The Cost of Turning Heads: A Comparison of a Head-Worn Display to a Smartphone for Supporting Persons with Aphasia in Conversation

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ABSTRACT
Current symbol-based dictionaries providing vocabulary support for persons with the language disorder, aphasia, are housed on smartphones or other portable devices. To employ the support on these external devices requires the user to divert their attention away from their conversation partner, to the neglect of conversation dynamics like eye contact or verbal inflection. A prior study investigated head-worn displays (HWDs) as an alternative form factor for supporting glanceable, unobtrusive, and always-available conversation support, but it did not directly compare the HWD to a control condition. To address this limitation, we compared vocabulary support on a HWD to equivalent support on a smartphone in terms of overall experience, perceived focus, and conversational success. Lastly, we elicited critical discussion of how each device might be better designed for conversation support. Our work contributes (1) evidence that a HWD can support more efficient communication, (2) preliminary results that a HWD can provide a better overall experience using assistive vocabulary, and (3) a characterization of the design features persons with aphasia value in portable conversation support technologies. Our findings should motivate further work on head-worn conversation support for persons with aphasia.

CCS Concepts
• Human-centered computing →Accessibility → Empirical Studies in Accessibility

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

1. INTRODUCTION
Aphasia is a language disorder acquired from damage to the brain through, for example, a stroke or car accident. Symbol-based dictionaries to support persons with aphasia in speaking provide groupings of text, images, and sound for dialogue or vocabulary. However, these tools are often treated as a last resort by persons with aphasia [7]. One issue is that, unlike commonly worn sensory aids such as eyeglasses or hearing aids, the dictionary support is typically provided through an external augmentative and alternative communication (AAC) device (e.g., Dynavox[1]) or a smartphone application (e.g., ProLoquo2Go[2]). The external form factor makes it difficult to employ the supported vocabulary unobtrusively as attention is explicitly diverted away from the conversation partner to operate the device. This diversion interferes with important aspects of communication such as managing speaking role, verbal inflection, error monitoring, or continuing the dialogue's pace [15, 34, 35]. Further, these solutions often generate text-to-speech from the words or phrases in the dictionary, which can replace the user's own natural voice and disrupt their speaking turn [35].

Figure 1. A participant is shown using vocabulary prompts from the head-worn display to support conversation during the study task (playing the card game Go Fish). The head-worn display sits over the participant's prescriptive lenses: positioning a small screen in front of his right eye.

As an alternative, a recent study explored head-worn displays (HWD) for vocabulary support [47]. In that work, 14 participants with aphasia were able to successfully use vocabulary prompts from a HWD in conversations in both private and public settings. Participant feedback suggested that, compared to existing communication tools, the HWD may allow the wearer to access support less obtrusively and better maintain focus on their conversational partner. However, that study did not directly compare the HWD to equivalent support on more traditional devices such as smartphones, nor did it include a detailed

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[1] http://www.tobiidynavox.com/t-series/
[2] http://www.assistiveware.com/product/proloquo2go

examination of how the vocabulary prompts were used within conversation.

To address these limitations, we conducted a study with 20 persons with aphasia. Participants used vocabulary support both on a HWD (Figure 1) and on a smartphone to support conversation during a simple card game (an adaption of Go Fish using picture cards) that requires primarily verbal interaction between two partners. Following Faroqi-Shah and Virion [37], we employed this game to simulate a natural, yet controlled conversation. We compared the two devices in terms of subjective experience, via measures of overall experience and perceived ability to focus on the conversation, and in terms of conversational success, via measures of how often participants employed the vocabulary prompts and how efficiently they were able to complete the conversation tasks in the game.[3] Finally, at the end of the session, we conducted a semi-structured interview to elicit feedback about the devices and the design of future unobtrusive, vocabulary support solutions.

Despite participants having little to no prior experience with HWDs, the quantitative results are promising and confirm the predicted benefit from previous work that the near-eye display of the HWD allows for efficient access to information [47]: the HWD was at least comparable to the smartphone on all quantitative measures, and resulted in a significant improvement in communication efficiency (i.e., how quickly participants played each game turn). Surprisingly, however, no significant subjective differences were found between the HWD and the phone in terms of supporting focus on the conversation or partner. During our semi-structured interview participants identified trade-offs between the HWD and the smartphone in terms of aesthetic choices, fit within current communication support strategies (both other tools and other people), compatibility with prescriptive lenses, and the ability to blend the use of the device with their current practices. Our work contributes (1) evidence that a HWD can support more efficient communication, (2) preliminary results that a HWD can provide a better overall experience using assistive vocabulary, and (3) a characterization of the design features persons with aphasia value in portable conversation support technologies. Our findings should motivate further work on head-worn conversation support for persons with aphasia.

