An Experience in Requirements Prototyping with Young Deaf Children

Jessica Korte
PhD Candidate
Griffith University
170 Kessels Rd
Nathan, Queensland
Australia
jessica.korte@griffithuni.edu.au

Leigh Ellen Potter
Lecturer
Griffith University
170 Kessels Rd
Nathan, Queensland
Australia
l.potter@griffith.edu.au

Sue Nielsen
Adjunct Senior Research Fellow
Griffith University
170 Kessels Rd
Nathan, Queensland
Australia
s.nielsen@griffith.edu.au

Abstract

Deaf children are an underrepresented group in technology development, despite the potential technology available to aid them in language acquisition. Requirements elicitation prototyping allows Deaf children to act in an informant role in the creation of key technologies. This paper presents a case study of requirements elicitation prototyping conducted with young Deaf children in order to identify issues within the process. Potential solutions to each issue are provided so that designers working with young Deaf children as informants can adjust their design process to obtain relevant information.

Keywords

children, deaf, deaf children, prototyping, requirements elicitation, design

Introduction

In this paper we will describe our experience conducting collaborative software prototype sessions with young Deaf children. The terms *deaf* and *Deaf* will be used according to their cultural definitions amongst the Australian Deaf community. Lower case deaf is used to describe an individual with some form of hearing loss; upper case Deaf describes individuals who identify as belonging to the signing Deaf community and who communicate using Auslan (Australian Sign Language).

It is important to support children's use of technology, not just as present users, but also as the future users and developers of technology (Korte, Potter, & Nielsen, 2014). The principles of user centered design emphasize the importance of understanding users' needs and expectations of technology, while participatory design encourages the inclusion of users in the design process to ensure accurate understanding of needs and expectations. Children should be included in designing their own technologies (Druin, 2002). Children often have their own needs and expectations of technology interactions. There is "recognition of the fact that children's views differ from those of adults" (Rabiee, Sloper, & Beresford, 2005, p. 387), and they expect a seamless and interactive experience with technology (Bearne, 2003). This includes children who are very young or who may have a communication gap that can be accommodated by adapting the design processes to their abilities and strengths (Farber, Druin, Chipman, Julian, & Somashekhar, 2002; Guha, Druin, & Fails, 2008). There is a breadth of work in the child-computer interaction area of research; however, research in collaborative design specifically with Deaf children is less common. What can a designer expect if they conduct collaborative sessions with young Deaf children?

The research described in this paper presents our experience examining prototyping as an approach to technology development that would truly reflect the usability needs of young Deaf children. The primary research question examined was, "What issues are implicit in eliciting requirements from young Deaf children, and how can the elicitation process be adapted to address these issues?" The identification of issues in the requirements elicitation process should inform future developers in finding approaches for designing with young Deaf children.

In this paper, we present a description of our early experience conducting an interactive software prototype review and collaborative design sessions with young Deaf children. Based on our experience, we propose an initial set of recommendations for undertaking participatory design with young Deaf children. The first section of this paper describes the key concepts relevant for this study, before describing the research approach and the prototype we used. We then present our experiences during the prototyping sessions, followed by our recommendations and a set of guidelines for usability practitioners.

The Reality for Deaf Children

Of deaf children, 95% are born to hearing parents (Deaf Children Australia & Deaf Services Queensland, 2008). Approximately 25,000 children received a cochlear implant between June 2012 and June 2013 (Hochmair, 2013); however, not all children are good candidates for receiving a cochlear and some recipients will either reject or not use their implant (American Academy of Audiology, 2014). When interviewing the parents and teachers of cochlear-implanted children, Hyde and Punch (2011) found that 15–20% of families with a cochlear-implanted child also used some form of signed communication to supplement children's spoken-language learning to provide a method of communication when children are unable to use their implant or to promote the children's identities as members of the Deaf community.

Deaf children show a number of characteristics that differentiate them from hearing children in the areas of academic development, communication, social and emotional development, and their highly visual nature. Deaf children, particularly those born to hearing parents, often have learning difficulties, language development delays, low literacy levels, and delayed mathematical skills (Potter, Korte, & Nielsen, 2014). Despite this, when they are motivated to communicate, they are active and innovative, and will use a variety of communication modes, including creative expressions such as drawing (Potter et al., 2014). Deaf children born to hearing parents have been reported to have delayed social and emotional development, with behavioral and attention problems potentially being attributable to the communication gap between deaf children and their hearing parents (Barker et al., 2009; Potter et al., 2014). Deaf

people have strong visual-spatial cognitive perception and experience more sensitive visual attention in their peripheral vision (Ebrahim, 2006; Potter et al., 2014).

Technological resources could play a significant role in exposing young Deaf children and their families to sign languages. Electronic resources are uniquely suited to displaying signs through videos and animations in a way that static images and written descriptions in books and posters cannot match. They are also appealing to children growing up in today's increasingly technical world (Prensky, 2001).

