sensory modalities. The prototype was created via Chat GPT (2023): a model for a grocery store was created through prompts, and the user who would theoretically be navigating through this store was specified to be blind. With these parameters set beforehand, the participants and facilitators collaborated to engage in a simulated interactive experience with this prototype, specifying what tasks and actions to do, such as seeking the ingredients for a recipe (pasta sauce, in this case), browsing at times and in specific places, and testing the limits to which the speech output could effectively inform and guide the participants in what could have been either a physical store (with the AI assistant on a smartphone accompanying the user) or a virtual shopping experience that uses parallel physical and sensory cues to structure the experience in a way that averts the common issue of information overload with current online shopping UIs in conventional ICTs. Major insights about interactive information foraging (Pirolli, 2007) and granularity needs were revealed by this process, resulting in findings summarized throughout Section 4, particularly Section 4.2.2, 4.2.3, 4.2.6, 4.7.2, and 4.7.3.

4. FINDINGS

This section covers key themes, observations and outcomes that have emerged from synthesizing data from the ICT Functional Usability Testing, RNI interviews and Co-Design Workshops during this project. It was found that the most critical factor for maximizing BPSIs' capacity for agency was for *contextually-specific information to be made available through an interactive interface*. This is a paradigm that prioritizes breaking the convention of sentential representations (Larkin and Simon, 1987) for text descriptions, instead using interactivity (i.e. questions and responses in language, in this case) to navigate and refine the output of an ICT based on relevance to the user (i.e. their intentionality). According to what will be reported in the following sections, this is a more preferable and practical approach to the design of agency-supporting virtual ICTs, though without precluding the potential of cross-sensory interactions in combination with the aforementioned information representation and navigation strategies that emerged through induction.

Further to this approach, the findings foreshadow a suite of design recommendations for those wishing to develop more accessible ICTs for virtual meetings (as one example), suggesting ways to incorporate features relevant to BPSIs through cross-sensory interaction design techniques and sensory-grounded descriptions for information foraging (Pirolli, 2007). These findings have been organized into broad categories that were established by analyzing the data and connecting it to the dimensions of the shared intentionality cube model (Lee et al., 2022). Hence, the categories are: *issues* *of matching or mismatching spatial-topological representations and hierarchies of relevance* (spatial-topological synchrony, X-axis); *issues of information foraging (Pirolli, 2007) and refinement* (feedback loops, Y-axis); *issues of knowledge creation and sharing* (mutual knowledge creation - Z-axis), and combinations of any two or all three dimensions (Lee et al., 2022). Beginning with the synergistic themes found during the ICT functional testing, RNI (Cladinin, 2000) and co-design phases, this eventual conclusion was built, and is summarized below.

A synergy of central themes emerged between all three of the research activity phases of which this study is comprised. In the ICT functional testing phase, quantitative accounts of the usability of current ICT platforms (Zoom, Microsoft Teams and Google Meet) were collected via a NASA TLX scale (NASATLX; Hernandez et al., 2021), and qualitative observational data further extended the eventual coding of themes found across all three phases. The ten interviewees from the RNI interviews discussed their lived experience with accessibility challenges, benefits, and workarounds for virtual ICTs, and these insights were used to plan and conduct the subsequent co-design workshops with ten additional participants, as well as one of the interviewees. The key findings and themes are summarized as follows:

4.1 *Issues of matching or mismatching spatial-topological representations and hierarchies of relevance*

4.1.1 *Balance between expected relevance and number of choices*

- ICTs typically provide either too many choices (i.e., in virtual shopping platforms) or too few (i.e., when shopping in-person at a store, where visual displays are dominant and BPSIs struggle to perceive the information) This must be balanced with how relevant the information is expected to be (i.e. if choices stand out enough when compared to others, the most relevant choices should neutralize the overwhelming aspect of an abundance of choices; however, in the absence of sufficient relevance, information overload is expected). Visual representations typically address this through visual hierarchy, suggesting that a similar strategy (based on relevance and relations between distinct bits of information) non-visually should be a priority.

4.1.2 *Repetitive auditory information overload*

- Screen reader software is often overly verbose, which may be improved by designing interfaces that do not present too many elements on a single screen and follow a logical and consistent hierarchical structure. For example, including dozens of links, buttons, and menus on one screen must be avoided wherever possible, since screen readers often verbalize all of this information sequentially, leading to interruptions in the flow of user experience, distraction (i.e. in virtual meetings when trying to focus on others speaking), or unnecessary information (repetition at the end of a list and starting again, automatically reading edits to a shared document, etc…)

4.1.3 Avoid information being "thrown at" users

- Relevant information must be prioritized and emphasized in interactions with ICTs, either by default (if well understood), or through simple customizations that stay consistent across different platforms and services of the same type. Options should be available and contextualized within the interface, rather than having information be thrown at a user outside of their control (i.e., through the use of shortcuts or hotkeys rather than continuous speech output for every piece of information and action in real-time - see Crasto, 2023). Such options provide invitations to act (Withagen et al., 2017) and aid working memory for tasks. Large language models (LLMs), such as Chat GPT (2023), curate relevant information based on user preferences and repeated behaviours specified with intentional prompts (i.e. "Please only describe items that I have not purchased before"). Thus, they build intuitive structures for digital interfaces over time. Although we did not prototype or test this, the voice output being customizable could also add distinguishability of relevant information: personification of categories of information through different voices (i.e. ones that sound masculine, feminine, robotic, use different accents, dialects, speech patterns and dictation speeds) could allow incoming information to be contextually streamlined.

4.1.4 Text and speech descriptions are often biased

- Text and speech descriptions may originate from biased sources, be missing critically relevant information, or be unable to effectively describe the information that is needed. The co-design workshops established examples of these phenomena: first, one participant described her husband as uninterested and unskilled with describing the colours and textures of clothing, and preferred shorter shopping trips, minimizing the detail he provided relevant to this desired goal (one that was not shared with his partner). Another participant outlined experiences with various store employees whom she asked for assistance in finding and retrieving products. She reported being given as little time and information as possible, presumably so that the employee could quickly finish interacting with her. This reliance on a single individual who did not share her goals, intentions, or the information relevant to her, significantly limited the choices available to her. Finally, when using Chat GPT (2023) to build and test the usability of an accessible shopping experience, the algorithm misrepresented, forgot and invented information due to issues with queries, insufficient source data, and possibly biases (the instructions reverted to providing visual-biased instructions, such as to look for distinctive labels, despite earlier instructions to provide non-visual information; it also once claimed that touching labels would be sufficient to identify products).

4.1.5 *Firsthand perceptual information may be necessary*

- Firsthand perceptual information is often required for information foraging (Pirolli, 2000), for example, in the context of spatial-topological properties of a map, being able to detect the shape of areas, feel and compare distances of different route options, or hear elevations might be far preferable relative to the example discussed during a co-design workshop. One participant described having four different people give her directions (provided via speech descriptions) to a train station's boarding platform, and all four descriptions were incompatible. While this is not a sufficient sample size to be conclusive, this anecdote is significant in how it suggests that the concrete spatial arrangement of the station could not be consistently described in language.

4.1.6 *Physical remote control devices should be explored*

- The computer mouse is not accessible for some BPSIs and those with intersectional disabilities (i.e. mobility restrictions, arthritis of the fingers), so they often use keyboards and touch screens to perform ICT-related tasks. This has limitations due to requiring users to remember many complex key combinations or locations of frequently used controls on a touch screen. More options for controlling ICTs should be explored: for example, hands-free options, gestures, and physical remote-control devices which could be configured to perform common tasks.

4.2 *Issues of information foraging (Pirolli, 2007) and refinement*

4.2.1 *"Zooming in" and "zooming out" to manage accessibility to different granularities of information*

- Complex representations with many small details should be scalable for analyzing the full range of patterns (i.e., *zooming in* for small details one segment at a time and *zooming out* so that spatial relations structure comprehension of the part within the whole). For example, the importance of the grocery store's granular scale of aisles, shelves, and products on shelves was discussed in relation to how this granularity would need to change depending on the task (i.e. searching for a product, thus differentiating aisles first, then shelves, then products to complete the task in sequence).

4.2.2 Interactivity of information representations supports agency by allowing users to filter and emphasize what is relevant

- Users' agency can be supported by including opportunities to think through and refine queries after receiving each response and alter the pace of output to effectively perceive and interpret it (i.e. interactivity). Interactivity further supports filtering out irrelevant information through requests for what is relevant and minimization of what is not and being able to request more information at any time, placing the flow and quantity in the user's control. This contrasts most information representations and ICTs, which cannot easily provide the user with non-visual dynamic control over output, thus being a "shared intentionality white hole" (Crasto, 2023). For example, a shared written document, particularly while in "suggestions" mode (text is not removed, but crossed out while replacement content is added), cannot dynamically provide relevant content or respond to such requests, instead flooding screen readers with all of the content in an unbroken sequence. One disadvantage of interactive ICTs is that considerations must be made for how to alert users (non-visually) when additional potentially relevant information is available after the user has decided that they have enough relevant information. This is a difficult aspect of user agency to provide a satisfactory solution to; it must not forcibly override the user's intentions.

4.2.3 Utility of scenario-based interactions

- Rather than facing a "shared intentionality white hole" (Crasto, 2023) in an effort to gather information, users have relative control over how much they are provided with, how frequently and at what pace, what the full scope of it is, how much detail is included, and how relevant it is to the context of their lived experiences. Scenario-based interactions are possible, for example: "I want to make a cake, what ingredients do I need?", followed by "Where can I find these ingredients?", eventually followed by "What is the spatula I need for the icing shaped like?", and so forth. They may also change their approach at any time, without necessarily losing prior specifications or needing to parse new information from unnecessary repetitions in a sequence, as would be the case with a written list of instructions and a screen reader. Finally, by learning the users' preferences and patterns for information gathering, changes in the users themselves are accounted for and smoothly adapted to without extra effort on their part. All of these challenges have been identified as issues faced with current assistive technologies (see Section 3.3) and accessible information representations (i.e. screen readers and magnifiers), and providing interactive experiences through LLM input and output instead allows information and users' intentionality to flow optimally and provide enhanced agency (Mendoza-Collazos and Zlatev, 2022) that was previously not practical or consistently available.

4.2.4 Platform and account overload

- Confusing different types of accounts and virtual workspaces is common, as the number of platforms, ancillary tools, email accounts, authentication methods and usage contexts are overwhelming when interacting non-visually, and exacerbated by the need to accomplish it while using assistive technologies such as screen readers. Further, confusion between these carries consequences (i.e., mixing up virtual ICT interfaces for work with one for school, or for personal life).