2. RELATED WORK

2.1 Aphasia and Conversation

Aphasia is an acquired language disorder that occurs from damage to the central nervous system [7, 36]. It ranges in severity from mild complications in the selection of an appropriate word to complete loss of the ability to comprehend or formulate language. A typology has emerged which classifies aphasia according to different combinations of deficits in naming, fluency, repetition, auditory comprehension, grammatical processing, reading, and writing [7, 36]. Aphasia affects people of all ages. However, the most common cause of aphasia is stroke, and so, the prevalence of aphasia increases with age [7].

Persons with aphasia encounter a sudden loss of language skills after a lifetime of proficiency, which can severely limit daily interaction. The challenges are particularly evident in public settings where conversation partners may not know anything about aphasia. Aphasia is often mistaken for incompetence and, as a result, persons with aphasia are often excluded from conversation and decision-making [3, 16]. Conversational success often depends on the facilitation skills and cooperation of the conversational partner [4, 16]. Yet, unfamiliar partners are not likely to assume the role of a language resource by anticipating and providing vocabulary just-in-time [16] as may be required to jointly establish meaning during conversation [8, 15, 16]. Assistive technology for conversation support may be able to address this need by providing these vocabulary prompts.

Picture-based support may help with initiating conversation, but can be difficult to access when needed to sustain conversation. Conversation partners put pressure on persons with aphasia to respond quickly, and long delays responding can lead to losing a conversation turn and can highlight the person's problems with speaking [46]. As a result, speakers with aphasia may adapt their speaking style to vocabulary content using more nouns and dropping function words and verbs in order to be perceived as competent [14, 46]. One study showed that picture-based assistive technologies facilitate this adaptive strategy by quickly communicating complex information such as progress on a gardening project or purchasing an item in a store through direct reference to the displayed image [2]. Similarly, one case study showed how directly referencing picture-based support contributed to rehabilitative goals: the participant independently named objects in a personal, living room photo using audio-recorded prompts on an interactive pen [32]. However, the technique did not extend to naming objects in her actual living room. By providing private access to audio prompts and picture-based support in the wearer's line of sight, HWDs may support both social and rehabilitative speaking goals by making prompts readily available in the desired context.

2.2 Computerized AAC for Aphasia

Research on assistive technology to support aphasia can be strongly influenced by the conception of the language disorder and what is being targeted for assistance. For example, AAC might draw "on a theory of the underlying language deficit; and, importantly, the efficacy of [the] device may provide a test of [the] theory" [23]. This has led some researchers to categorize assistive technologies as "disorder oriented" or "communication oriented" [35]. To this end, some research has focused on supporting persons with aphasia in activities of daily living to achieve functional goals that may be impacted by language (e.g., daily planning [5, 29] and cooking [40]) instead of providing general linguistic support.

As mentioned in the Introduction, symbol-based dictionaries of images, text, and sound (e.g., Lingraphica[4] or Proloquo2Go) are a common linguistic support tool. Navigating through their hierarchies, however, can be time consuming, so manual customization is often supported though requires effort to set up. Navigation time may also be reduced by organizing vocabulary based on semantic associations [30], or dynamically adapting the vocabulary based on the user's location or conversation partner [18], possibly using automated means of generating these contextual predictions [10]. While these approaches provide promising directions for content organization, issues remain with employing support mid-conversation. For many individuals, the audio and visual stimuli are sufficient for prompting speech, but most devices make the support audible and visible to others, effectively replacing rather than augmenting the user's own voice [21]. By providing private perceptual access to the device's content in a wearable form, HWDs may better support the wearer

[3] In comparisons of quantitative data, we considered only the first device each participant used, due to a software bug, as described in Section 3.6.

[4] https://www.aphasia.com/

in using the assistive vocabulary in conversation [47], a question we directly examine in our study.