Prototyping and Participatory Design

Prototyping for requirements elicitation is a powerful way of discovering new requirements, as well as confirming the correctness and completeness of those already discovered (Gomaa & Scott, 1981; ISO/IEC/IEEE 29148, 2011; Ravid & Berry, 2000). A prototype can aid communications by acting as a focal point for mediations and discussions on a proposed system, providing a common ground to bridge the differences between stakeholder groups. It can also act as inspiration, providing a starting point for users to discover additional requirements (Ravid & Berry, 2000). These attributes make it useful for eliciting requirements from children, when complicated requirements specifications would be unhelpful. A number of methods for designing with and for children utilize prototyping, including creating prototypes, evaluating prototypes, or both (e.g., Guha, Druin, & Fails, 2013; Large & Nesset, 2009; Scaife & Rogers, 1999). These prototypes often act as a catalyst for further discussion or reflection. Prototyping has also been used with Deaf adults (e.g., Ho-Ching, Mankoff, & Landay, 2003).

Eliciting requirements from child users early in a project falls into Druin's definition of children as informants. Informants are asked for their input at various points throughout a project (Druin, 2002). As a source of data, they are able to reveal new information and ideas, as well as confirming design team assumptions (Druin, 2002; Scaife & Rogers, 1999). Decisions about which informant suggestions to include is left to the discretion of the design team, providing a filter against infeasible and impractical ideas (Scaife & Rogers, 1999).

Druin and colleagues have promoted maximizing children's involvement in design projects, and have investigated working with young children and children with special needs as design partners (Farber et al., 2002; Guha et al., 2008). With appropriate support, Guha et al. (2008) posit that all children can act as design partners. Young children have been shown to be able to create and evaluate prototypes (Farber et al., 2002).

Methods

The following sections discuss the participants, case study, data collection, and prototypes used in this study. The data collection and initial analysis was conducted by the first author. The study followed our university's rigorous ethical clearance requirements, including informed parental consent.

Participants

Participants were drawn from amongst students attending an Education Queensland school with a Special Education Program focusing on Auslan. Criteria for selection were that the child should be Deaf and learning Auslan through the school. Three participants agreed to be involved with the study. In this paper, we refer to them as Pat, Roger, and Richard. Despite attending the same school, it is unknown if the participants were friends before prototyping sessions began. Teacher aides from the Special Education Program acted as Auslan interpreters.

Using a questionnaire, we gathered descriptive information on participants' use of and access to various technologies in their home life. The questionnaire was completed by participants' parents prior to the sessions. The following is a description of the participants based on questionnaire answers:

- Pat was 7 years old, profoundly deaf, and had delayed language development. He had been implanted with a cochlear implant at the age of 18 months, but it had failed. During the study, he wore a new cochlear implant, which had been implanted approximately two years before the study. He was learning English and Auslan. He enjoyed watching wildlife documentaries and playing on a computer and iPad at home.

- Roger was 7 years old and hard of hearing. He wore a hearing aid. He was able to communicate with vocalized English and Auslan, both of which he was learning. He was allowed one or two hours of supervised computer time at home each week, during which he watched videos, created artworks, and played learning and recreational games. He also had a Nintendo Wii and a Sony Playstation. When playing traditional games, he enjoyed solving puzzles, building things with Lego, and playing sports.
- Richard was 7 years old, hard of hearing, and wore a hearing aid. He was able to communicate with vocalized English and Auslan, both of which he was learning. He was permitted two to three hours of supervised computer time each week, three to four hours of supervised iPad use, and two unsupervised hours of iPad play. He played with learning games, drawing, and photography apps. He enjoyed music, puzzles, and adventure games.

Case Study

This research was undertaken as a case study utilizing a pilot study and then a main study, both using multiple data collection methods to ensure veracity of data. A case study was selected as it allowed working with a small number of participants who provided insights illustrative of groups to which they belong. In this case, we were looking at children who are Deaf and would benefit from participating in design activities and the items created as a result of the designs.

The methods used in this study were a questionnaire (as previously mentioned in the Participants section), observation of prototype sessions, and recording of participant comments. A user evaluation approach was taken to prototype sessions, as this allowed participants to engage with the prototypes in the way that seemed most natural and provided information about the "real" way users would engage with a similar program.

Observations of user behavior were made during prototyping sessions of a game based application that aims to support young Deaf children to learn Auslan. Particular note was taken of on-screen objects that drew participants' attention or that participants had trouble interacting with. This data collection method was used during both the pilot study and the main prototyping sessions. The prototype is described in detail below.

During the prototyping sessions, participants were also encouraged to speak and sign their thoughts and opinions. These provided an insight into participants' thought process when operating the prototype.

Data Collection

This study involved three rounds of data collection. The first round involved collecting background information about the participants via a questionnaire.

The second was a pilot testing session of the prototype, intended to examine the feasibility of prototyping with a young child. This involved a single test user, Pat, who was a profoundly deaf 7-year-old boy with delayed language development, and an Auslan interpreter. The pilot session was conducted with only one participant to allow for testing the principles of the prototype sessions in a less complex situation. Having one participant meant that it was not necessary to identify management plans for situations such as children fighting. Pat was also the only child for whom informed consent materials had been collected in time for the pilot session.

