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Improving the Learning Experience for the Deaf through Augment Reality Innovations

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Abstract

One challenge facing the deaf is the need to divide their attention between subject matter and sign language interpreters. Sign language interpreters provide a visual interpretation of speech. However, the observation of an interpreter distracts an individual from other visual stimuli such as a presentation, demonstration or video.
This paper proposes an augmented reality, head-mounted display system designed to improve the learning experience for the deaf, specifically a child's experience in a planetarium. The system uses augmented reality to enable a sign language interpreter to remain within the wearer's vision. This improves on subtitle-based alternatives by removing literacy as a requirement. The project is part of a three-year development calibration between three Brigham Young University departments and Gallaudet University, with funding from the National Science Foundation. This paper focuses on the design, prototyping and proposed usability testing performed by a team of six IT students for a senior capstone project.

Keywords

Augmented reality deaf, headset display, senior capstone, student project

1 Introduction

For a deaf child, a planetarium experience is different from that of a child with normal hearing. In the case of the deaf child, their attention is split between a sign language interpreter and the material being presented. Focusing on an interpreter can cause important visual media such as constellations, to be missed. Currently, the solution in place at the Brigham Young University planetarium is to repeatedly pause the show for interpretation. This process of interruption-for-interpretation continues for the duration of the show and often results in an overall degraded experience regardless of whether or not the participant is benefiting from the interpretation [Schick, Williams, Kupermintz 2005]. This can create a challenging environment for learning.

A potential solution for the split attention problem was proposed by Dr. Michael Jones and Dr. Jeanette Lawyer of the Computer Science and Physics & Astronomy departments. Their idea is directly targeted to deaf users in a planetarium show and is based on using augmented reality headsets to permanently display a sign language interpreter in the field of view. After securing research funding from the National Science Foundation, Dr. Jones and Dr. Lawler broke the project into three stages to be carried out over three years. The first of these, to develop a system prototype for usability testing, was completed by a team of six IT students as their final year capstone project and is the focus of this paper. This prototype represents a joint venture between the information technology, computer science and nursing departments within Brigham Young University and influenced by research into classroom designs at Gallaudet University.

1.1 Prototype

The proposed system consists of three parts:

- Filming of the interpreter in front of a green screen.
- A server to communicate the interpreter video to the headset.
- A user interface for testing headset projection manipulation and optimization.

