Designing Conversation Cues on a Head-Worn Display to Support Persons with Aphasia

Kristin Williams[1], Karyn Moffatt[2], Denise McCall[3], Leah Findlater[1]

[1] Inclusive Design Lab | HCIL
College of Information Studies
University of Maryland, College Park, MD

[2] ACT Research Group
School of Information Studies
McGill University, Montreal, QC

[3] Snyder Center for Aphasia
Life Enhancement
Baltimore, MD

krismw11@umd.edu, karyn.moffatt@mcgill.ca, dmccall@scalebaltimore.org, leahkf@umd.edu

ABSTRACT

Symbol-based dictionaries of text, images and sound can help individuals with aphasia find the words they need, but are often seen as a last resort because they tend to replace rather than augment the user's natural speech. Through two design investigations, we explore head-worn displays as a means of providing unobtrusive, always-available, and glanceable vocabulary support. The first study used narrative storyboards as a design probe to explore the potential benefits and challenges of a head-worn approach over traditional augmented alternative communication (AAC) tools. The second study then evaluated a proof-of-concept prototype in both a lab setting with the researcher and *in situ* with unfamiliar conversation partners at a local market. Findings suggest that a head-worn approach could better allow wearers to maintain focus on the conversation, reduce reliance on the availability of external tools (*e.g.*, paper and pen) or people, and minimize visibility of the support by others. These studies should motivate further investigation of head-worn conversational support.

Author Keywords

Aphasia; head-worn display; conversational support; wearable computing; accessibility.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (*e.g.*, HCI).

INTRODUCTION

Individuals with aphasia experience a sudden loss of language skills (*e.g.*, due to a stroke) [7]. Because of aphasia's impact on speaking and comprehension, this loss can make even simple day-to-day conversations challenging, leading to a sharp reduction in independence. Computer-based tools to support aphasia typically provide multimodal, symbol-based dictionaries that can be used either as a replacement or prompt for natural speech [7,17].

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Figure 1. Participant in Study 2 before entering the market to complete tasks with head-worn vocabulary. Each prompt provides an image, text and audio (*e.g.*, pumpkin is shown, top-right). A wrist-worn touchpad (smartphone) controlled the display for study tasks (bottom-right).

Unfortunately, adoption of these augmentative and alternative communication (AAC) tools remains low [17]. The causes are complex, but evidence points to issues in how external devices disrupt social conversation norms and draw undue attention to the disability [17]. Unlike prosthetics such as eyeglasses or hearing aids, traditional AAC tools, either on dedicated assistive devices (*e.g.*, Dynavox [1]) or more recently as mobile apps (*e.g.*, Lingraphica[2] and Proloquo2Go[3]), are *external* to the user—requiring the user to consciously seek out support and divert attention away from the current conversation (*e.g.*, to retrieve and interact with their device). Multi-tasking while conversing can be challenging for anyone, but for an individual with aphasia, it can significantly impact speech production [25].

In this paper, we investigate the design of vocabulary prompts on a head-worn display for individuals with aphasia (Figure 1). By providing always-available and glanceable support, a head-worn display may enable a fundamentally different communication experience than existing tools—potentially enabling the user to better maintain focus on their communication partner while unobtrusively controlling the conversational support. While research in wearable computing has long employed head-

[1] http://www.dynavoxtech.com/default.aspx
[2] http://www.aphasia.com/
[3] http://www.assistiveware.com/product/proloquo2go

worn displays for contextual information such as just-in-time memory support [24] and cross-language communication [23], supporting communication for individuals with aphasia has not yet been studied.

We conducted two studies to inform the design of head-worn vocabulary support and to assess the potential impacts of such support. Study 1 was an interview study to elicit feedback on the general idea from 8 participants. It included an introduction to and brief use of Google Glass, as well as presentation of two narrative storyboards as a design probe. Guided by findings from that study, we built a proof-of-concept prototype on Google Glass—that we call *GLAAC* (Glass AAC)—and evaluated it with 14 participants with aphasia. In Study 2, participants used GLAAC during conversations in a lab setting with the researcher and *in situ* with unfamiliar conversation partners at a local market.

Combined, our results show head-worn vocabulary prompts to be a feasible approach to conversation support. Findings from Study 2, in particular, suggest that glanceable vocabulary contributed to keeping participants' attention on their conversation partner and helped them stay engaged in the conversation task while seeking out support. While some participants discussed concerns with device input, there was generally a positive response to using head-worn vocabulary in busy contexts where environmental pressures challenge those with aphasia to respond quickly. Our work contributes (1) a proof-of-concept prototype for presenting vocabulary prompts on a head-worn display; (2) a qualitative evaluation of this prototype based on use in lab and field settings; and, (3) identification of potential contexts of use for which head-worn vocabulary prompts may be most beneficial. Secondarily, we reflect on the methods used in our studies and their efficacy for eliciting feedback from individuals with aphasia in the design and prototyping stages of new technology development.

RELATED WORK AND BACKGROUND

We provide a brief background on aphasia, as well as research on computerized AAC and head-worn cognitive and communication support.

Aphasia

Aphasia is an acquired language disorder that occurs from damage to the language areas of the brain [7]. It ranges widely in severity from mild complications in speech production to complete loss of language production and comprehension. Depending on the location and extent of the brain damage, individuals can experience different combinations of deficits in naming, fluency, repetition, auditory comprehension, grammatical processing, reading, and writing [7]. Aphasia affects people of all ages; however, as the most common cause of aphasia is stroke, the prevalence of aphasia increases with age.

Due to impaired language skills, those with aphasia can be perceived as incompetent and can find their opportunities to participate in conversation and decision-making limited [13]; delays while formulating a response can lead to a speaker with aphasia losing their turn [3]. Conversational success often depends on the facilitation skills and cooperation of the conversational partner [3,13]. These barriers to participation are particularly evident in public or community settings where conversation partners may be unfamiliar with aphasia and may not have the same patience and understanding as a more intimate partner.