4.2.5 Rehearsals

- BPSIs face challenges with exploration of spaces and objects when there is no additional guidance or predictable structure. For example, a BPSI who needs to shop at a grocery store would be interested in a list of the items to purchase, their prices, and how to move through the store to find each item in an efficient manner. Consequently, BPSIs tend to enact *rehearsals* to familiarize themselves with spaces, routes, tasks, layouts, organizational systems, and so forth prior to the performance of the task or activity in its real context. This provides a safe space with no risk of harmful errors or danger if mistakes are made and prepares the user for interactions later with simulations in the present. Another example of a rehearsal: when eating out at a restaurant, a BPSI would be interested in reviewing the menu and deciding what to eat in advance is a common priority (it is rare that a menu at the physical space of the restaurant is accessible). Additionally, familiarization with the prices is desirable since another common accessibility challenge is debit and credit terminals that force blind and partially sighted customers to inquire directly about the prices and specify their intended tip when the server must operate the terminal for them. While the issues of inaccessible stores and debit terminals would not be solved by providing *rehearsals*, digital lists and models might provide the necessary information in an accessible format before performance of the task or activity.

4.2.6 Minimize burden of preparation

- Consider Chat GPT (2023) as an example of a tool that can reduce the effort of information foraging prior to acting: it provides not only linguistic descriptions of relevant information beforehand but adapts to a user's preferences and behaviour patterns over time. Once the adaptations have been made, the burden of preparation and information foraging (Pirolli, 2000) is limited to significant deviations from predictable past behaviours, which is a comparatively simple preparation task.

4.3 *Issues of matching or mismatching spatial-topological properties and information foraging (Pirolli, 2007) and refinement*

4.3.1 *Lack of body language in conventional ICTs*

- Conventional ICTs poorly foster situational awareness, perception of contextual elements of the environment, comprehension of their meaning, and projection of their status into the near future (Endsley, 2000) for all users, particularly BPSIs. Visual and auditory body language cues such as nodding are difficult or impossible to perceive by BPSI, and auditory affirmations (saying "mhmm," "yes," and "uh huh") struggle with issues of temporal asynchrony, exacerbated by slow Internet connections and the practice of staying muted during virtual meetings.

4.3.2 *Misunderstanding of body language (unintentional "gestures")*

- Some common behaviours of BPSIs in virtual environments are misinterpreted by others: fidgeting, not making eye contact, not perceiving when to speak to someone with sufficient temporal synchrony, and keeping one's camera turned off, among other common behaviours exhibited by BPSIs in these scenarios are often interpreted as *gestures*, or signs of disrespect and disengagement. Shared intentionality (Tomasello et al., 2005; Lee e tal., 2022) and collaboration are thus impeded, due to the lack of perceivable shared knowledge, feedback loops and spatial-topological properties within these environments.

4.3.3 *Contextual behavioural changes*

- ICTs should support logical and contextual behaviour changes: for example, automatically limiting notifications or audio tones to subtler options that do not cause disruptions when in a virtual meeting, or delivering a pattern of tactile feedback in place of an audio cue when in a noisy environment.

4.3.4 *Multi-sensory information representation rationale*

- Different sensory modalities, or combinations of modalities, should be used for contextual needs. For instance, vibratory feedback when in loud environments that would make audio difficult to perceive in isolation, or auditory feedback in relatively quiet environments. Returning to Ghodke et al. (2019), three-dimensional models with spatial-topological and diagrammatic properties to represent complex concrete structures (the globe) work well to avoid prohibitively timeconsuming descriptions (Coppin, 2014; Coppin et al., 2016), and the speech output for the names of continents effectively communicates the abstract concept that country and continent names, as opposed to their shapes (i.e. identifying Africa and South America, which have similar shapes to one another, by name via speech output).

4.4 *Issues of knowledge creation and sharing*

4.4.1 *Leverage pre-existing familiarity*

- Opportunities should be provided for individual and shared meaning-making. Layouts, interfaces, sensory cues and spaces should leverage pre-existing familiarity (e.g., metaphors), or properties that facilitate shared representations (such as physical 3D models and materials for collaborative problem-solving – see Table 6, p. 29, Modular 3D diagram). ICTs that have simple features and continuity in how they are structured should have their interfaces maintained rather than disrupted by updates.

4.4.2 *"Lowering the bar"*

- A persistent lack of understanding of the lived experiences, needs and limitations of BPSIs by the general public frequently causes BPSIs to *lower the bar*, (i.e. intentional reductions of their own agency by expecting and accepting little external support). Expectations of resistance and ignorance from others may cause them to decline opportunities to disseminate this knowledge and self-advocate for sufficient assistance from others. Examples include BPSIs committing to living in specific areas (i.e. large cities over remote communities, at significantly higher costs, due to needs for proximate access to essential services), and to the use of costlier services (i.e. specialized transport services, grocery deliveries, local stores with higher costs over a variety of stores with more options, etc…) Similarly, BPSIs routinely adjust behaviours to anticipate issues with accessibility of the built environment, inability to receive accommodations for those who employ guide dogs (i.e. businesses and services such as taxis that refuse to accept BPSIs accompanied by guide dogs), and for expected time and efficiency of everyday tasks (i.e. planning for facing challenges that delay and frustrate others who interact with them).

4.4.3 *Case for standardization*

- Participants throughout this project have supported the need for standardization throughout the ICTs that they use or may use. Additionally, a common recurring challenge discussed is the fact that BPSIs are routinely forced to memorize arbitrary differences in the layouts, menu structures and shortcut commands of otherwise comparable ICT platforms. For example(see Section 3.3), when discussing differences between user interfaces for Zoom, Microsoft Teams and Google Meets, participants expressed preferences towards whichever platform they most frequently use, and complaints focused on other platforms having different shortcuts and primary functions being located in drastically different places within the menu hierarchy (for screen reader users) or on the screen (for screen magnifier users, who found tracking of the position of functions on the screen to be vital for timely navigation from place to place on the screen at very high levels of magnification). All of these challenges with non-standardized ICT interfaces create constraints on the users' memory and offer few affordances that might make them more intuitive in how and why they differ.

4.4.4 Case for customizability

- In contrast, ICT platforms that do provide standardized elements do so at the cost of flexibility that allows accommodations for individual differences and preferences, even strictly amongst BPSIs. For example, one ICT testing participant demonstrated their preference to use a highly customized Outlook calendar interface as the starting point for all interactions. Their workflow using this tool was streamlined and very efficient, however problems arose any time the necessary task required use of specialized interfaces for the individual platforms. The participant was frustrated with being required to interact outside of their preferred customizations and insisted that a test outside of these parameters would not accurately represent their capabilities with ICT-related tasks. This participant is a "power user", and while extremely capable if given specific customizations, their capabilities outside of that platform become constrained once their preferences are no longer available.

4.4.5 Avoid differences for purely cosmetic reasons

- Differences in the user interfaces of ICT platforms for use by BPSIs should only be made to accommodate customizable preferences that would be carried forward as a standard once made, and never for purely cosmetic purposes. Further, customizability and standardization within ICT platforms must be balanced to account for the differences in shared intentionality (Lee et al., 2022) between designers and blind or partially sighted users that result in different internal models for how the product, system or service should function.

4.4.6 Enforcement of "power usage"

- Many working and learning environments in which BPSIs must perform tasks and activities operate at an extremely fast pace and have high demands for independence. Consequently, BPSIs often feel pressure to perform at comparable levels to their peers and resist asking for assistance or disclosing their differences in abilities for fear of appearing less capable and being judged negatively. Adaptation to this generally leads BPSIs to become *power users* of a small set of ICTs with which their familiarity provides advantages for rapidly performing their tasks and activities. However, being *tethered* to specific platforms results in inflexibility in many scenarios in which the ICT platform that is used is not within their control.

4.4.7 The disadvantages of inflexibility in ICT platform use

- Becoming a *power user* is enforced by these working and learning environments, leading to compromises on the suitability of ICT tools chosen for the sake of the speed provided by a familiar tool being at hand. Several participants (see Section 3.3 and 3.4) discussed feeling pressured by the need to show their peers that they are consistently able to complete tasks quickly above all else.

4.4.8 "Passing it forward"

- The phenomenon of *passing it forward* was discussed: refers to a paradigm in which BPSIs dedicate themselves to single sources of information and assistance. For example, asking one specific store employee for help, shopping at one specific store location amongst many, using one specific website for a single E-commerce service, and using one specific smartphone application for slightly superior accessibility. These behaviours have an expectation that interactions will be optimized over time due to the source obtaining knowledge and experience for serving BPSIs, or familiarity with a source of information building to provide greater capabilities in shorter time periods (i.e. the *power user* phenomenon). *Forward* refers to the expectation that sharing and transferring knowledge due to these preferences will produce benefits for other BPSIs who use the same resources in the future (example cited during a co-design workshop: department store employee whose familiarity with serving BPSIs led to being called upon to serve all BPSIs who enter). However, this too comes at the cost of flexibility, as the reliance on optimized sources of information over all others reduces the effectiveness of information foraging (Pinolli, 2007) and service provision if the most suitable options are not familiar, and the additional perspectives and dimensions that using a variety of sources would theoretically provide are absent.

4.4.9 The checklist approach

- Receiving technical support as a BPSI is challenging. The reasons may include the community not being represented among decision-makers, a lack of accountability for prioritizing and serving people with diverse abilities, and rigidly following accessibility checklists rather than adaptively responding to diverse needs.

4.4.10 *Lack of organizational representation for BPSIs*

- Decisions are made and services are provided by the tech industry without sufficiently understanding or prioritizing the needs and lived experiences of BPSIs. This is reinforced by the lack of representation by BPSIs in decision-making and service provision at the highest levels to facilitate and maintain accountability in this regard (SeeingAI, an app developed by Microsoft, was cited by participants as a counterexample for this phenomenon). BPSIs lack agency in what technology and services are made available and how they are provided as a result.

4.4.11 *Stigma regarding capabilities or differences*

- The relative absence of BPSIs in workplace culture causes stigma and resistance on the part of blind and partially sighted workers with varying abilities and accessibility needs to disclose their abilities and needs, as there is fear of being judged as less capable than one's peers, and of working too slowly to keep pace, even with accommodations. In such cases, workers tend to rely on tools that are most familiar rather than ideal for the tasks at hand, rather than optimizing via planned adaptations and accommodations, or requests for support to their organizations. This highlights issues with workplace cultures and with the design of ICTs such that the *power user* dynamic remains dominant, rather than flexibility with ICT platforms.

