What We Talk About: Designing a Context-Aware Communication Tool for People with Aphasia

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ABSTRACT

Many people with aphasia experience difficulty recalling words extemporaneously, but can recognize those words when given an image, text, or audio prompt. Augmented and alternative communication (AAC) systems can help address this problem by enabling people with aphasia to browse and select from a list of vocabulary words. However, these systems can be difficult to navigate, especially when they contain large amounts of content. In this paper, we describe the design of TalkAbout, a context-aware, adaptive AAC system that provides users with a word list that is adapted to their current location and conversation partner. We describe the design and development of TalkAbout, which we conducted in collaboration with 5 adults with aphasia. We then present guidelines for developing and evaluating context-aware technology for people with aphasia.

Categories and Subject Descriptors

K4.2 [**Computers and Society**]: Social Issues–*Assistive technologies for persons with disabilities.*

Keywords

Accessibility, aphasia, augmented and alternative communication, context-aware computing, participatory design.

1. INTRODUCTION

Aphasia is a neurological disorder that affects an individual's ability to understand language [15]. Aphasia is a common side effect of stroke and brain injury, and can severely reduce an individual's ability to socialize, maintain a job, attend school, or live independently. Many people with aphasia use augmentative and alternative communication (AAC) systems for communication support. These systems may help their users communicate by providing audio or visual prompts to assist the user in speaking the word or phrase, or by speaking the word or phrase via synthesized speech [4]. Many electronic AAC systems allow users to pre-define words and phrases that would be difficult to produce extemporaneously, and to browse these words and phrases as needed.

Traditionally, electronic AAC systems have required specialized hardware and software. However, the growing ubiquity of mobile devices and applications has resulted in the introduction and widespread adoption of AAC software for mainstream mobile devices, tablets, and PCs [23]. Transitioning from specialized hardware to mainstream devices can provide assistive technology users with many benefits, including reduced cost, increased usability, and less social stigma [13]. Using mainstream mobile devices for AAC may present additional benefits, as mobile device hardware often has capabilities beyond traditional AAC hardware, such as network connectivity and embedded sensors.

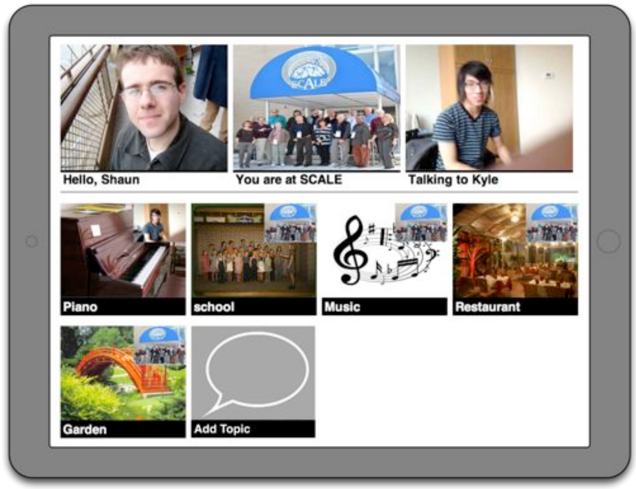

Figure 1. *TalkAbout*, a context-aware augmentative and alternative communication (AAC) device for people with aphasia, presents conversation topics relevant to the user's current location and conversation partner.

The capabilities of modern mobile devices present an opportunity to improve the usability of AAC through *context-aware computing*. Current AAC solutions often expect the user to navigate through a hierarchical menu of speech options in order to speak (*e.g., Food and Drinks→Drinks→Coffee*). A networked, sensor-enabled AAC device may be able to identify the user's current location, task, or conversational partner, and highlight conversational options that are most relevant to the user's context, such as ordering coffee when the user in a café, or discussing baseball when the user is with a fellow sports fan.

In this paper, we describe the design and development of *TalkAbout*, an adaptive communication tool for people with aphasia (Figure 1). We designed TalkAbout in collaboration with aphasic adults in an aphasia center. We introduce our underlying framework for context-aware AAC, and describe the design and evaluation of our prototype system. Finally, we provide guidelines, based on our experiences, for designing context-aware technologies for and with people with aphasia.

2. RELATED WORK

This research builds upon prior work in designing usable interfaces for people with aphasia, and in conducting participatory design with people with aphasia. Our research also builds upon prior techniques in the area of context-aware computing.

