Head Mounted Displays and Deaf Children: Facilitating Sign Language in Challenging Learning Environments

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ABSTRACT

Head-mounted displays (HMDs) are evaluated as a tool to facilitate student-teacher interaction in sign language. Deaf or hard-of-hearing children who communicate in sign language receive all instruction visually. In normal deaf educational settings the child must split visual attention between signed narration and visual aids. Settings in which visual aids are distributed over a large visual area are particularly difficult. Sign language displayed in HMDs may allow a deaf child to keep the signed narration in sight, even when not looking directly at the person signing. Children from the community who communicate primarily in American Sign Language (ASL) participated in two phases of a study designed to evaluate the comfort and utility of viewing ASL in an HMD.

Categories and Subject Descriptors

H.5.2 [Information Interfaces and Presentation]: User Interfaces; H.1.2 [Information Systems]: User/Machine Systems

1. INTRODUCTION

Spoken and signed languages are each difficult to use in certain environments. For example, spoken languages are difficult to use in noisy environments, but headphones with speakers and directional microphones allow people to communicate more easily. Signed languages are visual rather than auditory, and they are difficult to use in a different set of environments than spoken languages. However, as with spoken languages, technology can facilitate communication in these settings.

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There is much we do not know about how deaf and hard of hearing children learn and there is even less we know about how deaf children experience sign language in HMDs. The driving principle behind our work is to deliver instruction in sign language rather than in written captions. This is particularly important for young children who are learning sign language as their first language.

Compared to spoken language acquisition by children who hear, a child who is deaf or hard-of-hearing often experiences significant acquisition delays with their first language [5]. It is estimated that 95% of school-age deaf and hard of hearing children are born to hearing parents [6]. These children often do not begin learning sign language until entering school and may only receive fluent language input during school hours. Improved sign language learning may lead to increased learning in a second language such as English. Research shows “that children who learn through their first (minority) language for as long as possible not only tend to have improved final achievement, but also their English language skills tend to develop to a higher level than those who were taught through their second language with some first language support” [4].

In this paper we explore the configuration of and potential benefits of head-mounted displays for education done in sign language in difficult environments. Difficulties arise when students cannot see or are not looking directly at the signer. Our purpose is to evaluate the comfort and utility of viewing sign language in an HMD as perceived by a child who communicates primarily in sign language through the use of ASL video presented through an HMD. This may enable both teachers and deaf children to interact in new ways by allowing students to view instruction wherever they may look.

2. RELATED WORK

Methods have been developed for delivering written English captions to deaf or hard-of-hearing students in the classroom (such as C-Print [8]). While these methods are effective for children with strong English (or any other written language) reading skills, they are not effective for children with poor reading skills. Over 30 years of educational test-
ing in the United States, the average reading level is below the fourth grade level (which included children ages 9-10 in the United States). It included hearing children in grades K through 12. The fourth grade level is normalized against the reading level of their hearing peers. [7].

Several groups have explored methods for delivering captions in a planetarium setting. A planetarium is a particularly difficult environment to present ASL. One of the early, well-documented efforts is reported by DeGraff and Hamil [2]. DeGraff and Hamil used a slide projector to project captions near the horizon of the planetarium dome. Daniel [1] details a slightly different way of using captions in a live show. The words are either projected near the object of interest on the dome or a green arrow directs student’s eyes to the relevant area of the dome.

In Grice [3] we find the beginnings of a more modern approach to captioning systems. This is a major move into devices for planetariums and theaters. The first device they tested were Virtual Vision glasses that showed captions over the right eye in a small screen. Grice reported that most people put these away after a few minutes and experienced a “dizzying effect.” Grice experimented with an LED display system that was mounted behind the audience. This system would display the captions in reversed text. For the demo, Plexiglas was mounted on specific seats that would then reflect the captions back to the viewer correctly. Finally, Grice tested a Vacuum Fluorescent Display (VFD). This is a box that attached to a seat in front of the individual and had captions run across the screen. The planetarium installed four VFD captioning systems that could each support three people.

It was apparent during our review that very little work has been done using HMDs in Deaf education. Most work focused on using captions to address the issue of relaying information to deaf participants. However, this approach does not cater to younger deaf children as their reading skills have not fully developed.