4.4.12 *Systemic accountability for accessibility as organizational practice*

- For accessibility standards and Equity, Diversity and Inclusion (EDI) initiatives to succeed, an organizational and systemic level of accountability must be put into practice. Without this level of accountability, accessibility is treated as merely a checklist, without concern towards dynamic and emergent user experiences. Measures of accessibility quality are often manipulated to appear positive by largely self-regulated organizations.

4.4.13 *Majority-rule decisions when representation is low or non-existent.*

- Decision-making without sufficient BPSI representation results in low prioritization of accessibility needs (for example, participants discussed self-checkout terminals at grocery stores with inaccessible displays and audio feedback forcibly turned off by upper management), and outcomes are reached by majorities, to protect their own interests.

4.4.14 Scripted, rigid service support

- Service providers with customers who are BPSIs are often not sufficiently willing to accommodate or be educated on how to support, rather than ignore, the effect of visual disabilities on their approach to, for example, tech support (i.e. "is the blue light blinking?"). It was suggested in discussions that technicians may be rigidly adhering to a script, rather than proactively adapting to the customer's abilities and responses. Another example occurred in real time after a co-design workshop concluded: a taxi driver who was called to provide transportation at the end of the day for the participants adamantly refused to accommodate them upon realizing that they were accompanied by guide dogs, despite the request to the company including that information.

4.4.15 Protect good starting points

- There is a need to protect "good starting points" from harmful changes or revisions later, whenever progress towards inclusive design is made. The quick reversion from having the option to remotely work, learn, and have doctor's appointments and more in the later days of the COVID-19 pandemic highlights this well, despite the long-term needs and demands for such flexibility in services before the pandemic occurred. Participants also discussed an ongoing policy battle in which guide dogs have been at risk of being "lumped in" with a new proposal to heavily regulate service animals and require significant effort every year to continue owning a guide dog, despite how essential this service is to the BPSI community.

4.4.16 Inconsistent adherence to accessibility standards

- Existing accessibility standards are not maintained consistently: the persistent lack of usage of alt text in web and software design (Gorlewicz et al., 2018) shows that even this simple, standardized accessibility need is not prioritized highly enough in the tech industry to be reliable.

4.4.17 Comfort with exporting agency

- Individual differences among participants with the degree to which independence is preferred over reliance on others was observed throughout the research activities. For example, some prefer asking store employees for assistance with learning about products, navigating the store and obtaining products of interest, and a "sighted buddies" service was brought up specifically as a desirable option.

4.5 Issues of information foraging (Pirolli, 2007) and knowledge creation

4.5.1 Empowerment for independence using assistive technologies

- In contrast to participants who felt comfortable asking those with vision for help, others preferred technological assistance to maintain a high level of independence, as indicated by the discussions of apps such as Blind Square, Be My Eyes, SeeingAI and AIRA , each of which provide degrees of assistance through smartphones and other personal devices.

4.5.2 Risk taking to maintain low-technological independence

- Some participants expressed preferences for independence with as little reliance on technology as possible, often at the cost of a higher level of personal risk. For example, navigating spaces using the full extent of individual abilities, but often encountering problems such as bumping into hazards, spending extremely long periods of time to find relevant items, and minimal technological assistance such as telephone hotline for people who identify as disabled.

4.5.3 Shared language for collaborative prototyping

- Participants demonstrated collaboration strategies for physical model making using a Tinkertoy (2023) set to build a tangible model of a grocery store. Their collaboration was facilitated by a shared language of elements of lettering and numbering (a two-dimensional grid system, similar to a spreadsheet), spatial directions, shape, size, structural integrity, physical relations, speed, sound and metaphors to direct one another and share design decisions. This shared language is described in more detail in section 5.1.

4.5.4 Proposed navigation and granularity using grids

- The aforementioned grid-based system was used with the intention that a navigation system that follows this system could be mapped consistently between different stores (all types, not only grocery stores). The system would divide stores into equal-sized “cells” that contain different items and scale down in granularity of two-dimensional cells mapped onto shelves when needing to locate products (all differences in layout between different stores would be accounted for by rows and columns stretching farther, or being shorter, compared to others) rather than aisles. The participants not only constructed a physical model to demonstrate this, but described how they would use the system in detail during a collaborative prototyping session.

4.6 Issues of matches or mismatches in spatial-topological representations and knowledge creation and sharing

4.6.1 Sensory-grounded language can communicate familiar sensorimotor experiences via language

- In scenarios in which tactile qualities are relevant to BPSIs, descriptions of these qualities may be highly effective, since sensory-grounded descriptions were observed to have an effect comparable to repeated sensorimotor experiences with which the participants were familiar (i.e. touching and feeling the rigidity of a tomato to assess its ripeness). Descriptions of this type (*tactile labels*) may be a practical alternative to real non-visual cross-sensory interactivity (i.e. in the aforementioned example, shopping virtually does not provide access to the real products or their physical affordances). Tactile and haptic feedback also have issues with ambiguity when presented without the context of descriptions or labels: for example, participants were presented with a prototype audio-tactile globe, which happened to be in the same location, and though it was intriguing to interact with via touch and provided information that participants had no prior knowledge of (i.e. the shape of Alaska's southwestern peninsula), participants needed linguistic labels to meaningfully identify land masses besides their shape, relative size, elevation and spatial relations with one another (i.e. the identity of continents, countries, mountain ranges, etc…) This aligns with the concept of conceptual ambiguity (see Fig. 2; Coppin, 2014).

4.6.2 Disruptive software updates

- Software updates frequently disrupt the familiarity of ICT interfaces and change their screen-readable hierarchical structures. This creates mismatches in the user's mental model of the system navigation, the screen reader's focus, and the individual's awareness of what is being focused on. Participants suggested preserving existing navigational structures and restricting updates to new items in the structure or menus that do not disrupt the information architecture that they have adapted to, remaining explorable when time permits. Integration of a language-navigable diagrammatic structure via chatbots is also a recommendation for averting the update issues, as this interactive style allows flexibility in the navigation, rather than restriction to sequential menu hierarchies.

4.7 Issues of matching or mismatching spatial-topological representations, information foraging and knowledge creation and sharing

4.7.1 Strategy for collaborative artifacts

- Single-person input and manipulation of a shared artifact (i.e. models, documents) maintains consistent awareness of system status, and appropriate flows of contributions for such tasks, sharing, and updates on changes. The shared artifact would only change when one person is interacting with it, and when passed to another collaborator, changes can be inspected, and discussions can be held on new ideas.

4.7.2 Language-navigable diagrams

- Interactions with Chat GPT (2023) demonstrated the possibility for BPSIs to navigate diagrammatic representations through speech output, termed "language navigable diagrams" (Barter, Coppin, Mejia, Murgaski, Puvanesasingham, 2023). Queries that reference information described in terms of environmental sounds, textures, shapes, spatial properties, and spatial relations were demonstrated to map to the participants' internal representations of these phenomena, built upon prior lived experiences. The sensory-grounded nature of Chat GPT's (2023) speech patterns (in response to being prompted that the user is blind) can mimic real sensorimotor experiences with sufficient detail and relevance that these experiences are communicated and the information is perceived as more reliable.

4.7.3 Complementarity of cross-sensory interaction with sensory-grounded language

- This does not preclude the use of cross-sensory perceptual feedback as an augmentation of sensory-grounded speech descriptions. For example, a description of humming refrigerators being nearby on the user's right or left to orient them within the space of a virtual grocery store may be effective as-is, however including the actual sound of refrigerators via binaural audio would be both practical and potentially more effective, by reducing the time needed for interpretation to a nearly instantaneous reaction to environmental sensory feedback that is intuitive in real scenarios. Further, a properly descriptive and specific 3D model or metaphorical description was said to be preferable for complex descriptions that do not translate well to lived experiences.

4.7.4 Need for awareness of system status

- The design of ICT platforms often leaves users unaware of the system status (i.e., whether elements are active or not). This is due to the content often not being screen-readable, visually obscured by other content, blocked from inclusion in speech output (for example, empty spaces on touchscreens when in explorable modes provide no feedback if the user is not hovering over or tapping an interactable object), and located off-screen when using a screen magnifier (no guidance is provided for where to navigate in order to find the relevant content and interface elements).

5. RESULTS

The findings and the design recommendations for ICT design that are articulated here cannot be treated as universal solutions to all virtual information and communication design problems, nor as finalized works, as this work is ongoing as part of a larger project. The intention must be limited to *guidelines*, all of which originate from induction carried out with a group of BPSIs sharing their lived experiences and knowledge. However, it is worth acknowledging other prior, relevant guidelines, such as WCAG (2022), information design (Pettersson, 2010), as well as universal design (CAST, 2018), and connecting these principles with the preliminary results from this study whenever appropriate. In Section 5.1, a taxonomy of descriptive terms used during a co-designing activity (see Section 3.5.2.1), and produced by Chat GPT in another (see Section 3.5.2.3) is provided, along with the conceptual categories in which they fit. By drawing on the relevance of prior established design guidelines, it is intended that this taxonomy may establish a baseline for designers to further develop relevant and useful linguistic terms for BPSIs to navigate and comprehend information and communication structures (i.e. ICTs, diagrams, information representations).

Following this, in Section 5.2, the full list of preliminary design recommendations for inclusive and accessible virtual ICT design is provided through a high-level summary and categorization based on the relationships with the dimensions of the shared intentionality cube model (Lee et al., 2022). Like the taxonomy, prior related design guidelines (WCAG, 2022; CAST, 2018; Pettersson, 2010) are connected in order to provide the beginnings of a realistic route for designers of future ICTs to include the information and communication needs of BPSIs in design decisions, as well as to assist BPSIs in articulating the language of their needs and lived experiences into guidelines for others to comprehend and follow.

5.1 Taxonomy of conceptual categories and linguistic terms found to support language-navigable diagrams

Throughout the follow-up co-design workshops, participants engaged in collaborative prototyping activities and actively demonstrated a high level of shared intentionality (Tomasello, 2005) as their goals and actions became synergized when given a collaborative task to complete. While participating in these activities, they were observed to use linguistic terms as the *connective tissue* for planning and physically shaping their prototypes, so that changes made to the prototype by one participant at a time could be guided and explained prior to the prototype being passed along to another participant, and a larger plan could be formed and modified in real-time. These linguistic terms provide insights on how our blind and partially sighted co-designers understand and use language in sensory and spatial terms, to navigate diagrammatic representations (Larkin and Simon, 1987), and to both give and receive feedback. This foreshadows the possibility that the conceptual categories and terms listed here may be used as examples for developing appropriate descriptions of the concrete structures of physical and virtual environments. While this list is not exhaustive of all possibilities for linguistic navigation of diagrams, it is a starting point that emerged from a collaborative process of navigating and describing a complex physical artifact and ideas related to its structure and uses.

