Enhancing participation of deaf engineering students in lab discussion

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Abstract

Students who are deaf and hard of hearing (deaf) are underrepresented in engineering disciplines, in part because they do not have full access to spoken information even with aural-to-visual accommodations. In lecture or labs, they rely on captions that display speech as text in real-time, and usually watch captions through a personal display via laptop or tablet. While the deaf student is able to view the captions easily, the disadvantage is that they have to focus on a visually separated screen from the lab activities, and they cannot easily see the current lab activity or other students. They also cannot tell who is talking or when, and cannot interrupt. This viewing isolation contributes to student frustration and risk of doing poorly or withdrawing from introductory engineering courses with lab components. It also contributes to their lack of inclusion and sense of belonging. To a smaller extent, some hearing students misunderstand spoken information, especially in lab environments.

We report on the evaluation of an extension to our Real-Time Text Display (RTTD), to handle multiple speakers (RTTD-MS), for engineering labs. RTTD was developed to reduce frustration in following the teacher and other peers during laboratory and other academic settings. The system projects a real-time display of captions (RTTD) above a teacher who can move around the room during the class or laboratory, which may aid deaf students in viewing both the speaker and the speaker's words as text.

Our first study with RTTD found that deaf students in engineering course lectures significantly prefer RTTD over traditional classroom captions. Our second study revealed that hearing students also preferred it over no captions at all. The hearing students preferred it because they could review spoken information that they misheard or missed, by reviewing captions that are displayed for several seconds. We also asked them about their perception of accessibility and inclusiveness of course lectures and lab sessions. The answers indicated that deaf students felt lab sessions were more confusing than classroom lectures, and that they were not satisfied with the accessibility of captions, and did not feel included as they did not know who was speaking. New hearing students also felt they missed information when they did not understand unfamiliar words or concepts in group activities in lab sessions.

This paper examines how deaf and hearing students used the system to access speech presented as text, and inclusiveness in lectures and discussion. The study gathered both quantitative and qualitative information from each feature of the system display, such as speaker identification and the number of displayed lines. It reports the feedback and comments from the students on how direct and alternative access to spoken information promotes accessibility and inclusion of both deaf and hearing students in first year, engineering lab sections.

Introduction

The National Science Foundation (Committee on Equal Opportunities in Science and Engineering, 2013) and National Academy of Engineering (Chubin, May, & Babco, 2005; Wulf, 1998) have started to encourage research initiatives in inclusion and diversification in undergraduate classes, especially in Science, Technology, Engineering, and Mathematics (STEM) fields. The NSF and NAE have made these research initiatives a priority because studies have shown that teams that are diverse are more effective at problem solving (Hong & Page, 2004), making decisions (Shachaf, Oltmann, & Horowitz, 2008), and ultimately have a greater impact on the quality of science produced (Campbell, Mehtani, Dozier, &

Rinehart, 2013). Engineering is a creative profession that requires making unexpected connections between things we already know. Hence, creativity depends on our life experiences. Without diversity, the life experiences we bring to an engineering problem are limited, and we may not find the best or most elegant engineering solution (Wulf, 1998). Specifically, people with disabilities have created accessibility innovations to meet their needs, and many have become universally adopted. For example, Robert Weitbrecht, a deaf scientist and Andrew Saks, a deaf engineer, partnered with James Marsters, a deaf orthodontist to fund and develop a novel telephone typewriter (TTY) to transmit text over the telephone, so that deaf people could communicate through typing text. This technology contributed to the development of modems that transmitted data over the telephone. Modems became an essential, universal device that people used to connect to commercial services such as America Online, and then eventually the Internet, over their telephone lines.