Another class of computer-based tools for persons with aphasia support storytelling. These approaches attempt to address problems with diverting attention to external devices by supporting language composition prior to speaking. Storytelling scaffolds speaking by leveraging narrative structure [36], and emphasizing independent speaking while still realizing social goals such as indirect communication, self-expression, and establishing social proximity [9, 45]. Further, narrative provides for reusable language like prerecording material to later introduce conversation topics (e.g., TalksBac [44]). Yet, storytelling applications use a linear, temporal order through pre-recording [45] or creation of a timeline for the story [9], and are challenging to break with when there is a need to revise plots to make them relevant to the current telling [28]. Revision is important for engaging the conversation partner in co-constructing the narrative [8, 9, 28], and highlight issues with design approaches that align personal narrative with a specific temporal order. While our study focuses on dictionary-based support, investigating how our findings translate to storytelling tools could be a useful line of future work.

2.3 Head-Worn Communication Support

The design of an appropriate form factor for AAC must balance perceptual access to device content with sociolinguistic facets of communication. A clear view of the conversation partner's face can impact both the comprehension and formulation of language. Facial expressions, eye contact, and lip reading provide feedback on whether conversation partners have a shared understanding [12, 32], and further, can play an important therapeutic role [11].

As previously discussed, persons with aphasia have responded positively to the idea of using a HWD for vocabulary support in an exploratory study that, unlike our work, did not include a direct comparison to a control condition [47]. Other work with persons with aphasia used a head-mounted camera (without a visual display) to capture content for later use in storytelling, but not as a means of supporting communication in situ [25].

Beyond aphasia, a few studies have looked at HWDs to provide assistive support to older adults [20], persons with Parkinson's disease [27], and persons with cognitive decline [13]. These studies identified potential application areas such as short-term memory aids, experience capture, and instructions (e.g., for cooking), but did not look at how HWDs are incorporated into an active dialogue. Two studies developed algorithms for AAC on a HWD, but evaluation minimally involved only two individuals with cerebral palsy [42, 43].

Outside the realm of assistive technology, researchers have studied the use of HWDs during face-to-face communication and their impact on conversation quality and efficiency. When displaying information that is not directly related to what is being said, researchers have found that it can negatively impact eye contact and attention [26] and should be delivered visually, in batches, when the wearer is not speaking [31]. Similar issues with information timing while speaking were revealed in a study of a contextually appropriate speech command interface: the wearer had the most difficulty negotiating communication with their partner while also manipulating the HWD [24]. It is unclear whether these prior findings extend to AAC, where information shown on the display is directly relevant to the wearer's conversation. Others, in studying the role of a prompting tool for public speaking, found that when the information has a direct role it can have a positive impact [39]: one to two words delivered in short intervals can support the wearer in actively changing speaking speed and volume, and wearers preferred textual feedback to information visualizations for interpretability while speaking. These studies leave open the potential for symbol-based dictionaries on a HWD to provide support while speaking, but highlight the need for careful design in conversation contexts where AAC is most likely to be used.

3. STUDY METHOD

This study employs a controlled conversation task (playing the game Go Fish) to subjectively and objectively explore potential differences between vocabulary support on a HWD versus a smartphone. Our HWD prototype includes a custom-built remote control for Google Glass to address motor accessibility issues that arose in earlier work [47]. Further, we elicit discussion of device design for conversation support and the device's fit within a conversation ecology.

3.1 Participants

We recruited 20 persons with aphasia (5 females, 15 males) through local aphasia community centers, support groups, speech-language pathologists, listservs, and rehabilitation service providers. They ranged in age from 31 to 78 (M = 56.6; SD = 14.5). Fifteen participants owned a phone, 10 of which were smartphones. Six participants had used a HWD (Google Glass) for at most a few hours 6–12 months beforehand in a previous study we ran; these participants were evenly split in terms of device presentation order (HWD or phone first; Section 3.6). Based on discussion with caregivers and on participants' self-report, we screened participants for right-sided neglect (loss of visual awareness in the right-sided field of view which would interfere with our evaluating of the right-sided monocular display of Google Glass) and moderate to severe apraxia (problems with the articulation of sounds dependent on the motor system). We compensated participants $25 for the 90-minute study.