Computerized AAC for Aphasia

While some research has focused on supporting people with aphasia in activities of daily living (*e.g.*, daily planning [4,20] and cooking [26]), AAC support has been a more dominant theme in the literature. Some high-tech AAC systems focus on storytelling, by enabling access to pre-recorded stories that can be used to introduce topics (*e.g.*, TalksBac [27]). Others provide mechanisms for capturing and accessing photos for use in later conversation [1,2].

Another popular line of work is the use of symbol-based dictionaries of words and phrases—an approach that we use in this paper. These tools typically provide audio and pictures paired with text, and address the problem that individuals with aphasia generally know what they wish to say, but may experience difficulty in expressing the specific words needed. A primary challenge, however, is providing fast access to vocabulary that is typically organized in deep, cumbersome hierarchies. Manual customization is commonly supported, but effortful. Another approach is to reduce navigation time by organizing vocabulary based on semantic associations [21], or dynamically adapting it based on the user's location or conversational partner [14]—some research has begun to explore automated means of generating these contextual predictions [8].

While these approaches provide promising directions for content organization, they ignore how the form factor of the device may impact the user's ability to efficiently integrate support into conversation. For many individuals, the audio and visual stimuli are sufficient for prompting speech. However, because that support is audible and visible to others, the system tends to dominate, replacing rather than augmenting the user [17]. Moreover, use requires that the user turn their attention away from the conversation, which is not only socially awkward, but can impede the use of facial cues as an aid to comprehension [10]. We conjecture that the time to pull out the tool along with the negative implications of turning focus away from the partner compound the effect of navigation time on communication success. We thus explore the use of a head-worn display as an alternative form factor that is also compatible with automated approaches to efficient vocabulary organization.

Head-Worn Cognitive and Communication Support

To our knowledge, no research has investigated head-worn displays to support persons with aphasia, although one project used a head-worn camera to capture content for later use in storytelling [2]. A few studies have looked at head-worn displays to support older adults [16] and persons with

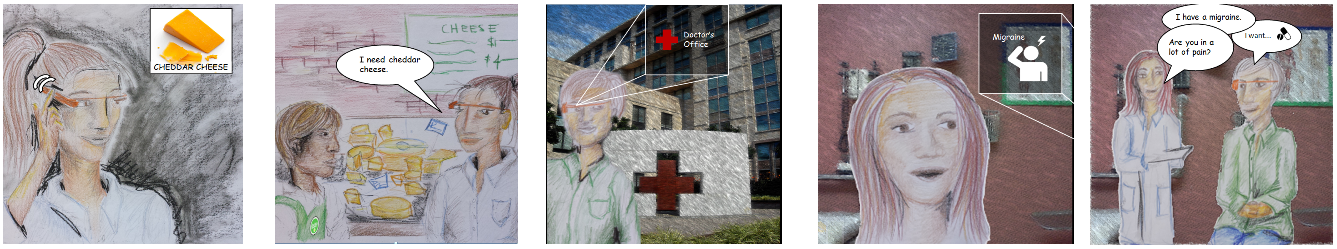

Figure 2. Example frames from the storyboards used as a design probe in Study 1: two frames from the grocery store scenario showing a woman searching for cheddar cheese, and three frames from a man with a migraine visiting the doctor.

cognitive decline [11]; these efforts have identified a number of potential application areas, including short-term memory aids, experience capture, and instructions (*e.g.*, for cooking). In addition, a study of Google Glass with persons with Parkinson's disease found no serious accessibility challenges due to motor impairments [19], a consideration that is also important for persons with aphasia, who often have right-side hemiparesis (weakness or paralysis).[4]

More broadly, the effect of delivering information via a head-worn display during conversation has been studied with unimpaired individuals, but whether these findings extend to the design of AAC remains an open question. One study on the timing and modality of information delivery during conversation found that it should be delivered visually in batches when the wearer is not speaking [22]. Another study showed that delivery during conversation negatively impacted eye contact and attention [18]; however, the information shown was not relevant to the conversation and the display was located just below the wearer's line of sight. It is unclear how these findings will translate when the information plays a direct role in the conversation, as with our approach.

STUDY 1: FORMATIVE INTERVIEWS

We conducted an interview study with 8 participants with aphasia to gauge initial reaction to vocabulary prompts on a head-worn display and to perform a preliminary assessment of the accessibility of Google Glass for users with aphasia.

Method

The study included basic tasks on Glass, and semi-structured interviews with storyboards as a design probe.

Participants

Language ability varies greatly with aphasia, and we predict that our approach will be most useful to persons with good auditory comprehension and mild to moderate verbal production deficits. However, as this first study relied heavily on discussion of the design probe, we targeted recruitment at the higher end of that range. Participants were screened by a licensed speech-language pathologist based on two standardized tests: (1) the Communication Activities of Daily Living (CADL-2), to assess the impact of impairment on daily communication [12], and (2) the Western Aphasia Battery (WAB), which assesses type and degree of aphasia [15]. Criteria for participation included a minimum of the 50^{th} percentile for the CADL-2, and for the WAB, 7/10 for auditory verbal comprehension and 5/10 for information content of spontaneous speech.

Eight participants were recruited at a local community organization for individuals with aphasia.[5] They ranged in age from 45 to 72 (M = 59.8, SD = 8.5); one was female. All participants acquired aphasia from a stroke that resulted in right-side hemiparesis (weakness). As a result, all participants were left-handed post stroke; pre-stroke, S5 was left-handed and S4 was ambidextrous.