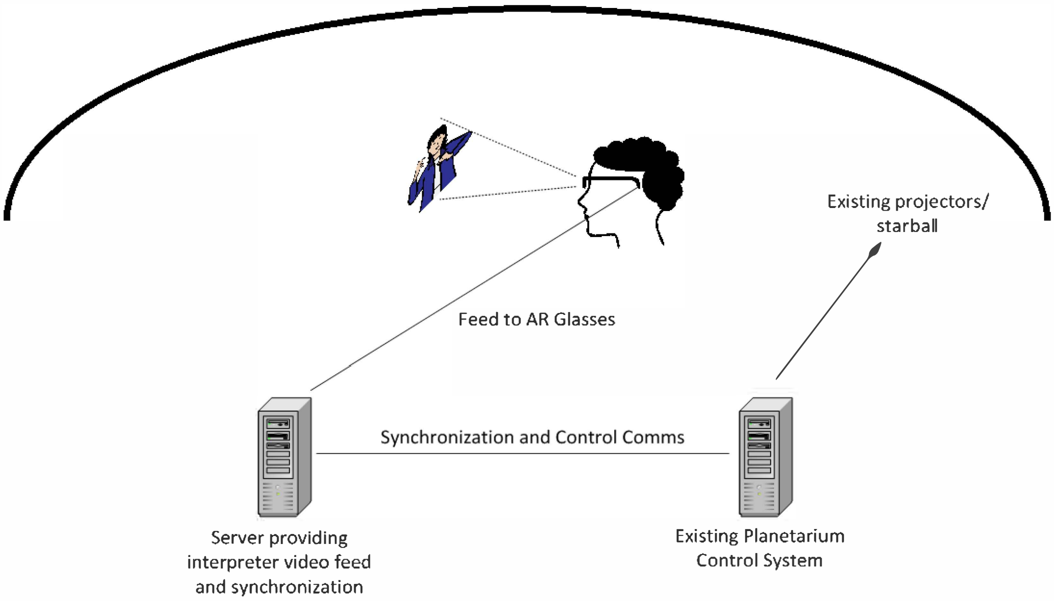

Figure 1: Prototype System Design

The prototype will not be implemented in the planetarium but in a laboratory for user testing. The videos filmed of the interpreter will be saved and stored on a server (Figure 2). The interpretation will then be streamed to the connected headsets. The users will simultaneously view the interpreter in the headset along with a coordinated video displayed on a monitor. The monitor will also display controls for video manipulation. The testing will reveal common video settings to implement in the existing planetarium system.

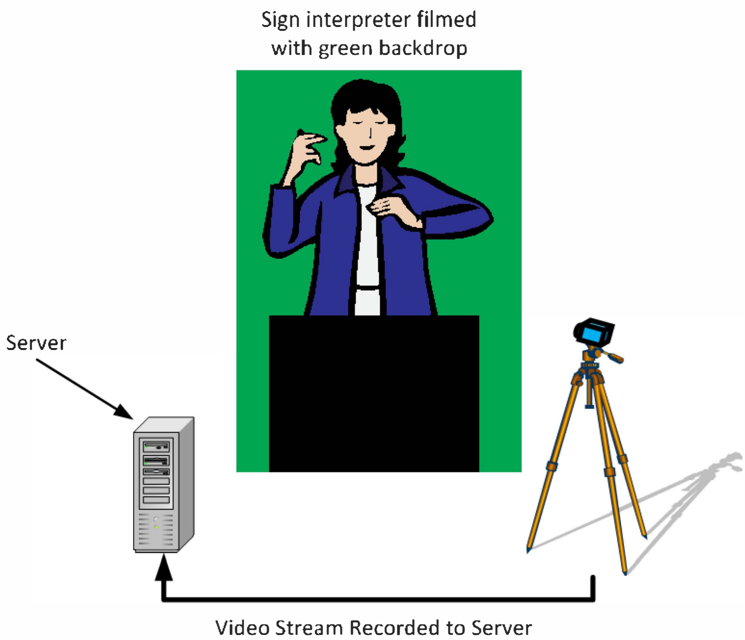

Figure 2: Interpreter Pre-Recording

The development of this solution could lead to changes in a variety of forums such as classrooms, theatres and museums. All of these scenarios can be problematic due to the split attention issues already discussed. For example, a child in a museum might find their experience greatly enhanced by an augmented reality solution [Azuma 1997]. Due to timing and budget restrictions, the proposal in this paper is based on a commercial-off-the-shelf head-mounted display. This could introduce a market for lightweight, ruggedized, mobile displays that have wireless streaming capabilities and long battery life.

1.2 Project Timeline

This paper discusses the capstone team's development role in a three-year collaborative project to improve the planetarium's environment for the deaf. Figure 3 displays the timespan for the entire project. In the first year, a prototype design will be created. This constitutes the capstone project. By the second year, usability testing will be performed. The system will then be implemented in the BYU planetarium during the final year.

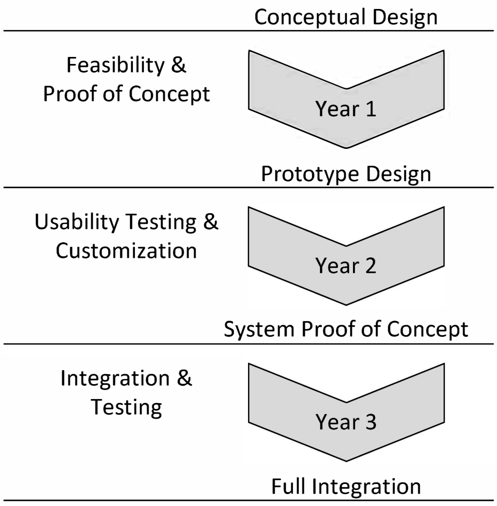

Figure 3: Three-Year Schedule

2 Existing Technologies

There are multiple systems and approaches that are designed to assist the deaf. In most settings, an interpreter is used to relay information. Interpreters are portable and require no technical expertise or infrastructure. A downside, the need to visually focus on an interpreter can cause the user to miss other visual material or cues. One must choose to watch the interpreter or the presentation; they cannot simultaneously view both [Schick, Williams, Kupermintz 2005]. This is exacerbated in a planetarium setting where the audience must frequently turn their head to view the full presentation.