Deaf and hard of hearing people are underrepresented both in college and in the workforce. Approximately 17 percent (36 millions) of American adults report some difficulty hearing, yet fewer than 5% of the STEM workforce is deaf or hard of hearing (National Institute on Deafness and Other Communication Disorders, 2015). In engineering classes and labs, deaf participants access spoken information, either through sign language interpreters, who translate to and from spoken English and American Sign Language (ASL), or through captioners, who type the speech as text. A common method of live captioning is called C-Print, where a trained captioner transcribes speech using a laptop. The person using the captioning services watches this transcription on their own computer in order to follow along with a lab discussion or lab presentation. In contrast to hearing audiences who listen to speakers while watching for body language cues and reading presentation slides, deaf audiences must multitask during lectures and panels, regardless of which accommodation is provided. To follow a presentation, deaf participants shift their attention from the interpreter to the lab demonstration, resulting in eye fatigue, distraction, and decreased engagement.

Deaf Student Challenges

Figure 1: Multiple information sources: teacher, slides, interpreter and notes

For captions, deaf participants juggle their attention from (1) the text to understand the content of the conversation, (2) the speaker to pick-up information conveyed by body language and facial expressions, and (3) the slides to read supplementary information (Cavender, Bigham, & Ladner, 2009; R. S. Kushalnagar, Cavender, & Paris, 2010). Alternatively, if an interpreter is available, an audience member must look back and forth from (1) the interpreter to hear the content, (2) the speakers to identify who is talking, and (3) the presentation slides to gain supplementary information as shown in Figure 1. Research indicates that a deaf individual's peripheral vision affects attention more acutely than a hearing individual's peripheral vision, as hearing people tend to focus more on the center of their field of vision (Dye, Baril, & Bavelier, 2007). This finding suggests that in presentation or panel settings where deaf viewers already redirect their gaze to various focal points, extra movement or changes detected in their peripheral view further compromises their attention on the current discussion, compared with hearing viewers' attention.

Laboratory Accessibility

Laboratory environments can be very challenging because there are often obstacles blocking sightlines, reducing access to information. These obstacles should be removed or negotiated if possible. Another issue is that laboratory instructors often point to laboratory equipment and materials as they speak. However, due to the lag of interpretation or the split attention between the real-time captioning and the instructor, the deaf student may not be aware of where the materials are located. One solution is for the instructor to physically move to where the materials are located to make their location visually apparent. This simple strategy may be beneficial to the entire class to make the location of the laboratory materials explicit, as well as help students to better conceptualize an activity as a "face" of the equipment is attached to a "name." The final issue is that if laboratory protocols are relayed verbally, the deaf student may not be able to write the information down.

Juggling and prioritizing various information streams and shifting focus repeatedly causes deaf viewers to miss out on content, to get tired, and to get distracted. Additionally, deaf participants can feel left out of the conversation and as though they do not grasp the material being presented. This disconnect between hearing presenters and deaf participants hinders the community, causing misunderstanding and miscommunication, a gap that can isolate deaf people from their professional and educational communities.

Related work

The basis of RTTD-MS comes from the Real-Time Text Display (RTTD) developed by Kushalnagar, et al (R. Kushalnagar et al., 2016). for classroom use. RTTD is a caption display method which tracks a single speaker moving across a classroom and projects captions transcribed by a C-Print captioner above them, allowing deaf viewers to more closely follow what a speaker is saying. The system is designed to be portable, easy to set-up, and low-cost, implementing a Microsoft Kinect 2 to track the position of the speaker. A C-Print captioner transcribes the captions, a projector displays the speech as text, with a laptop as shown in Figure 2.