2.1 Technology for People with Aphasia

AAC devices come in many forms, and have been studied for decades. An overview of past and present approaches to AAC is provided by Beukelman and Mirenda [4]. However, relatively little research in the field of human-computer interaction (HCI) has explored technology for people with aphasia. The most comprehensive work in this area emerged from the Aphasia Project [15], which introduced multiple technologies to support people with aphasia, including a daily planner [16], a visual recipe book [21], and a communication device [2]. This project explored both tools for people with aphasia and design methods for working with people with aphasia, but did not fully explore the potential of context-aware technology for people with aphasia.

Other research at the intersection of HCI and aphasia has explored communication support for e-mail [1,17], tools to support speech-language therapy for people with aphasia [18], and tools to improve empathy toward people with aphasia [9]. While it is important to take a broad approach to supporting people with aphasia, we have chosen to focus on the core challenge of improving interpersonal communication, as this challenge is central to many of the problems faced by people with aphasia.

2.2 Participatory Design and Aphasia

Involving individuals with disabilities in the design process is key to developing technologies that will actually work for those individuals. Involving people with aphasia in the design process raises additional challenges, as the person with aphasia may experience difficulties in communicating with members of the design team. Due to the challenges of working with individuals with aphasia, prior researchers have sometimes invited speech language pathologists or other subject experts to serve as proxies for individuals with aphasia (*e.g.,* [2,5]). In other cases, researchers performed participatory design with small groups of individuals with aphasia, often in a research lab or other neutral setting (*e.g.,* [6,16]). Our research was inspired by these prior studies, but our approach differs in some ways. Although we worked with a core design team of individuals with aphasia, we conducted this work within an aphasia center attended by approximately 40 regular members. Furthermore, our design activities focused primarily on the design and evaluation of context-aware and adaptive systems.

2.3 Context-Aware Computing and Aphasia

Context-aware computing typically refers to interaction with a computing device that is aware of the user's context, which may include his or her location, nearby people and objects, and other factors [19]. Most modern mobile devices are capable of detecting the user's location [11], and nearby people may be identified via a mobile device camera using computer vision techniques (*e.g.,* [22,24]). This project adopts existing approaches to creating context-aware computing applications, and applies them to the challenges faced by adults with aphasia.

Context-aware computing has previously been used to improve the accessibility of technology for people with other disabilities. For example, face recognition techniques have been used to help blind people interact socially [14], and location sensing has been used to help blind people navigate buildings [20].

Few research projects have explored the potential of context-aware computing for people with aphasia, as we do here. Converser [25] was an AAC tool that recognized speech produced by a conversation partner and propagated an AAC menu with contextually appropriate responses. The Friend Forecaster [7] and MyVoice [3] used location information to generate a list of friends' names or conversation topics, respectively, based on the user's location. While MyVoice provides location-specific adaptation for people with aphasia, as we do in this project, our work goes beyond this prior work by combining multiple forms of contextual information, and by documenting the process of designing context-aware software for people with aphasia.

3. DEFINING CONTEXT-AWARE AAC

As discussed previously, there are many ways that context awareness may enhance interaction with mobile devices. This project began with the idea that context-aware adaptation could improve the usability of AAC tools for people with aphasia, but without a specific technology in mind. Our early discussions thus focused on providing a conceptual framework for discussing and designing context-aware AAC technology. We initially explored these ideas through a series of meetings among the research team, which includes HCI researchers and a speech language pathologist. We considered both the capabilities of mainstream mobile devices, as well as the most significant challenges faced by people with aphasia.

Our discussions soon began to focus on the role of *context* within everyday conversation. While unstructured conversation can cover a tremendous number of topics, the scope of most conversations is constrained by the conversation's location, participants, or other factors. For example, conversations between coworkers may focus on topics related to the work environment, while conversations at the doctor's office may focus on topics related to health and the human body. While conversations may stray to other topics, such as the coworkers' shared hobby, or small talk in the doctor's office, a tool that could help a person with aphasia identify likely conversation topics could reduce the burden placed on a person with aphasia during conversations.

Through examining the relationship between everyday conversation and context, we developed a series of usage scenarios for a context-aware AAC device that would use contextual factors to scope conversation: *e.g.,* what *we* talk about, what I talk about *here.* These scenarios are summarized in Table 1. Based on these scenarios, we developed a framework for a prototype context-aware AAC device, and conducted a series of design activities to explore the potential uses of this prototype. Section 4 of this paper introduces the preliminary design of our context-aware AAC tool. Section 5 documents our process of designing, testing, and refining the prototype.

