Breaking Badge: Augmenting Communication with Wearable AAC Smartbadges and Displays

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ABSTRACT

People living with complex communication needs employ multimodal pathways to communicate including: limited speech, paralinguistics, non-verbal communication and leveraging low-tech devices. However, most augmentative and alternative communication (AAC) interventions undermine end-users' agency by obstructing these intuitive communication pathways. In this paper, we collaborate with 19 people living with the language impairment aphasia exploring contextual communication challenges, before low-fidelity prototyping and wireframing wearable AAC displays. These activities culminated in two low-input wearable AAC prototypes that instead, scaffold users' pre-existing communication abilities. Firstly, the *InkTalker* is a low-power and affordable eInk AAC smartbadge designed to discreetly reveal invisible disabilities and usable as a communication prop. Secondly, *WalkieTalkie* is a scalable AAC app that converts smartphones into a feature-rich public display operable via multimodal input/outputs. We offer results from communication interactions with both devices, discussions and feedback responses. Participants used both AAC devices to interdependently socialise with others and augment pre-existing communication abilities.

CCS CONCEPTS

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

KEYWORDS

AAC, Alternative and Augmentative Communication, Accessibility, Discreet and Wearable Devices, Smart badges

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1 INTRODUCTION

People with complex communication needs (CCN) can use augmentative and alternative communication (AAC) systems and devices to support their evolving communication abilities [39, 57]. The need for AAC will likely increase as people living with CCN become more common due to increased incidence of disability and an ageing global population increasing likelihood of stroke [13, 51, 52]. Most commonly, AAC device input includes mechanical (i.e., buttons), tactile (i.e., capacitive touchscreen), eye-gaze and brain-computer interfaces (BCIs), for audio output with the device generating dialogue-aloud using a synthetic voice [17, 26, 89]. Although critical for non-verbal people living with CCN, the interaction design of mainstream AAC technology often fails to *embrace* and *enhance* minimally verbal users' pre-existing communication strengths [42].

Specifically, AAC devices typically detract from users' intuitive and faster multimodal communication pathways such as the use of: natural voice (i.e., paralinguistics) [65], access to generative language through natural speech building blocks [90, 91], non-verbal communication (i.e., gestures, facial expression, body-language, appearance) [41] and total communication[1] [78]. Consequently, *many* pre-existing AAC technologies face low rates of long-term adoption across many communities [65, 98] and high rates of abandonment [6, 59]. Other identified problems with AAC interventions includes: slow communication rates [31, 65], restricted self-expression [98, 99], high learning demands [39], customisation difficulties [41, 42], limited agency [50, 54, 94] and social stigmas from prominent form-factors [18].

In light of this, Bircanin et al. [6], has advocated for more low-tech AAC interventions and Pullin [76] has called for greater interdisciplinary AAC research to improve AAC expression and interaction possibilities. Therefore, in this paper, we present the first contribution to explore badge form-factors to support CCN. Specifically, we co-design directly with communities living with CCN. The design of two wearable AAC prototypes take a strengths-based approach, by augmenting and scaffolding the pre-existing communication abilities of people living with the language impairment aphasia. Inspired by prior reported work, we use methods to build a comprehensive notion of technology-supported communication, which seeks not just to support verbal output but also enhance wider total communication strategies [18]. Overall, we:

[1]Subtle natural cues in body language, eye gaze, facial expression and the usage of props (e.g., drawing) to augment verbal speech and enrich overall self-expression have been termed total communication (i.e., leveraging all natural pathways beyond purely verbal speech) [78].

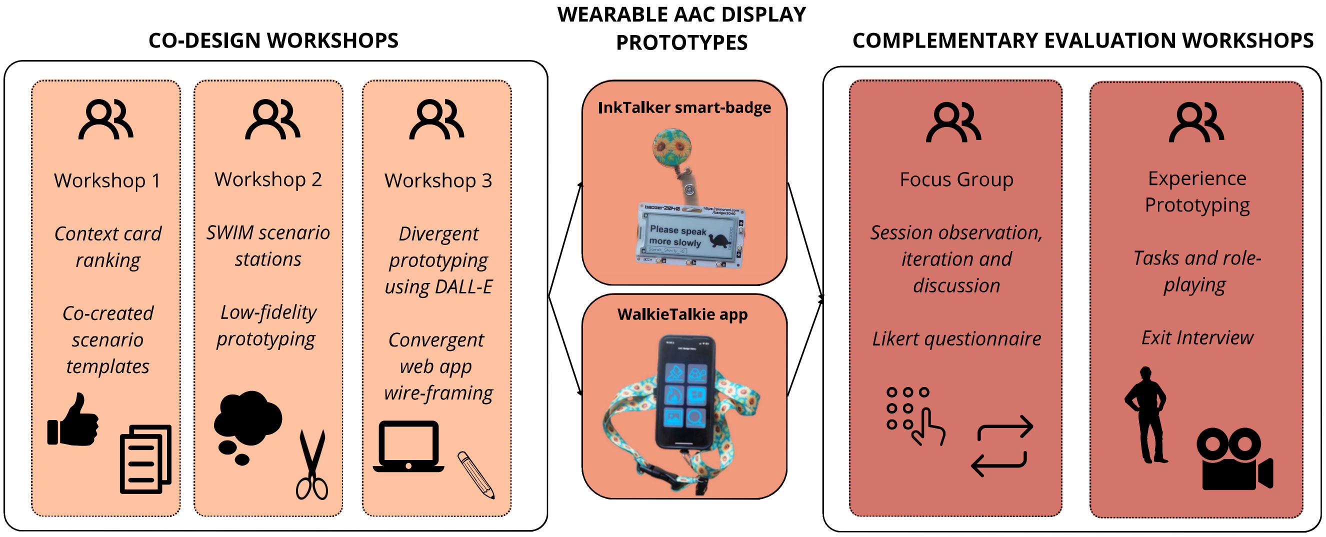

Figure 1: Research chronology: starting with three co-design workshops described in Section 3 and their results presented in Section 4. Supporting the development of two outward AAC prototypes: the *Walkie Talkie* app and *InkTalker* smartbadge outlined in Section 5. Followed by complementary evaluation of both AAC prototypes in Section 6.

(1) Co-design two low-input[2] wearable AAC prototypes in collaboration with communities with CCN, specialists and stakeholders: speech and language therapists (SLTs) and people living with aphasia.
(2) Provide insights from three co-design sessions with people with aphasia, which established challenging communication scenarios, supported tangible low-fidelity prototyping and divergent/convergent wireframing.
(3) Report results from an initial evaluation of two wearable AAC displays from focus group discussion, questionnaires, experience prototyping and interviews.
(4) Provide guidance on the accessible co-design of low-input wearable AAC displays and an evaluation of the methods and co-design techniques used within this research.

2 RELATED WORK

2.1 Aphasia and AAC Interventions

Aphasia is an acquired language impairment most commonly caused by stroke and other forms of damage to the language centers of the brain. It can affect reading, writing, speech and comprehension but intelligence remains unaffected [1, 5, 19]. However, the communication abilities of people living with aphasia vary significantly e.g., some may find speaking more challenging than writing or vice versa [5]. Equally, people living with aphasia can have hemiplegic paralysis on one side of their body, which limits dexterity [5]. The number of people living with aphasia is expected to increase due to ageing global populations increasing the likelihood of stroke [5, 13]. Yet, people with CCN like aphasia face barriers to accessing relevant support e.g., therapy for language rehabilitation as health systems face increased service demands [9, 40]. Additionally, people with aphasia's communication abilities can vary dependent on levels of fatigue [11], emotions (e.g., confidence) [2] and the context (e.g., communicating with strangers) [15, 68]. Due to these highly contextualised factors, it is ultimately challenging to provide long-term AAC interventions for people living with aphasia [17, 95]. Unlike dedicated AAC hardware and devices – downloadable software, tablet and smartphone apps have been posited as a less invasive and *more* accessible AAC intervention [66]. Key benefits of AAC software/apps include that they are: usually cheaper than dedicated AAC devices, more portable, highly scalable [18, 55] and consequently limit public stigmas [29, 67]. However, AAC apps still suffer from shortcomings, Faucett et al. [29] argue that apps may downplay the significance of people with aphasia's underlying disability in public spaces. Additionally, the form-factor of tablet-based AAC apps are a burden to physically carry for many living with both aphasia and hemiplegia [16, 18]. Instead, AAC devices should be designed to maximise social engagement and agency – supporting users ability to communicate and engage in fulfilling social activities in communal environments (e.g., public transport, gyms etc.). Within these public domains, communication with strangers can be very pressurising for people with aphasia as unfamiliar strangers regularly fail to recognise their underlying invisible disability and use inclusive communication practices [68]. Meanwhile, pre-existing AAC apps on tablets can be difficult for people with aphasia to socially regulate their stigmatising and prominent form-factors [6, 18].

Using AAC devices to support communication is often prohibitively slow – AAC users must navigate pages of symbol sets to transcribe messages during face-to-face conversation [6, 18] resulting in potentially unfulfilling and sender-receiver styles of communication [41]. In response, prior work by Kane et al. [45] amongst

[2]Both devices require limited user-input (even no input) versus mainstream tablet AAC apps and afford wearable form-factors supporting diverse body placements.

people living with aphasia, co-designed an app called *TalkAbout* which increased communication speeds via harnessing the context (i.e., communication partner and location) to filter to the most situationally relevant words. However, this AAC intervention equally did *not* look to supportively scaffold people with aphasia's pre-existing minimally verbal, non-verbal and total communication abilities (i.e., body language, proxemics, haptics, gesture, facial expression and eyegaze). Elsewhere, ethnographic research by McCord and Soto [54] has alarmingly found AAC to be abandoned amongst Mexican-American families as AAC devices detrimentally *obfuscated* intuitive, culturally significant and primarily non-verbal communication pathways with close family members [78]. Thus, AAC interventions can undermine *more* embodied and naturally accessible pathways to communicate – deterring non-verbal styles of communication and tangible prop-usage which is *very* common amongst people with aphasia (e.g., drawing on paper/using physical props) [6, 41, 42, 63, 64]. Indeed, AAC devices do *not* inform unfamiliar communication partners of these preferred, *more* inclusive and accessible communication practices. Rather, the synthetically generated dialogue detrimentally replaces minimally verbal users natural voice [41] and *most* AAC apps are *not* co-designed with their community of focus [6, 58]. Consequently Ibrahim et al. [41, 42], correctly assert that AAC devices should be more socially regulatable and support a diversified set of interactions for their user dependent on context and communication partner.

2.2 Wearable Displays and Badges

Wearable displays are a category of technology that can express publicly viewable information to co-located people [38]. Initially, Heller et al. [38] provide useful design guidelines for wearable displays with their taxonomy but Zeagler et al. [104] provide focused insights for designing accessible wearable displays [103] – developing body-maps to illustrate the *comfort* and *wearability* of device placement with optimal positioning for: bodily proxemics [35], weight distribution [104], visible feedback [37] and social acceptability [25]. Certainly, this research informs the design of wearable displays that maximise wearer comfort. However, wearable displays can *also* be used to support face-to-face interactions and potentially co-created communication [3, 41]. Indeed, previous human-computer interaction (HCI) research has explored the potential of wearable displays for supporting social interactions. The BubbleBadge communicated environmental information to non-intrusively support face-to-face interactions [28]. Whilst, the CueSense augmented appearance to display socially relevant personal information serving as a ticket-to-talk during encounters with strangers [43]; significantly, CueSense participants self-reported that they found the prominent wearable mobile-LED display distracting and it made them feel *more* self-conscious [43]. This reciprocates previous findings on the importance of social-cultural norms for assistive and wearable technologies – *ideally* devices should enable discretion [18, 25, 29, 72–74, 85]. In contrast, AlterWear used a more discreet eInk display, which integrated into items of clothing to enhance social interaction and support self-expression [22]. Outside of HCI research, badges[3] and medical alert bracelets are widely used to promote accessibility for vulnerable groups and communities. For example, on public transport in the UK, pregnant persons can wear a *"Baby on board!"* badge [33] whilst older adults and people with disabilities can wear a *"Please offer me a seat"* badge [34] – these discreetly let other passengers know that the wearer could need extra support. Elsewhere, Pullin [76], described the design of a badge communication aid for an AAC-user called Somiya – who wanted to spontaneously express frustration [76]. Therefore the Electriwig design group built a head-switch activated badge that lights up with the words: *"Somiya says sod off"* to playfully express her personality [76]. Aside from this, electronic smart-badges to promote accessibility and support communication have received limited attention.

2.3 Invisible Disabilities and the Sunflower Lanyard

Invisible disabilities, also known as hidden disabilities or non-visible disabilities (NVDs), are disabilities that are *not* immediately visible but significantly impair the normal activities of daily living [20, 49]. Current estimates posit that approximately 1 in 10 people and 1 billion people worldwide live with an invisible disability [24]. Such is the prevalence of invisible disabilities the charity *Hidden Disabilities* offer wearable Sunflower-themed products – most notably a wearable lanyard – to *discreetly* make members of the public aware of the wearer's hidden disability [24]. The wearable lanyard can prompt *more* understanding and assistance from others in public spaces and social settings (e.g., offer seats on public transport) [36]. Of note, one of the most common invisible disabilities is aphasia [19] – affecting one-third of stroke survivors despite less than 10% of the wider general population recognising the condition [14].