Subtitles and closed captioning can be included in a production to allow the viewer to read the transcript. This is ideal for a home setting where the primary user may be deaf. In public settings the equipment owner must make subtitles visible for all users, or provide a rear mounted captioning device [Navoy, Field, Botkin 1999]. Light is emitted from this monitor, which may still affect the viewing experience for the participant and surrounding audiences. Users may also incur split focus issues by changing perspective between observing the monitor and the film. This solution may be impractical for young children due to the literacy requirements imposed.

Sony is currently developing augmented reality headsets to project subtitles directly to the wearer in movie theatres. This will improve upon close captioning by converting the monitor display into a portable headset display. Distraction due to light noise (in rear-mounted captioning devices) most likely will decrease. This prototype is planned to be available in selective theatres by 2012 [Satchell 2011].

The premise for the suggested project is based off of these closed captioning technologies; however, subtitles require some level of literacy proficiency. Most deaf children in the target range lack the skills and speed required to comprehend the performance concurrently. Also Sony's scope is presently limited to cinemas; it does not benefit the classroom or educational settings. This project is based on, and will hopefully prove the hypothesis that an interpreter projection will be able to convey messages better than subtitles for these types of users.

3 Methodology

3.1 Program Overview

Students in the BYU Information Technology bachelors program are required to undertake a two-semester project. External clients including other University departments, industries and other groups sponsor projects. Sponsors submit a one-page project synopsis to the program faculty for review. Each project is reviewed for feasibility, innovative potential, suitability, learning experience and the supportive capabilities of the client. Selections of suitable proposals are then presented for 15 minutes to the students in class. Students submit their top three preferences and course instructors meet to discuss team assignments. Teams are organized with each team consisting of 4 - 6 students and a faculty coach.

The classroom experience is designed to support the capstone projects by teaching students various project management skills [IT446 Syllabus]. Early classes focus on project organization and selection of a development model. Each team is encouraged to choose between waterfall, spiral, iterative, agile extreme and agile scrum models and to be able to rationalize this choice. Students also learn the Tuckman Model for forming effective teamwork skills [Tuckman 1965]. In the first team meeting, students must elect a project manager and team lead, establish contact with the sponsor (hereafter referred to as the customer), arrange regular meeting times and begin to assess the project scope. The team lead is responsible for dividing out the workload among members and handling the day-to-day operations. The project manager is responsible for communicating with the client and ensuring the project milestones remain on target.

Working with the customer to define a constraints matrix along with building a Pert/Gantt chart is key in the early stages of project development [Clark, Polakov, Trabold 1922]. The constraints matrix prioritizes schedule, resources and scope in the context of quality and allows the team to review their organization, resource allocation and deliverables should the projects critical path be in jeopardy. Students are taught to use Microsoft Project to manage their projects and monitor their critical path. Part of this process includes producing a list of deliverables including hardware, software, documentation, test results and training. These deliverables are provided to the customer on completion and help ensure the usability and continual development of the provided solution.

Throughout the experience, students produce a product that leverages technology to support the customer's organizational goals. Teams are exposed to a variety of project threats and must analyze these in order to determine and assess risks. They must also produce formal test plans that will determine whether or not their project deliverables meet customer requirements and expectations. Their progress is reviewed with their faculty coach on a weekly basis and presented to the programs industry advisory board (IAB) for a more formal review in the middle and conclusion of the project time frame. The IAB consists of senior project and engineering managers who volunteer for a period of three years. As part of their responsibilities they help review performance and identify issues in capstone projects. In addition to their presentations, teams must furnish a written technical report at the end of each semester.