4. THE TALKABOUT PROTOTYPE

A major challenge in conducting participatory design with people with aphasia is that participants may have difficulty discussing or comprehending complex subjects [15]. As our participants were unfamiliar with context-aware computing devices, we developed an early prototype that could be used by our participants. This prototype, TalkAbout, is a context-aware communication application for touch screen tablets (Figure 1). We created a preliminary version of TalkAbout early in our research, and refined the prototype over the course of our interactions with our participants. Here we briefly describe the TalkAbout prototype and its current features. We describe recent refinements to the design, based upon user feedback, in Section 5.

Table 1. Proposed usage scenarios for context-aware AAC, based on our early design meetings, including the contextual data needed, and possible sources of this data.

	Scenario	*Context*	*Data sources*
1	When I am at the supermarket, I want to talk about food.	Location	GPS; GSM; Wi-Fi
2	When I am with my coworker, I want to talk about the office.	Conversation partner	Face recognition; tagged ID card
3	When my friend mentions her family, I want to discuss my family.	Partner's speech	Speech recognition
4	I want to ask about some object or landmark in the environment.	Objects in environment	Tagged objects; computer vision-based object recognition
5	I want to talk about recent news and the local sports team.	Current events	Web-based news, social networks

4.1 Hardware and Software

We developed TalkAbout for touch screen tablets, as tablets are commonly used at the aphasia center where we conducted this research. Our prototype was tested on a 2012 Apple iPad.

The TalkAbout software was developed using the PhoneGap application framework[1] and Google App Engine (GAE)[2]. TalkAbout's application logic was written in Python. User data such as saved locations and phrases were stored in the online GAE database, and could be accessed from multiple devices. The OpenCV library[3] was used for image processing.

TalkAbout's user interface was written in HTML and JavaScript. Creating a web-based user interface enabled the research team to make quick adjustments to the interface, even during site visits.

4.2 User Interface

Similar to many other AAC systems, TalkAbout's purpose is to enable users to store, organize, browse, and speak stored words and phrases. The current prototype enables users to *browse* items, to *add* new items, and to *filter* items based on the current context.

Browsing items. TalkAbout's main interface (Figure 1) comprises a scrollable grid of words and phrases. Each item comprises a picture and an associated word or phrase. Touching an on-screen item speaks the associated text using the iPad's built-in speech synthesizer. In its most basic form, the interface is similar to commercially available AAC software such as Proloquo2Go[4], but with additional features related to the user's context. A *context bar* at the top of each screen shows the current context as detected by TalkAbout. Currently, the context bar displays the current user, their location, and their conversation partner.

Like other AAC systems, words and phrases may be assigned to hierarchical groups. While many AAC systems organize words by topic (*e.g.,* food, vehicles, parts of the body), TalkAbout enables users to organize words and phrases by the *location* that they are spoken or the *partner* they are discussed with. TalkAbout also enables the user to view a master list of all saved words and phrases. Items that are associated with a specific context are tagged with an image of that context, as shown in Figure 2.

Adding new items. Users may add new words or phrases to TalkAbout's catalog, by themselves or with the assistance of an aide. Adding a new item requires the user to: 1) input the text to be spoken; and 2) add an associated image. This process is similar to how users add content to existing AAC systems, although TalkAbout takes steps to streamline the process. Words and phrases may be entered using the iPad's keyboard (with optional error correction), or may be spoken and recognized automatically. The associated image may be captured by the user via the iPad's camera, selected by the user from a set of previously captured images, or chosen automatically. If the user does not provide an image, TalkAbout uses Microsoft's Bing Image Search API[5] to automatically select an image from the web. Newly added phrases can optionally be associated with a specific location or conversation partner. This combination of speech input and automatic image selection enabled us, and our study participants, to quickly create sets of conversation topics.

Figure 2. Topics in TalkAbout's user interface are tagged with their contextual associations. The topic *piano* is associated with a specific conversation partner, while the topic *garden* is associated with a specific location. The accompanying images were chosen automatically via a web image search.

Filtering items by context. We experimented with several methods of adapting to context in TalkAbout. Initially, we thought that it would be best for the system to automatically adapt to the current context. However, participants seemed to have difficulty understanding when and why the interface was adapting. Furthermore, taking a picture of the user's conversation partner sometimes required the user to reposition the device, and thus could not always happen automatically. In the current prototype, users press an *Update* button to capture a picture of the user's conversation partner and update the device location. If TalkAbout identifies a previously seen location or conversation partner, the associated words and phrases are moved to the top of the word list. The user may also manually select their location or conversation partner if they wish, or if automatic recognition fails.