3.2 Apparatus

We wrote identical custom dictionary applications for Google Glass and a Samsung Galaxy Nexus 4G LTE smartphone, and built a remote control for the HWD to address motor accessibility with Google Glass [47]. Similar to the proof-of-concept prototype evaluated in [47], these applications consisted of a two-level hierarchy of words, where each item in the hierarchy included an image, text, and audio. Only one item was shown on the screen at a time (Figure 2 shows examples). The top level always consisted of two categories: *actions* and *objects*. The second level of the hierarchy included 10 action (e.g., 'balance', 'celebrate', 'wash') and 10 object (e.g., 'bird', 'pirate', 'telescope') words, which were configured to match the specific set of cards used for different versions of Go Fish card decks used in the study procedure (Section 3.4). Category images were black and white icons taken from the Noun Project [1], while the vocabulary in the second level of the hierarchy used black and white line drawings from the University of California of San Diego (UCSD) International Picture Naming Project [38]. To provide context in the second level of the hierarchy, a small version of the category icon appeared in the top-right corner of the screen.

For both the HWD and the phone, we designed similar controls to navigate the word hierarchy (Figure 2). While Google Glass offers manual control (swipes, taps) via a touchpad on the right-hand side of the device, persons with aphasia can have right-sided hemiparesis (weakness or paralysis) caused by a stroke, which makes it difficult to access these controls. To address this issue, previous work controlled Google Glass using gestures on a wrist-

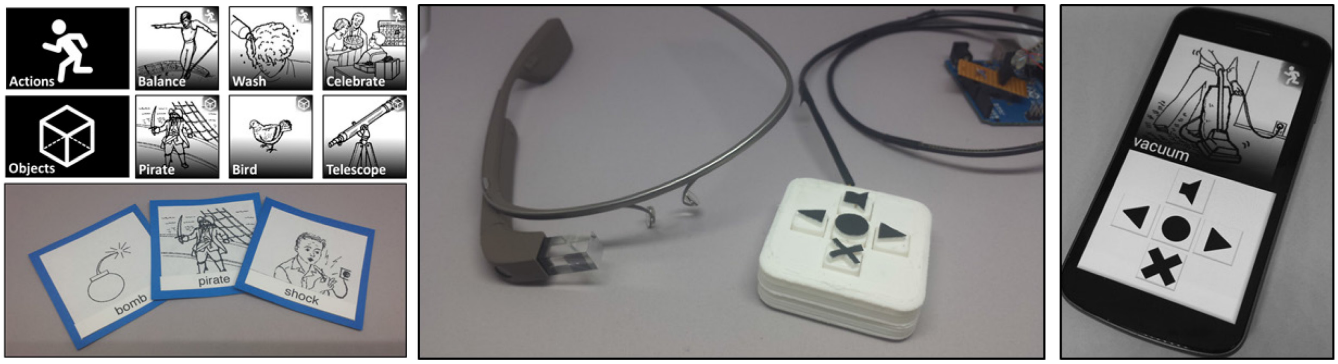

Figure 2. Top-left: Words from the vocabulary-prompting software, showing both the top level of the hierarchy ('actions' and 'objects') and examples of words from the second level. Bottom-left: Examples of Go Fish cards used for introducing the game; card sets used for the training and testing tasks were identical except they did NOT include text. Middle: HWD with remote control for navigation: cycle through words in the current level of the hierarchy (left/right arrows), select a top-level category and view its contents (circle), cancel out of the second level and return to the top level ('X'), and play audio for the current word (speaker icon). Right: Smartphone version, showing an action word above the navigational controls.

worn smartphone (similar to a smartwatch setup), but participants felt this solution was distracting [47]; an alternative recommendation was to use a button-based control. Thus, we created an Arduino Uno-based remote control (Figure 2, center) that linked to Google Glass via Bluetooth through a Galaxy Nexus mobile phone using the Amarino library [19].

We consider eyes-free input to be an integral aspect of an overall HWD user experience, so we created a 3D-printed case to minimize the need for visual attention to the remote control. It housed five buttons (each 12mm across); each with a raised icon (2mm in height) to allow for tactile identification. The buttons, shown in Figure 2, were: *forward* and *back* (right/left arrows) to cycle through words in the current level of the hierarchy; *select* (circle) and *cancel* ('X') to switch between the top-level and the second-level of the hierarchy; and *audio* (speaker icon) to activate text-to-speech for the current vocabulary word. For the smartphone, we created a comparable touchscreen button layout.