In the pilot session, Pat was provided with a laptop computer displaying a software prototype. Through the interpreter, he was told to play with the prototype. He was not prompted further throughout the 15-minute session and did not choose to communicate in English or Auslan. His interactions with the prototype were observed and noted. He was not prompted for comments.

The third round of data collection consisted of a series of prototyping sessions with two 7-year-old Deaf children, Roger and Richard. There were a total of seven half-hour sessions, occurring across three consecutive weeks. The two boys and a fluent Auslan interpreter were present at each session. As in the pilot session, the participants were provided with a laptop computer displaying a software prototype. The participants were instructed in spoken English and Auslan to play with the prototype, working together in an informal co-discovery approach, and to share their thoughts and opinions of it, as per Think Aloud Protocol (TAP) and Gestural Think Aloud Protocol (GTAP), the sign language equivalent (Roberts & Fels 2006). The participants communicated in a mix of English and Auslan, with a majority of comments made in English. If the participants went for a significant period without making any comments, they would be

prompted to share their thoughts, in both spoken English and Auslan. Comments and observations of their behavior were recorded in writing.

The interpreters in these sessions were teacher aides from the Special Education Program, as it was judged that a known presence would provide the participants with a sense of familiarity that would accelerate their becoming comfortable with the sessions. Due to this decision, it is important to draw attention to the fact that these teacher aides had a more active role in the sessions than a professional interpreter might have (Temple & Young, 2004), as they acted not only as interpreters but also as facilitators of the children's communication. At times, they would suggest, in English or Auslan, possible answers to questions posed to or by child participants, attempting to "fill the gaps" when participants did not know the signs or words to express themselves.

The prototype sessions were modelled on prototype testing sessions, with the children in an informant role (Druin, 2002). Their comments and reactions to the prototypes acted as input to guide future design decisions. They were not acting as full design partners. They were also not acting as usability testers, as the prototype they were interacting with was a concept prototype created specifically for the elicitation of informant ideas.

Prototype

In the context of this research, prototyping refers to iterative development of a PC-based proof of concept interface. The prototype was updated after each session according to an analysis of participants' behavior and comments.

The program prototyped in this research was called Sign My World. It provided rooms of a virtual house for users to explore, as shown in Figure 1A. When users clicked on items in the world, a video flash card was displayed, showing an image of the item clicked and the corresponding English word. A video of the corresponding Auslan fingerspelling, sign, and the spoken English word was then displayed. An example is shown in Figure 1B.

Figure 1. The initial screens of the Sign My World prototype, showing a virtual room (A) and a video flash card (B).

Results

The following sections discuss the results from the observations and user comments from the pilot study session and then the main study of the prototyping sessions. This section presents the findings from each session in detail. There was one pilot session with Pat, and there were seven sessions with Richard and Roger testing each iterative design of the prototype. Each section begins with a prose description of the session, followed by a table summarizing the key points.

Pilot Session

Pat had some difficulties at the beginning of the session, as he was unfamiliar with the laptop touchpad. After a short demonstration, he was able to proceed without difficulties.

The bright colors and cartoon style of the interface seemed to appeal to Pat, as he reacted positively. He quickly discovered that animated items could be clicked on. He did not click on the "tutorial" or "testing" buttons and, in fact, seemed to ignore them.

The first time he viewed a video flash card, he tried to return to the main screen by clicking on the faded black/transparent area behind the video (shown in Figure 1B). He seemed frustrated by this, scowling at the screen and clicking with more force than necessary, until he noticed and clicked the "back" button.

By the end of the session, Pat had clicked on all the items multiple times. He replayed some of the videos during early views. It seems likely that he would have enjoyed more content to explore, as he began looking for other programs on the laptop he was using.

As already mentioned, he was not prompted for his thoughts during the session and did not volunteer any comments in either English or Auslan. This may have been due to his already noted delayed language development. It did not prevent him from expressing his opinions on the existing prototype through his body language and actions, and useful data was collected from these.

Table 1. Summary of Pilot Session

Prototype	Participant	Key events	Remarks and reactions	Interactions
Provided initial prototype[a] on laptop computer with touchpad mouse control.	Pat was quiet but happy.	Researcher gave a demonstration of touchpad. Pat liked colors and style of interface. Pat discovered animated items could be clicked. Pat repeatedly tried to exit video flash card by clicking on background. Pat clicked on all items multiple times, replayed videos. Pat began looking for other programs on laptop.	No remarks were made. Pat had difficulties with laptop touchpad. Pat looked happy as he explored the prototype. Pat was frustrated when the video flash card did not work as he expected it to, clicking repeatedly and forcefully.	Only one participant

[a] As described in the previous Prototype section, also see Figure 1.

Prototype Sessions

The following sections go into detail for each of the seven prototype sessions with Roger and Richard.

Prototyping Session 1

Richard and Roger were both very quiet at the beginning of the first session. The session was started with some ice-breaker questions, which the participants were reluctant to answer at first. When the purpose of the session was explained—that they would be testing a computer game—both participants seemed cautiously optimistic. The prototype was provided on a laptop with a plug-in mouse, and taskbar and desktop icons were hidden. Throughout the session, they were prompted to share their thoughts.