4.3 Detecting Context

TalkAbout provides the ability to detect the user's context and adapt the user interface to that context. Currently, TalkAbout can automatically recognize the *current user* via the front-facing device camera, the user's *location* via GPS, and the user's *conversation partner* via the rear-facing camera.

TalkAbout detects the user's location using PhoneGap's location API, which relies upon GPS and Wi-Fi localization. The user may add a new location, attach a name and image to that location, and associate words and phrases with that location.

[1] http://phonegap.com
[2] https://developers.google.com/appengine
[3] http://opencv.willowgarage.com
[4] http://www.assistiveware.com/product/proloquo2go

[5] http://www.bing.com/toolbox/bingdeveloper

TalkAbout can also identify the current user and his or her conversation partner using automatic face recognition and the device cameras. TalkAbout uses the Viola–Jones algorithm [24] to detect faces, which are then matched using eigenfaces [22]. The user may also select his or her partner from a list of photos. We chose to include face recognition for several reasons. First, we were interested in exploring multiple ways to automatically detect useful context. Second, our research participants expressed interest in the idea of face recognition during early design sessions. Third, face recognition may improve TalkAbout's usability for individuals with comorbid conditions, such as visual impairment or prosopagnosia (face blindness), which is sometimes a side effect of stroke [10].

5. PARTICIPATORY DESIGN

The TalkAbout prototype, introduced in the previous section, was developed through a process of participatory design. In this section, we describe our process of researching, developing, and testing TalkAbout with adults who have aphasia.

5.1 The Aphasia Center

Our research was conducted at an aphasia center located in Baltimore, MD, USA. The center serves approximately 40 adults who previously experienced a stroke and currently experience some level of aphasia. Members attend classes for approximately 4 hours per day, two times per week. Classes are taught by trained facilitators, and cover such topics as reading, news, music, yoga, gardening, travel, and exotic animals.

Members also meet one-on-one with professional speech language pathologists and student volunteers. During these meetings, members practice conversations, learn to use or customize their current AAC technologies, or work on creating scripted stories for future conversations using AAC.

5.2 Participants

We conducted the majority of our design activities with a group of 5 research participants (4 male, 1 female), all adults with aphasia. These 5 were selected from the larger group of members based on their enthusiasm for the research activity, and diversity of ability. While we considered the possibility of choosing participants with the highest language abilities, we were strongly encouraged by our colleagues at the aphasia center to include people with a range of language abilities. Our participants are described here:

P1 (M, age 47, time post stroke onset (TPSO): 2 years). P1 presents with right-sided hemiparesis and severe expressive aphasia due to stroke. He is able to walk independently but uses his left hand for most motor tasks. His comprehension of language is mildly impaired, and his expressive language abilities are severely impaired. He is able to speak in short phrases fraught with semantic and grammatical errors (telegraphic speech). Functionally, he has significant difficulty retrieving words (names, places, objects) that accurately convey his thoughts. P1 frequently uses software on his mobile phone (Apple iPhone) and laptop to organize photos and to assist with reading and writing.

P2 (M, 43, 7 years). P2 presents with right-sided hemiparesis and moderate expressive aphasia due to stroke. He is able to speak fluently but has significant difficulty retrieving names and personal information. Although most of his sentences are well formed, the content is often incorrect. He substitutes words and leaves out words that he cannot retrieve. His comprehension of language is also moderately impaired. He is unable to follow complex commands or lengthy material. His functional communication abilities are fair but he benefits greatly from the use of pictures and written words to facilitate comprehension. He is able to walk independently but uses his left hand for most motor tasks. He did not use assistive technology during our meetings.

P3 (F, 63, 7 months). P3's functional communication abilities are severely impaired due to aphonia (loss of voice due to vocal cord paralysis) caused by stroke. Her receptive and expressive language abilities are within normal limits. She communicates using gestures and by writing with pen and paper. However, writing is limited to short phrases due to right-sided weakness secondary to her stroke. She is able to operate a computer mouse and keyboard, but has difficulty typing lengthy messages.

P4 (M, 72, 12 years). P4 presents with right-sided hemiparesis and severe expressive aphasia due to stroke. He also presents with severe apraxia of speech (a motor speech disorder). He is able to walk independently but uses his left hand for most motor tasks. His comprehension of language is mildly impaired. He has significant difficulty retrieving words. When he is able to produce a word, it is often unintelligible due to apraxia. His functional communication is limited to single words and gestures. He sometimes uses photos on his iPhone or laptop to support communication.