The following is a taxonomy of these categories and terms that were used during the co-design workshops. Additionally, prior related principles from web accessibility guidelines (WCAG, 2022), information design guidelines (Pettersson, 2010) and universal design guidelines (CAST, 2018) are indicated to highlight how the context of these observations relates to other common problems from these disciplines, and how much insight the findings have to add. These related guidelines do not indicate that the categories and terms found in the research activities are equivalent, rather they point to the fact that these issues are not mutually exclusive with the need for agency that is the focus of this study, and that expansions of existing guidelines are possible to foster agency and inclusive design within these disciplines.

Conceptual Category	**Terms Used**	**Prior Related Design Guideline(s)**
Architectural features	Entrance, door, exit, floor, "*landmarks*"	(Users can easily navigate…)[1] (2.1.5: The Context 2) (2.3: Providing Clarity 2)
Grid navigation	Rows and columns with codes (A1, D3, B9, etc…)	(Users can easily navigate…)[1] (2.2. The Structure 2) (2.3: Providing Clarity 2) (5.4 Facilitating Memory 2) (3.4 Maximize transfer and generalization 3)
Spatial relations	Right, left, up, down, back, top, bottom, horizontal, vertical, high, low	(Users can easily navigate…)[1] (2.1.5: The Context 2) (2.2. The Structure 2) (2.3: Providing Clarity 2) (7.2 Optimize relevance… 3) (2.2 Clarify structure and syntax 3)

Shapes	Lattice, wheel, rod, square, tube, stem, spike, ramp, corner, tip, round, paddle, wand, flag, fin, switch	(2.1.4: The Representation 2) (2.5 Providing Emphasis 2)
Size	Big, small, long, wide, short	(2.2. The Structure 2) (2.5 Providing Emphasis 2) (2.2 Clarify structure and syntax 3)
Structural integrity	Stable, flat	
Physical relations	Half, side, edge, quarter, point, raised	(Users can easily navigate…)[1] (Content appears and operates in predictable ways)[1] (2.2. The Structure 2) (2.3: Providing Clarity 2) (2.2 Clarify structure and syntax 3)
Speed	Fast, quick, slow	(2.1.5: The Context 2)
Sound	Loud, swish, beep	(Content is easier to see and hear)[1] (2.1.5: The Context 2) (2.5 Providing Emphasis 2) (5.1 Facilitating Attention 2) (3.2 Highlight patterns… 3)
Metaphorical	"board game", "wave", "camel (hump)-shaped"	(Content can be presented in different ways)[1] (2.1.5: The Context 2) (5.3 Facilitating Processing 2) (2.4 Promote understanding across languages 3) (3.1 Activate or supply background knowledge 3)
Sensory-grounded*	Broad, smooth, oval, needle, woody, firm, hum, crinkle, spongy	(2.1.4: The Representation 2) (5.2.1 Perception of Text 2)

Table 7: Conceptual categories described by participants using linguistic terms during co-design workshops
**Chat GPT (2023)-generated terms, participants noted as highly effective.*
1 WCAG, 2022
2 Pettersson, 2010
3 CAST, 2018

5.2 *Summary of preliminary design recommendations for new accessibility standards*

Moving on to the list of preliminary design recommendations that was produced by the findings, an effort to categorize them based on a process of thematic coding resulted in the following groups:

- Management of appropriate information quantity and structure (concerning organizational needs)
- Complex information representations may support agency through interactivity (concerning how to present relevant information most consistently and effectively)

- Balance standardizations of ICT interfaces with customization options to most appropriately take advantage of pre-existing or constructed familiarity (concerning building upon prior knowledge and skills, and providing context)
- Support shared intentionality (Tomasello et al., 2005; Lee et al., 2022) and shared agency by facilitating mutual knowledge creation (concerning aspects of collaboration and joint agency (Mendoza-Collazos and Zlatev, 2022), communication and awareness of system status)
- Cross-sensory language and perceptual feedback considerations (concerning the role that language and feedback that integrates multiple sensory modalities has in relation to the findings)
- Adopt organizational accessibility policies and standards to provide an environment in which accessible information representations can be consistently supported (concerning the repeated findings that some form of recommendation or set of standards and policies for organizations to foster inclusive and accessible working environments is as necessary as any of the information representation design interventions presented beforehand if inclusion and accessibility is to be provided consistently).

5.2.1 Complex information representations may support agency through interactivity (I)

- **Recommendation I1**: Allow for relevant information to be prioritized and emphasized through simple customization options maintained across ICT platforms.

Prior Related Design Guideline(s):	(Content can be presented in different ways)[1] (2.5 Providing Emphasis)[2] (5.1.3 Attention to Layout)[2] (1.1 Offer ways of customizing the display of information)[3] (3.2 Highlight patterns, critical features, big ideas, and relationships)[3] (7.2 Optimize relevance, value and authenticity)[3]

- **Recommendation I2**: Curate relevant information from one or more sources when faced with unavoidable information overload by providing interactive options (i.e. LLMs).

Prior Related Design Guideline(s):	(Text is readable and understandable)[1]

	(5.1.3 Attention to Layout)[2] (3.1 Activate or supply background information)[3] (3.2 Highlight patterns, critical features, big ideas, and relationships)[3] (3.3 Guide information processing and visualization)[3] (6.4 Enhance capacity for monitoring progress)[3] (7.2 Optimize relevance, value and authenticity)[3]

- **Recommendation I3**: Consider providing information through scenario-based interactions (i.e. shopping by recipe, navigating a city with a list of locations to travel to, etc…)

Prior Related Design Guideline(s):	(Text is readable and understandable)[1] (Content appears and operates in predictable ways)[1] (3.1 Activate or supply background information)[3] (3.3 Guide information processing and visualization)[3] (6.4 Enhance capacity for monitoring progress)[3] (7.2 Optimize relevance, value and authenticity)[3]

- **Recommendation I4**: Provide the option to differentiate speech output sources (pitch, timbre, dictation speeds, accents, monotony).

Prior Related Design Guideline(s):	(Content can be presented in different ways)[1] (Content is easier to see and hear)[1] (Text is readable and understandable)[1] (Users are helped to avoid and correct mistakes)[1] (1.1 Offer ways of customizing the display of information)[3] (5.1 Use multiple media for communication)[3]

- **Recommendation I5**: Complex representations should be capable of adapting to and retaining users' preferences and patterns for interactive information foraging (Pirolli, 2007).

Prior Related Design Guideline(s):	(Text alternatives for non-text content)[1]

	(Content appears and operates in predictable ways)[1] (2.2 Clarify syntax and structure)[3] (3.1 Activate or supply background information)[3] (7.2 Optimize relevance, value and authenticity)[3]

5.2.2 Management of appropriate information quantity & structure (Q)

- **Recommendation Q1**: Balance the number of available choices with their relevance to BPSIs in the given context (higher relevance allows more choices to be made available within other limitations, such as memory and attention).

Prior Related Design Guideline(s):	(3.3 Guide information processing and visualization)[3] (7.1 Optimize individual choice and autonomy)[3]

- **Recommendation Q2**: Cluster information into logical and consistent hierarchies whenever possible.

Prior Related Design Guideline(s):	(Users can easily navigate, find content, and determine where they are)[1] (Text is readable and understandable)[1] (Content appears and operates in predictable ways)[1] (2.2 Providing Structure)[2] (2.5 Providing Emphasis)[2] (5.2.3 Perception of Layout)[2] (5.4 Facilitating Memory)[2] (2.2 Clarify syntax and structure)[3] (3.3 Guide information processing and visualization)[3] (6.3 Facilitate managing information and resources)[3]

- **Recommendation Q3**: Make complex information representations scalable so that the full range of patterns, individual details and granularity of information are perceivable at all times.

Prior Related Design Guideline(s):	(Content can be presented in different ways)[1]

	(Users can easily navigate, find content, and determine where they are)[1] (Content appears and operates in predictable ways)[1] (2.2 Providing Structure)[2] (5.2.3 Perception of Layout)[2] (5.4 Facilitating Memory)[2] (3.3 Guide information processing and visualization)[3] (4.1 Vary the methods for response and navigation)[3] (6.3 Facilitate managing information and resources)[3]

- **Recommendation Q4**: Minimize unnecessary or unrequested repetitions of information, whilst still keeping it available if requested.

Prior Related Design Guideline(s):	(Text is readable and understandable)[1] (5.2.1 Perception of Text)[2] (5.4 Facilitating Memory)[2] (3.2 Highlight patterns, critical features, big ideas, and relationships)[3] (3.3 Guide information processing and visualization)[3] (7.3 Minimize threats and distractions)[3]

5.2.3 Balance standardizations of ICT interfaces with customization options to most appropriately take advantage of pre-existing or constructed familiarity (F)

- **Recommendation F1**: Provide standardized access options for the most important and consistent functions of individual ICTs or across ICT platforms.

Prior Related Design Guideline(s):	(Text alternatives for non-text content)[1] (Users can easily navigate, find content, and determine where they are)[1] (3.1.1 External Information Access)[2] (4.1 Harmony)[2] (5.4 Facilitating Memory)[2]

	(2.2 Clarify syntax and structure)[3] (3.1 Activate or supply background information)[3] (3.2 Highlight patterns, critical features, big ideas, and relationships)[3] (3.4 Maximize transfer and generalizability)[3]

- **Recommendation F2**: Offer enough customizability to extend "power user" capabilities across types of ICT platforms.

Prior Related Design Guideline(s):	(Content appears and operates in predictable ways)[1] (5.4 Facilitating Memory)[2] (1.1 Offer ways of customizing the display of information)[3]

- **Recommendation F3**: Avoid changes to standards of ICT interface designs for purely cosmetic reasons.

Prior Related Design Guideline(s):	(Users can easily navigate, find content, and determine where they are)[1] (Content appears and operates in predictable ways)[1] (5.4 Facilitating Memory)[2] (3.1 Activate or supply background information)[3] (7.3 Minimize threats and distractions)[3]

- **Recommendation F4**: Provide *rehearsals* via as much information for fully performing tasks and activities as possible that can be used and familiarized with beforehand, if a *failsafe* may be deemed necessary (i.e. due to the risks of making mistakes performing the actual task(s)).

Prior Related Design Guideline(s):	(Users can easily navigate, find content, and determine where they are)[1] (Content appears and operates in predictable ways)[1] (3.1.2 Internal Information Access)[2] (5.2.3 Perception of Layout)[2] (5.4 Facilitating Memory)[2] (2.2 Clarify syntax and structure)[3]

	(3.1 Activate or supply background information)[3] (3.3 Guide information processing and visualization)[3] (7.3 Minimize threats and distractions)[3]

- **Recommendation F5**: Ensure that as much contextual information is included in appropriate forms as necessary.