Roger and Richard enjoyed the animated buttons, and they grinned and giggled when looking at the animations. One responded, "I love it!" when prompted for their thoughts; however, they did not click on any of the buttons unprompted. Once they had clicked on an item, they were

pleased to see the Auslan video. They laughed when they saw it, and when prompted, explained that they were amused by the video, which had a female signer and a male voiceover.

Richard had more experience with computers and learned to interact with the prototype more swiftly. He took on a tutoring role, demonstrating functionality that Roger struggled with such as replaying videos or clicking within button hit zones.

Each boy happily clicked on all the animated items. They shared control amicably, each clicking on a few items and watching a few video flash cards before handing the mouse to the other.

The Auslan interpreter prompted the participants to copy the signs. This revealed that the fingerspelling in the videos was confusing for them. Richard seemed to realize that the fingerspelling was additional to the actual sign, so he did not try to mimic it. Instead, he would hesitantly attempt the actual sign. Roger, on the other hand, tried to mimic the fast movements of the fingerspelling, without success.

At the end of the session, we discussed what the participants would like to see in the next prototype. Roger suggested a kitchen and some signs that could be found there. Next they were asked, "How would you get to the kitchen?" Roger replied that he would "walk downstairs," apparently drawing on the layout of his own house.

Table 2. Summary of Session 1

Prototype	Participants	Key events	Remarks and reactions	Interactions
Removed back button from video flash card. Provided on laptop computer with plug-in mouse. Hid desktop icons and taskbar.	Richard and Roger were quiet, but cautiously optimistic after the purpose of sessions was explained.	Researcher asked ice-breaker questions and explained the purpose of session. Children explored animations without clicking. Interpreter prompted children to click. Children clicked on items and watched flash cards. Interpreter prompted both children to copy signs. We discussed additions to prototype: rooms and navigation.	One child said they loved the animated buttons. Both children laughed at video, amused by male voice-over for female signer. Fingerspelling in videos was too complicated for the children. Roger suggested to add "kitchen" and items found in kitchen to the prototype. All discussed the navigation and how it revolved around real-world experience. For the kitchen, Roger said: "I would walk downstairs."	Richard and Roger worked together to explore the prototype, showing spontaneous turn-taking. Richard tutored Roger when Roger struggled with replaying videos or clicking inside button hit zones.

Prototyping Session 2

Roger was much more comfortable with the prototyping process by the second session. His behaviour during this session was almost hyperactive. He was giggling and wanted to click on everything, but paid little attention to the sign videos even when he allowed them to play. He seemed more inclined to sing and make up stories about the items on screen.

Richard was still quiet and still seemed unnerved by the newness of the situation; he frowned more than Roger and was more hesitant to speak or sign his comments. On the other hand, he had no hesitation in approaching the prototype and was keen to explore the game and watch the sign videos.

The program started by displaying the "bedroom" area, as shown in Figure 1A. The only visible change at the start of this session was the addition of a "treasure map" button that the participants noticed immediately. When they clicked this button, a map of a house appeared, as

shown in Figure 2, both boys grinned and exclaimed over it. There were moments of confusion when the white area of each room and the red roof did not respond to clicks
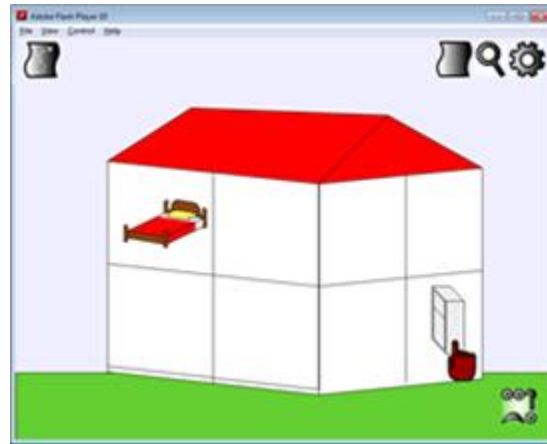

Figure 2. House map.

Seeing the map prompted Roger to suggest another room, for toys and video games. When asked what sorts of toys and games, Roger said "W games" (possibly referring to Nintendo Wii), pirates, superheroes, and "Star Wars dolls." Richard couldn't think of any toys he had at home, but he repeated the interpreter's suggestions of a ball or toy car.

Richard was the first to understand the "through the door" buttons added to the prototype, visible in Figure 3, and he showed Roger how to use them to move between rooms.

Figure 3. "Door" video flash card with "through the door" button at right.

Both participants liked the addition of a kitchen. Roger was disappointed that some of the items he had suggested were not present. To address this, the researcher demonstrated a paper prototype of finding items "inside" the fridge flash card, as shown in Figure 4. Both participants affirmed that this "made sense" to them.

Figure 4. Items "inside" fridge.

Because Roger was singing to himself, participants were asked if the items should have sounds as well as animations. Richard said yes, but Roger said no.

