ClassInFocus: Enabling Improved Visual Attention Strategies for Deaf and Hard of Hearing Students

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ABSTRACT

Deaf and hard of hearing students must juggle their visual attention in current classroom settings. Managing many visual sources of information (instructor, interpreter or captions, slides or whiteboard, classmates, and personal notes) can be a challenge. ClassInFocus automatically notifies students of classroom changes, such as slide changes or new speakers, helping them employ more beneficial observing strategies. A user study of notification techniques shows that students who liked the notifications were more likely to visually utilize them to improve performance.

Categories and Subject Descriptors

H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems; K.4.2 [**Social Issues**]: Assistive technologies for persons with disabilities; L.3.6 [**Methodology, Tools, Technology**]: Technology Enhanced Learning

General Terms

Human Factors, Design, Experimentation

Keywords

Classroom Technology, Multimedia Conferencing Technology, Deaf and Hard of Hearing Users

1. INTRODUCTION AND MOTIVATION

University-level classrooms are becoming more multi-modal. In addition to the instructor and other classmates, students receive information from slides, whiteboards, video, personal computers, handouts and other materials. Deaf and hard of hearing students use an array of accommodations to access the classroom: sign language interpreters, real-time captioners, FM systems for amplification, and note-takers to relieve the visual burden of taking personal notes. The choice of accommodation is largely dependent on student preference, course content and format (e.g. lecture vs. discussion), and options provided by the school.

Deaf and hard of hearing students face a number of barriers in the standard mainstream classroom [11] including:

- Visual dispersion (multiple, simultaneous visual sources of information: interpreter or captions, instructor, slides, other classmates) increases likelihood of missed information.
- Skilled sign language interpreters and captioners who understand and can correctly interpret advanced college-level material can be difficult to find.
- Classroom interaction can be strained do to language barriers.

ClassInFocus (Figure 1) seeks to alleviate these barriers by: (1) bringing classroom components together in one screen to enable better management of visual attention, (2) opening opportunities for remote interpreters and captioners through our affiliated Deaf and Hard of Hearing Cyber-Community, (3) engaging students in chat, communal note-taking, and group work, and (4) enabling classroom capture for review of missed information. We initially focus on mainstream, lecture-style classes as they continue to be the most common, pervasive classroom setting, but many lessons learned here apply to a variety of settings and the technology itself is not limited to that domain. The first of these goals, bringing classroom components together visually, is the current focus of this paper.

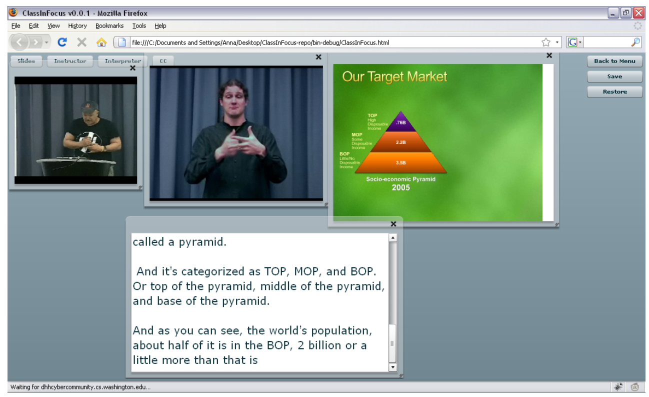


Figure 1: The ClassInFocus system, showing a window configuration chosen by one of our participants.

1.1 Visual Dispersion

Visual dispersion (juggling many visual sources of information) is often cited as one reason that deaf and hard of hearing students typically get less out of classroom lectures than their hearing peers [11, 12]. A deaf professor and researcher summarized the problem nicely in the context of a workshop for a new statistical software package (from [12]):

> *Superficially, the learning context seemed ideal: The lecturer was a sensitive individual who went to great lengths to ensure full access by deaf individuals ... He had a projection of his own computer display on a large screen behind him, and each participant had their own computer for hands-on activities. The sign language interpreters were the best that could be found: all experienced in interpreting under such conditions. The two deaf participants had strong backgrounds in the use of computers, research, and statistics. Yet, both quickly became lost, viewing the two days as a waste of time. What went wrong?*
>
> *Primarily the problem was one of multiple, visual tasks placing too many demands on the processing of information in the learning situation. While the hearing participants were able to look at their screens and listen to the presenter, the deaf participants had to look away from the interpreter to see the instructor's screen or to try a procedure on their own computer. Missing one sentence of the instructions was enough to slow down or even derail learning.*