P5 (M, 73, 17 years). P5 presents with right-sided hemiparesis and severe expressive aphasia due to stroke. He walks using a cane and uses his left hand for most motor tasks. His language skills are globally impaired. He is unable to read or write and has severely impaired comprehension. His expressive language is limited to a few single words. He uses gestures, drawing and pictures (often displayed on an iPad) to communicate.

5.3 Design Activities

Over the course of 6 weeks, we conducted several design activities intended to introduce our participants to the project, to solicit information about how participants might use a context-aware communication device, and to gather feedback about early versions of our prototype. These activities took place at the aphasia center, and were conducted by members of our research team, which included both HCI researchers and a speech language pathologist.

Due to variations in our participants' ability to communicate, and due to the variability of the schedule at the aphasia center, not all participants were able to take part in each study session. However, each participant took part in multiple sessions, and provided substantive feedback on the development of our prototype.

5.3.1 Interviews and Observations

During the first several weeks of our research, we conducted a series of preliminary interviews and observations with members of the aphasia center. During the interview sessions, participants demonstrated the technology that they currently used and provided feedback about what they liked and did not like about the technology. Our research team also observed class meetings and one-on-one sessions between members and staff. These interviews were intended to introduce members to our research team, to sensitize our research team to working with people with aphasia, and to learn about the technologies currently used by people with aphasia at the aphasia center.

5.3.2 Focus Groups

Based on our initial site visits, we identified a group of 8 potential participants. These participants were chosen based on their enthusiasm for participating in research and because they represented a range of language ability. Following our initial

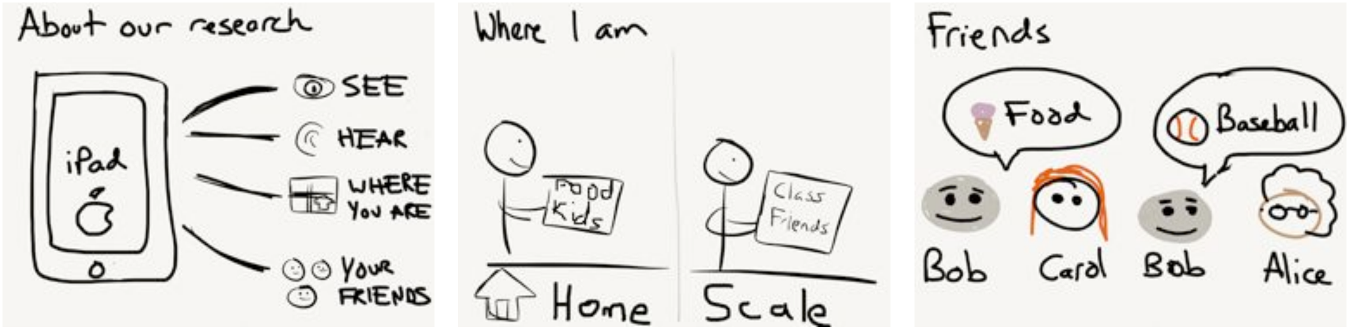

Figure 3. Storyboards used to introduce TalkAbout's proposed usage scenarios. Left: introducing the tablet's ability to detect information about the environment. Center: Adapting the word list based on location. Right: Adapting the word list based on conversation partner. Each drawing was accompanied with an interactive demonstration by the research team.

interviews, we conducted 2 focus group sessions (4 participants each) in which we introduced the concept of context-aware AAC and solicited feedback about our proposed usage scenarios.

As we had not yet identified the scenarios that we would develop for the initial prototype, a major goal of the focus groups was to identify the scenarios that were most compelling to our participants. We introduced the 5 scenarios described in Table 1, and asked the focus groups to consider the scenarios and provide feedback. As focus groups can present communication challenges for people with aphasia, a speech language pathologist (the fourth author) facilitated the meetings. The facilitator asked clarifying questions, wrote key terms on an easel, and paused the session if any of the participants seemed confused. To further reduce the difficulty of participating in the focus group, we created *storyboard diagrams* for each of the scenarios, as well as an overview diagram describing the broader goals of the project, and posted them on the wall during the focus group session. A selection of these storyboard diagrams is shown in Figure 3.