3.3 Conversation Task: Playing Go Fish

The conversation tasks consisted of playing the game *Go Fish* with different sets of cards. Go Fish requires structured requests and responses between two players. Each player is dealt the same number of cards (in our case, five cards) and the remaining ones are placed face down on the table. Players take turns requesting a card from the other person to match a card in their own hand. The object of the game is to make as many matches as possible. On each game turn, if the opponent holds a matching card, they hand it over and the player can make a new request; otherwise, the player draws a card from the deck and the game turn passes to the opponent. Following Faroqi-Shah and Virion [37, 41], we selected this language game as the basis for conversation tasks so as to strike a balance between constraining dialogue in a targeted manner and simulating natural conversation that can offer some generalization to everyday life [33].

We created five different decks with 10 pairs of action cards and 10 pairs of object cards each (40 total cards per deck). One deck was used for *learning* to play the game itself, two were used for *training* with the devices (HWD and smartphone), and two were used for *testing* with the devices. Each card consisted of the same black and white line drawings used in the HWD and smartphone software (Figure 2, bottom-left). The deck used for initially learning to play Go Fish also included text, but the four other decks did not. Each deck was created using a process that took into account frequency of words in the English language based on the picture naming study of Szekely et. al [38], that is: (1) one object and one action word were randomly selected from each tenth percentile (1st–10th percentile, 11th–20th, etc.) so that each deck included 20 pairs of cards that represented a variety of more common and less common words; (2) no word was selected twice across the decks; and (3) finally, cards were swapped across decks or replaced so that each deck contained the same number of one, two, and three syllable words at an equivalent frequency percentile.

3.4 Procedure

The study procedure lasted up to 90 minutes and was video recorded. At the beginning of the session, participants completed a baseline naming evaluation to roughly gauge their ability to name the cards that would be later used for testing. Here, participants described a series of 40 picture cards using a single word for each; the 40 pictures corresponded to those used across the two test decks. Then, to ensure that participants were familiar with the rules of Go Fish, they played the game once without the smartphone or HWD, using the card deck that contained both pictures and words.

Each participant then completed a training task and a test task with each device. The order of presentation of the devices was counterbalanced, as was the pairing of training and testing card decks with a given device. The tasks were as follows:

Training task. The researcher loaded the appropriate vocabulary set (to match the assigned Go Fish card deck) on the device, then introduced the device and controls to the participant—forward, back, audio, select, and cancel. The participant briefly tried out each function and explored the software. Each participant was free to hold and position the mobile phone and remote control however worked best for him/her. For the HWD, the researcher helped the participant to put on the device and to adjust the display arm to ensure full view of the display. The researcher then presented the 20 pictures from the card deck in series and asked the participant to locate each one in the software and say the associated word when they had found it. Participants were cut off at the 10-minute mark whether or not they had proceeded through all 20 pictures.

Test task. After loading the appropriate vocabulary on the device, the researcher and the participant played Go Fish with the assigned card deck. The two players sat across a table from each other, and stands were constructed to hold the cards and prevent the opponent from seeing a player's hand (Figure 1). Before beginning play, we instructed participants to use the device to support communication as needed during the game. The game proceeded until all cards in the deck had been matched or 10 minutes had passed, whichever was sooner. Following the game, participants rated the device in terms of overall experience and ability to maintain focus on the conversation as a whole and on the game partner.

Finally, following use of both devices, we conducted a semi-structured interview (about 15 minutes), with questions about each device's design, potential communication and social impacts of using vocabulary support with the two devices, and ideals for communication support tool design.

3.5 Research Questions

This study compares how well vocabulary support provided on a HWD versus a smartphone supports conversation for individuals with aphasia. Our goals were both to assess the projected benefits of HWDs identified in previous non-comparative work [47], particularly the ability to maintain focus on the conversation partner due to the glanceable nature of the display, and to explore additional dimensions of conversation quality, such as how efficiently the user can communicate with a partner. Specifically, our research questions included: How do the two devices compare in terms of overall user experience and perceived ability to maintain focus on the conversation and partner? How do the devices compare in terms of supporting efficient and accurate communication, measured indirectly through speed and success at playing the card game? Do participants employ vocabulary from the device more with the HWD versus the smartphone? Finally, we were interested in the more general question of how participants envisioned an ideal technology-based vocabulary support solution, as discussed in the end-of-session semi-structured interview.