3. METHODS AND RESULTS

We conducted a two-phase evaluation of comfort and utility for HMDs used to convey ASL to children in logistically challenging informal education environments. A total of 18 deaf or hard-of-hearing students who communicate primarily in sign language participated in this portion of the study. In the first phase, 8 participants provided subjective feedback after watching a short astronomy-based video on a screen with ASL narration viewed through an HMD. We provided software for repositioning the ASL video in the display and recorded changes made by each subject. In the second phase, 10 participants watched a 20-minute planetarium show with the narration provided in ASL. Five watched the narration projected directly onto the planetarium dome and 5 watched the narration in an HMD.

Test subjects were drawn from a local deaf school and a summer university program for high school students. In each case we limit the study to children who are deaf or hard-of-hearing and who communicate primarily in ASL. All of the participants were between 13-18 years of age.

Because the participants in this study communicate in ASL, care was taken to minimize linguistic barriers. Interactions with the participants were direct ASL-to-ASL communications without any intervening interpreter. Deaf and hard-of-hearing individuals who use ASL as their native language but who are not part of the investigation team were recruited to interact with and interview participants in order to avoid bias.

A video record was kept for all interactions with the subjects. Cameras were positioned to allow us to view sign language used by both the interviewers and the participants during interviews and focus groups. Cameras were also used to record interactions between the subject and the HMD hardware. The videos were later translated into English and coded both for verbal content and subject actions by both ASL-speaking and English-speaking investigators.

In each evaluation the subject could adjust the size, position, and brightness of the ASL signer video. Initially, participants adjusted the video using a laptop keyboard, but this required looking at the keyboard, which proved distracting while trying to watch ASL and a video at the same time. We later modified the system to use a video game controller rather than the laptop keyboard to collect the positioning data. All adjustments were logged for later analysis.

3.1 Displays

The three displays used in our evaluations are shown for comparison in Figure 1. We used only monocular displays to maximize the amount of light reaching the eye and because adding stereoscopic 3D to the display does not necessarily improve comprehension when viewing sign language. The display on the left of Figure 1 is a fully occlusive Virtual Realities VR1. The center display is a Vusix Tac-eye partially occlusive display. The display on the right is a Laster PMD-G2 see-through display with a half-silvered mirror that blocks some incoming light. Table 1 contains the diagonal viewing angle, resolution, color depth, and weight for each display. Viewing sign language at a resolution of 800x600 is not likely to negatively impact comprehension. Weaver et al.’s study [9] of ASL comprehension and video resolution found that novice signers could observe and reproduce specific signs with equal success when learning those signs from video rendered at 640x480, 320x240, or 160x120 on a mobile phone screen.
All three displays listed in Table 1 were too large, bulky, and heavy for use by children. The Laster offered the largest viewing angle but had a small eye box. The eye box is the volume of space in which the display is correctly aligned with the eye to allow viewing of the full image. A few participants spent quite a bit of time adjusting the display to make sure that the full field of view was visible.

### 3.2 Evaluation

The first phase of evaluation was conducted using video shown on a flat screen in a room. Four female and four male participants, ages 13 through 18 were recruited from a university summer camp for youth who are deaf. Each of the subjects watched a five-minute video while the narration in ASL was delivered through an HMD (Figure 2).

The individual subjects were interviewed about their experience. Eight children from the first phase were brought together into two mixed-gender groups of four to participate in a focus group. In both the individual and the focus group interviews participants were asked to discuss their opinions both of the concept and its execution. We encouraged them to tell us when, where, and how they thought an HMD could be used. We also asked about issues of design and comfort.

We coded both the transcripts and the video recordings of the interviews and the focus groups. Open coding of the transcripts allows us to identify themes from intentionally open-ended questions. We defined codes for the video recordings that related to comfort and utility. Video recordings of interviews and focus group discussions were translated from ASL to English by a deaf interpreter. All transcripts and video recordings were coded by three members of the research team.

The second phase was conducted in the planetarium so we could spread visual information over an entire viewable hemisphere in a controlled environment. Ten participants ages 13-15 were recruited from a local school for the Deaf. Spreading visual information out over the entire planetarium dome creates a logistically challenging environment for ASL instruction. The duration of the planetarium show allowed us to observe the use of the displays for comfort and utility over a longer period of time. In this phase we showed a video called “New Horizons” which was produced specifically for projection onto the dome of a planetarium. We obtained the English transcript of the narration for the show and asked a Certified Deaf Interpreter (CDI) to translate the narration into ASL.