In addition to these requirements, students learn a variety of other project, design and entrepreneurial skills throughout the two semesters. Topics include intellectual property, problem analysis, solution synthesis, managing change and communications skills [IT446/IT447 Learning Outcomes]. To be successful, teams should display creativity in understanding the client's problem and successfully apply technical concepts to provide a solution. They should be effective in managing change, communications and working together in project development. The primary objective is to allow students to put their technical skills and knowledge to use in as real an environment as possible.

Typically the team meets several times per week for different purposes. In group meetings, the team discusses challenges and tries to find solutions for current issues. Coach meetings allow the team to meet with IT faculty for professional guidance and suggestions. This is also an atmosphere that encourages constructive criticism and out-the-box thinking to resolve outstanding issues. Bi-weekly, a customer meeting is held to communicate progress and ensure the team is meeting the client's expectations.

3.2 Project Approach

Although clear documentation and communications are always desirable, they are even more critical in this instance. The overall concept of leveraging augmented reality displays, as a learning aid for the deaf is part of a much larger undertaking that is supported by the National Science Foundation (NSF) for the next three years. In contrast to this, the capstone project began in October 2011 and will complete in April 2012. At this point, team members will likely graduate and cease working on the project. The team must hence ensure that their documentation, code and designs are clear and concise to enable the various departments at BYU and Gallaudet University to continue development in their absence.

The team and customer determined that they were most constrained by schedule as stipulated by the course requirements. Resources are the next most concrete and come primarily from an allocation of NSF funding. Due to the ongoing research, scope is the most flexible. If the proposed scope can be completed ahead of schedule, then the team's role can continue into further project refinement. If the project goals cannot be met, then the team can meet with the customer to re-evaluate the project deliverables to ensure that future groups can continue the research. The scope agreed upon by the customer follows:

- Create a development environment.
- Build a working prototype.
- Setup a usability testing environment.

After developing more specific requirements, it was quickly realized that an iterative development approach would be beneficial to the project [Kruchten 2000]. This would allow development to begin quickly even without various hardware such as the AR glasses. Figure 4 displays a simplified task extract from the Gantt chart. The team developed different parts of the prototype concurrently. The user interface was designed at the same time as control functionality and the logging script were in development. Customer requests were address as the different parts began to integrate with the user interface.

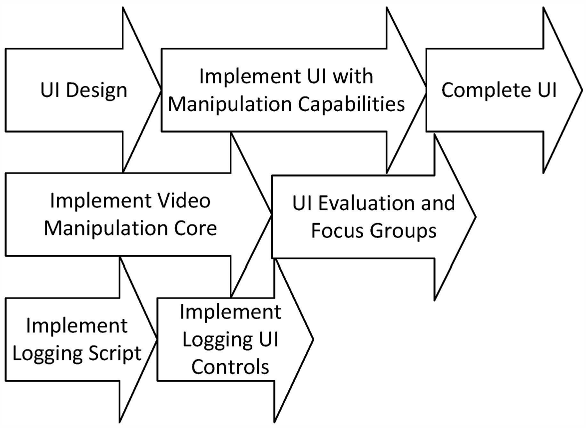

Figure 4: Concurrent Design (Simplified Gantt Chart)

Preliminary requirements were drawn up for each deliverable which allowed team members to begin developing components and working towards integration at a later date. As components reached a point of maturity the team reviewed them and the next phase of development was planned. This led to a natural cycle of continual improvement and promoted a 'try it' approach to problem solving.

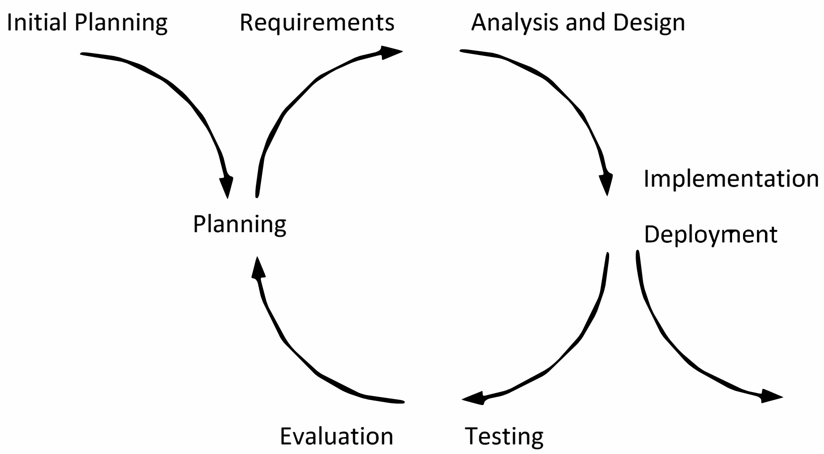

Figure 5: Iterative Design Cycle

The following sections discuss each deliverable and requirements.