2.4 Influential Co-Design Techniques

Accessibility scholarship has repeatedly emphasised the importance of integrating end-users and stakeholders within the design process as essential for developing technologies to support individuals with disabilities [66, 89]. However, co-designing with people with aphasia can be challenging as these communities experience difficulties with: communication, providing consent and cognitive fatigue [101]. To address these barriers, previous scholarship has developed *more* accessible co-design approaches that minimise language-based processes for people living with aphasia [64, 101]. Upholding a social model of disability, Wilson et al. [101] used these non-verbal and instead *more* tangible design languages to successfully co-design with communities of people living with aphasia. Recommended accessible activities include supporting people with aphasia's voice in design via short tasks and plenty of tangible prototyping [101]. Furthermore, they also recommend using the Someone Who Is not Me (SWIM) approach to better co-design for diverse aphasic language needs [62, 101]. Specifically, this encourages co-designers to think *more* broadly about technologies for a wider demographic of users living with aphasia. Other accessible co-design methods, include Raman and French [77] multi-method engagement techniques used during collaboration with young people with learning disabilities. Initially, they used tangible topic coasters to capture meaningful details from conversations about lived experiences (e.g., scenario setting, people involved and key issues). Then ideated solutions with co-designers using IDD-friendly scenario templates

[3]Historically, badges have been used to indicate accomplishments, accessorize, provide identification and more.

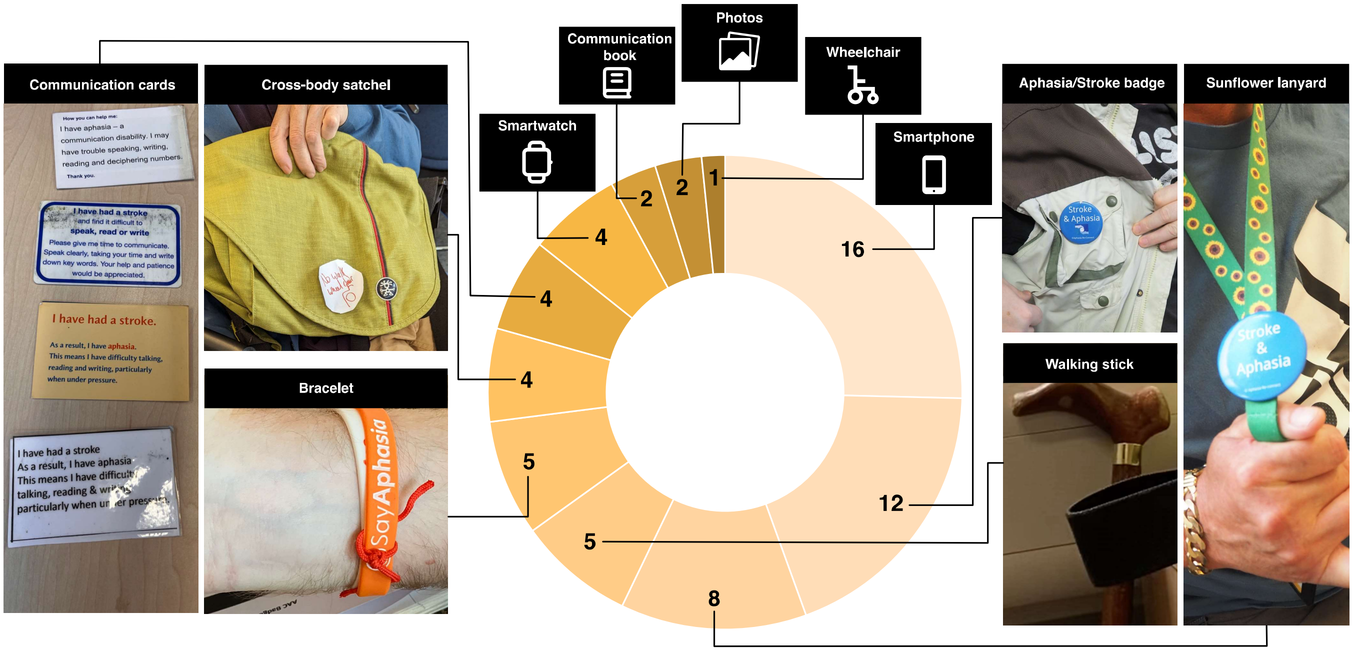

Figure 2: Summary of participants' daily assistive technologies brought to language therapy center and clinic.

– these tangible materials minimised conceptual demands and enabled meaningful participation [77].

3 CO-DESIGN OF WEARABLE AAC DISPLAYS

We began with three complementary co-design workshops with people with aphasia focused on ideation of wearable AAC displays for challenging communication scenarios. In co-design workshop one, we identified and co-created challenging communication scenarios. Co-design workshop two transitioned towards tangible wearable AAC prototyping using low-fidelity materials at scenario stations. Finally, co-design workshop three focused on divergent/convergent prototyping using AI-image generation, paper-prototyping and canvas web-application wireframing. Throughout, we prompted participants to explore wearable AAC display properties (i.e., size/weight), content (i.e., audience, information and temporality) and device placement (i.e., location, accessories, clothing and skin/body relations).

3.1 Procedure

Each co-design workshop lasted 1.5–2 hours. Throughout, we maximised accessibility by following guidelines from Mack et al. [53] – we operated in a familiar space, used accessible consent procedures, monitored needs and endorsed flexible participation. Ethical approval for this research was granted by the King's College London Health Faculties Research Ethics Subcommittee. Participants with aphasia were supported to access the information sheets and consented by SLTs. We provided a week to finalise their participation. The workshops used video/audio recordings to collect qualitative data and participants were asked if they wished to be identifiable in research outputs. All participants were paid 20 GBP per hour.

3.1.1 Research Environment. Participants were recruited from an aphasia charity. The Aphasia Re-Connect supports people with aphasia by providing community and group speech and language therapy. We conducted our research during the weekly face-to-face group drop-in at the Roberta Williams Speech and Language Therapy Clinic. These were familiar facilities – to avoid burdening participants with travel costs to a central research site.

3.2 Participants

In total, 15 people with aphasia participated in co-design workshops. Language abilities ranged from mild–severe as a result of stroke and six had right-side paralysis onset from hemiplegia. Ages ranged from 51–82 years old. Three SLTs supported the co-design workshops and their experience working with people living with aphasia ranged from 1–40 years. Complete participant information is presented in 1 and 2 (i.e., *CD* in attendance columns). All participants were six months post-stroke and had spoken English fluently prior to their stroke. In Figure 2, we present an analysis of participants' daily assistive technologies.

3.3 Data Analysis

The co-design workshops were analysed through structured observation of the video data, transcribed and organised using NVivo 14. Afterwards, we applied inductive Thematic Analysis – an iterative process whereby all qualitative data is restructured into themes [7, 8]. In line with Braun and Clarke's original interpretation, the coding process was initially carried out by solely the first author [7, 8], before all authors collaboratively refined themes to mitigate individual bias. We coded 387 instances of statements and discussion relevant to this research. For co-design workshop

Table 1: Overview of nineteen participants with aphasia across: co-design workshops, focus group and experience prototyping workshop. Assessed by an SLT are participants' aphasia, speaking, reading, hearing, and writing – scaled: Mild, Moderate and Severe; plus participants' hemiplegia. Participants names are pseudonyms.

PWA (Gender - Age)	Aphasia	Attendance	Difficulties
Mary (F - 74)	Moderate	CD1, CD3, FG	*Speaking: Mild / Reading: Moderate / Writing: Moderate / Physical: Hemiplegia*
Philip (M - 73)	Moderate	CD1, CD2	*Speaking: Moderate / Reading: Moderate / Writing: Moderate*
Elias (M - 80)	Severe	CD1	*Speaking: Severe / Reading: Moderate / Writing: Severe*
Kai (M - 67)	Moderate	CD1, CD2, CD3	*Speaking: Moderate / Reading: Severe / Writing: Severe*
Bruce (M - 57)	Moderate	CD1, CD2, CD3, EPW	*Speaking: Moderate / Reading: Severe / Writing: Moderate / Physical: Hemiplegia*
Arthur (M - 65)	Severe	CD1, CD2, FG, EPW	*Speaking: Severe / Reading: Severe / Writing: Severe / Physical: Hemiplegia*
Jade (F - 53)	Severe	CD1, CD2, FG	*Speaking: Severe / Reading Severe / Writing: Severe / Physical: Hemiplegia*
Hana (F - 61)	Severe	CD1, CD2, FG, EPW	*Speaking: Moderate / Reading: Severe / Writing: Severe / Physical: Hemiplegia*
Rowan (M - 51)	Moderate	CD1, CD2, CD3, FG, EPW	*Speaking: Moderate / Reading: Moderate / Writing: Severe*
Immanuel (M - 69)	Moderate	CD1, CD3, FG, EPW	*Speaking: Moderate / Reading: Mild / Writing: Moderate*
Emily (F - 70)	Severe	CD2	*Speaking: Severe / Reading: Severe / Writing: Severe*
Jacob (M - 69)	Moderate	CD2	*Speaking: Moderate / Reading: Mild / Writing: Mild*
Julia (F - 51)	Severe	CD2	*Speaking: Severe / Reading: Severe / Writing: Severe / Physical: Hemiplegia*
Olga (F - 82)	Moderate	CD2	*Speaking: Moderate / Reading: Moderate / Writing: Moderate*
Gabriel (M - 64)	Mild	CD3, FG	*Speaking: Mild / Reading: Mild / Writing: Mild / Physical: Hemiplegia*
Michael (M - 48)	Moderate	FG	*Speaking: Moderate / Reading: Mild / Writing: Mild*
Peter (M - 49)	Moderate	FG	*Speaking: Severe / Reading: Moderate / Writing: Moderate*
Yasmin (F - 61)	Moderate	FG	*Speaking: Moderate / Reading: Severe / Writing: Severe*
Janet (F - 72)	Mild	FG	*Speaking: Mild / Reading: Moderate / Writing: Severe*

Table 2: Overview of five SLT participants. Role refers to SLTs professional experience spent working with people with aphasia who supported participation. Participants names are pseudonyms.

Participants (Gender)	Attendance	Role
Sarah (F)	CD1, CD2, CD3, FG	SLT – 40 years
Victoria (F)	CD3, FG, EPW	SLT – 3 years
Eva (F)	CD1	SLT – 1 year
Sabrina (F)	FG	SLT – 5 years
Basheera (F)	FG	SLT – 1 year

PWA: People with aphasia EPW: Experience prototyping workshop CD: Co-designer FG: Focus group
SLT: Speech and language therapist M: Male F: Female NB: Non-Binary N/S: Not Specified

one, we analysed participants' reflections and their co-created scenario templates of challenging communication contexts. For co-design workshop two participants' low-fidelity AAC prototypes are categorised and analysed. Finally, for co-design workshop three, participants' AAC badge prototypes and discussions are evaluated.

3.4 Co-design Workshop One: Identifying Hard Communication Scenarios

Co-design workshop one explored participants' daily communication experiences in different locations [68]. Initially, we wanted participants to identify locations as 'hard' for their personal communication needs. Then explore participants' challenging communication experiences within those locations. At all times, co-designers had access to a pen/paper and a trained SLT to support their self-expression.

3.4.1 Location Card Ranking. In the first workshop activity, our co-designers openly discussed and collectively ranked 20 tangible location cards (i.e., Figure 3). The purpose of the activity was to encourage our co-designers to freely share stories about their unique communication experiences with different communication partners across a variety of locations. Using shuffled decks, participants spontaneously shared communication stories when prompted by a card and researchers supported reflection by probing for further meaningful details. Throughout, the tangible location card provided co-designers with an affordance to support their personal narratives [101]. Each card was presented in both visual/text format showing different social locations (e.g., supermarket/hospital). These locations were initially derived from Parr's ethnographic data tracking the lives of people with aphasia with additional locations added by participants using blank context cards [68]. Once the entire deck had been thoroughly discussed, co-designers then ranked cards on a scale of *Easy–Hard* for their communication abilities. The activity finished with consensus reached after 30 minutes.

3.4.2 Abstract and Concrete Scenario Templates. The second workshop activity transitioned to more structured and deliberate discussion concerning the specific location cards ranked as 'hard' for communication in the first activity. Influenced by Raman and French [77], aphasia-friendly scenario templates (i.e., Figure 3) enriched overall discussion and improved participants' reflections on lived experiences of challenging communication locations. Figure 3's, scenario templates structured researchers' questioning along two dimensions from 5Ws/1H vertically (i.e., what, why, when, where, who and how) and horizontally from concrete to abstract questioning. Concrete questioning probed participants about deliberate tangible characteristics of their challenging experiences (e.g., *"Time of day?"*) [30]; whilst, abstract questioning honed on *more* emotive/generalizable insights [30] (e.g., *"How did you feel before/after?"*). The interplay of questioning styles, established a deeper understanding of participants challenging communication experiences [30]. After approximately 60 minutes, the activity finished with 5–6 scenario templates successfully completed.

3.5 Co-design Workshop Two: Low-Fidelity Prototyping at SWIM Scenario Stations

Using insights gathered from workshop one's challenging communication scenario templates, we developed six scenario stations. At each scenario station, participants prototyped a high-volume of low-fidelity wearable AAC displays to support communication thus ideating novel solutions for each SWIM design-brief.

3.5.1 SWIM Scenario Stations. We deployed six scenario stations with low-fidelity prototyping materials. Each scenario station provided a design-brief: an imagined SWIM (someone who is not me) person living with aphasia [62, 101], details of their communication challenges and a concrete contextual image we generated using DALL-E text-to-image prompts[4]. The scenario stations were *directly* based on co-design workshop one's insights – specifically, we used participants recorded reflections on 'hard' communication locations from the scenario templates activity – to make the SWIM design-briefs. Meanwhile, SWIM techniques established a broader constituency, which is critical given the greatly varied language abilities of people living with aphasia [101]. The six challenging communication scenario stations, which participants prototyped at were: (1) bus commutes (i.e., Figure 3), (2) evening party group conversations, (3) busy cafe coffee ordering, (4) an unhelpful friend in a restaurant, (5) asking for directions at a hospital reception and (6) finding supermarket goods with a shop clerk.