Storyboards

Two storyboards depicting everyday conversational tasks were used as a design probe, to elicit feedback on the idea of glanceable, head-worn vocabulary prompts:

- *Grocery store* (Figure 2). A woman visits a grocery store while wearing a head-worn display preloaded with her grocery list. At the store, she cannot locate the cheddar cheese nor can she express the words "cheddar cheese" to ask a clerk where it is. She activates the device, navigates a hierarchy to the entry for cheddar cheese, and taps to play text-to-speech. After practicing saying "cheddar cheese" on her own, she seeks a clerk and successfully asks for help with finding the cheese.
- *Doctor's office* (Figure 2). As a man approaches a clinic, the head-worn device recognizes it and automatically loads personalized medical prompts. Once in the examining room, the man points to his head and the doctor guesses that he has a headache. But, to be more specific, the man accesses two prompts on the head-worn display to help him say that it is a "migraine" and that he wants the medication "Zomig".

The storyboards were initially hand-drawn, revised with image manipulation software, and augmented with comic-book grammar to convey text-to-speech features, GPS triggers, projected displays, and gestural interaction. Finalized panels were printed on paper for a low-fidelity look-and-feel to encourage critical discussion.

Interviewing and Communication Technique

Because communication is inherently difficult with aphasia, past work has proposed guidelines for including individuals with aphasia in the design process. Accordingly, our

[4] Aphasia results from damage to the left side of the brain. As motor-function is contralateral, right-side deficits are common.

[5] A ninth participant withdrew.

method employs aspects such as working one-on-one with participants [9] and phrasing questions in a closed manner when necessary [13]. The lead researcher was also trained in *supported conversation*, a set of methods designed to create opportunities for an individual with aphasia to contribute to the conversation [13]. While we primarily asked open-ended interview questions, we used supporting materials to adapt to each participant's needs: pictures, visual scales with close-ended alternatives to the open-ended questions, paper and pen, and finally, markers, sticky notes, and transparent sheets to annotate the storyboards.

Procedure

We developed protocols in consultation with clinicians, such as an aphasia-friendly consent process; our institutional review board (IRB) approved these protocols. Study sessions were one hour long. Following informed consent, participants were asked demographic questions as well as questions about their current conversation support strategies. The following two parts were then completed:

Part 1: Google Glass Use. The researcher introduced Glass and demonstrated directional swipes (forward, back, and down) and taps on the arm of the device. During this demonstration, participants viewed the effects of the input via screencast on a paired Bluetooth phone. Next, participants put on Glass. After the participant had tried out and confirmed that they understood each gesture, the following set of tasks was presented (~10 minutes): (1) navigate to a photo album, (2) view a recent New York Times article, (3) activate the audio feature to have the headline text read aloud, and (4) return to the home screen. These tasks required at a minimum 3 forward, 3 backward, and 1 downward swipe, and 2 taps. After, participants rated each of the following on 7-point scales (easy to difficult): swiping the touchpad, tapping the touchpad, seeing images/text on the screen, and hearing audio output.

Because 3 of the first 6 participants encountered difficulties in using Glass's touchpad, we adjusted the above protocol for the last 2 participants to include a second input option. These participants completed the task set on the Glass touchpad, and then repeated the task set using the Bluetooth-connected phone as a touchpad to control Glass.

Part 2: Storyboard Scenarios. The storyboards were introduced one at a time (grocery store then doctor's office), and participants were asked to give feedback and discuss the role of Glass in each one. Once both storyboards had been shown, participants were asked open-ended questions about whether and how a head-worn display could provide support during conversation.

Data and Analysis

The entire session was video recorded with the exception of S1, for whom only audio was recorded. Open-ended responses were analyzed for themes of interest [6].

Aspect of Use	Mean	SD	Median	Range
Swiping	4.1	1.0	4.0	2–6
Tapping	3.5	2.1	4.0	1–7
Seeing	3.9	1.6	3.5	2–6
Hearing	4.0	2.3	5.0	1–7

Table 1. Study 1 ratings of Google Glass accessibility, including swiping and tapping on the touchpad, seeing the display, and hearing the audio (1=easy; 7=difficult). (N = 7)

Findings

Participants identified accessibility issues with Glass and offered feedback on the idea of head-worn word prompts.

Accessibility of Glass

While some participants were able to use Glass with relative ease, others encountered substantial challenges. Ease of use ratings were mixed as a result, as shown in Table 1. Based on video analysis, swipes and taps were particularly problematic for 3 participants and the researcher had to step in and control their finger or the device itself to help them complete the tasks. One of the three, S7, was not able to use the touchpad on Glass without the researcher's help, so did not rate its ease of use; he was however able to use the phone as a touchpad and rated its ease of use: swiping, 4; tapping, 1; seeing 2; hearing 1. In total, 6 of the 8 participants expressed a preference for inverting the device's design so that the touchpad and display would be on the left.

In terms of the display, 3 participants gave low ratings for being able to see it, either due to poor eyesight or weakness in the right eye, or a preference for having a display on both sides. Two participants encountered issues with the audio being hard to hear or too fast.

Feedback on Glanceable Vocabulary Prompts

Overall, 7 out of 8 participants spoke positively of the ideas presented in both storyboards. S6 only responded positively to the doctor's office scenario, finding the vocabulary depicted in the grocery store scenario too easy to require support. We summarize the main themes here, particularly focusing on those related to the head-worn form factor.

Enabling stronger conversational roles. Five participants discussed how support during conversation can impact their identity within a group and ability to influence group decisions. Important roles included being a fully informed patient at a doctor's office, providing customer service at work, or asking questions at a board meeting. S1, for example, expressed a desire to return to his previous job as a restaurant owner. To do so, he envisioned using the head-worn display to ask customers for their preferred ingredients while making sandwiches with his hands. As another example, S3 sat on the executive board of a family business, but found his opinion skipped over at meetings when he needed to use paper and pen to communicate. He felt a head-worn display could address this problem.