Table 3. Summary of Session 2

Prototype	Participants	Key events	Remarks and reactions	Interactions
Added "Treasure map" button to all screens. Added house map for navigating between rooms, see Figure 2. Added "Through the door" buttons to door video flash card, see Figure 3.	Roger was hyperactive: giggling, clicking on everything, paying little attention, and singing. Richard was quiet: frowned, hesitated to comment, but keen to test the prototype.	Children immediately noticed and clicked on the new map button. Interpreter asked about toys Richard might own. Researcher showed paper prototypes of items "inside" other items (e.g., food in fridge example, see Figure 4).	Roger grinned and exclaimed over the house map. Both were confused when areas they expected to be clickable were not. Roger suggested toy room and items found in toy room. Both liked new kitchen area. Roger was disappointed not every item he had suggested was present. Both said paper prototype made sense. Richard liked the idea of sounds on items; Roger did not.	Both children happily talked together about the new areas. Richard showed Roger how to move between rooms with the "through the door" buttons.

Prototyping Session 3

Both participants were lively during this session. During this session, participants fought over control of the mouse. Richard tried to control the mouse using the laptop touchpad while it was Roger's turn. The touchpad had to be disabled and a control-sharing system established, which led to collaboration. The participants played off each other to draw attention to things they found interesting. Richard rarely commented, but Roger would comment on Richard's actions as well as his own. Richard drew Roger's attention to particular objects by pointing and saying, "Click here!"

During this session, participants were able to see other children who were outside the room through a window. Once, Richard was distracted by them while waiting for his turn to control the mouse.

Both participants were very excited about having a new room (games room) to explore. The videos in this room had a louder volume, and Roger said he preferred this to the earlier ones.

A navigation bug was encountered in the prototype that made participants agitated until it was fixed and they could resume using the prototype.

Roger was quite excited to see that the "roof" now had a video flash card and to find items inside the fridge, as he had previously requested. Neither participant had difficulty with the navigation and expected more of the same, asking "Where's the stuff inside [the cupboards]?"

Animated buttons continued to be well-received, with realistic animations, such as a water tap turning on, holding attention.

Roger seemed to feel that either the signers or the voice-overs were angry, asking, "Why is he angry?" Unfortunately, he was unable to elaborate on this cryptic statement.

Roger suggested further expansions of the prototype.

Table 4. Summary of Session 3

Prototype	Participants	Key events	Remarks and reactions	Interactions
Included items "inside" fridge, as paper prototyped in Session 2; see Figure 4. Provided new games room.	Both Roger and Richard were lively.	Richard tried to use touchpad during Roger's turn. Researcher implemented turn-taking system. Richard distracted by other children outside the room. Both children found a navigation bug.	Roger preferred louder volume on new videos. Both children were excited that items that hadn't been clickable were now clickable. Both children expected more items "inside" other items: "Where's the stuff inside the cupboards?" Both children liked the animated buttons. Roger thought voice-overs were angry. Roger suggested expansions.	Roger and Richard fought over control of the mouse. After turn-taking was implemented, they collaborated by advising each other's turns. Roger commented on Richard's actions. Richard directed Roger on items to click.

Prototyping Session 4

Richard attended the fourth testing session alone, as Roger was sick. Richard was quiet and subdued throughout the session. He did not smile much during the early part of the session and made comments when prompted.

This version of the prototype had a new start screen, with icons for a matching game (matching one of three pictures to the sign video) and the house. Richard began by clicking on the house icon and exploring the house again, but he seemed bored. He was prompted to try the matching game. All of his answers were correct, and when prompted he said he liked it but the game was "too easy." He had no suggestions on how to make it more challenging. He also had no suggestions for symbols to use as a shortcut for the game.

Richard examined all the items and video flash cards again. Having run out of things to explore, he chose to replay the matching game. He got some of the answers right before the signer had finished, suggesting that he could be recognizing the signers from the videos rather than the signs themselves.

Table 5. Summary of Session 4

Prototype	Participant	Key events	Remarks and reactions	Interactions
Provided new start screen: icons for house and a matching game (matching one of three pictures to sign video).	Richard was quiet and subdued. He did not smile much, but he made comments when prompted. Roger was absent due to illness.	Richard clicked on the house. Researcher prompted him to try the matching game, in which he answered all correctly.	Richard seemed bored with the house, which he had already explored. When prompted, Richard said he liked the matching game, but it was "too easy." He offered no suggestions for making it more difficult and no suggestions for changing the icons. Richard clicked answers in the matching game based on signers, not the sign.	Only one participant

Prototyping Session 5

Both participants attended this session, in silly, joke-telling moods. They again had difficulty in sharing control of the mouse. Richard decided he wanted to use the touchpad during one of his turns. Roger wanted to do so as well, despite quickly growing frustrated by the lack of precision he had in moving the cursor that way.

Richard began the session by playing a new matching game (matching one of three videos to a picture). He said he liked it, and that it was harder than the original game "in a good way." However, he still seemed to be identifying signers, rather than actually observing the signs they were making, for he would often click before the sign was finished.

Roger was not interested in playing the matching game. He wanted to see if there were new areas in the house. When he saw there were none, he began suggesting more while continuing to explore the old rooms. Roger was pleased to hear voiceovers in the house videos, as the videos in the matching game were silent.