3.5.2 Low-fidelity Prototyping. At each scenario station, participants were given approximately 15 minutes to prototype a high-volume of wearable AAC displays with low-fidelity materials and fabricate solutions for each SWIM design-brief (i.e., Figure 3). Researchers oversaw fabrication and focused participants using Heller et al. [38] design guidelines i.e., focus on AAC display content or placement. Colourful craft materials (i.e., fabric/card/string etc.) let participants creatively design AAC of varying temporality and information density. Whilst, sticker paper supported diverse on-body placements. Collectively, participants discussed different wearable AAC display prototypes and their integration into personal clothing. To maximise accessibility, participants could prototype for themselves before considering the needs of the SWIM person with aphasia presented at each scenario station in the design-brief. Sometimes participants were assisted with SLTs/researchers performing dexterous building activities (e.g., cutting sticker paper) using closed 'yes/no' questioning (e.g., *"What colour could draw public attention?"*). Some participants felt *more* comfortable building in small groups with an SLT/researcher mediating discussions. After approximately 90 minutes, the low-fidelity building process finished with group demonstrations of all participants' AAC prototypes.

3.6 Co-design Workshop Three: Divergent–Convergent AAC Badge Prototyping for Personal CCN

Co-design workshop three focused on divergent and convergent prototyping of wearable AAC badges to support our co-designers

[4]DALL-E is a mainstream text-to-image model developed by Open AI using deep learning methodologies to generate digital images from natural language descriptions called "prompts" [69].

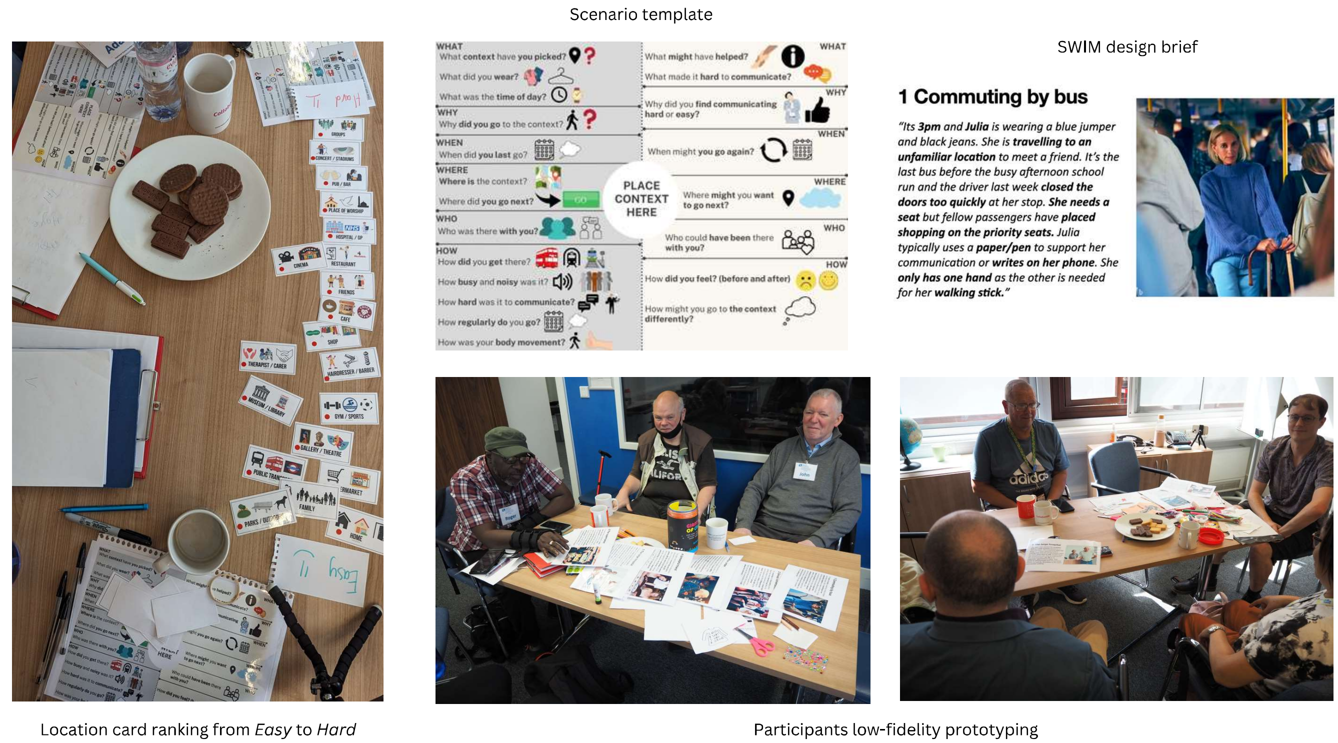

Figure 3: Images of co-design activities: ranking location cards, aphasia-friendly scenario template with abstract/concrete questioning, commuting by bus SWIM design-brief and participants low-fidelity prototyping. Participants gave permission to have photo shared.

varying personal CCN. Previously, Curtis et al. [18], have encouraged using divergent then convergent co-design approaches with people with aphasia. Initially, DALL-E text-to-image prompts supported creative risk-taking and a high-volume of divergent ideas. Then participants transitioned to convergent prototyping using paper materials and a canvas web-application with built-in design restrictions.

3.6.1 DALL-E Text-to-Image Prompts. Mitigating the pressures of on-the-spot creativity, we began with the divergent group activity of co-authoring DALL-E text-to-image prompts to generate images of wearable AAC badges for our co-designers varied CCN. For approximately, 40 minutes participants worked in small groups to co-author prompts generating multiple images of wearable AAC badges. After a round of generation, participants would review, rank the images of AAC badges and consider strengths/weaknesses. Throughout, mixed-method communication styles were supported with prompts written down on paper and explained by an SLT – ensuring all participants had equal input. Once the group had settled on a prompt, the researcher would input the prompt to generate imagery. During image generation, we encouraged group discussion around the badges similarities/differences, settings of usage, display and device properties (i.e., colour, shape, size, and body placements). Ideally, DALL-E image-generation supported creative risk-taking, removed fabrication pressures and allowed unrestrained critique of high-fidelity AI-generated outputs. We finished after the group was satisfied with their portfolio of designs.

3.6.2 Paper-Prototyping and Canvas Wireframing of Badges. Next, participants ideated wearable AAC badges using paper-prototyping materials and wireframed on a canvas web-application we built to design encodable images for eInk smart-badges. The co-design activity was deliberately *more* constrained. The paper-prototyping materials were *just* black pens, scissors and white sticker paper. Whilst, the web-app canvas had built-in eInk wireframing restrictions – only supporting black/white colouring, importing of basic symbols/images and restricted participants to a canvas size (i.e., 296mmx128mm). Participants began with paper-prototyping before wireframing using the canvas web application in solo/pairs with the assistance of a researcher on two laptops. For approximately 40 minutes, participants collaboratively designed different black/white displays – to support their CCN across different contexts.

4 RESULTS FROM CO-DESIGN WORKSHOPS

The complementary co-design workshops occurred one week apart. Results in Section 4.1 are drawn from thematic analysis of the transcripts and video footage of the co-design workshops. Section 4.2 discusses the low-fidelity AAC prototypes built by participants with aphasia in co-design workshop 2 – eight participant designs centred on wearable badge form-factors to support communication. Consequently, Section 4.3 presents outputs from divergent-convergent prototyping of AAC smart-badges in co-design workshop 3.

4.1 Thematic Analysis of Co-design Workshops

4.1.1 Theme 1: Ableism and discrimination is often experienced living with an invisible disability. This theme describes participants with aphasia's experiences in challenging social environments with an invisible disability. Crafted sub-themes are: (1) public social adversities from living with aphasia and (2) private anguish and internal traumas.

Ableist discrimination from strangers. Participants with aphasia reflected upon experiences of ableist discrimination due to the hidden nature of their disability. Initially, many co-designers encountered frequent difficulty finding seats on public transport and *even* public judgement whilst using priority seating. In other settings, co-designers reflected on prejudiced and patronising communication interactions with strangers: *"Mary: If you forget or stumble over a word! They talk to you like this [patronisingly]... Philip: They think you're drunk!"*. Frequently participants face the exasperation of explaining their aphasia due to its lack of public recognition.

Judgement and neglect from close friends and family members. Our participants revealed that close friends and family members overlook the severity of their disability – committing both microaggressions and making – often derogatory assumptions. In one example, ability-based assumptions are regularly made by participants' family members, *"Mary: I was thrilled walking up to the end of the road and I was helping myself! But to my family, I was lazy because they have had operations and could walk much farther than that!"*. Indeed, family and friends often policed participants' bodies, minimised their disability and assumed communication was easy. Indeed, Arthur noted that friends sometimes refused to acknowledge his needs – excluding him from meaningful conversations: *"Arthur: My friends... arguments and arguments as well but no talking [pointing at himself]! Researcher 2: [...] you'd want to join in? Arthur: Yeah! Yeah! Yeah!"*.

Ill-designed social environments for older adults with hidden disabilities. Many participants reflected on the fact that public spaces were ill-designed to support their needs. Public transport, hospitals, GPs, supermarkets, concerts, cinemas and pubs/bars were all identified as *not* stroke friendly. *"Researcher 2: Concerts and stadiums? Immanuel: Noisy!... Rowan: Hard! Jade: But its, its, my ears that's the problem! Arthur: And stairs them! Staging up! Rowan: You have to walk up high – stadiums are not easy to walk around!"*. Usually, communication difficulties arose due to excessive stairs, noise, crowds and unsympathetic service staff. Equally, businesses automating people-facing services – the loss of high street banks (i.e., online banking) and supermarket staff (i.e., self-checkouts) was considered *especially* frustrating.

The second sub-theme considers the private anguish and internal traumas faced by participants living with aphasia. Participants reflect on the emotional toll of *not* appearing outwardly disabled *enough* in public and consequent frustration with normalised communication expectations.

Masked feelings of anger, rage and fatigue. In many situations, participants recognised they masked feelings of anger at people *not* acknowledging the difficulty of living with aphasia – eventually termed by the group as 'stroke rage'. *"Kai: As far as the aphasia is concerned... everybody tells me that you've got no aphasia problem at all! I want to tell them no! Its difficult for me! I can't read or write."*. Elsewhere several commented on the frustration of bags occupying priority seats: *"Researcher 1: Does the cane help at all? Mary: [Nods head] But I use it as a weapon! I lift it up and think I'm threatening people with it! [Gestures with arms] For god sake, using priority seats! [...] On the tube! with there shopping on the seat!"*. Travel can be especially challenging when unexpectedly fatigued: *"Kai: I'm travelling quite a lot and sometimes I get tired very quickly.. so [...] I really need to sit down!"*.

Loneliness and depression from normalised communication practices. Persistent communication difficulties from aphasia manifest into feelings of disillusion and depression. Philip reflected on his long-term aphasia and heart arrhythmia's: *"Philip: It will never be like it was before! You don't know how much you rely on speech until you lose it!"*. Participants remarked on the immediate trauma of having a stroke and frustration with living with a permanent change to their bodies. In group-settings, many noted challenges following threads of conversation and difficulties communicating at *normalised* fast speeds: *"Rowan: You don't [follow group conversation] really! [...] Rowan: No! Let's say you're a bit... errr... you just listen and nod your head! Immanuel: The conversation will have moved on by then! [...] Researcher 2: How does it make you feel in general? Rowan: Lonely! Just lonely in general... you're not part of the group! Jade: Stressed! Hana: Yeah!"*.

4.1.2 Theme 2: Assistive devices and total communication practices enhance confidence and communication abilities. This theme considers adopted strategies that empower participants communication in their day-to-day lives. The sub-themes are: (1) assistive devices improve mutual understanding and (2) total communication practices facilitate access.

Walking sticks, lanyards and badges socially signify disability. In public domains, participants with aphasia use walking sticks, hidden disability lanyards and badges to signify their underlying disability and increase chances of community support. On the bus Mary is often offered a seat due to her prominent walking stick: *"Mary: I use this [holding up walking stick]... because otherwise people think that I'm alright... and make myself understood!"*. In contrast, Philip wears a Stroke/Aphasia badge with Hidden Disabilities lanyard yet it is sometimes *not* a prominent enough social signifier: *"Philip: Sometimes I wish my stroke was more physical as you can't see aphasia – it's a hidden disability – it's really tough! If it was more difficult people could see – if you were in a wheelchair or on two crutches!"*.