Privacy & social perception. The privacy of the audio and visual output was seen by two participants as potentially enabling natural speech. S5 liked private access to phonetic cuing because she would still have the opportunity to say the word herself: *"I can't say it…um…but I know what it is…so this device can say it for me, and [then] I'll say it."* S3 wanted access to the audio, text, and visual aspects of the prompts to support his communication without circumventing his place in conversation. When asked why those aspects, he said: *"Because [the prompts are] working now I mean…its…I'm the one asking, not [my wife] or someone else but me."* The ability to retain the ability to speak for oneself while accessing support was important for these participants. None of the participants raised concerns about privacy or negative social perception when asked about the drawbacks of using Glass.

Overcoming contextual pressures. Six of the 8 participants highlighted situational pressures that make timeliness of support important. S3 was keenly aware of having a limited amount of time to find support because otherwise he may lose his turn to ask a question or steer the topic of conversation during group meetings: *"But I can't say it, or write it down, or have me a pen and paper…4 or 5 minutes and then that's it."* S6 provided the example of wanting to use head-worn support when taking the bus so that he could respond to the bus driver's requests: *"talk to bus driver, money, what kind of money, $1 okay."* This hurried context of boarding a bus while retrieving the required fare highlights the potential of glanceable support.

Related, 4 participants described how support mechanisms may be unavailable or misplaced at the time they are needed. A wearable, always-available display could mitigate this issue. S2, for example, uses voice recognition on his phone but sometimes misplaces the phone. In this respect, he viewed Glass positively: "*[taps the side of his glasses] click away and the eyes see it and there is no distractions [like] with 'where's my cell phone?"*

Perceived advantages. Participants additionally noted a number of general advantages relative to their current compensatory strategies. Two mentioned trouble with audio-only conversations, noting the need to both hear and see. S6, for example, explained that he does not use a cell phone because he needs to see facial expressions. This points to problems with assistive tools that require the user to look away from their partner to access the support. A head-worn display would allow the wearer to monitor their partner's facial expressions while accessing support.

Another general advantage, raised by 3 participants, was that while writing was useful, it was also time consuming, inefficient, and dependent upon finding a pen. Particularly relevant to our focus on vocabulary retrieval, 4 participants described elaborate support strategies for when precision is needed. S2 described that when he needs a specific medication he relies on the availability of a particular pharmacist who knows him. S3 described telephoning his wife when stuck, who would then list off possible words until finding the right one. Both of these examples point to the potential of AAC vocabulary support as a solution, though a head-worn display may not be necessary.

Perceived drawbacks. Apart from the widespread concern about the right-sided touchpad on Glass, other concerns that arose regarding head-worn vocabulary support included: one participant who did not like the idea of assistive technology in general (whether a tablet, phone or head-worn display), concern by 2 participants about the learning curve for our proposed solution, and 1 participant who did not want more than five prompts on the device, feeling that it could detract from efficient navigation mid-conversation. Note, however, that this lattermost participant changed his mind after also participating in Study 2.

Summary

Overall, participants responded positively to the idea of head-worn conversational support, seeing potential for it to provide a stronger role in conversation for the wearer and to allow for more efficient communication than existing strategies. While the study did reveal accessibility issues with Google Glass, the use of alternative input options alleviated these concerns.

STUDY 2: PROTOTYPE AND EVALUATION

While the findings from Study 1 suggest promise for head-worn vocabulary support, the experience of using a working prototype could be different. For this second study, we built a proof-of-concept prototype called *GLAAC* and asked 14 participants with aphasia to complete conversational tasks with the prototype in a lab setting and at a public market.

Proof-of-Concept Prototype

For the proof-of-concept prototype, we wrote a custom Android application for Google Glass. The design was informed by common participant feedback in Study 1 (*e.g.*, the need for a different touchpad placement) and user interface guidelines for individuals with aphasia (*e.g.*, [5,10]). Although Study 1 explored the number and types of prompts that should be included in such a tool, these remained open design questions in Study 2.

The prototype consisted of a simple two-level hierarchy of words the user could navigate with swipes and taps (Figure 3). The top-level categories were 'baseball', 'groceries', and 'you', which correspond to the study tasks described below; 'you' was customized to each participant. Each category included five words. Category and word screens consisted of an image, a text label, and an audio prompt (provided by Android's text-to-speech engine). To visually differentiate between category screens and word screens, categories used white icons on a black background, while words included color photos and had the parent category's icon superimposed on the upper-right corner (Figure 3).

Only one screen in the hierarchy was visible at a time. We used standard Glass interactions for navigation: *forward* and *backward swipes* scrolled through items in the current level of the hierarchy, *tap* moved down a level (*i.e.*, from a category to its specific words), *downward swipe* canceled

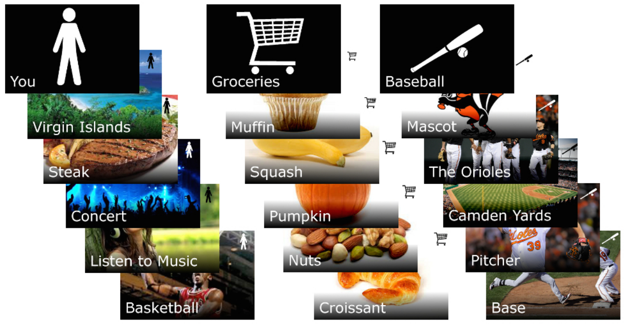

Figure 3. Vocabulary in the proof-of-concept prototype for Study 2. This two-level hierarchy consists of three categories (you, groceries, baseball), and five words in each category. Each screen provides an image, text, and audio. The 'you' category was customized in advance for each participant.

out of a level (*i.e.*, from a specific word back to its category screen). In addition, we implemented a fifth gesture, a *two-finger tap*, to play audio for the current screen.

Because of the difficulties observed in Study 1 with Glass's right-sided touchpad, we used a Bluetooth-paired Samsung Galaxy S4 phone to control the prototype (Figure 1). Pairing the phone in this way mirrors the Glass display on the phone's screen and allows use of the phone's touchpad to control Glass. We covered the phone screen in black tissue paper that still allowed for touch input while visually hiding the display.. The phone was placed in a sport armband, which could then be attached to the user's right wrist to allow for left-handed control of Glass. While this approach is not designed for long-term use, it allowed us to sufficiently circumvent the accessibility issues with Glass's right-sided touchpad to conduct an exploratory evaluation.