Development Environment

The objective of the development environment is to facilitate the prototyping and testing of the system. The environment must allow transparency, brightness, size and position video manipulation. The development environment includes the platform, application framework, user interface and tracking log to provide and analyze this functionality to a usability tester.

The platform was specified by the customer to be Microsoft Windows 7. The Windows platform is familiar to a large user base and has many libraries and projects for manipulating graphics and video. The application development framework is based on Microsoft Visual Studio, which allows a variety of languages and libraries to be used. Several API's were evaluated to find a best fit based on capabilities and familiarity to the team. The choice of API's were constrained by the operating system, application development framework and by the requirement to allow video manipulation in real time providing the subject-under-test with immediate visual feedback. The API's reviewed included MMF, OpenGL, Allegro, OpenMax and OpenML. While all of these met project requirements, the team selected Microsoft Media Foundation (MMF). The reasons for choosing this platform are as follows [MSDN]:

- Branch of DirectX with all the features of DirectShow.
- Active development with new functionality, bug fixes and support.
- Simple platform dedicated to 2D graphics that can achieve all desired manipulations. Other libraries support 3D but this is superfluous to the requirements.
- Compatible with the operating system chosen for the server.
- Free to use for development and distribution.
- Comes with several sample projects including MFPlayer, which has several of the required features for the project. This application source code can be modified in addition to a creating new interface to meet all specifications.

On top of video manipulation capabilities, the application must synchronously control the interpreter and educational video feeds. When the user pauses or rewinds the educational video, the interpreter must also pause or rewind. The enhanced MFPlayer controls can link to both videos but in order for them to be in sync, both videos must be the same length. The customer accepted this requirement.

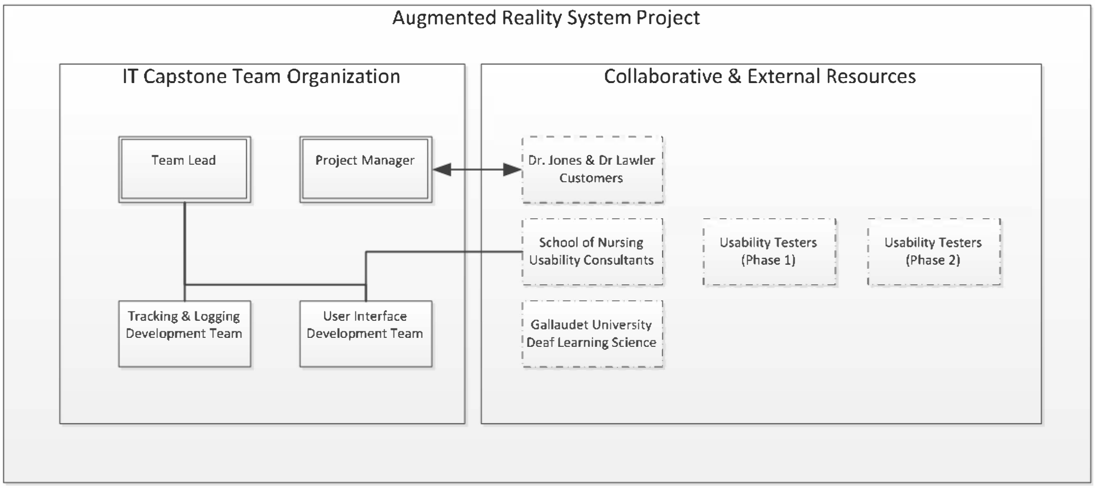

Figure 5: Team Organization and Collaborators

The team divided into two separate groups seen in Figure 6 to develop the logging functionality and UI design development in parallel. Rapid prototyping and weekly meetings helped to ensure the component interfaces remained compatible. While the objectives and scope were clearly defined, this iterative approach allowed the team to gain early customer feedback and testing results.