Empathetic conversation partners remove communication pressures. Participants noted that experienced conversation partners removed the fear/pressure to communicate at *more* normalised fast paces: *"Philip: The barber is very good! He gives me time to get the words out! No rush! Knows I've got aphasia and how to talk to me!"*. Equally, these partners show compassion during communication breakdowns by providing filler time. In particular, the aphasia clinic was refreshing as people provide sufficient communication time: *"Immanuel: This groups alright! Rowan: Okay because everybody's got aphasia, and everybody knows – they give you time! [...] Bruce:*

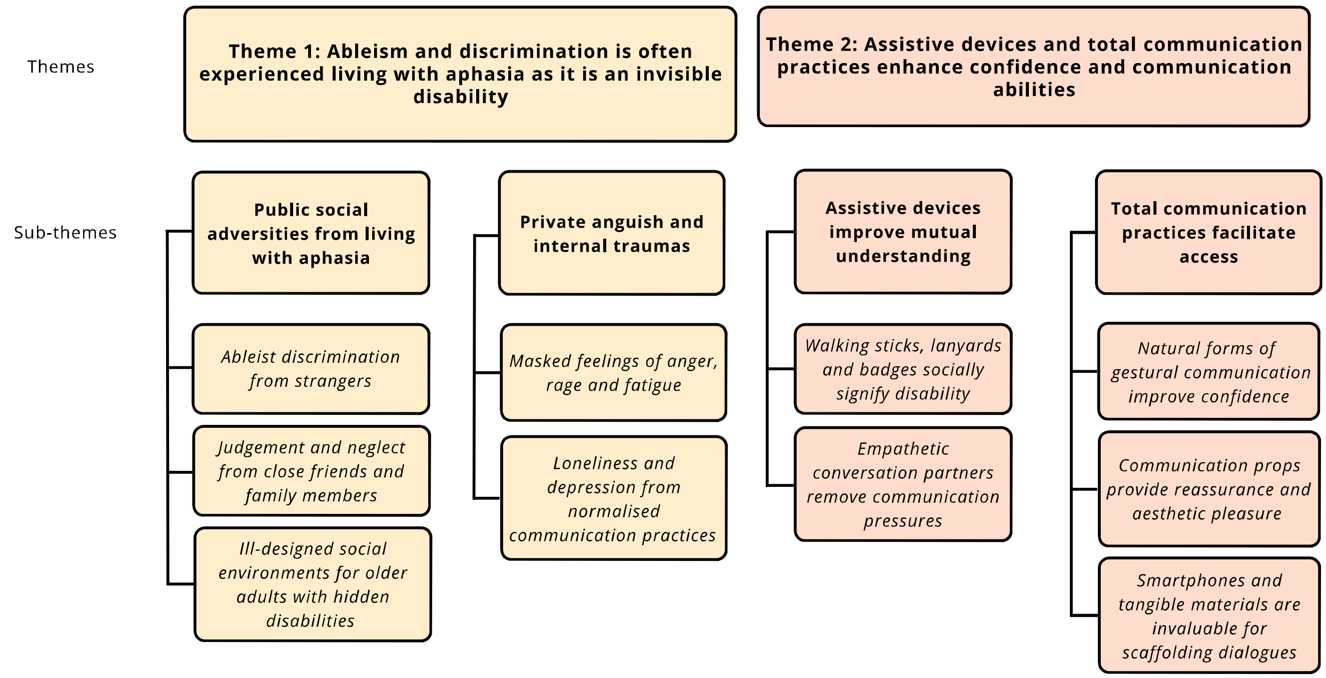

Figure 4: The structure of themes and associated sub-themes from Thematic Analysis of co-design workshops.

Because people here... you've got time to hear talk and people give you time to talk! [Thumbs up] Rowan: Yeah!".

Turning to the second sub-theme, which considers the role of non-verbal/total communication practices that facilitate access and confidence. Participants reflect on their use of natural non-verbal gestural forms of communication supplemented with both tangible props and smartphones.

Natural forms of gestural communication improve confidence. Many participants thrive communicating via non-verbal body language. For Jade this ability to communicate non-verbally and visit the hospital on her own instils feelings of confidence and independence: *"Jade: I want to do it myself! No! Its errr... Err... my phone! Its everything else! Wrong okay! So that's it! I want to be on my own! Bruce: Independent!"*. For Elias who lives non-verbally – conversation partners support his preferred alternative communication styles – letting him write/draw on paper, *"Elias: Yes but people [gesturing]... Yes [writing down]! [...] Mary: Yes if people have innate kindness they'll be patient with your writing and kind!"*. These critical accommodations give Elias the confidence to socially participate.

Communication props provide reassurance and aesthetic pleasure. Communication props are integral backups during communication breakdowns – *many* participants carry wallet communication cards to describe their aphasia: *"Kai: I always carry that and show [strangers] what it means [Bringing out stroke card]... I use that and carry it with me all the time and use it and show it to people!"*. In contrast, Mary prefers writing in her trusted communication book, which supports her memory: *"Researcher 1: so you always write everything down? Mary: In a book! [...] Because it stops me getting sort of panicky about stuff!"*. Finally, props serve an aesthetic pleasure for communicating participants talents and passions – it brings Elias great joy to share his photography collection: *"Researcher 1: And do you have fellow friends who do photography? Elias: Yes! Yes! Ahaha! Yes umm... [showing photographs] And this one a month ago!"*.

Smartphones and tangible materials are invaluable for scaffolding dialogues. Smartphones and tangible materials are integral for supporting participant's fluctuating communication needs, *"Researcher 1: But your dialogue is quite good? Philip: [Shakes head].. today its good! But on some days I can't say a word at all! Philip: [On bad days] I write messages on my phone and point! [Gesturing]"*. For those with aphasia that struggle to read – pointing gestures to smartphone pictures/menus become integral for requesting: *Hana: Picture! Picture on your phone!"*. Finally, tangible materials including letters/bills serve as reminders and facilitate independence: *Rowan: Especially when [the bank] say do you want to go paperless? I don't want to go paperless!"*.

4.2 Low-Fidelity AAC Prototypes

At the scenario stations, we recorded 16 wearable AAC participant designs providing communication solutions for challenging SWIM design-briefs. Here, we describe 11 low-fidelity designs that were *most* popular. Throughout, device sizes were explored via group cutting activities. Overall, participants expressed a strong preference for AAC badge form-factors with 8 low-fidelity smartbadge prototypes. Reciprocating earlier observations in Figure 2: smartphones, stroke/aphasia badges and sunflower lanyards were collectively the

Figure 5: Outputs from co-design workshop two, specifically high-volume tangible low-fidelity ideation of wearable AAC displays at challenging communication scenario stations. In total, thirteen images of participants low-fidelity prototypes.

most popular daily assistive technologies amongst our participants living with aphasia.

AAC Jumper. Rowan designed an AAC jumper, which prominently lights up to request seats, *"press a button and it would flash up... I need a seat"*. However, Julia critiqued the prominence of the jumper design.

Cross-Device Smartbadge. Instead, Philip and Jacob proposed a discreet smartbadge controllable by your smartphone. On the bus, they envisaged the potential of communicating needs to the driver whilst boarding: *"Jacob: Please close the doors slowly"* plus smiley face symbol to communicate with the driver. Following this, prominently flash multi-colour *"Jacob: I need a seat please"* to fellow passengers and finally blend into clothing: *"Julia: Matching the colour of what their wearing"* before switching off. At all times, politeness was important: *"Julia: Yeah! Manners! You know!"* and *"Philip: Say thank you"*. Furthermore, Philip, Jade and Rowan collectively proposed the smartbadge potentially operating *"Philip: Like traffic lights"*: going from green, orange and red – to depict growing impatience.

Shh! Smartbadge. Hana, Kai and Bruce considered a *"Shh!"* smartbadge to quieten excessive crowd noise. However, Julia and Rowan still felt this wouldn't resolve issues concerning following threads of conversation, *"Julia: Changes of conversation! [hand gestures]"* and *"Rowan: How would you understand with everyone talking at the same time? [...] One [speaking] at a time!"*. Philip proposed the smartbadge could display *"Slower!"* in capitals. Elsewhere Arthur, Olga, Kai and Hana collectively proposed useful gestures to capture attention in groups *"Olga: Shouting! Standing up! Holding up arms! [...] Slow! Slow! Slow!"*.

Attachable Smartbadge AAC. Initially, Jacob suggested a smartbadge displaying *"I'm slow"* – but this ableist language was dismissed as *"Rowan: A bit discrimative"*. Instead, Philip proposed the badge display *"I've had a stroke and aphasia"* – albeit Philip admitted its *not* the most publicly recognisable disability. Collectively it was agreed for the smartbadge to request *"Rowan: I need further help"* and *"Rowan: I find it hard to walk"* with wheelchair iconography providing the necessary abstraction. Furthermore, Hana, Bruce and Arthur suggested attaching the badge onto lanyard or cross-body satchels.

AAC Bell. Kai considered a AAC bell to notify the driver of incoming passengers accessibility needs – *"Kai: So he knows! [...] Straight away that this person needs help!"*. Finally, Arthur and Bruce considered the importance of the bell enhancing gestures such as pointing *"Arthur: To the [priority seats] sign!"*.

Speed-aware AAC. Philip proposed a conversation speeds AAC to communicate on his behalf, *"talk a lot slower... I can't understand what you're saying!"* when group discussions became too fast.

AAC Smart Ring. During group conversation Hana and Kai considered a smart ring that flashes in *"Hana: Red!"* to get the attention of family across the room – something potentially even *"Kai: Secret!"* to *not* draw overt attention.

Image-Based AAC. Turning to AAC devices that express interests, Julia suggested sharing of personal photographs like photos from her latest cruise holiday. Rowan proposed an image-based AAC that provides a carousel of imagery related to verbal storytelling and *"you could load up yourself!"*. Then group discussion moved to reinforcing dialogue with the image-based AAC able to pull up images *"Philip: pre-loaded pictures from Google! [...] If you say cruise ship it pulls it up [an image]!"* using the speakers live dialogue. Collectively, it was agreed images help starting conversations.

AAC Lanyard Display. Julia, Bruce, Arthur and Rowan envisaged an AAC lanyard-based display for *showing* orders (e.g., Americano) to the barista with supplementary dialogue and gesture – *"Julia: Here it is!"*. Bruce and Arthur felt the lanyard AAC display could show *"Bruce I need assistance"* and that *"Arthur: can't carry!"* hot coffee to his table. Consequently, Bruce proposed that the lanyard AAC display could *"flash!"* to draw attention. Yet, Jacob presented the challenge of ordering the correct coffee size: *"How do you say small, medium or large?"*. To resolve this problem, Julia and Philip proposed the display providing TTS. In contrast, Philip suggested the AAC lanyard display could show graphics of an optimal coffee order before *"finish[ing] with a smiley face"* to communicate thanks. In contrast, Arthur proposed integrating *"Photographs!"* of previous perfect orders. Instead, Julia envisaged using the AAC lanyard with supplementary dialogue and pointing gestures, *"this is what I want! [pointing]"* with lanyard display extended. Finally, Philip suggested for the AAC lanyard to display, *"Table number!"* to facilitate carrying of the hot beverage to a specific table. In other contexts, Philip proposed for the AAC lanyard to support his use of alternative communication modes displaying, *"wait a minute... giving [him] time to write"* and maintaining conversational flows.

Interdependent AAC. Initially, Rowan proposed a partner-focused smartbadge AAC to communicate better dialogue practices to conversation partners, *"Please do not finish my words!"* with an unhappy face. Whilst, Philip and Jade proposed the displays *"Philip: I've got it handled"* and *"Jade: More time to speak!"* to the friend.

Smartwatch AAC. Meanwhile Julia suggested a gesture-focused smartwatch app that could enhance pointing gestures, *"that one please [pointing gesture]"*. The smartwatch and badge could serve as extension of bodily gesture with arrows supplementing non-verbal gesture. Equally, Hana and Kai also order in restaurants primarily through pointing and hand-based gestures. Consequently, Kai asked for the smartwatch to prominently display, *"No meat! Vegetarian!"*. As a precaution, Kai tends to go to restaurants, *"always with my wife and family!"*.

4.3 Divergent–Convergent AAC Badge Prototyping

Participants expressed a strong preference for badge form-factors – most used an Aphasia/Stroke badges everyday (i.e., Figure 2) and in the previous co-design workshop Section 5 most of participants low-fidelity prototypes were badges. Consequently, we began focused divergent-convergent exploration of potential AAC badges directly with participants. Firstly, we wanted participants to divergently co-design using DALL-E. In total, participants successfully co-authored[5] 9 DALL-E text-to-image prompts to divergently generate 36 wearable AAC badges to support their personal CCN. Notably, 4 divergent DALL-E participant designs incorporated lanyards. Following this, we supported constrained AAC badge designs letting participants build user interfaces immediately deployable on badge hardware. In these convergent activities, participants paper-prototyped 12 black/white badges and then wire-framed 5 badges using a canvas web-application to support their personal CCN. Results are described from analysed transcripts and material outputs.

4.3.1 Outcomes from AI-Assisted Image Generation. None of the participants had used text-image models so the group co-authored short prompts to develop familiarity. Then the group proceeded to prompting for an AAC smart-badge on the *"Immanuel: breast pocket"* and thus *"Mary: attachable to a shirt"*. DALL-E rejected the term *"breast"* so they changed to prompting for a smart-badge attached to the *"shirt pocket"*. Upon results, Bruce and Rowan approved of initial DALL-E generated circular smart-badge designs but Immanuel felt, *"they did not show up enough"* and Mary agreed they were too discreet noting, *"Mary: nobody knows what aphasia is! And its too discreet!"*. Bruce, Mary and Kai collaboratively refined the prompt to be for *"colourful"* and *"large"* smart-badges. At the next iteration of colourful AAC smart-badges, Rowan commented, *"No! It's not right – looks like something to do with LGBTQ+ [community]"* – with onlookers *potentially* misinformed. Collectively, prompts were made for *more* colour specific smart-badges, *"Mary: Blue or red!"*. Equally, Kai suggested adding, *"older adult"* onto the smart-badge display but Bruce contended, *"younger people can have a stroke"* and *"communication disorder"* was then agreed. After dissatisfaction with images of the red AAC smart-badges. The group decided to prompt for *"Bruce: lanyard"* wearable AAC displays. Rowan proposed a *"blue"* lanyard with *"red"* smart-badge. Immanuel suggested its, *"Got to be seen by bus drivers before getting on! Quite big!"*. Broadly, the group were satisfied with the images for lanyard-attached AAC badges. However, Rowan wanted a *"more discreet"* lanyard and badge. Then, Rowan adapted the prompt to request AAC badges to be smaller thus *"Rowan: credit card size"* blending into his clothing. The next round many felt the AAC lanyard badges generated looked, *"Kai: Too much like an oyster card!"* and *"Mary: identity card!"*. After a further round of images generated, Kai suggested upon *"button press"* the smart-badge could display text on his wallet communication cards and Mary suggested displaying, *"links for stroke and aphasia websites! [...] Something you could point too!"*.

4.3.2 Paper Prototyping and Web-App Wire-frames. Shown in Figure 6, participants paper-prototyped 12 wearable AAC badges. Initially, Mary designed a prominent Stroke/Aphasia badge, *"because people [i.e., strangers] think you're being difficult and a nuisance. It never occurs to people you've had a stroke"*. Next, Bruce made an *"I have got an invisible disability"* badge. Whilst, Rowan drew a photo ID display with image. Discussion turned to difficulties with seat requesting so Mary suggested, an *"I cannot stand!"* badge, which

[5]Co-authoring involved working in pairs, small groups or directly with researchers to author prompts.