#### 3.2.1 Themes from First Evaluation

The primary codes found among all participants are split focus, fit and position, signer position, occlusion, and attention. Among all groups, position and fit was the most common theme with split focus as the second most common. The position and fit theme includes comments related to the position and fit of the HMD itself on the participants’ head or face. The split focus theme contains comments related to splitting visual focus between the signer in the HMD and the external world. Each theme is addressed below.

**Signer Position.** We provided two ways for subjects to change the position of the signer. Subjects could move the signer in the display and subjects could move the display itself. The majority of the participants had the HMD positioned on the top-right of the right lens of the glasses with one exception: One participant being left-eye dominant preferred the top to middle-left of the left lens.

Once the HMD was properly positioned on the glasses, subjects exhibited a slight preference to moving the sign language presenter down and toward to the center of the subjects’ field of view. This preference was evident in both the subjects’ comments and in the positioning log. Some subjects turned or tilted their heads in order to place the signer at the center of their field of view. Subjects may have turned their heads to reposition the signer because they did not know how to adjust either the HMD itself or the position of the signer in the video.

**Split attention.** Subjects talked about the challenge of splitting their visual focus between the signer in the HMD and either the video or the people around them. All of the subjects mentioned splitting visual focus between the signer and the screen. Two made positive comments which are given in the subsequent section. Comments from the other six, three male and three female, indicated difficulties focusing on both the interpreter in the HMD and the movie projected onto the screen. A male subject reported, “I feel like it is separate, and it is jarring to look back and forth.”

In contrast, two female participants stated that they liked being able to see both the signer and the visual presentation at the same time. One said, “I liked the HMD; it was good. I liked being able to see the screen and the interpreter to see the speech and the sign interpreter on the screens. I liked that. It was neat.”

**HMD Fit.** Subjects described discomfort related to the fit of the HMD. These issues are concerned primarily with occlusion and with issues related to weight and balance. The Vuzix Tac-eye is designed for military and tactical use where ruggedness and durability are more important than weight.

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Figure 2: Example of what was seen in an HMD by a participant. A) Shows the ASL interpreter in the HMD view. B) Scene from the video watched on a screen. C) Illustration of a child wearing an HMD.
Table 2: Recorded final adjustment of signer position in an HMD.

<table>
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<th>Subject</th>
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<th>Vertical</th>
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and balance. Adding some weight to the frame of the glasses may have corrected the balance problem but would have added more weight to the HMD unit. In a comment typical of others, a female subject said, “It felt uneven having to compensate for my head being pulled to the side.”

We observed some participants, that used the Laster display, continued to make adjustments with their hands to steady the display in proper viewing position. This may be due to the small eye box found on the Laster display.

3.2.2 Adjustments of Signer Position

Subjects could use software controls to reposition and resize video of the ASL signer. All adjustments were recorded for later analysis and a summary of repositioning data is shown in Table 2. The data suggests a bias toward viewing the signer in the center of the field of view. In the table, negative numbers represent movement to the viewers’ left and positive numbers represent movement to the viewers’ right. For example, movement in the negative direction by a subject viewing ASL with the right eye indicates movement toward the center of the subject’s field of view. Adjustments by subjects 1, 2, 7, 8 and 9 moved the signer toward the center of the field of view while adjustments by subject 3 moved the signer away from the center. Vertical adjustments were less common. The data in Table 2 only includes changes made in software. Subjects also repositioned the signer in their field of view by tilting their heads and physically moving the display on their face.

4. CONCLUSIONS

We identified two sources of discomfort in using HMDs to view ASL by children who are deaf or hard-of-hearing and who communicate primarily in ASL. First, the displays we used were too large and bulky for children to use effectively. Second, participants struggled to split their attention between the signer in the HMD and the external world. This may be due to the design of HMDs tested, their utility, and the novelty of the device. In addition to these limiting factors, finding the appropriate number of deaf children from our community was an issue. Future recruitment from other Deaf communities outside our area will be necessary to broaden the pool of potential participants.

We consistently found a slight preference to position the signer in the center of the field of view but this was not a universal preference. This was demonstrated both in the ASL position data and the physical adjustment of the HMD on the participants head. Placing the signer in the center of the field of view may allow the subject to switch between visual inputs with minimal eye movement thereby minimizing the effort and latency involved with shifting visual attention between the signer and what is being presented in the environment.

Based on the feedback we received and from our observations, a smaller and lighter HMD designed for the geometry of a child’s head should be developed. In addition, the use of participatory design will be paramount to maximize the potential of a child specific HMD design. The outlook for the successful use of HMDs for deaf children in educational settings is promising and should be explored.

5. REFERENCES