3.6 Design and Analysis

We used a single-factor within-subjects design to allow for subjective comparison between the two devices. The independent variable was the device (HWD or smartphone), and the order of presentation for the two conditions was fully counterbalanced. However, after running 15 participants, we discovered that due to a software bug, the HWD test task cutoff was 15 minutes rather than the intended 10 minutes, while the smartphone test task was cut off at 10 minutes as intended. Although we fixed the problem for the remaining five participants, we chose a conservative approach for analyzing our quantitative data, by only examining data that is comparable across participants: objective measures from the first 10 minutes of gameplay for the first device used and subjective measures from only the first device used. Note that for completeness, we also conducted a within-subjects analysis on all data, which provided results consistent with the between-subjects analysis presented here. To compare measures between the two conditions, we employed unpaired t-tests or, when appropriate (e.g., with the rating data), non-parametric Mann-Whitney U tests.

For each device, we collected subjective ratings using 7-point Likert scales (1-poor, 7-excellent) for *overall experience*, *ability to maintain focus on the conversation*, and *ability to maintain focus on the conversational partner*. We included separate measures for focus on the conversation and conversational partner, distinguishing the former as the ability to concentrate on one's own speaking ability, word finding, and conversation planning and the latter as the ability to concentrate on the partner's behaviors, including eye contact, facial expressions, and intonations. However, as suggested by the results, it is unclear whether or not participants made a distinction between the two.

For objective measures, we divided the video from the test tasks into game turns using transcription software supported by the aphasia research community, CHAT/CLAN[5], and transcribed the conversation for each turn. From the video and log data, we then extracted three main measures to address our research questions: the *number of card pairs matched* out of the 20 possible matches (i.e., how far players made it through the game); the *number of vocabulary words* the participant retrieved from the device and employed; and the *average time per game turn*, only for turns where the participant used the device—that is, a direct indication of how device interaction impacted the speed of the turn.

Responses to the design questions were transcribed, subdivided by speaking turns [4, 47], and coded for themes of interest (*e.g.* aesthetics or discrete use) by a person trained in supported conversation techniques and who had prior experience interviewing persons with aphasia [16]. We applied a coding method that allowed for inductive codes tied closely to the data to also emerge [6]. A person independent of the research group with a background designing technology for persons with cognitive disabilities (though not language disorders) independently coded two randomly selected transcripts. Coding differences were reconciled through discussion. The independent coder was later asked to assess the resulting summarization, and its match with the groupings identified in the data; no questions or problems were identified.

We excluded four participants from the final analysis. Two were excluded because their log data revealed that they did not use the device at all during the task, so their subjective ratings and performance data did not reflect device experience. Further, they did not appear to need its support: one completed 20 turns (higher than average), while the other completed the full game. Two more were excluded due to much lower language ability than the rest of the group: they scored only 1 and 0, respectively, on the baseline language evaluation test, compared to an average score of 19.1 (*SD*=6.7) for the 20 participants overall. Our final participant set included eight participants who used the HWD first and eight who used the phone first.

4. Findings

We present subjective and objective quantitative findings before going into more depth on the qualitative findings that arose from the semi-structured interview portion of the study.

4.1 Task Performance and Experience

As noted in Section 3.6, we analyzed quantitative data only for the first device that participants used, effectively employing a between-subjects analysis. Over the 10-minute test task period, participants using the HWD completed 14.8 game turns on average (*SD*=4.8), while smartphone participants completed 13.4 (*SD*=4.1). Of course, the device's vocabulary support was not employed for all of those turns. With the HWD, the vocabulary support was used on average in 8.3 turns (*SD*=2.9), while the smartphone was used in 5.0 (*SD*=3.4) turns. Participants were closely matched in naming ability across the two devices as evaluated in the baseline naming task: for the HWD, *M*=18.6 (*SD*=7.5, range=6-28), and the phone, *M*=19.6 (*SD*=5.8, range=8-29). With this context, we present our primary quantitative measures.

4.1.1 Comparing Form Factors

We begin with our main analysis, comparing the HWD to the smartphone over our dependent measures.