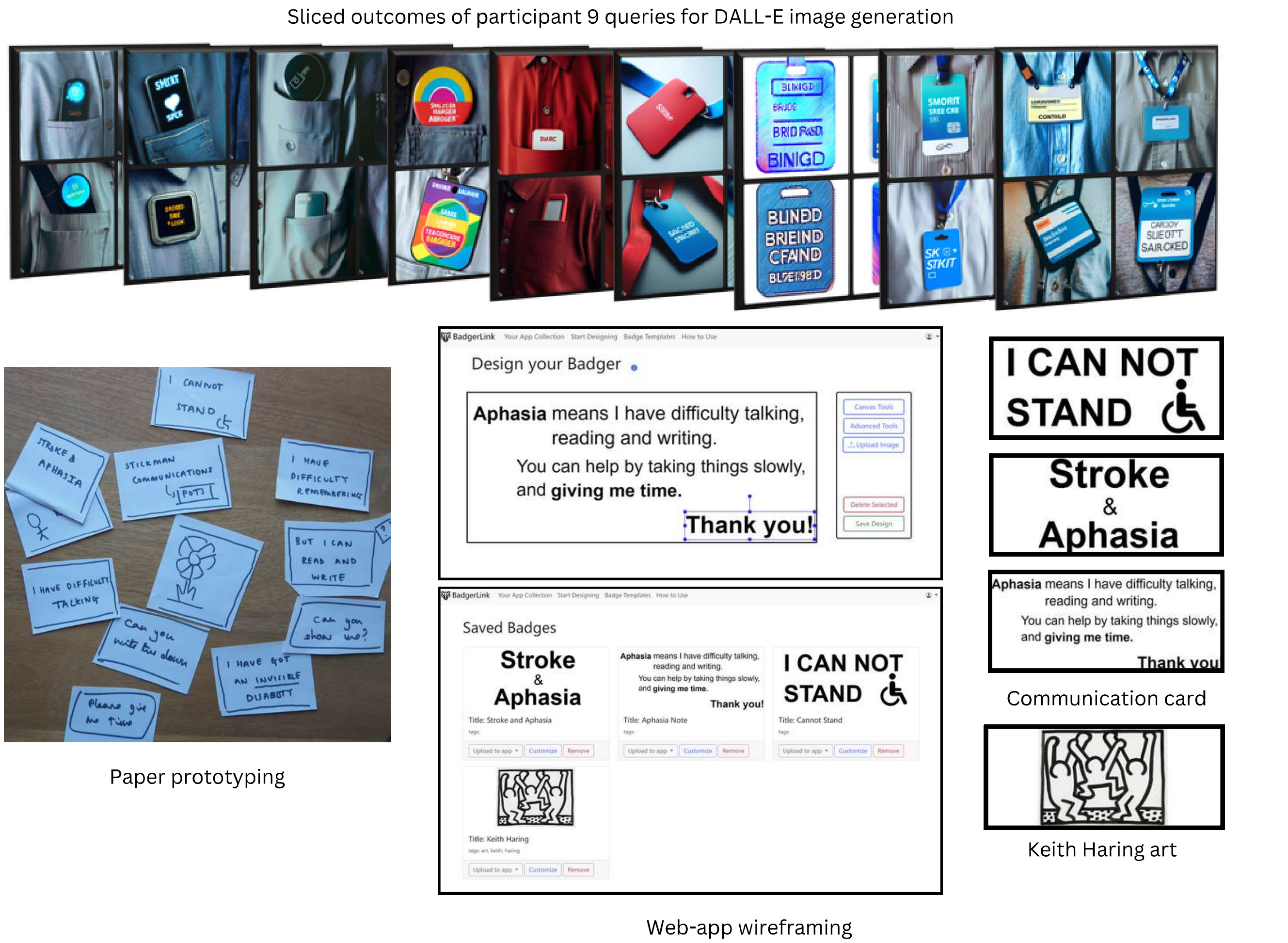

Figure 6: Outcomes from co-design workshop three on divergent-convergent AAC badge prototyping. From top to bottom, sliced images of the 9 queries images of prompted badges generated by participants using DALL-E. Then, an image of 12 participants paper prototypes. Finally, images of the accessible web-app canvas built by the research team called *BadgerLink*, which participants used to wire-frame high-fidelity designs.

she could gesture too as, *"[strangers] see a [walking] stick and think its a prop!"*. Next, the group began prototyping badges that emphasized the wearer's communication strengths, Mary suggested sequentially displaying, *"I have difficulty talking and remembering but can read and write"* with wheelchair iconography. Supporting this idea further, Sarah paper-prototyped three further badge designs: *"Can you show me?"*, *"Please give me time and a pen or paper"* and *"Can you write this down?"*. Next, Gabriel proposed a destination badge, *"thinking if you point to the badge and destination and that's where you want to go!"*. Bruce proposed a badge asking onlookers to, *"Please talk slowly!"*. Importantly, Sarah suggested that, *"people carry about phones on their lanyard"*. Lastly, Victoria paper-prototyped a black/white sunflower badge and reflected on her daily use of Stickman communications key-ring cards due to her, Postural Orthostatic Tachycardia Syndrome (POTS). Following paper-prototyping, some participants used the accessible web-app canvas application to wire-frame 5 high-fidelity badge designs. Initially, Kai wanted to, *"tell people what the situation is"* so he wire-framed a *Stroke and aphasia* badge plus his wallet communication card. Mary wire-framed an, *"I cannot stand"* badge. Arthur wire-framed a badge importing Keith Harding artwork. Finally a, *"Thank you!"* badge was wire-framed by Gabriel as manners are critical whilst requesting support.

5 INKTALKER AND WALKIETALKIE AAC

Informed by our participants pre-existing daily assistive technologies (i.e., Figure 2) and the co-design process, we built two complementary low-input wearable AAC prototypes to scaffold people with aphasia's communication. The *InkTalker* smart-badge is a mechanical-input and low-power customisable electrophoretic (eInk) AAC smart-badge designed to support communication in common situations. Next, *WalkieTalkie* is a co-designed AAC iOS

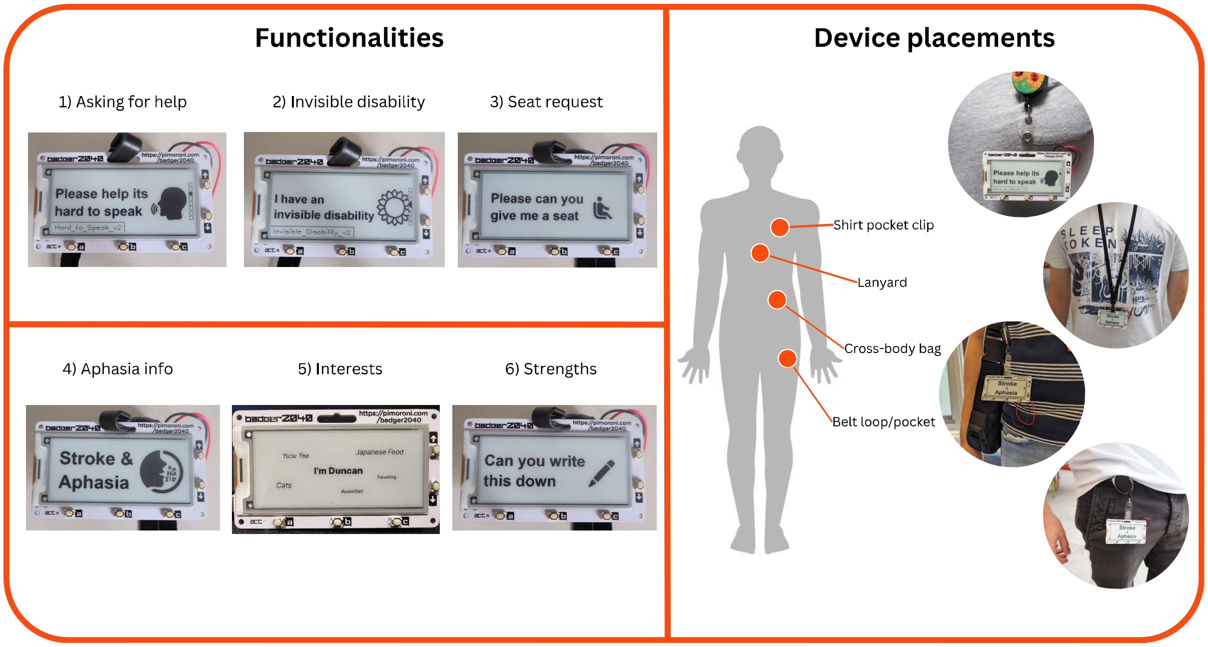

Figure 7: The *InkTalker* functionalities and body placements.

application that converts smartphones into wearable public displays to supplement communication. Both AAC prototypes reinforce total communication abilities and agency as the devices are designed to be supplemented with limited verbal and non-verbal communication. Much like prior AAC research, high-fidelity prototypes can reduce cognitive exertion and support comprehension. Therefore, using available hardware we sought to actively gather participants perspectives on both prototypes and suggested refinements.

5.1 InkTalker

The *InkTalker* is a low-power wearable AAC smart-badge designed to scaffold people with aphasia's communication with strangers in everyday locations. The *InkTalker* smart-badge was prototyped using the Pimoroni Badger2040W platform, which is a Raspberry Pi Pico-W with a 296x128 eInk display. Prototyping with eInk was considered optimal due to aesthetics, low power consumption, high visibility, durability and affordability. Although fully customisable, insights from co-design activities and thematic analysis resulted in a portfolio of initial displays for non-verbal people with aphasia to use 'on the go'. These badge displays include: firstly, *Asking for help*, which provides support in stroke-unfriendly locations noted in theme 1 e.g., concerts/stadiums and operates equivalently to co-designers' pre-existing wallet communication cards. Secondly, *Invisible disability* socially signals the wearer's disability and functions like our co-designers adopted assistive devices e.g., walking sticks noted in theme 2. Thirdly, *Seat request* supports co-designers requesting priority seats during unexpected bouts of fatigue noted in theme 1 and based on two low-fidelity prototypes: the *AAC Jumper* and *AAC Bell*. Fourthly, *Aphasia info* is designed to improve public awareness of aphasia by informing strangers of the wearer's hidden disability and derived from co-designers low-fidelity *Attachable Smart-badge AAC* prototype and canvas wire-frames. Fifthly, *Interests* supports our co-designers pointing gestures by providing a ticket-to-talk in challenging group conversations noted in theme 1 and reciprocates the wire-framed *Keith Haring artwork*. Finally, *Strengths* shows the wearers' preferred gestural communication styles derived from theme 2 and reciprocates two low-fidelity prototypes: the *Interdependent AAC* and *Speed-aware AAC*. The wearer can display all these expressions through either an eye-catching transition which maximises font-size for readability or static-displays with manual transitions using buttons. In co-design session 3, unbeknownst to our co-designers they successfully used the canvas web application we built to accessibly design up-loadable *InkTalker* displays. The lightweight smart-badge supports diverse on-body placements for hemiplegic users attachable to: shirt pockets, lanyards, key-chains, cross-body satchels/bags. Equally, the smart-badge supports configurable power supplies: AAA, button-cell and rechargeable batteries.

5.2 WalkieTalkie

An iOS app that converts the wearer's smartphone into a low-input wearable AAC display supporting multimodal forms of communication with strangers. Initially, the app opens to a menu screen showing six different functionalities derived from co-design activities and thematic analysis. The first functionality *Custom Badges*, allows the user to create, customise and save wearable displays – letting the wearer make *many* contextual displays, including individual designs e.g., "Shh!" and "No meat!". Based on theme 2's findings concerning the importance of smartphones for scaffolding dialogues, displays can be adapted through text, colour or rotation

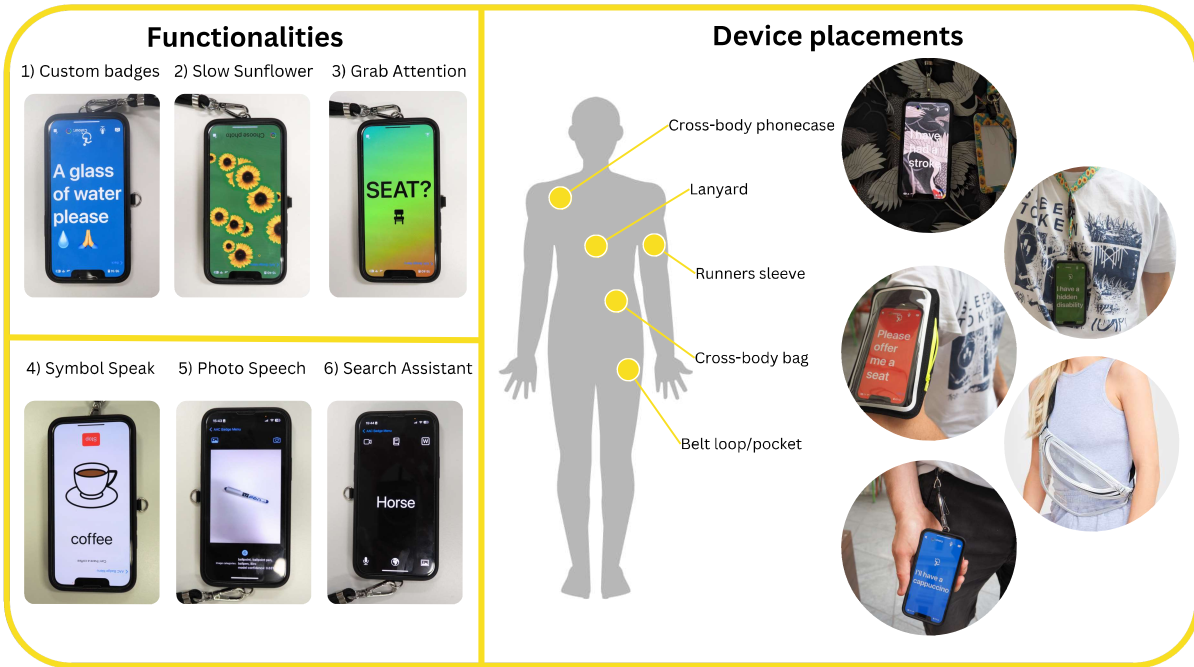

Figure 8: The *WalkieTalkie* functionalities and body placements.