Prior Related Design Guideline(s):	(Text alternatives for non-text content)[1] (Users are helped to avoid and correct mistakes)[1] (3.1.2 Internal Information Access)[2] (5.2.1 Perception of Text)[2]

5.2.4 Support shared intentionality and shared agency by facilitating mutual knowledge creation (S)

- **Recommendation S1**: Provide opportunities for shared meaning making and facilitation of shared representations. This may be done through cross sensory representations or interactive verbal descriptions wherever possible.

Prior Related Design Guideline(s):	(Text alternatives for non-text content)[1] (Content appears and operates in predictable ways)[1] (5.2.1 Perception of Text)[2] (5.2.3 Perception of Layout)[2] (3.1 Activate or supply background information)[3] (5.1 Use multiple media for communication)[3] (8.3 Foster collaboration and community)[3]

- **Recommendation S2**: Collaborative artifacts or systems should either restrict the ability to change it to a single contributor or provide minimized awareness of the artifact or system's status to all other collaborators.

Prior Related Design Guideline(s):	(Content appears and operates in predictable ways)[1] (Users are helped to avoid and correct mistakes)[1] (2.2 Providing Structure)[2]

	(6.3 Facilitate managing information and resources)[3]

5.2.5 Cross-sensory language and perceptual feedback considerations (C)

- **Recommendation C1**: Use conceptual categories and related terms from the language-navigable diagram taxonomy (Section 5.1) to inform interactive, sensory-rich descriptions of complex sets of information.

Prior Related Design Guideline(s):	(Text alternatives for non-text content)[1] (Users can use different input modalities besides text)[1] (Text is readable and understandable)[1] (3.1.2 Internal Information Access)[2] (5.1.3 Attention to Layout)[2] (5.2.1 Perception of Text)[2] (2.2 Clarify syntax and structure)[3] (3.1 Activate or supply background information)[3]

- **Recommendation C2**: Provide cross-sensory information in addition to sensory-rich descriptions whenever practical.

Prior Related Design Guideline(s):	(Content can be presented in different ways)[1] (Content is easier to see and hear)[1] (Content appears and operates in predictable ways)[1] (3.1.2 Internal Information Access)[2] (2.5 Illustrate through multiple media)[3] (5.1 Use multiple media for communication)[3]

- **Recommendation C3**: Use tactile labels (sensory-rich descriptions) to provide relevant sensory information for context, if cross-sensory information representations are not practical.

Prior Related Design Guideline(s):	(Text alternatives for non-text content)[1] (Content is easier to see and hear)[1] (Text is readable and understandable)[1]

	(3.1.2 Internal Information Access)[2] (5.2.1 Perception of Text)[2] (3.1 Activate or supply background information)[3] (3.2 Highlight patterns, critical features, big ideas, and relationships)[3] (7.2 Optimize relevance, value and authenticity)[3]

5.2.6 Adopt organizational accessibility policies and standards to provide an environment in which accessible information representations can be consistently supported (O)

- **Recommendation O1**: Include BPSIs in ICT design decision-making processes at the highest levels within organizations.

Prior Related Design Guideline(s):	(3.4 Securing Quality)[2] (7.1 Optimize individual choice and autonomy)[3]

- **Recommendation O2**: Prioritize user experiences verified by BPSIs over minimum-viable accessibility checklists.

Analogous Design Guideline(s):	(7.3 Minimize threats and distractions)[3]

- **Recommendation O3**: Enact organizational and policy changes to protect progress on accessibility and inclusion of BPSIs in ICT platform design decisions (require BPSIs' input for any proposed changes).

Analogous Design Guideline(s):	(7.3 Minimize threats and distractions)[3]

1 WCAG, 2022
2 Pettersson, 2010
3 CAST, 2018

6. DISCUSSION

6.1 Limitations

There were several circumstances during this project that limited the scope and contributions, mainly due to time and resource constraints. First, the study results and findings are constrained by a relatively small sample size, particularly during the co-design phase, for which continuity was prioritized over statistical reliability. There were only thirteen participants total in this phase, with 92% overlap in between the co-design festival workshops and the follow-up co-design workshops. Further, the participants for all research activities were over-represented by affiliations with the CNIB, a natural outcome of the choice in recruitment methods, over BPSIs from the general public, a matter that should be addressed in future studies to increase reliability of the results. The format of the research activities was very open and unstructured, another intentional choice to prioritize the inductive design process, however this may have come at the expense of less explicit focus on prior established inclusive design challenges. Instead, participants were encouraged to focus on challenges, benefits, conditions of working and learning environments and solutions to everyday problems encountered in lived experience. Consequently, the findings were relatively unfocused and the scope of the project was larger than could be completed during the allotted time frame. Finally, by introducing AI algorithm-powered voice assistant technology to the possible prototyping tools and solutions near the end of the project, the privacy and trust issues that this entails (i.e. techniques for safeguarding personal information in extensive future use, trusting output in moderation, verifying sources whenever possible or necessary, etc…) could not be sufficiently explored, and remains another necessary aspect for future studies to consider.

6.2 *Future Work*

Significant future research studies of accessible and inclusive ICTs will be conducted to follow up on this major research project. Many possible research questions remain to be explored, including that of how and in what scenarios might BPSIs benefit most from cross-sensory approaches to ICT interactions. Additionally, this concept is balanced by the potential of language-navigable diagrams as an alternative, and there should be interest in establishing their limitations and how suitable the former approach could fill this gap. Agency provided by technology use and representations of information for communities of varying abilities is also a deep and promising research area, which this study only covers in basic terms, including the absence of the aforementioned examination of enhanced agency in relation to the trustworthiness and bias mitigation possibilities of AI algorithm-powered voice assistant technologies that are emerging rapidly. For BPSIs, a natural extension of the ideas from this project is consideration of how ICTs could facilitate digital content creation and collaboration with other stakeholders on creative outcomes, a concept with greater potential as non-visual recommendations for ICT interface designs are increasingly proposed, developed and put into practice.

7. CONCLUSION

This study represents significant steps towards establishing a joint goal of supporting user agency between ICT designers and BPSIs (and those who are both). The findings summarized and recommendations proposed in this paper demonstrate that a technical understanding of the affordances of the diagrammatic representations [30] that shape ICT interfaces is achievable. The outcomes of the study were unexpected, however, they establish a starting point for near-future adoption of far more effective accessibility practices for ICTs than in their conventional present day forms. As the study progresses, it will be important to review sources relevant to both LLM interactivity and deepen the knowledge of when and how to use cross-sensory information representation for firsthand perception to provide accessibility and agency to the blind and partially sighted community, a scenario that this study has demonstrated to be more specific than expected.

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9. APPENDIX A: RETROSPECTIVE NARRATIVE INQUIRY INTERVIEW GUIDE

9.1 Objectives:

- Discovery of participants' preferred ICT SPMs
- Gain insights on existing accessibility challenges with ICT SPMs
    - What are participants' needs?
    - How are these needs failing to be met?
    - How might new ICT SPMs meet them?
- Record accounts of lived experiences with ICT SPMs that resulted in adaptations and / or failures in accommodation
- Discovery of participants' preferences for materials to co-design prototypes in the next phase of the study

9.2 Introductory Script:

Thank you for agreeing to participate in our interviews and welcome! We have several questions we would like to ask you, but this interview will be more like a conversation. Our plan is for the entire session to last between thirty and forty-five minutes, however, if the conversations naturally lead to more or less time than that, we will accommodate as long as that is also your preference.

We're interested in discussing your experiences with the accessibility and usability of various virtual and blended ICT service provision models (ICT SPMs for short) that you use to [work / learn] virtually, rather than through physical presence at your [workplace / school]. For example, video chat platforms like Zoom, Microsoft Teams, and Google Meets; virtual document creation and sharing services like Office 365 and Google Drive; content management systems like Canvas, [example 2], and [example 3]; or anything else that might be relevant to virtually participating in your [working / learning] environment, like digital content that you need to interpret, user interfaces, images, charts, graphs and so on. We will also check in at the end on whether or not you're interested in participating in a follow-up co-design session, where you'll get the chance to collaboratively build test versions of these kinds of ICT SPMs with our team, and if so, we will ask about some of your preferences related to that.

We want to remind you before we begin that your participation is completely optional, and if you at any time before, during or after our session today feel like you want to withdraw and have us remove your responses and contact information from the study, you are welcome to. Just let us know at any time, and we will follow through on that. If you do decide to participate fully, you can be confident that the information we gather from this session with you will be kept confidential and be stored securely, and all reports or publications from the study will make the responses and data anonymous and avoid revealing any potentially identifying information.

[pause for signing of consent form, if not already complete]

Okay, thanks again for agreeing to participate. Let's get started!

9.3 Questions:

1. Please tell us about which ICT SPMs you normally use for virtual [work / school]. Which of these do you use the most, and why is that? Which of these are required, and which do you use entirely by choice, if any?

    a) If it was entirely your choice, which ICT SPMs would you choose to keep and why would you choose those ones, specifically? Choose as many or as few as you prefer.

2. Please describe for us how these ICT SPMs support your [work / education]. How do they make [working / learning] easier, or more effective?

3. How do some of the ICT SPMs you use for [work / school] cause you to struggle with using them for the necessary tasks or activities in that environment? Why do you suppose this happened?

    a) What kind of adaptations have you had to make in order to make it easier or more effective to use some of these ICT SPMs?

        i. [If necessary] What led to you discovering that adaptation? Why did you think to do [adaptation process / activity / question asked to someone / etc] when you were faced by that challenge, specifically?

    b) If there have been ICT SPMs that you could not adapt to enough to overcome the struggles you experienced, what were they, and why was adapting to them not possible for you?

4. Tell us about situations in which you have needed to use more than one program or service in combination. Describe how you feel about these situations. Which combinations are the ones that work the best? Which ones cause you to struggle, and why do you think that is?

5. If you could change how some, or all, of these ICT SPMs work in order to meet your needs as best as possible, which ones would you change? Name as many, or as few as you prefer.

    a) How would you change them? Discuss as many or as few as you prefer, and in as much or as little detail as you can.

        i. [If necessary] When we say "change the ICT SPMs", what we mean is that if they could be in a different form, or have a different design that supports your needs more effectively, what would that be like?

        ii. [If necessary] For example, an ICT SPM for virtual [work / learning] could be made into "mixed reality", like this [show example], or virtual reality, like this [show example].

        iii. [If necessary, otherwise go to (1) below] It could also include different kinds of interfaces, like sound that surrounds you and can be distinguished from a specific direction [show binaural audio example].

iv. [If necessary, otherwise go to (1) below] It could even have parts of it that you can touch, like this [show example of tangible / haptic interface].