Evaluation Method

The proof-of-concept prototype was evaluated with 14 individuals with aphasia to assess usage and response to head-worn vocabulary prompts during conversation.

Participants

We recruited 14 participants (3 female) through our partner organization, including the 8 who had participated in Study 1. As Study 2 relied less on verbal feedback than Study 1, we did not restrict participation to those with high verbal skills. Participants were screened by a licensed speech-language pathologist. Participants ranged in age from 46 to 75 (M = 61, SD = 8.1). Scores on the CADL-2 ranged from the 31st–99th percentile. Composite scores on the WAB ranged from 51.5–82 (M = 68.6), while the sub-component ranges were 5–10 (M = 7.6) for information content, and 5.85–9.5 (M = 8.1) for auditory verbal comprehension.

Procedure

Study sessions were two hours long and were IRB approved. Participants wore Google Glass and controlled it via the paired Samsung phone, which was attached to their right wrist. The researcher introduced the application and how to control it with the touchscreen gestures by using the 'baseball' category; this category was chosen because it is a popular conversation topic at the partner organization. Participants then completed tasks in two settings: an autobiographical task in the lab with a researcher, and two shopping tasks at a nearby market with unfamiliar store clerks. Finally, a semi-structured interview was conducted.

Autobiographical task. To provide practice using head-worn prompts, the researcher and participant had a brief conversation (~5 minutes) on a familiar topic and in a quiet environment. To support this conversation, the 'you' category was customized in advance based on a short questionnaire on personal interests administered before the session. The researcher then asked 3 open-ended questions, such as "What would you like to do this weekend?" or "What do you enjoy doing in your spare time?" Participants were asked to use the prompts when responding.

Market tasks. During the second hour, participants visited a nearby market with the researcher to use GLAAC for *in situ* conversational tasks with unfamiliar partners (*i.e.*, store clerks). We chose a setting with an unfamiliar partner as it is a challenging—but important [25]—setting for high-tech AAC design. The tasks were: (1) ask for an out-of-season item that would not be easily found (a pumpkin), and (2) ask whether a particular product (a muffin) contained an allergen (nuts). These tasks were chosen because of their everyday nature and because they would be difficult to accomplish through other compensatory strategies like pointing and gesturing. The 'groceries' category contained 5 prompts: 3 ('pumpkin', 'muffin', and 'nuts') to support the tasks, and 2 ('croissant', and 'squash') as distractors.

Before leaving the lab setting for the market, the researcher explained the goal of each market task by using pictures but without verbally naming the items (pumpkin, muffin, nuts). For example, for the second task participants were instructed to clarify whether 'this bakery item contains this common allergen.' Participants were given a chance to ask questions in the lab and again before entering the market.

Semi-structured interview. Finally, upon return to the lab, the researcher asked open- and close-ended questions on the experience of using GLAAC.

Data Collection and Analysis

All interaction with the device was automatically logged. The autobiographical task and semi-structured interview were video recorded, while the market trip was only audio recorded due to IRB concern that video was invasive of bystanders' privacy. Clerks were told about the study in advance, but they were not given detail about the tasks or goals. To supplement the market audio data, the researcher took notes in situ and filled out a more thorough observation sheet immediately following the study session. This sheet included topics like whether the participant said the target vocabulary word or whether the device created noticeable disruption during conversation with the clerk.

Semi-structured interviews were transcribed and coded for themes of interest [6], while allowing for new, inductive codes tied closely to the data to emerge. We developed our themes from 22 codes, such as 'line of vision', 'timing of support', and 'learning curve'. Speaking turn was used as the basic unit of analysis for coding. However, because supported conversation requires the interviewer to act as a resource for the person with aphasia, a "turn" could cover more than one speaker or even the same speaker multiple times [3]. In cases requiring gestures for interpretation, the video data was also referenced. Finally, to validate our approach, a person independent of the research team used the code set to independently characterize participant-initiated topics and to jointly code a transcript with a member of the research team to verify whether consensus held. The two coders disagreed in 65 of 1034 cases, conflicts were resolved through discussion, and when interviewed on issues of bias, completeness, and characterization of participants' responses, the independent coder thought the codes were being applied fairly.

Findings

We begin with an overview of the autobiographical and market task results, focusing on the log data use and Likert scale feedback, before covering the themes that arose in the end-of-session interview portion of the study. Participant numbers for repeat participants are the same as in Study 1.

Overall Task Success

Autobiographical task. Overall, participants responded positively to using GLAAC to answer the researcher's questions about their personal interests (7 positive, 4 mixed, 2 neutral, 1 negative). Negative responses were largely directed at the physical form factor, with 9 participants suggesting modifications (*e.g.*, adding physical buttons, improving gesture detection, and moving to the left the touchpad/display). Four participants criticized the limited vocabulary, wanting it customized to their needs or interests. For example, S2 highlighted how our design does not capture his main need for help linking vocabulary: *"…'how', 'is', 'its', 'have', […] a lot of times [my conversation partner] can't help me [with those]."* A summary of log data from interactions with the device is shown in Table 2.[6]

Market tasks. Accessing the word prompts appeared to help participants correctly say the target vocabulary while at the market. Based on observational data, 7 participants used the prompts and said the target vocabulary for both the pumpkin and muffin tasks, while 3 more did so for at least one of the tasks (another participant was successful but did not need the prompts at all). The participant who had scored the lowest on the functional language profile of the CADL (S14) was not successful. However, 5 of 7 participants who scored in the middle of the range were successful with at least both tasks—a promising finding particularly given the complexity of using a new device in a busy environment.