to make prominent/discreet dependent on context. We also explored supporting users photo-taking, which would then act as device background – making the AAC less visible and based on Pearson et al. [70]. Secondly, *Slow Sunflower* provides sunflower animations to discreetly complement our co-designers' adopted hidden disability lanyards noted in Figure 2. Thirdly, *Grab Attention* facilities eye-catching large font transitions of an expression with the display slowly transitioning to red for urgency, accessible buttons support rotation, TTS and muting the public display – this feature came directly from our co-designers' low-fidelity *Cross-Device Smart-badge* and suggested 'traffic-light' functionality. Fourthly, *Symbol Speak* performs speech recognition of the wearer's dialogue and pairs with matching symbol library – this feature came from co-designers' low-fidelity *Image-based AAC* and ideation of speech-to-text for images. Fifthly, *Photo Speech* uses the MobileNetv2 deep learning architecture to provide image classification of objects of taken photos – derived from our co-designers' low-fidelity *AAC Lanyard Display* and discussions regarding using photographs as a communication prop. Finally, *Search Assistant* lightens cognitive load by supporting on-the-go searches of Google, Images, Wikipedia, an English Dictionary and YouTube – derived from discussions on preferred internet resources whilst our co-designers made the *Image-based AAC* low-fidelity prototype. Throughout the app, symbols and TTS are employed to improve accessibility. With a variety of body placements, the *WalkieTalkie* app can be outwardly worn: on a neck lanyard, cross-body strap, runners sleeve, belt clip and in a clear cross-body bag.

6 EVALUATION OF WEARABLE AAC DISPLAYS

Both prototypes, the *InkTalker* smart-badge and *WalkieTalkie* app were evaluated during complementary workshops. Initially, the focus group facilitated questionnaires and group discussion. Following this, participants voluntarily proceeded to an experience prototyping workshop and role-playing with both devices.

6.1 Setting and Procedures

6.1.1 Setting. The workshops occurred within the context of an Aphasia Re-Connect support group at the Roberta Williams Speech and Language Therapy Clinic. Ethical approval for this research was granted by the King's College London Health Faculties Research Ethics Subcommittee. Participants with aphasia were recruited from the charity. All participants were paid 20 GBP per hour.

6.1.2 Participants. **Focus group.** The focus group involved 10 participants with aphasia and 4 SLTs (i.e., *FG* in Tables 1 and 2). Language abilities ranged from mild–severe and two participants had right-side paralysis onset from hemiplegia. Ages ranged from 49–74 years old. All participants were at least six months post-stroke and had spoken English fluently prior to their stroke. Of note, *most* participants wanted to engage with the two prototypes but did not feel comfortable experience prototyping with an SLT. Therefore, we adjusted our sessions to support maximum engagement amongst our participants with aphasia.

Experience prototyping workshop. Afterwards, 5 participants with aphasia participated in the experience prototyping workshop and 1 SLT was recruited for role-playing activities (i.e., *EPW* in Tables 1 and 2). Speaking ability was severely limited for two

Figure 9: Images from focus group with *WalkieTalkie* app and *InkTalker* smart-badge. Top left, Immanuel uses *WalkieTalkie* custom badges camouflaging capabilities to blend into his striped shirt. Bottom left, Hana tries the *WalkieTalkie* in a runners sleeve on hemiplegic arm. Top centre, participants test *InkTalker* smartbadge attached to Adam's cross-body satchel. Top right, Rowan tries *InkTalker* buttons whilst wearing his arthritis wrist-splints. Bottom right, image of group discussion. Participants gave permission to have photo shared.

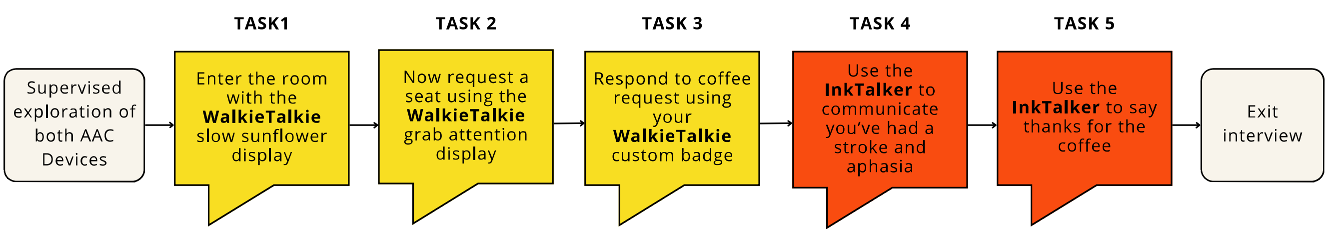

Figure 10: Experience prototyping procedure: three *WalkieTalkie* interactions followed by two *InkTalker* interactions – performed with an SLT acting as conversation partner.

participants and moderately limited for three participants. Some participants experienced mild–moderate difficulties in understanding spoken language and two participant had vision difficulties, which limited their ability to read all text with both devices. Participant ages ranged between 51–69 years old. All participants were at least six months post-stroke and had spoken English fluently prior to their stroke. Three participant had hemiplegic paralysis which restricted the use of their right arm and leg.

6.1.3 Procedures. **Focus group.** The focus group lasted 1 hour. Initially, participants arrived whilst a researcher and SLT introduced and demonstrated both the *InkTalker* smartbadge and *WalkieTalkie* app on an iPhone 12 Mini and iPhone 12 SE. Sequentially, participants were presented with either device – encouraged to engage and test. One researcher and SLT supervised and supported participants' engagement. After approximately 30 minutes of usage, participants

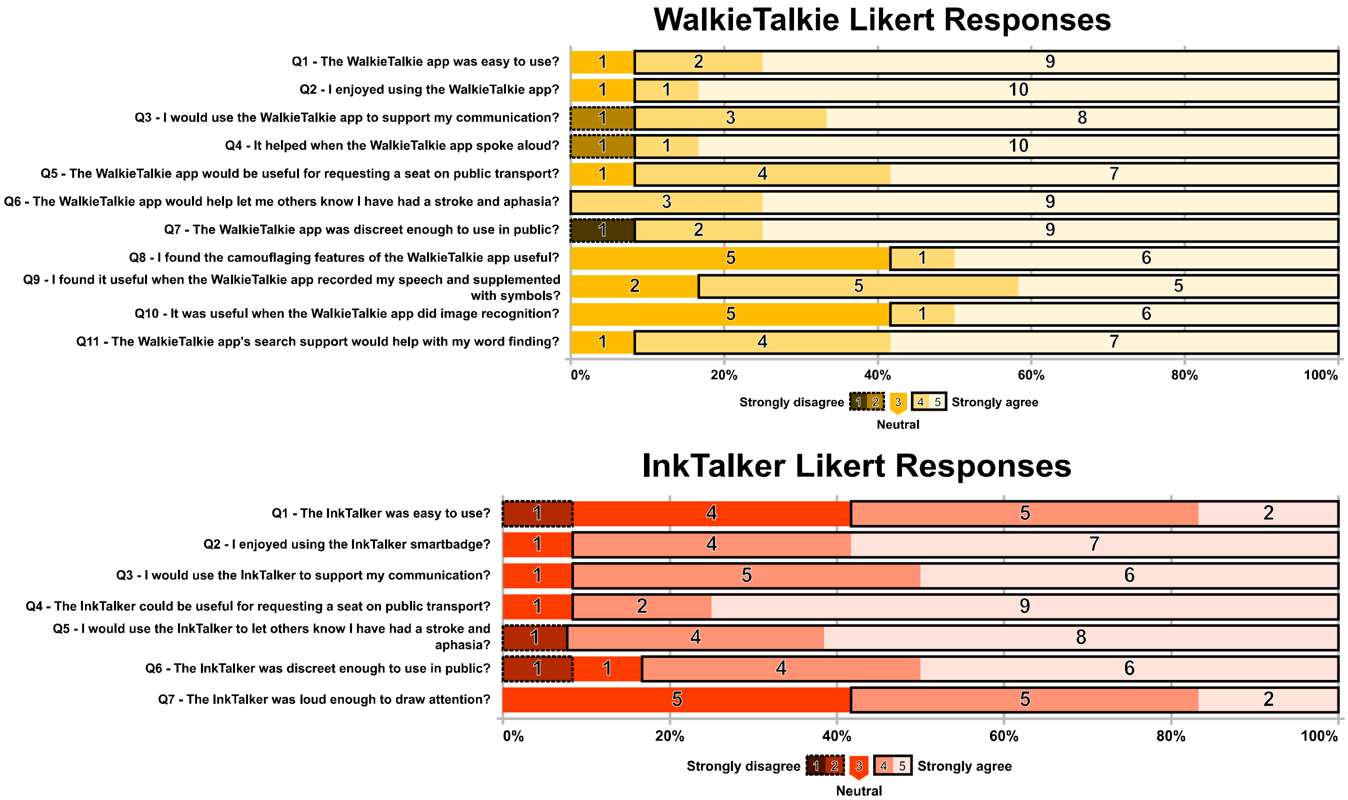

Figure 11: Recorded likert responses to both AAC devices: *WalkieTalkie* and *InkTalker* from 12 focus group participants: 8 living with aphasia and 4 SLTs.

completed a feedback questionnaire. Next, the SLT/researcher facilitated a group discussion about the app, and garnered consensus about potential future refinements to each app.

Experience prototyping workshop. Outlined in Figure 10, we wanted to determine the efficacy of our AAC in simulated 'real-world' scenarios, therefore we asked 5 participants to use both AAC devices in a role-playing scenario with a recruited SLT. Beginning with supervised exploration, the tasks then took approximately 15 minutes in total for each participant. At all times, one researcher was present to video record experience prototyping and support device interactions. *WalkieTalkie* was deployed on an iPhone 12 Mini.

6.1.4 Data Analysis. **Focus group.** Both the focus group and experience prototyping workshop were video/audio recorded for data analysis. For the focus group, data was compiled from the feedback questionnaires in Section 6.2.1, analysing transcription from discussion and structured observation of the video data of participants using the *InkTalker* smartbadge and *WalkieTalkie* app. Transcripts were analysed thematically in Section 6.2.2 to explore positive/negative perspectives of each device and suggestions for future refinements.

Experience Prototyping. Video analysis was used to investigate the class-based interactions performed by participants during the role-playing tasks outlined in Figure 10. As participants had varied verbal speech we could analyse interactional phenomena associated with communication modes including: looking behaviours, gesture, proximity, voice-tone and loudness. We took a whole-to-part inductive approach, whereby videos of device usage were initially time-marked using NVivo 14. In order to investigate the participants' non-verbal and total forms of communication, we used a social-semiotic approach that investigated unique communication styles (i.e., looking/expressive bodily gestures). Alongside video segments and transcripts – we extracted stills from the videos i.e., Figures 12 and 13 these considered spatial elements and environmental factors whereas video footage enabled us to delineate talk utterances, movement and non-verbal modes. Videos were watched multiple times to exhaust interpretations. Results are discussed in Section 6.2.3 – this process resulted in Table 3's, four core interaction categories and 13 sub-categories.

6.2 Results

6.2.1 Focus Group Likert Results. The feedback questionnaire was delivered during the focus group and results are presented in Figure 11. There was 126 instances of 'strong agreement' in positively phrased questions – 86 instances for the *WalkieTalkie* app and 40 instances for the *InkTalker* smartbadge. In sum, there was 56 instances of 'agreement' – 27 instances for the *WalkieTalkie* app and 29 instances for the *InkTalker* smartbadge. Whilst, there was 29 instances of 'neutrality' – 16 instances for *WalkieTalkie* app and

Table 3: Interaction analysis of five participants' verbal, non-verbal and device-based interactions during the completion of tasks with *WalkieTalkie* and *InkTalker*.

Interaction	Instances	Task 1	Task 2	Task 3	Task 4	Task 5	Total
Researcher assistance with interaction	Count	1	5	1	2	1	10
Device interactions	Display rotation	0	0	0	0	0	0
	WalkieTalkie text-to-speech	0	3	2	0	0	5
	Looking at device	7	9	12	5	4	37
	Capacitive touch/button press interaction	6	13	14	1	5	39
Verbal communication	Participant dialogue	7	2	3	7	3	22
	Change in loudness	1	0	1	0	0	2
	Change in tone	2	1	1	1	1	6
	Use of conversational fillers	4	2	4	4	3	17
Non-verbal communication	Bodily gestures	0	3	3	3	3	12
	Use of AAC display as prop	5	6	7	6	4	28
	Proxemic manipulation	4	10	6	4	5	29
	Looking at speaking partner	7	12	9	8	5	41
Total		**40**	**56**	**57**	**37**	**29**	**248**

13 instances for the the *InkTalker* smartbadge. Overall, this indicates that the majority of feedback concerning both AAC devices was positive. Our 1 point of 'strong disagreement' came from a younger participant with *more* fluent aphasia. Nonetheless, participants collectively enjoyed the focus group with 10 points of 'strong agreement', 1 point of 'agreement' and 1 'neutral'. Notably, 3 participants with aphasia elected to join focus group discussions but felt *too* fatigued to complete questionnaires.