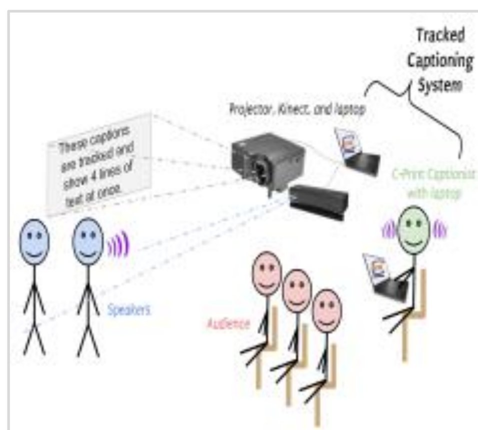

Figure 2: RTTD-MS - multiple speakers

Kushalnagar et al., (Behm, Kushalnagar, Stanislow, & Kelstone, 2015; R. Kushalnagar et al., 2016) found RTTD to be an effective captioning method in the classroom setting, improving students' ability to follow along with a lecture and to understand lecture content over traditional captioning. This is promising work toward developing a system for other settings, such as laboratories. However, the system is optimized for one speaker only; if more than one person stands in the Kinect's image field, the program randomly selects a person over whom to display the text. In this study, we expand the capabilities of RTTD to accommodate more than one user and evaluate the effectiveness of these enhancements for multi-user laboratory settings.

Setup

The RTTD-MS system uses the same equipment as the RTTD system: a Microsoft Kinect 2 to track the speakers, a C-Print captioner to transcribe the text, a projector to display the captions, and a computer for processing power. The main difference is an addition to the RTTD codebase to establish a thread which parses visual information about speakers and one which positions the captions above the correct speaker based on spatial information. The program allows the speakers to indicate to the system who is speaking and where captions should be located. To assist the audience in detecting speaker changes, the captions glide from presenter to presenter, as opposed to popping-up over the new active speaker and requiring the audience to look for the current speaker. The RTTD-MS system can be used in two modes, a panel-style setting and a presentation-style setting, though the focus of this paper is on the presentation mode.

Lab Discussion Accessibility

During a lab discussion setting where the speakers are seated or communicating back-and-forth, the program detects which speaker raised a hand and gives that person the floor. A person raises any hand and lowers it to obtain control of the captions until another person raises a hand. The program continues to update the display's location if the speaker walks around on stage, as shown in Figure 4b.

This form of control based on hand raising takes advantage of social dynamics - when someone motions with a hand, others know that person would like to speak or to add something to the conversation. It is a method which reflects physical-world experiences.

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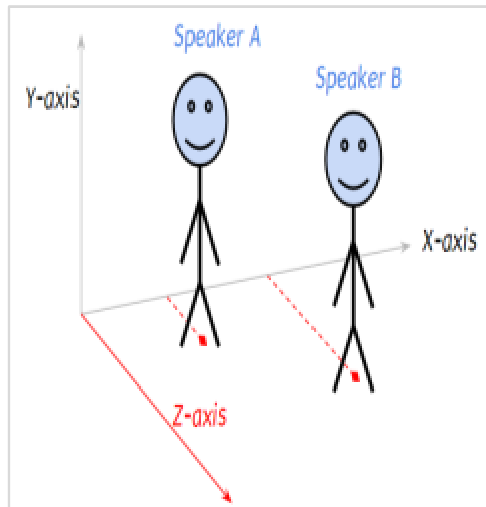

Figure 3: RTTD-MS - z axis

Lab Presentation Mode

During a presentation-style setting where the speakers are standing or otherwise moving around on stage and giving a planned presentation, the program detects which speaker is closest to the Kinect, in terms of the Z-coordinate depicted in Figure 3, and gives that person the floor. A person needs to be merely centimeters in front of all other speakers to obtain control of the captions; when someone finishes speaking, that person takes a step back, while the new speaker takes a step forward to indicate a request for the captions. The program updates the display's location as a speaker walks around on stage, allowing the current speaker to move freely, so long as all other presenters remain further in the Z-direction from the Kinect than the current speaker.

This form of control based on body positioning aims to keep the interface simple for speakers; rather than remembering to make a formal request to speak, presenters physically indicate a request for attention by moving closer to the audience, an action that may feel more natural than raising a hand. It intends to allow speakers to coordinate caption control with one another with relative ease. For example, if a passive speaker would like to add to the active speaker's discussion, the passive speaker can lightly tap the active speaker or make themselves visible in the active speaker's peripheral vision to politely interrupt and indicate a request to speak.