- Based on these examples, how might the ICT SPMs you use for virtual [work / school] work more effectively *for you*?
- [If necessary] Feel free to take some time to think about this. Would you like some more examples? [show more examples, if asked]

6. So, now that we have talked about how some of these ICT SPMs work, and how they sometimes fail to really support your needs effectively, what do you think about helping to create new test ideas for some of them? Would you be interested in participating in a "co-design" session with us later on, in order to try to make something new that could be better?

a) [If yes] Okay, in that case, please let us know what kind of materials you would like us to provide for you when we conduct this co-design session with you.

i. [If necessary] For example, if we want to make quick "prototypes" of how some of these ICT SPMs might work, we could use [list examples – clay, cardboard, Lego, marbles, Post-it notes, sandpaper, plastic containers, playing cards, **etc**]

ii. [If necessary] As an example, have a look at this [show example of a low-fi UI prototype for something similar to these ICT SPMs being discussed]

b) [If no] Okay, well in that case, thank you very much for participating in our interview today! Your responses have been very helpful to moving our project forward. Since we are now at the conclusion of the interview, let me remind you once again that if you at any point decide that you would like to withdraw your responses from our records, please contact us via [method we have specified for continuing contact with participants], and we will remove it right away. Please note also that in [time frame], we may be publishing our findings in a [journal, conference proceeding and / or thesis paper]. After this time, while it will always be anonymous, your response will be permanently recorded in some form. If you decide to withdraw after that time, we will be happy to remove your responses from any further publication, but we will not be able to alter one that has already been published.

9.4 *Closing comments*

Thank you again for choosing to lend us your time today for this session, it is very much appreciated, and will go a long way to making this study a success! [If participant agreed to participate in co-design session] We look forward to having you participate in co-design in [time frame prior to co-design sessions beginning to take place], and we will be contacting you very soon to arrange for a date and time [if expected to be in-person: date, time and location] to host you. Have a great day [if agreed to co-design participation: and see you again soon]!

10. APPENDIX B: CO-DESIGN FACILITATION GUIDE

10.1 Objectives:

- Collaboratively build low-fidelity prototypes of participants' representations of ICT SPMs in preferred materials and form
- Collaboratively translate insights from participants' lived experiences of accessibility challenges and adaptations of ICT SPMs into high-fidelity ICT SPM prototypes
- Describe, discuss, and iterate on new ideas for ICT SPMs with participants that meet their needs

10.2 Team Member Roles

- ____________: Codesign facilitator
- ____________: n/a
- ____________: Codesign facilitator
- ____________: Codesign facilitator

10.3 Activities Prior to Phase 1

1. Review responses from semi-structured interviews, if applicable
2. Prepare prototyping kits, by facilitators for in-person session, by participants for virtual session

10.4 Greeting and Confirmation of Consent (Phase 1)

To start the session, if participants have not already agreed to and signed our Informed Consent Form, [**facilitator**] will, after a greeting, ask them to read, fill out and sign a copy of the form prior to the session getting underway. Participants will be notified that they have the opportunity to withdraw from the study, any individual identifying information will be destroyed, however, any work that they have contributed to the larger group prototype will remain a part of this study.

1. **Location(s)**: Video conferencing (Zoom, Teams, Mozilla Hubs); Ontario Tech Campus; CNIB Community Hubs; Cogsci 2022 Conference workshop venue
2. **Number of participants**: 4-5
3. **Materials required**: Informed Consent Forms (digital copies)
4. **Time required**: 0-3 minutes

10.5 Phase 1: Modeling ICT SPMs

1. **Location(s)**: Video conferencing (Zoom, Teams, Mozilla Hubs); Ontario Tech Campus; CNIB Community Hubs; Cogsci 2022 Conference workshop venue
2. **Number of participants**: 4-5
3. **Materials required**: Prototyping kits matching preferences established in Stage 1 session (semi-structured interview), or for Cogsci participants, a pre-workshop survey on their preferences will be used to inform what materials we will provide for prototyping

10.6 Activities:

1. Participants will individually make a choice of which ICT SPM and tasks involving it they prefer to model. Ask participants about common activities that require the use of ICT SPMs that they normally encounter, and based on their choice(s), brainstorm how the user experience might be represented in a model.

Time required: 7-10 minutes

2. Participants will build models of ICT SPMs using the prototyping kits, while facilitators monitor the process and ask questions. If needed, facilitators may assist participants with construction of their prototypes, following the participants' instructions and suggestions, and may also provide feedback and ask questions about the participants' decisions and suggestions.

Time required: 25-40 minutes

BREAK: 10 minutes (after first 20 minutes of activity 2)

BREAK: 5 minutes (after activity 2)

3. Wrap-up discussion: Facilitators will guide participants to show each other their prototypes, discuss their rationale for representing the ICT SPM in the way that they chose, and demonstrate

how one might use an interface like the one implied by the prototypes for one or more tasks that the participant envisioned.

Time required: 15-25 minutes

10.7 Activities Prior to Phase 2

1. Construct ICT SPM feature prototypes for Stage 2 prototyping

10.8 Greeting and Confirmation of Consent (Phase 2)

1. To start the session, if participants have not already agreed to and signed our Informed Consent Form [**see Appendix E Codesign Informed Consent Form**], a facilitator will, after a greeting, ask them to read, fill out and sign a copy of the form prior to the session getting underway.
2. **Location(s):** Video conferencing (Zoom, Teams, Mozilla Hubs); Ontario Tech Campus; CNIB Community Hubs; Cogsci 2022 Conference workshop venue
3. **Number of participants**: 4-5
4. **Materials required:** Informed Consent Forms (digital or physical copies)
5. **Time required:** 0-3 minutes

10.9 Phase 2: Participatory prototyping of new ideas for ICT SPMs

1. **Location(s)**: Video conferencing (Zoom, Teams, Mozilla Hubs); Ontario Tech Campus; CNIB Community Hubs; Cogsci 2022 Conference workshop venue
2. **Number of participants**: 4-5
3. **Materials required**: PC / laptop, camera, Oculus Quest headset, AR/mixed reality headset, speaker/headphone system for binaural audio setup, custom AR/VR pilot project software, custom ICT SPM features, VR controller, IMAGE software plugin (https://image.a11y.mcgill.ca/ - translation of image contents to binaural audio and haptic feedback), optional - haply 2diy device (https://2diy.haply.co/)

10.10 Activities:

1. Information session: Demonstrate the tools participants will have access to in order to collaboratively prototype high-fidelity ICT SPM interfaces (Zoom, Teams, Mozilla Hubs, etc

widgets). Participants will be given the opportunity to try using at least one widget as currently designed, prior to considering a new prototype.

Time required: 5-10 minutes

2. Participatory prototyping – first portion:

Similar to the prototyping activity in Phase 1, facilitators will work with participants to make sure that they have the support they need to materialize new ideas using the tools available to them, which will include not only the prototyping kits containing their preferred materials, but also software such as Adobe Aero, Mozilla Hubs, Spatial, Altspace, and the AR Authoring Tool.

Facilitators will monitor their progress and both ask and answer questions, intervene in the prototype building process if necessary, and support their decisions and suggestions throughout the process.

Time required: 20-30 minutes

BREAK: 10 minutes

3. Participatory prototyping – second portion:

After the first portion of the prototyping activities, participants will be given the option to choose between continuing to build and improve upon their current ideas for a prototype, or switch to a new idea that could be built. They will also be encouraged by facilitators to, if they wish, share their previously built prototypes and ideas with other participants in the session, and exchange insights.

Once they make their decision on how to proceed, which may be individually or partnered with one or more other participant, they will proceed with a second portion of prototyping, with facilitators monitoring their progress, asking and answering questions, and supporting their decisions and suggestions.

Time required: 20-30 minutes

4. Wrap-up discussion:

Facilitators will guide participants to show each other their prototypes, discuss their rationale for representing the ICT SPM in the way that they chose, and demonstrate how one might use an interface like the one implied by the prototypes for one or more tasks that the participant envisioned. The question of what should be done next will be asked to the group, and a round of discussion should follow. Participants will be encouraged to think about success criteria for the design of these tools, in other words, how they might be evaluated and considered a successful intervention.

Once this discussion reaches its natural conclusion, participants will be thanked by the facilitators for contributing their time and thoughts to these tasks, and invited to continue their participation in the project through the next phase, usability testing, which will occur at a later date.

Time required: 10-15 minutes

11. APPENDIX C: EMAIL RECRUITMENT SCRIPTS

11.1 Email script for narrative inquiry / semi-structured interviews

Hello [Insert name],

I hope this email finds you well.

This is [Insert name] from OCAD University inviting you to participate in an online one-on-one interview as part of a research study led by ___________ of ___________. The project is about accessible and inclusive virtual Information and Communication Technologies (ICTs) (e.g. video conferencing platforms, such as Zoom) in post-COVID-19 Canada.

The purpose of the **one-on-one interview** is to investigate the significant needs for virtual ICTs for diverse audiences in a virtual learning or working context. Your knowledge and lived experience will help contribute to this study.

We will ask you questions about your day-to-day use of ICTs for [work or education], including challenges you have faced related to accessibility, adaptations you have made, and ideas you may have to improve accessibility and user experience.

Study details and logistics:

- Duration: 1-1.5 hours
- Date: [Insert date of interview]
- Location: [Online password-protected video conference - Insert link to meeting room]

Your participation in this study is completely voluntary and you may choose to stop participating at any time. Your decision to stop participating will not affect the nature of your relationship with the Canadian National Institute for the Blind (CNIB) either now, or in the future.

Possible benefits of participation may be that you find it beneficial to share your lived experience in order to contribute to research on developing accessible and inclusive ICTs.

We do not foresee any risks or discomfort from your participation in the research.

If you have any questions about this study or require further information, please ask. If you have questions later about the research, you may contact the Co-Investigator, ___________ (___________), or the Principal Investigator, ___________ (___________). This study has been reviewed and received ethics clearance through the Research Ethics Board at OCAD University (File #). If you have any comments or concerns, please contact the Research Ethics Office through ___________.

Would you be interested in sharing your ideas, knowledge and lived experience by contributing to this study?

If yes – Great! Would you be available to attend a session on [Insert date of interview/focus group] online?

If no – I understand. Thank you so much for your consideration. Have a good day.

If undecided – Could I follow-up with you in a few days? Great. Have a good day.

11.2 Email script for codesign session

Hello [Insert name],

I hope this email finds you well.