6.2.2 Collective Refinements. **InkTalker smart-badge.** The eInk had aesthetic and nostalgic appeal, *"Rowan: Reminds me of a Nokia screen"* and *"Sarah: very nice!"*. The long battery life was popular and *"Immanuel: rechargable"* versions were suggested for future testing. Many liked the customisability and wanted to use the parter web-canvas software and *"Gabriel: plug it into my [home] computer!"*. Many approved of the multiple badge displays, *"Gabriel: pulling up multiple badges it would be excellent"*. In terms of placement, Hana liked the ability to clip the lightweight smart-badge onto her cross-body bag. Michael felt the smart-badge did a good job, *"people with aphasia have very different language abilities [...] and great for older adults without a smartphone"*.

In terms of refinements, the *most* prevalent critique from Gabriel, Arthur, Basheera, Sabrina, Victoria and Sarah to, *"Arthur: Make buttons bigger"* to make more *"Sarah: accessible for one hand inputs"*. Elsewhere, participants wanted to be *"Mary: more in control"* of the eInk refresh-rate to prevent the smart-badge from being *"too slow"* argued Jade and Immanuel. Equally, many wanted to customise font-size, *"Immanuel: the bigger the text the better!"* and *"Arthur: Font-size bigger for me"*. A few advocated making the smart-badge *less "chunky"* and lighter, *"Rowan: Its a bit weighty around your neck!"* and *"can't you get a watch battery? [...] take the size of the back down"*. Many desired a case to improve sturdiness,*"Rowan: Feels maybe a bit too easy to break [...] go into a case — protect the screen and all [...] like the old Kindles – they may break!"*. Plus, a case would hold wires at the back of the smart-badge ensuring, *"Gabriel: connections [are] not exposed."*. Some advocated coloured eInk or further LEDs for,*"Immanuel: More [eyecatching] colours"*. Peter even suggested a novel change of form-factor, *"Peter: An e-ink wristband!"*.

WalkieTalkie app. Arthur liked using the app *"one hand!"* with a cross-body lanyard. Mary and Sabrina enjoyed the slow-sunflower and were pleased to raise awareness of the Hidden Disabilities charity. Many appreciated the ability to create *new* badge displays – Sarah even commented, *"Its really easy! I love it!"*. Meanwhile Jade wanted the app available *"as soon as possible!"* and Philip, *"to alleviate [his] anxiety"*. Janet thought the app would be very useful communicating through, *"glass barriers at train stations"* and to request, *"people to speak slowly to me"* with a tortoise icon. Elsewhere, Arthur felt it was, *"really good! Yeah!"* for helping with seat requests and liked the mutable display. *Photo Speech* caught many by surprise and was described as, *"Janet: really clever!"*, Philip, Mary and Sabrina agreed, *"would help with word my word-finding"* whilst Sarah felt picture-taking practices would be, *"helpful"* for language therapy. The *Symbol Speak many* felt would support living with partially verbal speech – *"Peter: I love to use speech-to-text with my IT"*, *"Jade: very good!"* and *"Sabrina: Very good if you can't read or draw"*. The *Search Assistant* was popular with Janet and Immanuel, *"Janet: That is excellent!"* – they prompted *"Pink Floyd"* and *"horse"* to test the app. In terms of body placement, Arthur preferred his belt loop letting him store the smartphone in his pocket: *"Arthur: Good idea!"* and Victoria preferred the cross-body placement plus argued it was better than her Cardzilla app.

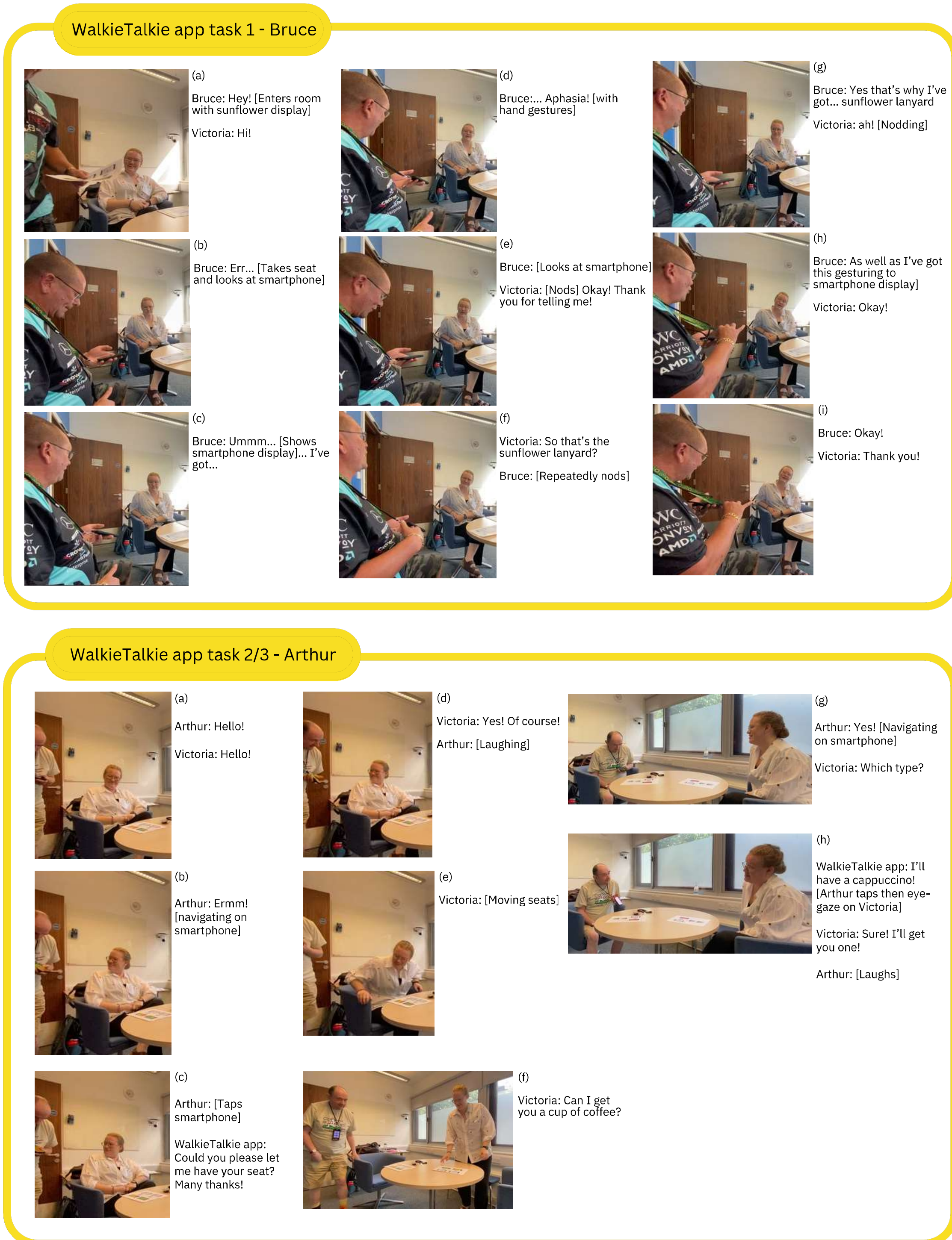

Figure 12: Bruce's interactions during *Task 1* using the sunflower display on the *WalkieTalkie* app. Bruce uses filler whilst performing interactions on the smartphone (b) and then uses the phone as a communication prop (d). The lanyard AAC critically does *not* interrupt his dialogue and non-verbal gestures showing his sunflower lanyard: (h)/(i). Next, Arthur's interactions during *Task 2/3* using the grab attention and custom badge on the *WalkieTalkie* app. Arthur uses filler dialogue whilst navigating on the phone: (b)/(g). Then the app's TTS twice: (c)/(h) to request a seat and cappuccino. Despite hemiplegia, he can easily take a seat with his free left-hand providing stability (f). Participants gave permission to have photo shared.

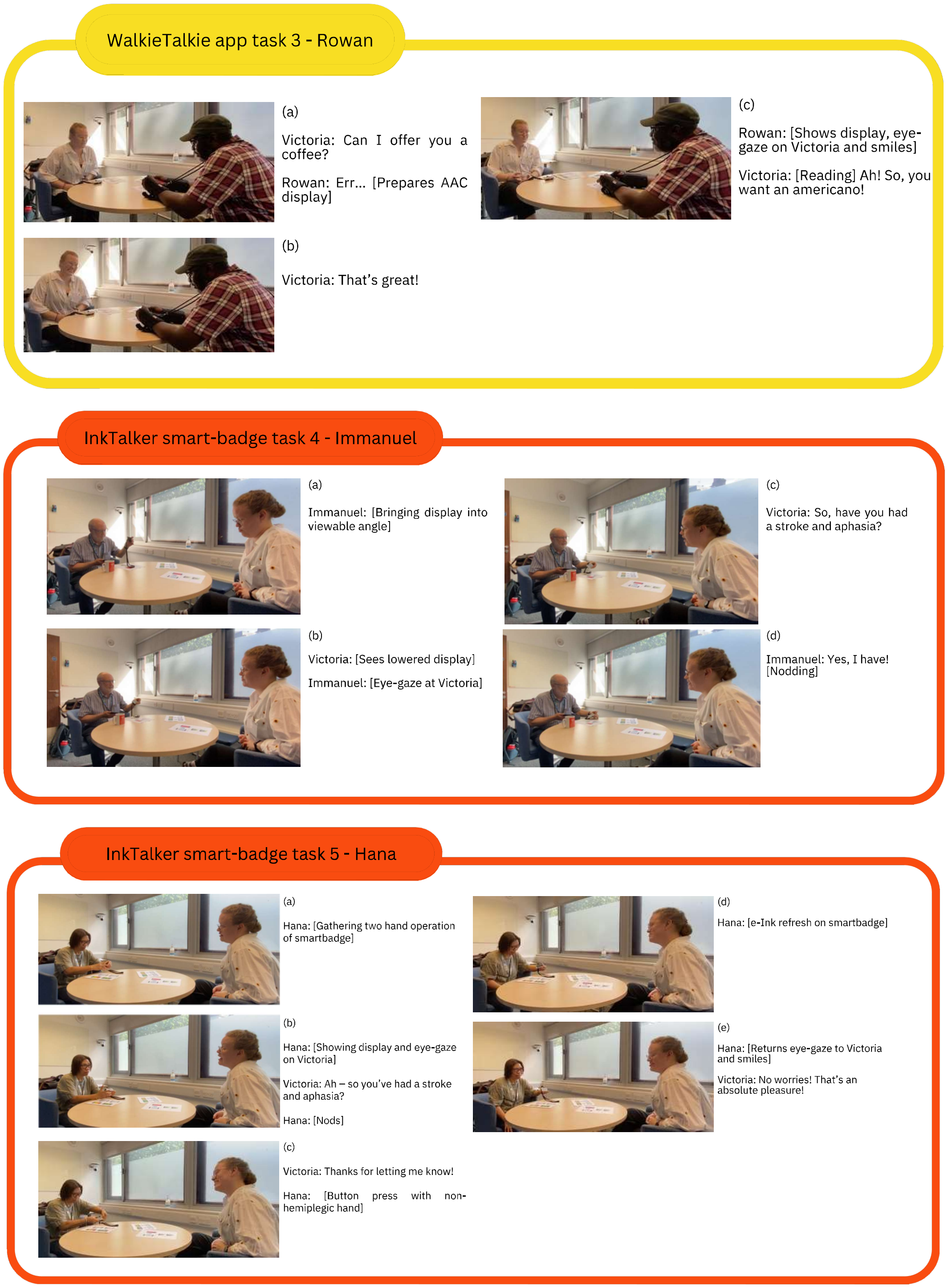

Figure 13: Rowan's interactions during *Task 3* using the custom badges on the *WalkieTalkie* app. Rowan uses filler whilst navigating on the smartphone (b) and shows the custom "americano" badge with supplemental smile and looking gesture. Immanuel's interactions during *Task 4,* he uses the *InkTalker* smart-badge as a communication prop (c) before using dialogue and nodding gestures (c)/(d). Hana's interactions during *Task 5* using the *InkTalker* smart-badge to communicate thanks for the coffee. She seamlessly performs the button press (d) with the display in view of Victoria then non-verbal looking gesture and smile (e). Participants gave permission to have photo shared.

In terms of refinements, some more verbal participants were hesitant to use the device in public, *"Janet: Depends if I'm on the tube – then no!"*. Equally, some interface buttons were identified as too small if *"Arthur: Shaking! [indicating his challenges with pressing the buttons due to manual dexterity]"*. Meanwhile, Peter suggested an easier feature, to let you flick through *"multiple related "* communication cards during dialogues and *"to [supplement with] something when stressed"*. Whilst, Basheera suggested adding some *"preset badges"* when the app is first downloaded. Yasmin, Sarah and Mary suggested a further settings page to *"change the voice gender"* and *"text colour"*. Many debated if the grab attention page and voice was *"too quick!"* so control over speed of text is perhaps necessary. Some were critical of image classifier accuracy, the small photo-capture button and subsequent *"Arthur: American!"* classification of objects e.g., *"coffee mug"* rather than, Arthur and Mary,*"tea mug"*. Meanwhile, *Symbol Speak* was found to sometimes place pressure to, *"Janet: Speak properly"* and Sarah requested a section to, *"explore the symbols"*. Arthur wanted the app's TTS slightly louder for use on the tube. Collectively Siohan, Immanuel, Victoria, Arthur, Hana and Janet wanted the app to better explain, *"what aphasia is!"* with a QR code suggested as an initial option. In terms of body placement, Victoria and Hana considered the app in a runner's sleeve *"a bit heavy"* but the lanyard over the shoulder was *"a lot better!"*.