We began the session with an introduction to the idea of context-aware computing. We presented a diagram of the iPad hardware and its associated sensors. While participants had seen the iPad before, they had not previously considered its ability to sense context. We stated that the iPad is a computer that can gather information about the environment, and that it contains sensors that could see, hear, identify its location, and identify who is around. To demonstrate the iPad's image capture capability, we took a photo of the focus group and displayed it to the group. To demonstrate the iPad's ability to detect location, we opened the native Maps application and used GPS to locate the aphasia center. All participants were able to follow this demonstration, but some were surprised that the iPad could identify its own location.

Following this introduction, we walked through each of the scenarios presented in Table 1. For each scenario, we presented the relevant storyboard diagram and talked through the scenario. Once the focus group had examined the storyboard diagram, the research team *play-acted the scenario* using low fidelity user interface sketches presented on the iPad. These play-acted scenarios emphasized the relationship between the users and the software, and the adaptation of the software to the current context. For example, to show how the software could adapt to different conversation partners (scenario #2 in Table 1), we introduced the "Friends" diagram shown in Figure 3. The diagram shows that Bob talks to Carol about food, but talks to Alice about baseball. One member of our research group portrayed Bob, while others portrayed Carol and Alice. In our play-acted scenario, Bob first talked to Carol. At this point, the researcher showed the iPad screen, which displayed a series of food-related terms, to the participants. Bob then turned to Alice. Again, the researcher showed the iPad screen, which transformed to display baseball-related terms, to the participants. The facilitator narrated the scene as it was acted out. Following each scenario, participants were given time to ask questions and provide feedback.

Overall, the focus group participants seemed to understand the scenarios we presented, although not all participants provided feedback. Participants seemed to gain the most information from the facilitator's narration and from the play-acting of the scenarios. In several cases, participants seemed confused about a specific scenario, but then indicated their understanding during or after the demonstration.

5.3.3 Prioritizing Usage Scenarios

In general, the focus group participants were enthusiastic about the concept of producing "smarter" AAC technologies, and were eager to test this new technology. Of the scenarios we presented (summarized in Table 1), participants were most excited about an AAC that could adapt to location (#1), an AAC that could adapt to conversation partner (#2), and an AAC that could recognize the speech of others (#3). As the Converser project [25] previously combined automatic speech recognition with AAC, but suffered from low recognition accuracy, we decided that our initial prototype would support the other two popular scenarios: adapting based on location and adapting based on conversation partner.

5.3.4 Gathering Contextual Data

After deciding to focus on two usage scenarios (adapting to location and adapting to conversation partner), we began to develop those features of the prototype, as well as to consider how to evaluate our prototypes of this system. Evaluating context-aware and adaptive technologies can be difficult, as these systems must gather sufficient data about the user's context in order to function, and are susceptible to recognition and other errors. Furthermore, as our participants already experienced significant challenges when communicating with others in everyday life, conducting a field study with early prototypes could be stressful.

As a result of these concerns, we decided to evaluate the TalkAbout prototype via a Wizard of Oz study at the aphasia center. We selected 5 participants (described in Section 5.2) to continue testing the prototype. As we decided to evaluate the system using Wizard of Oz techniques, our research team began to collect the contextual data needed to construct the prototype. Over the next several visits, we collected data about our participants' favorite conversation topics, commonly visited locations, and common conversation partners.

We used two methods to collect this contextual data. As we were still developing the interactive prototype, we first created a *paper-based questionnaire* that asked participants about what they talked about, or wished to talk about, in specific contexts (Figure 4). Each page of the questionnaire focused on a single location or conversation partner. As most of our participants experienced some difficulties in reading and writing, participants worked through the questionnaire with assistance from the research team[6].

Figure 4. The contextual data questionnaire captured topics that the participant liked to discuss in a specific location.

Overall, participants had difficulty understanding the motivation behind this activity, and thus had difficulty completing the questionnaire. P4 and P5 required significant amounts of coaching in order to complete the questionnaire, and the participants only filled out between 1 and 3 pages of the questionnaire each, providing little contextual data.

Overall, the limited information we collected using the paper forms did not provide us with enough to configure the TalkAbout prototype. In our second visit, we performed a similar data collection activity, but instead used an early version of the TalkAbout prototype. This version of the prototype allowed users to add items, but did not provide context-aware adaptation. We met with each of the participants, introduced the prototype, and showed how it could be used to group together important people and places. We then gave the participants an opportunity to enter data into the prototype, or to instruct the researcher to enter the data, depending on their motor ability and confidence.