Participants rated their use of the prototype at the market highly. The overall average rating of the experience was 7.5

	Lab		Market	
	M	*SD*	*M*	*SD*
Number of prompts used	20.9	12.3	36.7	21.3
Time spent on irrelevant vocabulary (%)	32.3	17.0	69.2	20.0
Number of touch events	26.9	17.5	42.5	26.8
Elapsed time of interaction bursts (s)	1.4	0.2	2.0	0.9
Number of times the most relevant word category was closed	0.7	1.2	3.1	2.2

Table 2. Interactions with GLAAC in the autobiographical (lab) and market tasks. Unsurprisingly, participants encountered more difficulties in the market setting; however, overall subjective response was still positive.

on a 9-point scale, where 9 is positive (SD = 1.3, median = 7.5). Participants also felt that they were able to concentrate on conversing with the clerk while using the prototype (M = 7.6/9, SD = 1.5, median = 8.5), and that the device generally supported rather than disrupted their conversation with the clerk (M = 7.1/9, SD = 1.4, median = 7.5).

The log data, shown in Table 2, suggests that differences between the lab and market settings impacted use of the device. On average, participants viewed more prompts at the market, spent less time on relevant vocabulary, and interacted with the device both more often and for longer than they did during the autobiographical tasks. This trend is not surprising given the additional distractions in the market setting. Aside from one participant who did not use GLAAC at all during the tasks,[7] all participants viewed the prompt 'muffin' at least once while 11 viewed 'pumpkin' and 9 viewed 'nuts'. On average, each participant activated the 'pumpkin' audio 3.5 times (SD = 4.7), but use quickly dropped off for the second task at least partly because the audio was difficult to hear in the noisy environment. Audio use also varied by participant, with 5 participants using it over 6 times, and 4 not using it at all.

Despite these successes, some issues arose. Six participants encountered a problem in at least one of their conversations. S7, S9, S12, and S14 tried using the device during conversation but had to walk away before reattempting. The time it took for them to find the needed word caused either the clerk to excuse themselves and promise to return, or the participant to volunteer to take a moment and return. S6, S7, S9, and S10 got stuck with the device interaction at least once, for example, tapping repeatedly when tapping was not applicable or interacting at length with unrelated vocabulary. Of these 6 participants, 3 had problems saying the target vocabulary in both tasks. The others persevered and successfully completed at least one of the tasks.

Semi-Structured Interview

Our interview results illustrate how GLAAC was perceived as offering support for maintaining conversational focus, reducing reliance on others to support conversation, managing perceptions, and handling stressful conversations.

[6] Log data is unavailable for S1 due to an application malfunction.

[7] This participant was able to complete the tasks without support, as indicated in their feedback and by the researcher's observations.

Important overall feedback was that, though the market was described as a place where it is typically difficult to converse, almost all participants (N = 10) thought that GLAAC had a strong role in such environments. For example, while S3 acknowledged that it was easier to use GLAAC one-on-one in the lab, he stressed it had a bigger role in busy, public places like the market. *"Busy place, and friends or enemies, then [GLAAC has] really [a] much livelier [role]."*

Glanceable display. Nine participants discussed how the glanceable nature of the display allowed them to maintain visual awareness of their conversation partner. S5, for example, said: *"[My focus was] right on the money…he was standing right there and the…I can see him…and I can see the pumpkin".* One person, S8, discussed being able to pay attention specifically to his partner's nonverbal communication: *"Oh, yeah, I could read her."*

Some scenarios of use for GLAAC envisioned by our participants touched on the ability to immediately access support for time-sensitive exchanges. For example, S8 described how he wanted to be able to be part of a roaring stadium of fans and yell at a soccer player right when they made the wrong play: *"Yeah, 'You're doing the wrong f[*%#]in' thing!'… And they would get it."* S1 similarly expressed the desire to present his personality, by aspiring to be seen as courteous to hostesses. He felt the prototype could support these quick exchanges.

The quick access to support was also seen as helping the wearer reorient himself/herself mid-conversation. S11 described becoming anxious while talking to the clerk, but glancing at the display got him back on track: *"And the glasses, and then…I could do it. And then, other one, muffin, good."* Frequently, participants realized they did not have the word they wanted midway through speaking. S8 said:

> *"Oh yeah. I can see it really, it really come to life. I didn't have it, I can, I…right. And I can't even remember now, the prompts, but…yeah, it came to life."*

This quote describes how GLAAC helped with inserting the needed word into speech mid-conversation. Overall, 11 participants described a halt mid-speech, and 9 described seeing the support vocabulary mid-conversation.

Issues with multitasking. While the display was regarded positively overall, interacting with it was still seen as demanding by some participants. For the autobiographical tasks, 2 participants described feeling time pressure to respond while trying to read the displayed information: *"Five things, six things [on the display] and I thought, so there was no time for me to see them,"* (S8).

The wrist-based navigation was seen as particularly problematic, with 10 participants commenting that it detracted from speaking. For example, S13 felt as if the wrist navigation added a second task in addition to talking:

> *"Well this…[she mimics the swipe gesture on her wrist]. It's very hard to concentrate. Two things. This conversation, two different things of happening." (S13)*

After finishing the market tasks another participant, S6, explained: *"I like talking to people face-to-face… [but] the eye, the arm, and talking, [are] too much [at once]."*

Availability of support. The market task prompted participants to reflect on how their existing support strategies sometimes fail in similar environments. Similar drawbacks arose as in Study 1. S2 again stressed that the wearable display would be useful because it was always easily available and did not require *"fumbling around."* He mentioned the typical experience of needing to ask for help at the grocery store and having to find a paper and pen.