6.2.3 Experience Prototyping Interaction Analysis. Outlined in Table 3, we coded video footage to analyse participants' multimodal communicative interactions during five tasks with both AAC devices. We coded the number of times the researcher had to assist, participants' verbal dialogue, device interactions and non-verbal communication. In total, we coded 248 instances of interaction – with the researcher assisting device interactions on just 10 occasions. Overall, participants favoured looking at the speaking partner (N=41) with the AAC device display used as a prop (N=28) for communication with the actors in tandem shifting closer to show the expression on the device display (N=29) e.g., Bruce using *WalkieTalkie* as a communication prop in Figure 12 Task 1(d). Whilst, performing dexterous interactions with the AAC devices participants successfully employed conversational fillers (N=17) i.e., *"Err"* and *"Umm"* to signal to the conversation partner for patience e.g., Rowan preparing the AAC display in Figure 13: Task 3(b). Mainly participants favoured their own verbal dialogue (N=22) – in doing so, participants remained expressive changing tone (N=6) and loudness (N=2). But also sometimes used *WalkieTalkie* TTS capabilities to support requesting (N=5) e.g., Arthur using the *WalkieTalkie* TTS to communicate twice in Figure 12: Task 2/3(c)-(h). Importantly, both AAC devices did not appear to interfere with natural pathways of communication with almost equivalent instances of looking at the device (N=37) and speaking partner (N=41) e.g., Hana using the *InkTalker* and looking at Victoria in Figure 13: Task 5(e). Equally, whilst using both AAC devices participants *critically* retained agency to use their preferred bodily gestures for communication such as hand gestures, facial expression, nodding and raising arms (N=12) e.g., Imannuel using the *InkTalker* and nodding in Figure 13: Task 4(d). Of note, for Hana whom infrequently uses a smartphone – it was sometimes cognitively/visually challenging to communicate and use both AAC devices.

7 DISCUSSION

Our findings provide insights on the potential of using smart-badges and wearable AAC displays to support communication for people with communication challenges. In this section, we discuss the efficacy of both AAC prototypes: the *InkTalker* smartbadge and *WalkieTalkie* app, future directions and reflect on our co-design approaches. By co-developing working prototypes with people living with aphasia, we contribute empirical research on new AAC solutions that acknowledge and build on people's multimodal communication profiles across different contexts.

7.1 Efficacy of Wearable AAC Displays

During experience prototyping, participants were able to quickly use both the *WalkieTalkie* app and *InkTalker* smart-badge to supplement their pre-existing communication abilities. Equally, early results from iterative discussions and self-reported questionnaire data indicate that both devices are effective at supporting an array of different language needs from people living with aphasia. Both devices look to scaffold users' pre-existing total communication abilities (i.e., both verbal/non-verbal) [78], support discretion [67, 73, 85], portability [65, 80, 87], custom wearability [18] and require minimal learning demands [98, 100]. Equally, both AAC devices look to support users *just* during communication breakdowns as *"safety nets"* unlike mainstream AAC interventions. During our experience prototyping workshop, we had only 10 instances of researcher assistance suggesting both devices were intuitive with minimal cognitive load [15, 44]. Indeed, both devices look to support the personal, fast and intuitive multimodal forms of communication, which are commonly favoured amongst communities living with aphasia [6, 78]. In contrast, the – often exerting [98] – communication interactions facilitated by mainstream AAC interventions are often found to be too slow [31, 46, 60, 84, 92, 93], unfulfilling [41, 99] and depersonalised [97, 102].

InkTalker and *WalkieTalkie* have been strongly shaped by people with aphasia's experiences of hard and stressful communication settings [68]. Within these contexts, people living with aphasia can ill-afford to operate heavy AAC tablet form-factors and navigate cognitively exerting AAC symbol-sets – particularly if hemiplegia means one-handed input [41, 100]. Equally, our co-designers have a strong sense of autonomy and agency thus AAC should not interfere with their communication strengths or draw public attention [16, 41, 94]. Both devices support the varying personal challenges of living with aphasia by encouraging co-constructed communication and scaffolding intuitive total communication strengths or even outwardly educating conversation partners on desired accessible communication practices (e.g., *"Do not finish my words!"*). Importantly, the AAC displays also support customisable device placement depending on: user preference, bodily paralysis (i.e., hemiplegia), arm braces, cross-body bags and walking sticks [58, 83]. Both AAC displays deliberately augment pre-existing technologies people with aphasia employ everyday – they can be discreetly attached to Hidden Disability Lanyards, attached to belts and cross-body bags – minimising stigmatization and social exclusion [6, 67, 68]. Notably, in terms of input both devices operate differently to pre-existing AAC, requiring low amounts of user-input and usable as a supplemental prop [78]. Deliberately, this *scaffolds* and *augments* communication styles without replacing minimally verbal users pre-existing communication with TTS [41].

Concerning future improvements, some co-designers criticised the small buttons of the *InkTalker* resulting in 'fat finger' problems and preventing ease of one-handed inputs [86]. Furthermore, the small-size of the e-Ink badge led some to worry about its robustness. Consequently, future iterations could look to add a 3D-printable case to increase both *InkTalker's* robustness and button size. Although the e-Ink guaranteed low battery consumption, some felt they would need a more eye-catching display in busy contexts (e.g., public transport/coffee shops) where it was difficult to draw attention [22]. Yet, the affordability of the smart-badge and long-battery life proved popular. Turning to the *more* eye-catching but battery-intensive smartphone *WalkieTalkie* app. Some participants expressed hesitance at using a smartphone as an external display in public versus a dedicated badge – especially as badges (e.g., TFL badges) have greater public recognition and credibility [33, 34]. As previously noted by Faucett et al. [29], assistive apps might potentially *downplay* the significance of disability within public domains. Albeit, the *WalkieTalkie* app does support integration into the publicly recognisable *Hidden Disability* lanyard, plus the downloadable nature of the smartphone app provides scalability and promotes ease of adoption[6] [55]. Another notable critique of the *WalkieTalkie* app considered Photo Speech's *'Americanised'* classification of objects. These findings renew salient discussions concerning ethical AI-enhanced AAC features and design [47, 65, 81, 89, 93]. Similarly, previous AI-enhanced AAC apps (e.g. [32, 66]) have also had issues with AI-accuracy and misclassification of photographed objects for their users. In response, Fontana de Vargas et al. [32] stressed the importance of AI-human co-operation and Obiorah et al. [66] encouraged the design of *augmentative* AAC. At all times, AI-enhanced AAC features should respect user autonomy, privacy and preferences – Valencia et al. [93] study investigating the potential of integrating LLMs into AAC found users were concerned about people using their data without consent, theft/data breaches and personal data processing.

Extending this previous guidance, we strongly believe that AAC devices should be *regulatable* – thus support and encourage the pre-existing unaided competencies of their users [41, 42]. Critically both the *WalkieTalkie* app and *InkTalker* smart-badge, provide the adaptability to be concealed by the user and *not* always used – with the pocketable size of the *InkTalker* and *WalkieTalkie* selectively camouflaging into clothing [70]. Furthermore, the small and regulatable form-factors of both devices do not discourage from the wearer's usage of their pre-existing non-verbal communication abilities i.e., paralinguistics, gesture, body language, personal space, eye–gaze, appearance and low-tech artifacts [41, 42]. Indeed, both devices can *even* be used to emphasise wearer's alternative communication strengths e.g., *"I prefer to write/draw on paper"* [63, 78]. Whilst, the small size of the *InkTalker* badge can be leveraged with a pull reel and used as a prop to supplement a myriad of personal communication styles. In contrast, the *WalkieTalkie* app is designed to support multimodal interactions for differing communication needs. For instance, custom badges supports text-to-speech if the user is non-verbal or can be used with *just* supplemental non-verbal gestures. Equally, Symbol Speak imagery associated with the wearer's minimal dialogue – enabling hand and attention-free input – just speak and use intuitive bodily gestures. Furthermore, the *WalkieTalkie* app supports word-finding via both the accessible photo-classifier or cognitively lightened web-querying prioritising resourceful independence [21] and ensuring users have the freedom to use an AI-enhanced feature or not [66, 93]. Ultimately, both AAC devices operate as supportive communication aids in challenging instances rather than permanent assistive interventions that limit agency [6, 41, 94].

[6]Previously, McNaughton and Light [55], have discussed the range of benefits and key challenges regarding AAC apps for smartphones/tablets.

7.2 Considerations for AAC Research

Every day, many people living with aphasia effectively employ minimally verbal dialogue, embodied/non-verbal communication, total communication strategies, props and low-tech devices (i.e., Figure 2) to live independently. AAC interventions should appropriate from these pre-existing strategies and popular low-tech communication technologies thereby seek to *augment* and *enhance* the pre-existing abilities of people living with CCN [66]. Currently, *most* mainstream AAC devices are cognitively demanding and rigid interventions with learning demands for, what is ultimately sender-receiver styles of communication [41, 42]. Repeatedly research has found these AAC interventions place *significant* adjustment pressures on the user – their friends, family and community [42, 65]. Repeatedly, McCord and Soto's ethnographic investigation of AAC amongst Mexican-American families found AAC users abandoned devices and preferred to communicate using unaided language systems rather than their AAC device [54].

Aphasia, like many other CNNs, is a fluctuating language impairment. Consequently, people living with aphasia may *only* choose to use their AAC device when they feel cognitively fatigued or in specific highly pressurised language environments [56]. Echoing previous research by Ibrahim et al. [41] amongst children with severe speech and physical impairments (SSPIs), AAC devices should have their status/visibility regulated via shifting in shape/function will provide more socially acceptable interventions for users with differing and evolving CCN [73]. AAC designs should also always consider the socio-cultural norms of device usage and the individual's natural desire to blend in such considerations are extremely important for long-term adoption and usage [29, 73, 75, 85]. Vitally, given the importance of confidence in communication for communities with CNNs [16, 18, 23], we argue that AAC interventions should aim to scaffold *pre-existing* communication skills; not merely augmenting communication but *confidence* too.

We recommend future AAC reconsider the – often adopted – *medicalised* perspective; that AAC users *must* replace users' pre-existing multimodal communication abilities with TTS speech generation [42, 82]. Previously, Ibrahim et al. [42], has correctly asserted that these AAC devices problematically suggest disability resides within the individual with AAC devices 'repairing' users pre-existing communication with TTS. Instead, as revealed through our co-design process, AAC devices might look to highlight communication strengths or *interdependently* [4] educate better communication practices to unfamiliar conversation partners on behalf of the AAC user – such as slowing speeds (i.e., *"Please talk slower"*), giving time for people with CCN to repair their dialogue (i.e., *"Do not finish my words"*), recommend useful alternative communication modes (i.e., *"Please write this down"*) and reveal the wearer's interests (i.e., Keith Harding artwork) [4]. Within the literature, Sobel et al. [88], *AAC Awareness Displays* for people with amyotrophic lateral sclerosis (ALS) similarly successfully provided speaking partners with *more* context via a partner-facing display, which improved conversational flow and better co-constructed communication.

7.3 Co-design with Communities Living with Aphasia

This work provides further evidence for more direct engagement with communities with CCN and co-design of human-centred AAC technologies [18, 66]. Co-design workshops began with an analysis of employed assistive technologies, enabling us to collaboratively design AAC that more seamlessly intervenes in people with aphasia's everyday lives. Many of the participants were non-verbal but still communicate effectively each day – especially with friends and family [54]. Instead, communication breakdowns most commonly occurred during communication with strangers in busy/stressful contexts – therefore these scenarios were identified most optimal for AAC intervention [68]. Furthermore, our results from thematic analysis of the co-design workshops found high-tech AAC would be more effective if devices sought to embrace and enhance people's pre-existing abilities boosting confidence and self-esteem [10]. Indeed, as argued by Dietz et al. [23], AAC should serve as an empowering tool to encourage people with CCN to pursue further independence and life-affirming activities – supporting during potential communication breakdowns. Low-fidelity tangible prototyping using Epp et al. [27], scenario stations supported participants' ideation of low-fidelity AAC: including *interdependent*, lanyard accessible and attachable devices. Meanwhile, divergent-convergent AAC badge prototyping supported participants assisted engagement with AI-image generation and wireframing of badges [18]. AI-image generation supported *fast* divergent design and provided an opportunity for participants to critique high-resolution contextual imagery without associated fabrication costs. Nonetheless, we *must* highlight the associated environmental [96] and human costs [12, 48] of using these tools[7].

8 LIMITATIONS

This research has several limitations. Initially, it accounts for a limited context – there was widespread technology literacy – almost all participants owned a smartphone and were comfortable using a smartphone. Significantly, people with disabilities are *very* diverse, not all people with aphasia could produce equivalent results [71]. Consequently, it may be challenging to generalise the findings of this paper to a broader population. Turning to methods, we performed an initial evaluation of both AAC devices using experience prototyping over a relatively small sample size, with a familiar SLT as an actor and repeated sampling of participants. Instead, short to medium-term field deployment of both AAC devices in real-world contexts of usage would provide more concrete findings. Indeed, our participants reported that they felt unrealistically comfortable role-playing with a familiar SLT using both devices to support their communication abilities in a controlled setting.

[7] Although a small sample size, our co-designers – who are diverse and multicultural in background – noted the comparably fewer people of colour generated by DALL-E image-generation tools [61, 79].

9 CONCLUSION

With increased barriers to long-term speech and language therapy for many people living with CCN – we need *more* intuitive AAC interventions, which better augment and scaffold the pre-existing multimodal communication abilities of their user. In this work, through co-design and appropriating from pre-existing technologies used by people living with aphasia – we shift towards *more* socially regulatable and interdependent low-input wearable AAC technologies. Outputs from this enabled us to create and iterate two wearable AAC displays: (1) the *InkTalker* smartbadge and (2) the *WalkieTalkie* app. To evaluate both technologies, we then held task-based experience prototyping and focus groups. Subsequent insights from the design process and evaluation can inform the design of future AAC technologies that do *not* restrict agency and better support multimodal communication.

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