Participants responded much more positively to the interactive prototype than to the paper forms, perhaps because the prototype was similar to AAC software they had previously seen. Participants were eager to add new content to the prototype, and to use the prototype to explore this new content. However, the level of interaction with the prototype did vary with the participant's level of ability: P1, P2, and P3 were relatively independent in adding content, adding content that related both to conversation partners and places. P4 and P5, having lower linguistic ability, were less independent. The researchers suggested topics that had been discussed in prior meetings, and the participant indicated which should be added. Figure 5 shows words and phrases added by P3 to a word list related to the doctor's office.

[6] P3 was unable to complete the questionnaire due to scheduling conflicts, but provided similar feedback using the interactive prototype later.

Figure 5. Conversation topics related to the doctor's office, added to the prototype by a study participant (P3).

In addition to providing data needed to configure the prototype, this contextual data collection provided useful information about the people and places that were most important to our participants. Not surprisingly, all 5 participants wished to create content relevant their friends and conversation partners at the aphasia center. In addition to these, P1 added content relevant to his alma mater; P3 added content relevant to the supermarket, doctor, and paratransit; and P5 added content relevant to his partner, going to restaurants, and riding in taxis.

5.3.5 Prototype Testing

Once we had gathered enough contextual data to customize the prototype, we imported this data into TalkAbout and presented the customized prototype to each participant. This version of the prototype contained the features described in Section 4, but used the Wizard of Oz method to set the location and conversation partner.

The researcher introduced the participant to the prototype, and explained that the data shown in the prototype had been gathered in prior sessions. The participant was given an opportunity to explore the prototype for as long as he or she wished, and was able to both explore existing content and add new content. The researcher provided verbal guidance, and help using the touch screen, as needed. Because the evaluation occurred at the aphasia center, participants were unable to test the location-based adaptation in the real world. Instead, the researcher manually changed the device location, and asked the participant to imagine using the device in the other location. As participants were familiar with how the system could adapt to different locations, they understood the instructions and were able to complete this portion of the study.

Following their use of the prototype, the participants completed a brief questionnaire about the current prototype[7]. The questionnaire contained 4 questions, each accompanied by a picture-based, 9-point Likert-type scale designed for people with aphasia [12]. The questionnaire contained the following questions:

1. How much did you like the software?
2. Is the software better or worse than technology you use now?
3. Would you use this software?
4. Where would this software be most helpful?

[7] P5 found the questionnaire activity difficult, and asked to be excused from this session.

Numerical responses are provided in Table 2. Given the small sample size and the early stage of the technology, we have omitted a deep quantitative analysis of the scores. Instead, we note general trends in the data. P1, P3, and P4 were strongly positive about the prototype. P2 was less enthusiastic about the prototype, but noted that he had not had much success in using technology in the past, and was thus cautious about adopting new technology. P1 and P3 were especially enthusiastic. P3 said that the software was "cool," and indicated that it could help her act more independently. When asked where she might use the prototype, P3 indicated that it would be most helpful at the doctor, and wrote, "I could go myself." When asked where he might use it, P1 stated that he wanted to use it "all the places."

Table 2. Evaluation of the TalkAbout prototype, rated on a 9-point scale (1=negative, 9=positive).

	Liked software	*Better than current*	*Would use*
P1	**7**	**7**	**9**
P2	**6**	**7**	*5*
P3	**9**	**9**	**9**
P4	**8**	**9**	**8**

6. DISCUSSION

In this section, we reflect upon lessons learned in developing TalkAbout, and provide recommendations for designing context-aware communication tools for people with aphasia.

6.1 Benefits of Context-Aware AAC

We began this research with the belief that context-aware adaptation could improve the usability of AAC devices. While we have not yet conducted a rigorous performance comparison between adaptive and non-adaptive AAC, we observed our participants struggling with several specific challenges that may be addressed by an adaptive user interface:

1. *Motor impairments.* Most of our participants had some motor impairment due to their stroke (especially P3, P4, and P5). This impairment sometimes made it difficult for participants to navigate using the touch screen. Context-based adaptation could reduce the amount of search needed to find commonly used words and phrases.
2. *Lack of organization.* Participants often experienced challenges organizing content on their mobile devices, including photos (P5), AAC phrases (P1, P5), and applications on their device's home screen (P1, P4, P5). Often these items were not sorted into categories, but were instead stored as a single-level list. Finding items in this list was sometimes frustrating. Context-based adaptation could improve users' ability to find AAC phrases hidden in long lists by hiding irrelevant content.
3. *Encouraging recognition over recall.* Participants often experienced difficulty when attempting to produce words or phrases extemporaneously. Recalling a word was much easier if the participant was presented with a photo, text, or spoken audio of the word. Context-based adaptation could help in such situations by identifying appropriate words and phrases and automatically presenting them to the user, increasing the likelihood that the user would see the desired word or phrase.