Four participants currently use social support strategies in these kinds of contexts, but desired more independence. S8's wife goes grocery shopping with him and provides vocabulary support, which S8 combines with gestures, but still he does not speak with the clerk in the way he experienced using our prototype. When leaving the market S8 remarked:

> *"I would never thought to do that myself...I wouldn't. [...] No, I would go with my wife. She would help me and I would have to point." (S8)*

Vocabulary prompts could replace strategies that rely on the availability of a partner to fill mid-conversation gaps. S6 uses a similar approach when at the library: he gets the librarian to list off titles until he signals that she has guessed the correct one. He would prefer to use GLAAC to initiate his own request, *"I would. Nobody [would have to] ask me."* He emphasized that their conversation would be more efficient by eliminating the guesswork: *"Oh, I know what you want,"* enabling them to proceed directly to the desired book.

Privacy. While not a common theme, we were interested in comments about discreet use and privacy. S8 stressed the importance of audio for allowing him to feel in control during a conversation: "*if we had so we can hear at the same time… then it would be easier because we can… [take] control of the situation."* S5 also mentioned privacy, in describing wanting to store contact information and vocabulary, but not wanting anyone but her family to have access to this information. Finally, while our study design did not allow us to directly examine third party perceptions of GLAAC use, one anecdote suggests use was relatively inconspicuous: the researcher incorrectly recorded S4 used GLAAC for the word "nuts" during the market task, yet afterward, S4 clarified that he had been able to say "nuts" but "muffin" was hard. The personal display had concealed the exact words used for support.

Summary

Study 2 reinforced our findings from Study 1, with observations and feedback from use in the lab and the market highlighting similar themes, including a better ability to maintain focus on the conversation, reduce reliance on the availability of external tools or people, and minimize visibility of the support by others. Nonetheless, multitasking between accessing the support and engaging in conversation was challenging for our participants and further work is needed to improve input and navigation.

DISCUSSION

Symbol-based dictionaries can help individuals with aphasia find the words they need, but are often seen a last resort because they tend to replace rather than augment the user's natural speech [7]. Our findings, though exploratory, suggest that head-worn support may mitigate this issue. Participants commented on form-factor related aspects such as being able to keep their conversation partner within their line of sight and how the privacy of the audio and visual prompts could support them in speaking for themselves. It may even be possible to provide fully discreet assistance in the future—during the market task, even we had difficulty ascertaining when participants were viewing prompts. Despite this promise, our work is only a first step and raises many challenges and questions for future research.

Reflections on Design

Cognitive demand. Manipulating a wearable device may ultimately be less demanding than using a mobile phone for the same support, not least of all because it does not need to be retrieved from a pocket or bag. Many participants in Study 2, however, found the multitasking demanding and some even needed to step back and re-orient themselves in the middle of an exchange with a clerk. A lack of familiarity with the device most likely contributed to this cognitive demand, since participants had only briefly used it before being placed in a complex, real-world setting. Even with more practice, further refinement of the input mechanism and vocabulary structure will likely be needed.

Toward an accessible head-worn display. The right-sided touchpad of Google Glass was problematic at times due to right-side motor deficits that are common with aphasia. While we circumvented the motor issues by using a Bluetooth-paired phone as a touchpad, it presented its own problems and a more refined solution is needed for long-term practical use. A wristband with physical buttons to support eyes-free input may be effective. We had also expected the visual display location on the right side to be problematic due to right-side visual deficits, but received only a few complaints in Study 1. Still, other display placements should be explored.

Scalability. A notable limitation of our proof-of-concept prototype was that it included only 15 words in three categories. Because our goal is to provide communication support *during an exchange* it is critical that needed vocabulary be available quickly. Any complete system will need to assess how many prompts are appropriate to include for this use scenario, and how these prompts should be created and managed. The most effective solution will likely combine manual customization and automatic context-based adaptation (*e.g.* [14]) to present a short list of words. The user could, for example, enter their grocery list before leaving home; similar desktop-phone hybrids have previously been explored for aphasia [4].

Target users. Aphasia varies substantially in manifestation and severity. We targeted individuals with relatively intact auditory comprehension and mild speech deficits as we see this profile as likeliest to benefit from head-worn vocabulary support. We also targeted interactions with unfamiliar partners as the primary context for use as this is an underserved area. With intimate partners, in contrast, low- and no-tech AAC solutions (such as pointing, gesturing, and drawing) are often sufficient due to the partner's familiarity with the person and with aphasia.

Reflections on Study Method

Although both studies were exploratory, they played different but complementary roles. Study 1 relied heavily on verbal description to collect feedback on early design ideas, which can be challenging for individuals with aphasia [2,9,14]. As such, we recruited participants with high verbal abilities and drew heavily on recommendations for incorporating individuals with aphasia into the design process [14]. Study 2 instead focused on use of a working prototype. This approach greatly broadened the range of feedback we received and allowed us to recruit participants with lower verbal abilities, supplementing their feedback with observation. Success in lab or therapy settings has not always translated to less controlled environments [25]. The fact that so many participants completed the market task successfully despite the prototype's rough edges, receiving little training, an unfamiliar conversation partner (clerk), and a noisy setting (market) is very promising. Due to the complementary successes of both studies, we recommend that this combined method be used more broadly in working with participants with aphasia.

Limitations

Further studies are needed to confirm our findings and to assess detailed impacts on conversation dynamics and long-term use. A main limitation is that we did not employ a control condition in Study 2 due to the early nature of the work. As a result, some positive feedback was not clearly attributable to the head-worn form factor; we have tried when possible to note these cases. A comparison may also have mitigated novelty effects, a common concern in design research. A second limitation is that 8/14 participants in Study 2 also participated in Study 1. This consistency enabled us to iterate on a well-defined set of user needs, but there is the danger that participants felt more invested in the design than they would have otherwise. Finally, data analysis in both studies relied on participant transcripts, which were sometimes difficult to interpret due to communication difficulties. To lessen this concern we referred to video and observational notes to aid analysis, but the sometimes-cryptic nature of the transcripts made it difficult to perform reliability analysis on the coding.