This is [Insert name] from OCAD University inviting you to participate in your choice of an in-person or online codesign session as part of a research study. The study is being led by ___________, Principal Investigator, ___________, OCAD University, as part of a joint Accessibility Standards Canada (ASC)-Ontario Tech University and OCAD University project on accessible and inclusive virtual and blended Information and Communication Technologies Service Provision Models (ICT SPMs) (e.g. video conferencing platforms, such as Zoom) in post-COVID-19 Canada.

The purpose of the **codesign session** is to codesign [Option 1: an external representation (physical or digital) that allows you to demonstrate and share your internal representation(s) of one or more ICT platform(s) and / or common tasks from your day to day life in a working or learning context] [Option 2: accessible medium to high-fidelity ICT feature prototypes in collaboration with the research team, using digital media tools that will be built in response to early findings]. Your knowledge and lived experience will help contribute to this study.

In this codesign session you will be asked to [Option 1: choose one or more types of ICT platform(s) and/or common tasks that you use them for, and build one or more low-fidelity prototype(s) that reflect(s) your experiences with them] [Option 2: shape the form and functions of new types of accessible ICT platforms, in collaboration with facilitators and possibly other co-design session participants, to best match your needs and share ideas among the group.

Study details and logistics:

Option 1:

- Research method: Participatory design/codesign
- Codesign session structure:
    1. Introduction 5 minutes
    2. Ideation: 10-15 minutes
    3. Prototyping Activity Part I: 20-30 minutes
    4. Break: 10 minutes
    5. Prototyping Activity Part II: 20-30 minutes
    6. Break: 5 minutes
    7. Wrap-up Discussion: 20-25 minutes
- Duration: 1.5-2 hours
- Timeline of sessions: July 2022 to March 2024
- Number of sessions: One*
- Date: [Insert dates of codesign session]
- Location: [Insert physical hosting location] or [Online password-protected video conference - Insert link to meeting room]

Option 2:

- Research method: Participatory design/codesign
- Codesign session structure:
  1. Introduction 5 minutes
  2. Information Session (tools demonstration): 15-20 minutes
  3. Ideation: 10-15 minutes
  4. Break: 10 minutes
  5. Prototyping Activity Part I: 20-30 minutes
  6. Break: 10 minutes
  7. Prototyping Activity Part II: 20-30 minutes
  8. Break: 5 minutes
  9. Wrap-up Discussion: 15-20 minutes
- Duration: 2-2.5 hours
- Timeline of sessions: July 2022 to March 2024
- Number of sessions: One*
- Date: [Insert dates of codesign session]
- Location: [Insert physical hosting location] or [Online password-protected video conference - Insert link to meeting room]

Your participation in this study is completely voluntary and you may choose to stop participating at any time. Your decision to stop participating will not affect the nature of your relationship with [Option 1: the Canadian National Institute for the Blind (CNIB)] [Option 2: the Cognitive Science Society] either now, or in the future.

Possible benefits of participation may be that you find it beneficial to share your lived experience in order to contribute to research on developing accessible remote ICT platforms.

We do not foresee any risks or discomfort from your participation in the research. However, digital prototyping in the codesign session may involve testing virtual reality headsets. If you have any concerns about discomfort, we would be happy to discuss the process and mitigation strategies in more detail with you. Please contact, Co-Investigator, ___________ (___________).

If you have any questions about this study or require further information, please ask. If you have questions later about the research, you may contact the Co-Investigator, ___________ (___________), or the Principal Investigator, ___________ (___________). This study has been reviewed and received ethics clearance through the Research Ethics Board at OCAD University (File #). If you have any comments or concerns, please contact the Research Ethics Office through ___________.

Would you be interested in sharing your ideas, knowledge and lived experience by contributing to this study?

If yes – Great! Would you be available to attend a session on [Insert dates of codesign session: February-April 2023] in person or online?

If no – I understand. Thank you so much for your consideration. Have a good day.

If undecided – Could I follow-up with you in a few days? Great. Have a good day.

11.3 Email script for usability testing session

Hello [Insert name],

I hope this email finds you well.

This is [Insert name] from OCAD University inviting you to participate in your choice of an online or in-person usability testing session as part of a research study. The study is led by ___________, Principal Investigator, ___________, OCAD University, as part of a joint Accessibility Standards Canada (ASC)-Ontario Tech University and OCAD University project on accessible and inclusive virtual and blended Information and Communication Technologies Service Provision Models (ICT SPMs) in post-COVID-19 Canada.

The purpose of the **usability testing session** is to evaluate prototypes that have been previously designed to investigate and address the significant needs for remote ICT platforms for diverse audiences in a remote learning or working context. Your knowledge and lived experience will help contribute to this study.

In this usability testing session, you will test the forms and functions of new, collaboratively designed ICT platform prototypes to evaluate how well they address your accessibility-related needs in your work or learning environment. We will ask you to verbalize your actions and decisions as you make them while completing simple tasks and activities with the prototypes. Following this activity, you will then be asked to complete a standardized Google Forms survey on usability, performance, and perceived system effectiveness.

Study details and logistics:

- Duration: 1-1.5 hours
- Date: [Insert date of usability testing session]
- Location: [Insert physical hosting location] or [Online password-protected video conference - Insert link to meeting room]

Your participation in this study is completely voluntary and you may choose to stop participating at any time. Your decision to stop participating will not affect the nature of your relationship with [Option 1: the Canadian National Institute for the Blind (CNIB)] [Option 2: the Cognitive Science Society] either now, or in the future.

Possible benefits of participation may be that you find it beneficial to share your lived experience in order to contribute to research on developing accessible remote ICT services.

We do not foresee any risks or discomfort from your participation in the research. We do not foresee any risks or discomfort from your participation in the research. However, digital prototyping in the codesign session may involve testing virtual reality headsets. If you have any concerns about discomfort, we would be happy to discuss the process and mitigation strategies in more detail with you. Please contact, Co-Investigator, ___________ (___________).

If you have any questions about this study or require further information, please ask. If you have questions later about the research, you may contact the Co-Investigator, ___________ (___________), or the Principal Investigator, ___________ (___________). This study has been reviewed and received ethics clearance through the Research Ethics Board at OCAD University (File #). If you have any comments or concerns, please contact the Research Ethics Office through ___________.

Would you be interested in sharing your ideas, knowledge and lived experience by contributing to this study?

If yes – Great! Would you be available to attend a session on [Insert date of interview/focus group] in person or online?

If no – I understand. Thank you so much for your consideration. Have a good day.

If undecided – Could I follow-up with you in a few days? Great. Have a good day.

12. APPENDIX D: INFORMED CONSENT FORM FOR NARRATIVE INQUIRY / SEMI-STRUCTURED INTERVIEW PARTICIPANTS

Date:

Project Title: A Study of Accessible and Inclusive Virtual and Blended Information and Communication Technologies (ICTs) for the Federal Public Service and Federally Regulated Industries in post-COVID-19 Canada

Principal Investigator:	Co-Investigator:
Co-Investigator:	Co-Investigator:

12.1 PURPOSE

12.1.1 Background/problem:

This study aims to investigate and address the significant needs for accessible and inclusive delivery of virtual and blended information and communication technology (hereafter referred to as "ICTs") service provision models, such as video conferencing, for the sight loss community. For this audience, using ICT platforms in a working or learning environment brings with it many challenges and benefits in regard to accessibility. There is a clear need to develop an understanding of the constraints in ICT platforms that determine whether certain representations are appropriate choices for diverse audiences.

12.1.2 Objectives/challenges:

- Discovery of participants' preferred platforms
- Gain insights on existing accessibility challenges with ICT platforms
    - What are participants' needs?
    - How are these needs failing to be met?

    - How might new ICT platforms meet them?

- Record accounts of lived experiences with ICT platforms that resulted in adaptations and / or failures in accommodation
- Discovery of participants' preferences for materials to co-design prototypes in the next phase of the study

12.1.3 Research questions:

1. How might we develop recommendations for ICT platforms for individuals with sight loss?
2. How might we support agency of ICT platform users with sight loss to inform these recommendations?

12.2 WHAT'S INVOLVED

Participation entails: 1 - 1.5 hour one-on-one interview online, using Online password-protected video conferencing, which will be audio/video-recorded with your permission.

12.3 POTENTIAL BENEFITS

You may find it beneficial to share your lived experience in order to contribute to research on developing ICT platforms.

12.4 POTENTIAL RISKS

We do not foresee any risks or discomfort from your participation in the research. If you have any concerns about discomfort, we would be happy to discuss the process and mitigation strategies in more detail with you. Please contact, Co-Investigator, ____________ (____________).

12.5 CONFIDENTIALITY

All information you provide during the research activities will be held in confidence, unless you specifically indicate your consent, your name will not appear in any report or publication of the research (See "**Attribution in study reports and publications**" below). All collected data from interviews, recordings, consent forms, personal information will be confidential. Your data will be safely stored on a password protected drive and only accessed by the project team. Confidentiality will be provided to the fullest extent possible by law.

12.5.1 Audio- or video-recording:

Interviews will be videotaped and audiotaped. Any identifying information in the video recordings or transcripts will be kept confidential. Please note that participants may be referred to by name in video recordings. This will be necessary so as to connect their responses to the data collected about them.

Data collected during this study, including written records from the researcher, video/audio recordings, transcripts and any other artifacts will be kept on the OCADU OneDrive, which will be encrypted and password protected.

Data will be kept for 2 years after study completion, after which time these will be securely disposed after the project is complete. Printed notes and forms will be shredded and digital files will be securely disposed, using a secure erase application.

Access to this data will be restricted to the project team.

12.6 VOLUNTARY PARTICIPATION

Participation in this study is voluntary. If you wish, you may decline to answer any questions or participate in any component of the study.

Further, you may decide to withdraw from this study at any time, or request withdrawal of your data prior to data analysis and you may do so without any penalty or loss of benefits to which you are entitled. Your choice of whether or not to participate will not influence your future relations with OCAD University, the Canadian National Institute for the Blind (CNIB), or the investigators involved in the research.

To withdraw from this study, let the co-investigator know at any point during the study by contacting ____________ via email at ____________.

To withdraw your data from the study, please contact ____________ via email at ____________ at any point without any consequence.

12.7 PUBLICATION OF RESULTS

Results of this study may be published in the OCAD University Open Research Repository. Potential other publication venues may include: professional and scholarly journals, and/or presentations to conferences and colloquia. Quotations from interviews or surveys will be published under a pseudo-identity and will not be attributed to you without your permission (See "**Attribution in study reports and publications**" below).

12.8 CONTACT INFORMATION AND ETHICS CLEARANCE

If you have any questions about this study or require further information, please ask. If you have questions later about the research, you may contact the Co-Investigator, ____________., or the Faculty Supervisor, ____________., using the contact information provided above. This study has been reviewed and received ethics clearance through the Research Ethics Board at OCAD University [REB #:].