(a) Traditional captioning; static, no tracking

(b) Tracked Captioning in Presentation Mode

(c) Tracked Captioning in Panel Mode

Figure 4: Environment

Evaluation

We recruited 18 deaf and hearing engineering student participants who regularly used captions in their classroom, and focus on qualitative response analysis. The breakdown of the 18 participants was nine deaf and nine hearing individuals, ranging in age between 18 and 29 years-old. The evaluation had three parts: a face-to-face interview, a lab presentation evaluation, a lab discussion evaluation and a feedback survey. The participants were assigned identification numbers to maintain confidentiality.

Then for the lab presentation and lab discussion sections, we set up the environment and seating for each study phase. The study was run in three study phases over three days. In the first phase, 6 deaf and 4 hearing people participated on the first day. In the second phase, 1 deaf and 5 hearing people participated on the second day, and for the third phase, 2 deaf people participated on the third day. For the lab presentation evaluation, 2 people presented together, sequentially. For the first four minutes of this presentation, C-Print captions were projected to the left of the presentation area; they were not tracked and remained stationary, as shown in Figure 3a. Then, the moderator of the study indicated to the audience there would be a change in captioning technique, and for the next four minutes of the talk, the presentation mode of RTTD-MS was implemented, so that the position of the C-Print captions moved above the appropriate speaker when she stepped forward, as in Figure 3b. The participants took a ten-minute break before beginning the second part of the study, which was a discussion between the same two presenters. Like the lab presentation, this panel was split into two six-minute sections. The first with the panel mode of RTTD-MS enabled and the second with static captions to the left of the stage area, so that the position of the C-Print captions moved above the appropriate speaker when she raised her hand. Figure 3c shows RTTD-MS with Panel Mode enabled.

To collect audience feedback on the captioning methods for both talks, each participant answered twenty-four multiple-choice questions using an online survey relating to the ease of following the tracked captions, the helpfulness of the tracked captions, and their engagement due to the tracked captions. Additionally, the individuals had the opportunity to share their thoughts and comments on these two experiences with RTTD-MS in two optional, open-ended questions.

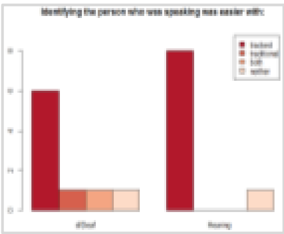

Figure 5: Speaker Identification

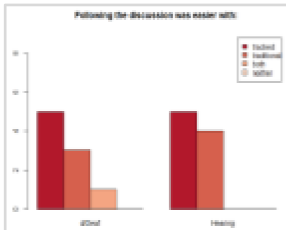

Figure 6: Following the discussion

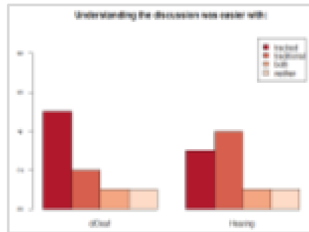

Figure 7: Understanding the discussion

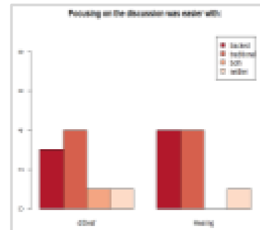

Figure 8: Focusing on the discussion

Results

The demographic survey asked four open ended questions related their perception of accessibility and inclusiveness of engineering labs sessions. When asked to compare lectures and labs, all deaf participants said that their class lab sessions were more confusing than their class lectures. Every deaf participant also said that the main reason that the labs were more confusing was because the instructor moved all over the lab during their demonstrations, and that there was no predictable place to put in the display that showed the captions. Of all deaf participants, 6 of the 9 said that they did not know who was speaking, since their classmates also moved around. The other 3 deaf participants said that in their labs, the seating arrangement was fixed, so there was no difference in identifying who spoke, between the classroom presentations and laboratories. Surprisingly, 2 of 9 hearing participants said that they had difficulty in following who was talking and what they said, because their mechanical engineering laboratories usually had a lot of background noise with machinery running in the background.