Richard would mimic signs being shown while Roger had control of the prototype.

A bug in the interface required the prototype to be restarted. During this process, Roger saw the laptop's Music folder and suggested that the prototype should have music. Richard agreed and suggested that there could be different music for each room.

When the prototype restarted, Richard told Roger to play the matching game. Roger was less successful than Richard. Some difficulties were due to imprecision of his touchpad control, but he also seemed not to realize the point of the game. Richard tried to explain, telling him which option to pick several times while watching Roger play.

Table 6. Summary of Session 5

Prototype	Participants	Key events	Remarks and reactions	Interactions
Provided new matching game (matching one of three videos to picture).	Richard and Roger were silly and told jokes.	Richard decided he wanted to use the touchpad. Richard played the new matching game. Roger wanted to see if there were new areas in the house. After restarting the interface due to an issue, both children saw the computer's Music folder.	Roger was frustrated by the touchpad, yet refused the plug-in mouse. Richard said the new matching game was harder "in a good way." Richard clicked answers in the matching game based on signers, not the sign. Roger liked voice-overs on the videos. Roger suggested the prototype should have music. Richard agreed.	Roger struggled to use the touchpad, but wanted to because Richard was using it. Richard mimicked signs while Roger controlled the mouse. Richard told Roger to play the matching game. He told Roger which answers to choose.

Prototyping Session 6

Both participants were cheerful and eager to give their opinions in this session. Roger was delighted to find a new room to explore, although he was very disappointed that one of the signs in the game (TV) did not match the sign he had expected (MOVIE).

The buttons in this new room were not animated, which upset both participants. They explained and demonstrated the type of animation they expected to see. They also offered other suggestions to improve the new room and to expand the prototype to show a city.

Interface bugs were encountered again, although participants were not disturbed, merely instructing the researcher to fix them.

Roger suggested the creation of a memory-style card matching game similar to the one he had played on computers before.

Table 7. Summary of Session 6

Prototype	Participants	Key events	Remarks and reactions	Interactions
Provided new room: TV room (buttons not animated).	Both Richard and Roger were cheerful and eager.	Both children explored the new room. Interface bugs were encountered.	Roger was happy to find a new room, but was disappointed that the sign in the game was not the same as before. Both children were upset that buttons were not animated and explained in detail how they should be animated. Both wanted the game expanded into a city. Interface bugs no longer fazed the children. Roger suggested a memory-card matching game.	Both children were focused on interacting with the prototype and offering suggestions to the researcher.

Prototyping Session 7

Both participants were again eager to give their opinions in this session, although they again fought over control of the mouse.

Roger again had a list of suggestions for signs that should be included, and he was happy to see that some of his previous suggestions had been implemented, including the animations they had requested previously.

A visual change, moving the "bookshelf" item from the "TV room" to the "computer room" confused Roger. Richard was confused by the static poses of human characters who had been added to the prototype.

When asked, both participants said they would like to have an avatar that appeared on every screen, and they would like to be able to personalize it. They were directed to the avatar personalization section that had been added to the prototype, shown in Figure 5. It required users to click on part of the face to begin, which was unclear to participants. They grew frustrated when it did not work the way they expected it to, although they were able to figure it out through trial and error. Then they were pleased with it and offered suggestions for improvements.
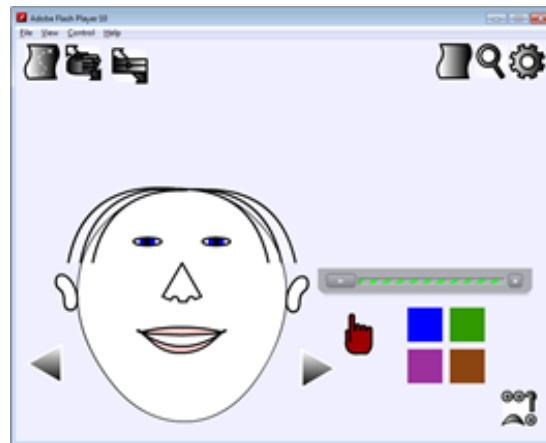

Figure 5. Avatar personalization screen.

Table 8. Summary of Session 7

Prototype	Participants	Key events	Remarks and reactions	Interactions
Provided new room: computer room. Moved "Bookshelf" from "TV room" to "computer room." Provided avatar customization screen added, see Figure 5.	Richard and Roger were eager to give opinions.	Both children explored the house. Both children were asked if they would like a customizable avatar. Both children were able to figure out the avatar screen through trial and error.	Roger suggested new signs. Roger was happy to see some of previous suggestions incorporated into the prototype. Both children were happy to see animations. Roger was confused by the moved bookshelf. Richard was confused by non-animated human characters. Both children said they would like an avatar. Both were frustrated when avatar customization did not work as expected.	Both children fought over control of the mouse.

Recommendations

A number of issues were identified from the testing sessions. These issues are described in the following sections, along with suggestions for requirements for elicitors to minimize disruption caused by these issues.