The UI group was required to use the API to create user interfaces for the subject-under-test and test controller. They are also responsible for assuring the interpreter and presentations are in sync. The logging functionality records video manipulations during a test. This log will be used to assess common user settings and viewing preferences in order to determine the optimum settings and placement. It should be noted that the ability to manipulate the video during a performance is not a requirement of the final system as its sole purpose is to help determine optimum image placement and settings.

System Prototype

Building a prototype suitable for usability testing also involves selecting hardware that is suitable for the target audience. This led to a discussion of what features or characteristics would be needed in an augmented reality display. The team and customer agreed that the headset should be durable, lightweight, provide an image in at least one eye and have a resolution and focal length capable of displaying an interpreter's expressions without causing eyestrain. While some of these features can easily be determined from the product specification, the team decided that more accurate results could be obtained by discussing their requirements directly with deaf users. Potential issues that the team hopes to determine include irritation from the headset resting on the hearing aid, weight/fitting problems, eyestrain and even aesthetics. (For example: some young children are averse to wearing eyeglasses for fear of being teased by their peers. The aesthetics of a solution should be considered to some extent).

The following headsets' features were reviewed to find the most suitable hardware for the prototype system.

Augmented Reality Sets		
Brother Airscouter	Liteye	VRealities VR-1
Intevac I-Port EX3	Lumus Video Eyglasses	VRealities Z800 Pro AR
I-Port Universal	Vrealities I-Port	Vuzix Tac-Eye LT
Laster Pro Mobile Display	VRealities VR Pro WUXGA	Vuzix Wrap 920AR
Laster SmartVision		

Table 1: Reviewed Headset Models

From these, Vuzix Tac-Eye LT headset display was selected. This display met all the project requirements for the prototype design set by the capstone team [Vuzix]. In particular the following was particularly beneficial:

- It is of military grade durability, this headset is more likely to be able to withstand heavy child use than other models.
- The display is lightweight, around 150g, and should be comfortable for smaller users.
- It can attach to prescription or non-prescription lenses to create an augmented reality allowing any user to wear the headset display and clearing see.
- The cost, $3,500, was within the project budget.

Unfortunately, despite ordering the Vuzix Tac-Eye LT in October of 2011, the glasses are on back order until March 2012. The headsets are a critical element to the project. In order to compensate for this setback, a second headset had been ordered to continue building a proof-of-concept model. After contacting numerous manufacturers to request shipping times, the VRealities VR-1 was ordered. Fortunately this arrived within a week. As a final fallback, the team was prepared to develop the development environment and server with use of a second monitor to display the interpreter as substitute for the headset. This would delay usability testing. The VRealities VR-1 headset display was not the original model selected for the project but it still meets the required specifications [Virtual Reality].

- Durable for child use.
- Built with a headband instead of normal glasses to support the monitor, does not cause issue with a hearing aid.
- The display is around 85g, it is light and should be comfortable for a smaller user.
- The headset allows room underneath the monocle for prescription glasses if required by the user.
- The cost, $1,699, was within the project budget.

Development is currently continuing using this headset. It should be noted that this headset is much larger and more visible than the Intervac solution.

Usability Testing Environment

BYU's College of Nursing was contacted to help better understand user needs and ideally find deaf users for feedback. Dr. Kent Blad and Dr. Sabrina Jarvis were able to provide insight from their own experiences into what issues to look into while performing user testing. Dr. Blad provided contact to a family with two deaf teenagers, 13 and 17 years old for prototype feedback. This opportunity allowed the student team to gain feedback from potential users towards the prototype design.

The usability testing environment will be built to allow users to choose their own settings for the display. The testing will consist of a lab computer exhibiting controls for the interpreter display along with an education film. The user will be able to wear the headset display and view an interpretation of the educational video. Any changes they make to the interpreter picture will be recorded. These logs will then be reviewed to find the most popular settings that can then be used in the planetarium. It is also very important to consider how effective the prototype was to the user's learning. Following the test, the user will provide feedback for their actions taken during the experience.