Do tracked captions improve deaf participants' understanding?

In terms of identifying the speaker, the participants overwhelmingly reported that the system made it easier to identify which person was speaking, as shown in Figure 5. Six deaf participants (67%) reported that it was easier to identify the speaker with the system and 8 hearing participants (89%) reported that it was easier to identify the speaker with the system. Overall, 14 participants (78%) reported that it was easier to identify the speaker with the system.

In terms of ease of following the discussion, the system was helpful for both deaf and hearing participants, as shown in Figure 6. 5 deaf participants and 5 hearing participants (56%) reported that it was easier to follow the discussion with RTTD-MS. Overall, 7 participants (39%) reported it was easier with traditional captioning, and 1 (6%) reported both made it equally as easy. 1 participant noted that the slow movement of the RTTD-MS made it hard to follow.

In terms of understanding the discussion, the system was more helpful for deaf participants to understand the discussion, while traditional captioning was slightly more helpful for hearing participants. Results by hearing identity are shown in Figure 7. Overall, 8 participants (44%) reported that it was easier to understand the discussion with the system and six (33%) reported it was easier with traditional captioning.

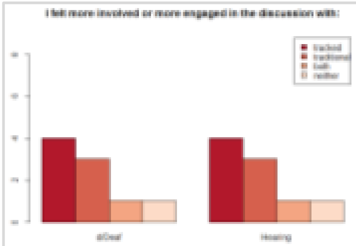

Figure 9: Involved/Engaged in Discussion

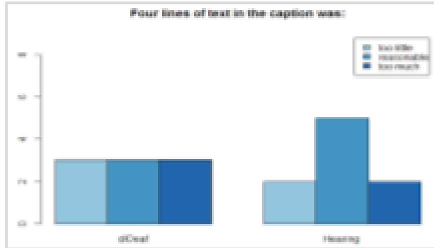

Figure 10: Four Caption Lines

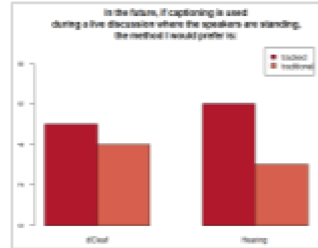

Figure 11: Preferred method

Do tracked captions enhance deaf participants' engagement?

In terms of focusing on the discussion, traditional captioning was more helpful for deaf participants, while most hearing individuals split their votes equally between both captioning methods as shown in Figure 8. Three deaf participants (33%) reported that it was easier to focus on the discussion with the system and 4 (44%) reported it was easier with traditional captioning. Similarly, 4 hearing participants (44%) reported that it was easier to focus on the discussion with RTTD-MS and 4 reported it was easier with traditional captioning. Overall, 7 participants (39%) reported that it was easier to understand the discussion with the system and 8 (44%) reported it was easier with traditional captioning. Two participants commented on their focus being hindered. 1 participant indicated that the lighting of the space caused a glare on the wall and made it and tiring to keep-up with the captions. Another participant shared that the tracked captions moved too slowly and sometimes were projected on the presenter.

In terms of feeling engaged, Deaf and hearing participants reported that RTTD-MS made them feel more involved or more engaged in the discussion with a slight plurality over the other options. The distribution of votes by deaf participants exactly matched the distribution of votes by hearing participants. Four participants (44%) of each hearing identity felt more engaged or involved with RTTD-MS, three (33%) of each hearing identity felt more involved or engaged with traditional captioning, one (11%) of each hearing identity felt that both methods were equally engaging, and one of each hearing identity felt that neither method was engaging.

What are audiences' preferences?