CONCLUSION

We presented two design investigations toward the goal of head-worn conversational support for individuals with aphasia. Study 1 elicited feedback based on a design probe of two narrative storyboards, and the findings further motivated the potential benefits of a head-worn approach over traditional AAC tools. Study 2 evaluated a proof-of-concept prototype in lab and field settings, showing that despite limitations, most participants were able to complete constrained conversation tasks successfully and reacted positively to the experience. While these exploratory studies are only a first step, the findings should motivate further investigation of head-worn conversational support—support that could ultimately improve the wearer's ability to maintain their sense of identity and use their own natural voice for a range of daily interactions.

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REFERENCES

1. Allen, M., McGrenere, J., and Purves, B. The design and field evaluation of PhotoTalk: A digital image communication application for people. *Proc. ASSETS'07*, ACM (2007), 187–194.
2. Al Mahmud, A., Gerits, R., and Martens, J. XTag: designing an experience capturing and sharing tool for persons with aphasia. *Proc. NordiCHI'10*, ACM (2010), 325–334.
3. Ball, M.J., Muller, N., and Nelson, R.L., eds. *Handbook of Qualitative Research in Communication Disorders*. Psychology Press, 2014.
4. Boyd-graber, J., Nikolova, S., Moffatt, K., et al. Participatory Design with Proxies: Developing a Desktop-PDA System to Support People with Aphasia. *Proc. CHI'06*, ACM (2006), 151–160.
5. Brandenburg, C., Worrall, L., Rodriguez, A.D., and Copland, D. Mobile computing technology and aphasia: An integrated review of accessibility and potential uses. *Aphasiology 27*, 4 (2013), 444–461.
6. Braun, V. and Clarke, V. Using thematic analysis in psychology. *Qualitative Research in Psychology 3*, 2 (2006), 77–101.
7. Chapey, R. *Language intervention strategies in aphasia and related neurogenic communication disorders*. Lippincott Williams & Wilkins, Philadelphia, 2001.
8. Demmans Epp, C., Djordjevic, J., Wu, S., Moffatt, K., and Baecker, R.M. Towards providing just-in-time vocabulary support for assistive and augmentative communication. *Proc. IUI'12*, ACM (2012), 333–36.
9. Galliers, J., Wilson, S., Roper, A., et al. Words Are Not Enough: Empowering People With Aphasia In The Design Process. *Proc. PDC'12*, ACM (2012), 51–60.
10. Galliers, O., Galliers, J., Wilson, S., et al. City Research Online Accessibility of 3D Game Environments for People with Aphasia: An Exploratory Study. *Proc. ASSETS'11*, ACM (2011), 24–26.
11. Ha, K., Chen, Z., Hu, W., Richter, W., Pillai, P., and Satyanarayanan, M. Towards wearable cognitive assistance. *Proc. MobiSys'14*, ACM (2014), 68–81.
12. Holland, A., Frattali, C., and Fromm, D. Communication Activities of Daily Living: CADL-2. (1999).
13. Kagan, A. Supported conversation for adults with aphasia: Methods and resources for training conversation partners. *Aphasiology 12*, 9 (1998), 816–830.
14. Kane, S.K., Linam-Church, B., Althoff, K., and McCall, D. What We Talk About: Designing a Context-aware Communication Tool for People with Aphasia. *Proc. ASSETS'12*, ACM (2012), 49–56.
15. Kertesz, A. and Poole, E. The Aphasia Quotient: The Taxonomic Approach to Measurement of Aphasic Disability. *Can. J. Neurol. Sci. 1*, 1 (1974), 7–16.
16. Kunze, K. Wearable Computing for Older Adults – Initial Insights into Head-Mounted Display Usage. *Adj. Proc. UbiComp'14*, ACM (2014), 83–86.
17. Lasker, J. and Bedrosian, J. Promoting acceptance of augmentative and alternative communication by adults with acquired communication disorders. *Augmentative and Alternative Communication 17*, 3 (2001), 141–153.
18. Mcatamney, G., Street, S.V., and Uk, G. An Examination of the Effects of a Wearable Display on Informal Face-To-Face Communication. *Proc. CHI'06*, ACM (2006), 45–54.
19. McNaney, R., Vines, J., Roggen, D., et al. Exploring the acceptability of google glass as an everyday assistive device for people with parkinson's. *Proc. CHI'14*, ACM (2014), 2551–2554.
20. Moffatt, K., Mcgrenere, J., Purves, B., and Klawe, M. The Participatory Design of a Sound and Image Enhanced Daily Planner for People with Aphasia. *Proc. CHI'04*, ACM (2004), 407–414.
21. Nikolova, S., Tremaine, M., and Cook, P. Click on Bake to Get Cookies: Guiding Word-Finding with Semantic Associations. *Proc. ASSETS'10*, ACM (2010), 155–162.
22. Ofek, E., Iqbal, S.T., Strauss, K., and Way, O.M. Reducing Disruption from Subtle Information Delivery during a Conversation: Mode and Bandwidth Investigation. *Proc. CHI'13*, ACM (2013), 3111–3120.
23. Patokallio, J. and Ward, N. A wearable cross-language communication aid. *Proc. ISWC'01*, IEEE Comput. Soc (2001), 176–177.
24. Rhodes, B.J. *Just-In-Time Information Retrieval.* PhD Dissertation, MIT, 2000.
25. Van de Sandt-Koenderman, M. High-tech AAC and aphasia: Widening horizons? *Aphasiology 18*, 3 (2004), 245–263.
26. Tee, K., Moffatt, K., Findlater, L., et al. A Visual Recipe Book for Persons with Language Impairments. *Proc. CHI'05*, ACM (2005), 501–510.
27. Waller, A., Denis, F., Brodie, J., and Cairns, A.Y. Evaluating the use of TalksBac, a predictive communciation device for nonfluent adults with aphasia. *Int. J. Lang. Commun. Disord. 33*, 1 (1998), 45–70.