4 Prototype Design

There have been challenges in developing a prototype without knowing the user. To compensate for this, the team has created personas, sought information from Gallaudet and put together focus groups to gain better feedback from the user. The initial user focus group provided positive feedback on the design. The attendees consisted of a family with two deaf, teenage boys and their parents along with a local signer. Both children from the family have cochlear implants. Even though these children are technically not in the project's targeted user group, they still provided new input beneficial to development. The purpose of this focus group was to become more informed about the learning environment of a deaf child and to test the headset displays with the user for compatibility.

It was discovered, that even with the cochlear implants, the users still tend to loose information conveyed. They discussed how it was difficult to attend cinema functions because often times they would miss hearing a key concept and be left confused for the continuing duration of the film. The two teenagers both preferred waiting to rent a movie, to watch at home with subtitles. The existing technologies to improve the viewing experience for the deaf in place at theatres are limited to locations and are often not commonly available for films that the boys are interested in seeing.

The users were presented with a mock-up model of the expected Vuzix Tac-Eye LT and the actual received VRealities VR-1 headsets (Figure 7). The users indicated that the Vuzix Tac-Eye LT model was easier to put on and adjust. However, having an actual, working headset provided an idea of the focal lengths and if they would provide an issue. The elder son commented that he could focus on both an interpreter video and an instructor at the same time. Other important findings were:

- The smaller Vuzix Tac-Eye LT was preferred for aesthetic reasons.
- Both children said there was no interference with their hearing aids
- Both agreed that instead of an interpreter, they would prefer subtitles.

Figure 6: Vuzix Tac-Eye LT, VRealities VR-1 and Tac-Eye LT Mock-up for focus group testing

The latter proposes a change in the prototype design to not only project an interpreter but to provide the option for subtitles depending on the audiences preference. It is still believed that a younger audience without an implant, would prefer an interpreter. With the looks of both headsets currently, the elder child was not enthusiastic about drawing attention to himself by wearing a pair in a public setting. However, the project is looking towards obtaining funding towards purchasing more discrete headsets. Overall, the focus group was successful and helped the team develop a better understanding of the user.

Another challenge has been learning the API and building a user interface. The team had little experience with the MMF API and needed to quickly learn the environment in order to produce a prototype meeting customer requirements. Changes have had to be made to the plan throughout development to the back-end of the user interface as more was learned about the application. The initial layout for the user interface was to include brightness, transparency, size and position video controls. The most difficult control to implement was transparency. It was discovered that transparency and brightness performed a similar function with a display visible to just one eye. As brightness is increased the user perceives reduced transparency and vice-versa. This information was presented to the customer, however as units with a display for each eye may at some point be used, both controls will be implemented.

The most difficult obstacle throughout the process has been getting the headsets in time for development to continue. This is in part due to the need to go through the universities procurement team as well as delays from the manufacturer. Ideally a route for capstone teams to work directly with manufacturers may help increase communications in this situation.

The university support included two faculty advisers assigned to the capstone team. They provided coaching and advice based off of project management experience in the field. This was particularly beneficial in preparing for the Fall industry advisory board (IAB) presentation where faculty coaches took on the role of IAB members to help improve both the presentation content and style. In this instance it led to this team having the most positive feedback from all other projects! With 17 votes, the team received the highest overall score of 5.48/6 on the presentations and project.

5 Conclusion

The iterative approach used in this project has been key in its success. Had the team used a traditional waterfall style approach it is quite likely the project would have been stalled for several months pending the arrival of the AR unit. Concurrent engineering practices allowed parallel development to build component level prototypes which could then be re-evaluated and integrated as they matured.

The results of this project will benefit deaf children desiring to visit the BYU planetarium. The AR glasses will allow users to look at the planetarium show and their interpreter at the same time. This will allow the show to play continuously without breaks for interpretation. The possible implications of developing this solution could lead to major changes in the experiences of the deaf in a variety of environments including planetariums, classrooms, museums, sporting events, live theaters and cinemas. This project has the potential to significantly improve the experience of not only children in the planetarium but the learning environment for the entire deaf community.

Acknowledgement

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