Amount of text

Most hearing thought that four lines was reasonable, but deaf participants did not agree, as shown in Figure 10. Three deaf individuals responded that four lines was too little, three responded that four lines was reasonable, and three responded that four lines was too much. Two hearing participants felt four lines was too little, two felt four lines was too much, and five felt that four lines of text is reasonable.

Do deaf participants prefer RTTD-MS over traditional captioning?

More participants would prefer to use RTTD-MS over traditional captioning. Results by hearing identity are shown in Figure 11. Deaf participants show a weaker preference for RTTD-MS than hearing participants show, with five deaf participants (56%) preferring RTTD-MS in the future compared to six hearing participants (67%) choosing tracked, presumably due to the familiarity factor.

Discussion

The results suggest that RTTD-MS can be a more inclusive accessible technology alternative to traditional captioning. The results show RTTD-MS improves deaf participants' experiences with live presentations by more than one speaker over traditional captioning. It helps them more easily identify the speaker, understand the discussion, and follow the discussion. Additionally, it facilitates their engagement and involvement in the discussion. Overall, RTTD-MS bolsters the experience of deaf audiences without impeding the experience of hearing audiences, supporting it as a universal access rather than simply indirect access.

Direct versus Indirect Access

The ideal classroom situation is one in which students and instructor share the same language, and ASL is no exception. At institutions adapted for deaf and hard of hearing students, such as Gallaudet University and the National Technical Institute for the Deaf at Rochester Institute of Technology, many students directly learn from faculty who are fluent in ASL. However, most engineering classes and labs are neither taught by teachers fluent in ASL, nor structured to provide visual access for deaf or hard of hearing students.

One option for universities that do not have expertise in educating DHH students directly, is to invest in bridge programs with institutions that have faculty expertise with DHH students. These bridge programs could provide teaching and research collaborations between faculty members at different institutions could lead to opportunities for teaching support, mentoring, research experiences and visiting scientist positions. These collaborations could lead to research, for example, to understand the impact of participation in ASL/English bilingual environments on the retention of DHH students in engineering fields.

Another option for these universities would be to promote collaboration between DHH and hearing students in class through technology, such as using eye-tracking or face-tracking to locate the classroom focus (R. S. Kushalnagar & Kushalnagar, 2012) This is particularly important for deaf students, because, unlike hearing students, deaf students are frequently seen as "not able," which creates a cycle of low expectations and gaps in students' meta-knowledge (Marschark & Hauser, 2008). These strategies to engage students may create a more inclusive learning environment for students. More research on deaf-hearing collaboration is needed to be done to determine the impact inclusion and engagement by both deaf and hearing students in engineering classrooms and labs.

Finally, engineering programs should consider maintaining full visual access through various strategies: for example – arranging seating in a large circle rather than row by row seating. For visual learners, whether deaf or hearing, this arrangement allows for visual connection to enable whole-class discussion. This seating arrangement is beneficial for hearing learners as well, as it encourages social interaction. Research shows that hearing people are more likely to contribute to discussions when they can see each other's faces. For example, research about K-12 students indicates that learners ask more questions when seated in semi-circles (Marx, Fuhrer, & Hartig, 1999). Students are also more likely to engage in on-task behavior when seated in a circular arrangement (Rosenfield, Lambert, & Black, 1985). Traditional seating precludes eye contact, while circular arrangements promote face-to-face contact.

Future work

Future work on RTTD-MS includes improving the system in speed and responsiveness, and the evaluation methodology. Some participants commented that there was an apparent slowness of the sliding animation as the captions moved from one speaker to another, which should be fixed. Improvements to the RTTD-MS system include optimizing the speed of caption movement between speakers, incorporating an audio recognition feature to display captioning for remarks or questions made off stage, and designing a more user-friendly graphical interface for the operator of the system. Improvements to the evaluation methodology include increased precision of survey questions, longer presentation demonstrations for both traditional captioning and RTTD-MS, the use of presentation slides in the discussions, and larger sample sizes.

Acknowledgements

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