6.2 Designing with People with Aphasia

Active involvement from our research participants was key to the success of this work. However, participatory design with people with aphasia presents many challenges. While prior research has offered guidelines for conducting participatory design for people with aphasia [6,16], we encountered unexpected challenges during this work, and gained additional insights about how to collaborate with this population. Over the course of this research, we identified several strategies that were especially helpful:

1. *Prepare alternative activities.* Given the diversity of our participant group, not all participants were able to participate fully in each research activity. For example, P4 was unable to provide much feedback in the written questionnaire due to his limited vocabulary. As an alternative, we asked P4 to show us photos that he had stored on his computer, and together identified locations of the photos using the iPad's Maps app. This activity provided an alternate means for learning about the people and places that were most important to our participant.
2. *Support rapid prototyping and UI tweaks.* Our study sessions were conducted during and between class sessions. Because participants often had limited time, it was important that we be able to quickly generate, test, and tweak prototypes. We designed TalkAbout to make it easy to add new content and to make UI changes in the field, enabling us to discover problems, fix them, and evaluate the fix in a single site visit.
3. *Balance focus groups by communication ability.* Some research sessions required us to meet with 2 or more participants simultaneously. In one such instance, a participant with high language ability (P1) was paired with a participant with low language ability (P5). Even though a facilitator was present, P5 had difficulty sharing his opinion in the session, and became frustrated. In subsequent sessions, we made sure to group participants with similar levels of communication ability.

Conducting participatory design with people with aphasia can be quite challenging. Our experience has shown that these challenges may be magnified when designing context-aware technologies, as these may be more difficult to explain or understand. We found the following techniques helpful in communicating the nuances of context-aware technology to our participants:

4. *Present scenarios using multiple formats.* We presented our usage scenarios verbally, as storyboards, as low-fidelity prototypes, as acted-out demonstrations, and as interactive prototypes. Participants were sometimes slow to engage with the material, but often became more interested and responsive after experiencing the information in multiple formats.
5. *Make demonstrations concrete and personalized.* Participants seemed to respond best to the most concrete demonstrations, specifically play-acting with low-fidelity prototypes and testing the interactive prototypes. Participants also responded with enthusiasm when testing prototypes that contained content that they themselves had entered in previous sessions.
6. *Clearly illustrate changes in the user interface.* Our early prototypes provided minimal feedback when adapting to the current context. Some participants did not understand what changes were happening to the interface, or that a change had happened at all. Our later prototypes announced changes to the interface with an audible camera click (when snapping a photo), and a clear visual refresh, which helped participants understand how the user interface was adapting.

7. FUTURE WORK

A major limitation of the current work is that we have not conducted a rigorous comparison between adaptive and non-adaptive AAC. We intend to continue to develop the TalkAbout software, and to evaluate it with the community at the aphasia center. We intend to distribute our prototype to more participants, and to test it in the lab as well as in the field.

The current version of TalkAbout considers only two contextual factors: the user's location and conversation partner. Future versions may incorporate additional contextual factors to further improve the adaptability of the user interface. Furthermore, while the current TalkAbout prototype uses contextual information only to retrieve previously added phrases, future versions could use contextual information to suggest new words and phrases. For example, TalkAbout could identify that the user is at a bank and present common words and phrases used in banking, even if the user did not pre-program them.

Finally, some study participants experienced difficulty when using the touch screen and aiming the tablet camera, due to comorbid motor impairments. While other researchers have explored touch screen accessibility for people with motor impairments (*e.g.,* [8]), we hope to build upon this work and explore new methods for creating more accessible touch screens and camera interfaces.

8. CONCLUSION

In this paper, we have explored how context-aware computing may improve the usability of AAC for people with aphasia. We presented a framework for designing context-aware AAC technologies, developed a prototype of a context-aware AAC device, and tested this prototype through a series of iterative, participatory design activities with a group of adults with aphasia. Our participants enjoyed using the prototype and preferred it to their existing technology solutions. We hope this work will encourage the development of a new generation of smarter, more aware, and more adaptive communication devices.

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