If you have questions regarding your rights as a participant in this study please contact:

Research Ethics Board c/o Office of the Vice President, Research and Innovation

12.9 AGREEMENT

I agree to participate in this study described above. I have made this decision based on the information I have read in the Informed Consent Letter. I have had the opportunity to receive any additional details I wanted about the study and understand that I may ask questions in the future. I understand that I may withdraw this consent at any time.

Name: ________________________

Signature: ________________________ Date: ________________________

12.9.1 Audio- or video- recording

☐ I agree to be [audio-/video-recorded] for the purposes of this study. I understand how these recordings will be stored and destroyed.

_________________________________ ________________

Signature of Participant Date

12.9.2 Attribution in study reports and publications

☐ I agree to the attribution of my contributions to this study by name in future reports and publications produced by the outcomes of the study.

_________________________________ ________________

Signature of Participant Date

Thank you for your assistance in this project. Please keep a copy of this form for your records.

13. APPENDIX E: INFORMED CONSENT FORM FOR CO-DESIGN WORKSHOP PARTICIPANTS

Date:

Project Title: A Study of Accessible and Inclusive Virtual and Blended Information and Communication Technologies (ICTs) for the Federal Public Service and Federally Regulated Industries in post-COVID-19 Canada

Faculty Supervisor:	Co-Investigator:
Co-Investigator:	Co-Investigator:

13.1 PURPOSE

13.1.1 Background/problem:

This study aims to investigate and address the significant needs for accessible and inclusive delivery of virtual and blended information and communication technology (hereafter referred to as "ICTs"), such as video conferencing, for the sight loss community. For this audience, using ICT platforms in a working or learning environment brings with it many challenges and benefits in regard to accessibility. There is a clear need to develop an understanding of the constraints in ICT platforms that determine whether certain representations are appropriate choices for diverse audiences.

13.1.2 Objectives/challenges:

- Collaboratively translate insights from participants' lived experiences of accessibility challenges and adaptations of ICT platforms into low-to-mid-fidelity ICT platform prototypes
- Describe, discuss, and iterate on new ideas for ICT platforms with participants that meet their needs

13.1.3 Research questions:

1. How might we develop recommendations for ICT platforms for individuals who are neurodiverse and individuals with sensory disabilities?

2. How might we support agency of diverse ICT platform users to inform these recommendations?

Participation entails: 3 hours long, conducted with the other participants for this co-design session and facilitators with subject matter expertise. These sessions will take place either in-person at Ontario Tech University's Software & Informatics Research Centre, or through a video conferencing platform, which will be audio/video-recorded with your permission. In this codesign session, you will be asked to discuss ICT platforms and / or common tasks that you use them for, and build one or more low-fidelity prototype(s) that reflect(s) your experiences with them. Then, you will shape the form and functions of new types of ICT platforms, in collaboration with facilitators and possibly other co-design session participants, to best match your needs, and share ideas among the group

13.2 POTENTIAL BENEFITS

You may find it beneficial to share your lived experience in order to contribute to research on developing ICT platforms.

13.3 POTENTIAL RISKS

We do not foresee any risks or discomfort from your participation in the research. If you have any concerns about discomfort, we would be happy to discuss the process and mitigation strategies in more detail with you. Please contact, Co-Investigator, ____________. (____________.).

13.4 CONFIDENTIALITY

All information you provide during the research activities will be held in confidence, unless you specifically indicate your consent, your name will not appear in any report or publication of the research (See "**Attribution in study reports and publications**" below). All collected data from co-design activities, recordings, consent forms, and personal information will be confidential. Your data will be safely stored on a password protected drive and only accessed by the project team. Confidentiality will be provided to the fullest extent possible by law.

13.4.1 Audio- or video-recording:

Co-design sessions will be videotaped and audiotaped. Any identifying information in the video recordings or transcripts will be kept confidential. Please note that participants may be referred to by name in video recordings. This will be necessary so as to connect their responses to the data collected about them.

Data collected during this study, including written records from the researcher, video/audio recordings, transcripts and any other artifacts will be kept on the OCADU OneDrive, which will be encrypted and password protected.

Data will be kept for 2 years after study completion, after which time these will be securely disposed after the project is complete. Printed notes and forms will be shredded and digital files will be securely disposed, using a secure erase application.

Access to this data will be restricted to the project team.

13.5 VOLUNTARY PARTICIPATION

Participation in this study is voluntary. If you wish, you may decline to answer any questions or participate in any component of the study.

Further, you may decide to withdraw from this study at any time, or request withdrawal of your data prior to data analysis and you may do so without any penalty or loss of benefits to which you are entitled. Your choice of whether or not to participate will not influence your future relations with OCAD University, the Canadian National Institute for the Blind (CNIB), or the investigators involved in the research.

To withdraw from this study, let the co-investigator know at any point during the study by contacting ____________ via email at ____________.

To withdraw your data from the study, please contact ____________ via email at ____________ at any point without any consequence.

13.6 PUBLICATION OF RESULTS

Results of this study may be published in the OCAD University Open Research Repository. Potential other publication venues may include: professional and scholarly journals, and/or presentations to conferences and colloquia. Quotations from interviews or surveys will be published under a pseudo-identity and will not be attributed to you without your permission (See "**Attribution in study reports and publications**" below).

13.7 CONTACT INFORMATION AND ETHICS CLEARANCE

If you have any questions about this study or require further information, please ask. If you have questions later about the research, you may contact the Co-Investigator, ____________, or the Faculty Supervisor, ____________., using the contact information provided above. This study has been reviewed and received ethics clearance through the Research Ethics Board at OCAD University [File #____________].

If you have questions regarding your rights as a participant in this study please contact:

Research Ethics Board c/o Office of the Vice President, Research and Innovation

13.8 AGREEMENT

I agree to participate in this study described above. I have made this decision based on the information I have read in the Informed Consent Letter. I have had the opportunity to receive any additional details I wanted about the study and understand that I may ask questions in the future. I understand that I may withdraw this consent at any time.

Name: _______________________

Signature: _______________________ Date: _______________________

13.8.1 Audio- or video- recording

☐ I agree to be [audio-/video-recorded] for the purposes of this study. I understand how these recordings will be stored and destroyed.

________________________________ _______________

Signature of Participant Date

13.8.2 Attribution in study reports and publications

☐ I agree to the attribution of my contributions to this study by name in future reports and publications produced by the outcomes of the study.

________________________________ _______________

Signature of Participant Date

Thank you for your assistance in this project. Please keep a copy of this form for your records.

14. APPENDIX F: ICT FUNCTIONAL USABILITY TESTING SCREENING SURVEY

14.1 ASC ICT Pre-Screening and Schedule

If this form successfully submits, then you have been approved to take part in the study.

*14.1.1 Email**

*14.1.2 Full Name**

Please select a session time slot that works for you. You are expected to show up for the in person testing at this date and time. The testing location is [CNIB Community Hub Address].

If the Google form fails to submit, it is because the timeslot is now unavailable. So please try refreshing the page or selecting another timeslot.

*14.1.3 A session is 1.5 hours in length. **

*14.1.4 Optional: Would you like to disclose a disability you have?**

Visual Impa

Hearing Im

Autism Spe

Learning di

Physical dis

I don't want

Other…

*14.1.5 Which mobile operating system do you prefer? **

Google And

Apple iOS

*14.1.6 What desktop operating system do you prefer?**

Microsoft W

Apple MacC

*14.1.7 Rank the communication technologies you have the most experience with.**

	Most experience	Some experience	Least experience
Microsoft Teams	O	O	O
Google Meets	O	O	O
Zoom	O	O	O

14.1.8 List the assistive technologies you use to access digital content including information communication technologies such as Zoom or Google Meets.

- JAWs
- NVDA
- Magnifier
- VoiceOver
- Talkback
- ZoomText
- Fusion
- Narrator

Other...

14.1.9 What size mouse pointer do you use?

- Default
- 150% large
- 200% large
- 250% large
- 300% large

14.1.10 If screen reader is used, what is your preferred speech rate?

Slowest									*Fastest*
1	2	3	4	5	6	7	8	9	10
O	O	O	O	O	O	O	O	O	O

14.1.11 Do you have any colour correction settings on your personal device?

[ ]

14.1.12 What is your preferred screen font size?

< Default

Default

1 - 50% larg

50 - 100% l

100 - 200%

> 200%

14.1.13 What is your preferred internet browser?*

Google Chr

Microsoft Ed

Apple Safar

Mozilla Fire

Opera

Other…

14.1.14 Are there any other considerations or settings that you require?

[ ]

15. APPENDIX G: ICT FUNCTIONAL USABILITY TESTING DATA COLLECTION QUESTIONNAIRE

15.1 Introduction

15.1.1 Testers email address for gift card.

[ ]

15.1.2 Optional: Does the user want to disclose a disability that they have?

- Visual Impairment
- Hearing Impairment
- Autism Sectrum

- ○ Learning Disability
- ○ Physical Disability
- ○ Does not have a disability
- ○ Did not want to answer
- ○ Other:

15.1.3 First tested ICT Platform.

- ○ Microsoft Team
- ○ Zoom
- ○ Google Meets

15.1.4 First tested ICT Platform device.

- ○ Windows
- ○ MacOS
- ○ Android
- ○ iOS

15.1.5 Assistive technologies used for the first ICT

- ☐ JAWs
- ☐ NVDA
- ☐ Magnifier
- ☐ VoiceOver
- ☐ Talkback
- ☐ ZoomText
- ☐ Fusion
- ☐ Narrator
- ☐ Other:

15.1.6 Second tested ICT Platform.

- ○ Microsoft Team
- ○ Zoom

- ○ Google Meets

15.1.7 Second tested ICT Platform device.

- ○ Windows
- ○ MacOS
- ○ Android
- ○ iOS

15.1.8 Assistive technologies used for the second ICT

- ☐ JAWs
- ☐ NVDA
- ☐ Magnifier
- ☐ VoiceOver
- ☐ Talkback
- ☐ ZoomText
- ☐ Fusion
- ☐ Narrator
- ☐ Other:

15.2 Platform # testing – Task #

15.2.1 Did you complete the task?

- ○ Yes
- ○ No

15.2.2 It was easy to complete the task

- ○ 1 (strongly disagree)
- ○ 2
- ○ 3
- ○ 4
- ○ 5 (strongly agree)

15.2.3 It was quick to complete the task

- 1 (strongly disagree)
- 2
- 3
- 4
- 5 (strongly agree)

15.2.4 It was challenging to complete the task

- 1 (strongly disagree)
- 2
- 3
- 4
- 5 (strongly agree)

15.2.5 Please, describe the steps you had to take to complete this task and highlight any challenges.

9.