[5] More detail at Aphasia Bank, http://talkbank.org/AphasiaBank/

Design trade-offs. One motivation for using a HWD was the potential to provide private and unobtrusive support, but our results revealed a tradeoff, indicating that this unobtrusiveness may come at a cost. While participants described the HWD as empowering wearers to speak for themselves and providing a way to manage external perceptions of language ability, in some cases, that very privacy may inadvertently limit social assistance. Persons with aphasia can sometimes have difficulty translating a prompt into speech; for example, some individuals commonly replace the first phoneme with that of a different word (*i.e.,* they might say "present" in place of "pheasant"). Within our data, we saw a small number of instances where such transformations happened, and while these were easily mitigated in the phone condition (as the listener could hear and see the original prompt), such problems were less readily resolved with the HWD. A shared display or audible text-to-speech would have helped ground the conversation, allowing the partner to infer what the participant intended to communicate. This observation highlights the importance of accommodating each user's needs and preferences, suggesting the best form factor may depend on the individual characteristics of the user, including their specific communication profile, and the degree to which unobtrusive support is valued.

Balancing conversation and device use. Findings from our study provide preliminary support for using HWDs to balance the challenging task of conversing while accessing assistive vocabulary. In particular, our results suggest the HWD enabled more efficient, and possibly more effective, communication. Participants took significantly less time per turn with the HWD. As well, despite lack of statistical significance, large effect sizes suggest participants may have gotten further in the game (as measured by the proportion of correct matches), and had a better overall experience with the HWD. The underlying mechanism for these gains, however, is less clear. Contrary to our initial expectations, there were negligible differences between the HWD and the phone for perceived impacts on focus. This lack of difference may be related to individual adeptness with using the device, whether the HWD or phone, as seen in our secondary analysis comparing fast versus slow participants. Those who were more adept with the technology (i.e., fast) also reported a higher ability to focus on the conversation and partner, which suggests that technology training could be important for participants who experienced more struggle with the device interaction, or that other cognitive factors (e.g., fluid intelligence) influence success.

Lessons learned. Constructing the study task as a language game supported comparison of speaking turns and time frames of device interaction while still enabling participants to proceed through the trials and advance toward a larger objective: winning the game [22]. This allowed the study to model how assistive devices may be employed during the dynamic shifts of naturally occurring conversation, and to examine how participants used the device when challenged by the required vocabulary (a language game has also been used for aphasia emulation [14]). This shifts focus from the device as a support tool for speaking to its fit within broader aspects of conversation such as listening, clarifying, and comprehending. Overall, we found the language game task successful in simulating a conversational ecology to examine device use in a lab setting. Surprisingly, we saw in the video-taped sessions a few participants using the device as a reflexive tool to verify guessed words against the supplied picture, to coach their own pronunciation, and to resolve ambiguity on whether they understood what the researcher was requesting. These kinds of uses are so minute as to be difficult to catch in a field study, and suggest future work on how a language game task could help investigate when participants might appropriate a vocabulary support tool to help with their personal language challenges.

Limitations. One limitation of our study is that, discarding half of our data for the quantitative measures and switching to a between-subjects analysis substantially reduced statistical power. Nonetheless, absolute differences were generally in the direction favoring the HWD, and even comparable findings between the HWD and smartphone are encouraging given that participants had limited to no experience with HWDs but many had at least some experience with smartphones. A related limitation is that our study only included a single session, which allowed for only a short training period with both of the devices. Future work should revisit our research questions after longer-term exposure to the technology. Finally, the particular HWD design we used may have impacted results. We used Google Glass—a HWD that offers a visual display that is offset to the right and above the user's center of vision—which may have negatively impacted participants' ability to maintain visual focus on their conversation partner while accessing support. Further, we did not examine to what extent the use of a remote control to address accessibility issues with Glass's right-sided touchpad supported eyes-free input and diverted visual attention. Other HWD designs, particularly those with a display in the viewer's line of sight and supporting eyes-free input accessible to individuals with aphasia, may provide different results.

6. CONCLUSION

In order to employ assistive technology in conversation, individuals with aphasia must balance interaction with the device and maintaining the conversation. Our comparative study confirms a previously predicted advantage of HWDs over smartphones: providing vocabulary support on the HWD allowed for more efficient communication than doing so on the phone. Subjective ability to focus on the conversation partner, however, was found to be no different between the two conditions, possibly due to the offset display of the particular HWD device we used (Google Glass). These findings should motivate future work on using HWDs for language support, including investigating the effectiveness of the support after longer-term use and with greater experience, and examining issues of social acceptance and obtrusiveness in field settings.

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