Deaf Children
The following recommendations apply specifically to Deaf children.

Visual Concerns

Deaf children are generally very visual. Even minor changes, such as the addition of a single button to the prototype in Session 2, are very obvious to them. They are also prone to being distracted by activity in their peripheral vision. Even small movements in a Deaf child's peripheral vision can draw their attention, as shown by Richard's distraction in Session 3.

Consider the necessity of making visual changes between sessions, as children are likely to fixate on the changes. The physical location of requirements elicitation sessions should also be assessed to minimize any external distractions.

Communication Difficulties

Young children, and those with a communication gap, are likely to struggle to express themselves clearly. Examples from this case study include Roger's questions about why the voiceover was angry.

When working with children, especially children who are young or have a communication gap, allow for as many forms of communication as possible. Examples include signing, speaking, drawing, and other expressive activities. Following up unclear statements with clarifying questions may help, but it may also frustrate participants who feel their meaning is being lost.

All Children

These recommendations can be applied to all children, but were particularly relevant to our study with young Deaf children.

Participants' Level of Familiarity with Technology

Despite participants' reported familiarity with technology, we observed a range of struggles that the children experienced with the technology used in the sessions. For example, in Session 5, Roger wished to use the touchpad despite being unfamiliar with it and subsequently experienced difficulties with the prototype. It is unclear whether his trouble stemmed from the prototype or simply from using an unfamiliar technology.

During the pilot session, Pat's familiarity with computers presented a problem. He was able to find and launch programs on the laptop desktop. Hiding desktop icons and operating system taskbar during testing sessions seemed to address this difficulty.

When working with children, use hardware configurations that informants are familiar with to allow a focus on difficulties caused due to the prototype. Schools or parents may be able to provide this information. Remove or hide any software that could be accessed by informants who are not being tested.

Obtaining Data from Prototyping Sessions

Pat did not make comments during the pilot session, so no data was obtained about his thought process. During the testing sessions, Roger and Richard were prompted for feedback when they seemed particularly thoughtful, happy, or frustrated, as recommended in TAP and GTAP usability evaluations (Roberts & Fels, 2006). As they became more familiar with the testing process, they would begin to comment to each other and then to the researcher directly.

Gently prompt children to share their thoughts when they show a strong reaction to the prototype, but do not make comments, particularly early in the requirements elicitation process. Children who are familiar and comfortable with the requirements elicitation process will be more likely to comment without prompting.

Participant Nervousness

Richard and Roger's early nervousness at the newness of the testing process caused them to withhold their comments. The most effective solution to this seems to be allowing participants the time to familiarize themselves with the process and the elicitor involved and to see that their input has an impact on the developing product. This is in-line with Guha, Druin and Fails (2013) acknowledgement that time and experience with design activities is one of the best ways to build a trusting relationship.

Aim to build trust with the children: Allowing time to increase familiarity with us and the requirements elicitation process and showing children that their contributions were respected and valued, were effective in this research. Other researchers have recommended the use of "icebreaker" or "getting to know you" activities and training (e.g., Dindler, Eriksson, Sejer, Lykke-olesen, & Ludvigsen, 2005; Farber, Druin, Chipman, Julian, & Somashekhar, 2002). Future research could examine the effectiveness of particular icebreakers and training in speeding up this process.

Participant Groups

Working with participants in a pair had some positive effects, such as encouraging spontaneous peer tutoring and discussion of new features. It also seemed to bolster the participants' confidence during early nervousness. There were also negative effects, such as conflicts over whose turn it was to control the mouse. Scaife and Rogers (1999) found that having children work in pairs was highly effective in idea generation, while Farber et al. (2002) recommended having young children work in small groups. Druin (2002) spoke of collaboratively setting expectations as a way of promoting equality and respect among team members.

Consider having children work in pairs or small groups to gain the advantages, identified in this paper, while taking steps to minimize and prevent conflicts. For example, conflicts over control

of the mouse could be averted by having the children decide on a control system during the first session.

Technical Issues and Bugs

Technical issues can disrupt testing sessions; participants may be upset by errors. If they encounter bugs, participants might dismiss parts of the prototype as being "unfinished" and safe to ignore. In our study, familiarity with the requirements elicitation process, and with encountering bugs, helped in this situation. For example, the third time a bug was encountered, the boys stayed calm, well aware that the bug could be fixed.

Be prepared to work around technical difficulties through alternate approaches, such as paper prototyping or reflective discussions. Despite the advantages found in familiarity, we cannot recommend relying on multiple bugs in your program.

Eliciting Direct User Input to Guide Development

Seeking direct user input through discussion is useful, but also has limitations. During paper prototyping, we found that participants were good at describing concrete ideas, such as particular items that should be included, but struggled to apply real world knowledge ("going down the stairs to reach the kitchen" when navigating in-game) to the game world. This is perhaps to be expected, as children do not bring design experience to such sessions, but their real-world expertise of "being children" (Druin, 2002; Large & Nesset, 2009, p. 387).

Attempt to phrase questions so they make "in-game" sense to the children. Further research should examine ways of phrasing questions and helping children to make the connection between their experiences and the prototypes being discussed.

Participants Who Weren't "In the Mood"

A number of times during prototyping sessions, Roger or Richard would not be in the mood for testing the prototype. This presented as hyperactivity, singing, boisterousness, and being easily distracted.

Be aware that, particularly when dealing with young children, not every child will be in the mood for testing during every session booked. Alternate activities, such as brainstorming, may be appropriate in such situations. Patience is also vitally important in such situations.

Shy Participants

Richard remained shy during testing sessions for much longer than Roger. This can have negative effects, as more outgoing participants may dominate the sessions and the data collected. The unintentional solo session with Richard, when Roger was sick, seemed to help build his trust in the researcher.

When a child participant is shy and quiet, attempt to establish a one-on-one rapport before and during sessions. Further research should be conducted to identify the best ways to build such rapport.

Scope Creep

Seeing part of a prototype can inspire participants to request further changes, particularly if they become more comfortable with the process and are enthusiastic about participating. These suggestions can be elicited from a prototype with even minimal functionality and may be unexpected. Participant suggestions can be helpful, but it can also lead to scope creep as requests get grander. Our children's requests towards the end of the sessions would have required an entire virtual world to be built to encompass all of the signs they were suggesting. This problem is not confined to designing with and for children and has been recognized in ISO/IEC/IEEE 29148:2011.

Rely on your professional discretion to evaluate what is useful for the current project and what is out of scope.

Conflicting Participant Responses

Conflicting responses from participants, such as Richard and Roger disagreeing over whether the prototype should have music, should be investigated further.

If time and resources permit, create prototypes that allow children to explore a range of options, such as allowing them to see the rooms with or without music, in order to clarify conflicting responses.

Conclusion

In this paper we have described our experience conducting collaborative prototype sessions with young Deaf children. This research has shown that designing with young Deaf children as informants can be a rewarding and fruitful experience. Requirements elicitors and designers will need to adapt their requirements elicitation process to accommodate the needs and abilities of these children. The recommendations provided in this paper address particular issues encountered in our research and provide a base for elicitors and designers considering working with children, young children, and Deaf children as informants.

Our key recommendations relate to dealing with children and to specific considerations for Deaf children. In summary, make allowances for participants' familiarity with technology and for the nature of the technology itself. Be aware of how enthusiastic, confident, or shy child participants may be. Minimize any nervousness they may feel by working in pairs, also by working in groups they can assist each other; however, be aware of the strength of each personality in the group. When working with young Deaf children, an awareness of the physical environment is critical, and attention to communication channels is vital. With consideration to the needs of the children, a positive collaborative experience can be achieved.

In addition, this research forms a basis for ongoing research that is exploring how young Deaf children can be involved in the design process at a greater level of involvement. Druin and her colleagues have promoted increasing children's involvement in the design process (Guha et al., 2013) so that designs truly reflect children's needs and expectations. This is particularly important for groups such as Deaf children, for whom an adult representative would traditionally be asked to provide proxy information (Guha et al., 2008). The next stage of our project is exploring the development of a design method specific to the needs of young Deaf children.

The results of this future research will be compared with the findings presented in this paper to identify if working with different groups of children, with different characteristics, generates any different recommendations for working with young Deaf children.

Tips for Usability Practitioners

The following tips should aid requirements elicitors and designers working with young Deaf children as informants to obtain useful information for the creation of their products. Many of these tips could also be applied to design work with other groups.

- Minimize potential distractions: Hide or lock programs that are not being tested and choose physical locations for testing that are low in visual distractions. Don't make unnecessary visual changes, as these will distract your informants.
- Gently prompt informants to share their thoughts when required. Informants who are familiar and comfortable with the requirements elicitation process will give more and higher quality feedback. Prepare simple alternative activities, such as low-tech prototyping or reflective discussions, in case of technical difficulties or unfocused informants.

- Have informants work in pairs or small groups to prompt more natural commentary, as they will discuss the prototype amongst themselves. This will also assist to ease nervousness and encourage collaboration. When working with pairs or groups, circumvent arguments by encouraging informants to formalize their own control roster. Use the prototypes to explore different options if your informants are unsure or have conflicting opinions.
- Support as many different channels of communication as possible. Examples include speech, signing, writing, drawing, and other artistic activities.
- Always be patient.

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About the Authors

Jessica Korte
Ms. Korte is a PhD candidate at Griffith University. She has been involved in the Seek and Sign project from the start. Her Honors and PhD research examine how to involve Deaf children in the creation of technologies they and their families will use. She speaks English and some Auslan.

Leigh Ellen Potter
Dr. Potter co-founded the Seek and Sign project in 2011 to explore the use of technology to support young hearing impaired children to learn Australian Sign Language (Auslan). Other interests include improving user experiences, improving relationships between IT professionals and users, and attracting people to the IT industry.

Sue Nielsen
Dr. Nielsen co-founded the Seek and Sign project in 2011 with the aim of improving the communication environment of very young deaf children through the innovative use of information technologies. She has degrees in linguistics, communication, library science and information systems. She has supervised more than thirty post-graduate students.