As research indicates that (hearing) students benefit from combined visual and verbal materials [15], multi-modal classrooms are becoming the norm. With hearing students receiving ever more *concurrent* information, deaf students must switch between primarily *consecutive* information (the visual channel permits only one information source at a time). Adding to this problem, text captions and sign language interpretation required to access the class can "overpower" other visual materials causing deaf or hard of hearing students to miss the benefits of all classroom materials [13, 14].

1.2 Notifications

One of the goals of ClassInFocus is to minimize the cognitive and visual load of managing visual attention in the classroom. With ClassInFocus, classroom components appear on screen reducing their visual proximity and notifications guide students' visual attention during class.

ClassInFocus acts like an aware digital classroom detecting potentially interesting changes and, if deemed important, directs the student's attention to those changes. For example, slide changes, an interpreter or other student transitioning from not-signing to signing [4], or changes in speaker references in the captions (captioners typically indicate a new speaker by typing that person's name or position in large uppercase letters) are all aspects of the classroom that can be automatically detected. This paper investigates the usefulness of automatic notifiers, their effects on learning, and user preferences for receiving visual notifications.

We conducted a user study testing three types of visual notification designs for slides changes and new speakers using a pre-recorded university lecture. Using participant eye movement data, answers to lecture questions, and participant preference scores and feedback, we found that students who liked the notifications were both more likely to look at them and better able to answer content questions when notifications were turned on. Furthermore, a distributed visual strategy (looking at more than one information source) improved performance, indicating that awareness of classroom changes may enable students to better manage their visual attention and relieve the cognitive load of searching for new information.

2. FOCUS GROUP AND PROTOTYPE TEST

The work presented here was inspired by an initial prototype test and focus group with eight students from the University of Washington's Summer Academy for Advancing Deaf and Hard of Hearing in Computing [3]. The students ranged in age from 16 to 22 (4 female, 4 male), 2 typically request captions in class and 6 typically request sign language interpretation. The students were from all over the U.S. and attending the academy for nine weeks to take introductory computer programming and animation courses.

We conducted a prototype test and two hour-long focus group discussions in a mock classroom setting. The prototype test used Adobe's Connect: students used personal laptops and webcams, the instructor and sign language interpreter (who were physically present in the room) appeared as a video stream on the screen. The students were asked to observe as if they were in an actual classroom. Afterward, group discussions focused on barriers students face in the classroom and the potential for a technological solution like ClassInFocus. The questions we asked were intentionally broad enough to encourage students to freely offer feedback about their impressions of the technology. We asked:

- *What do you think about the idea of having all of these components (slides, interpreter, chat, etc.) on one screen? Would this be useful or would it be distracting?*
- *What do you think about the system itself (Connect)? What's good? What's bad? What's missing?*

During the setup, the scene was a bit chaotic. Students varied in the time needed to setup webcams and join the chatroom. Those that joined the room early played with chatroom features while they waited and/or chatted with friends as they joined the room. By the time everyone had joined, some students were already engaged in the technology and engaged in conversations with friends and it was very difficult to get everyone's attention. During the brief lecture (10 minutes), some students used the chat feature or signed to others to ask brief questions. Most people tended to watch the interpreter, and occasionally looked at the slides.

Through observing the prototype test and conducting the focus group, we observed a number of findings. Perhaps most salient was the difficulty noticing changes on the screen that were outside the current focus of attention.

2.1 Noticing Changes

Even though Connect was successful in bringing classroom components visually closer together and some students commented that they liked having everything on one screen, it was not always possible to notice informative changes that were on the screen but outside the current focus of attention. The following student quotes best capture this phenomenon:

> *"To be honest, it's a little distracting with the video. I haven't looked at the slides at all."*

> *"When people are signing it's easy to overlook what's going on and then realize you're behind. So you need something to let people know there's a new message, new information."*

Video can be very distracting, perhaps even more so when it contains language-rich information like sign language or captions. This can work to a student's advantage when watching an interpreter who is signing important content. But, it can also work against the student. The focused attention required to watch the interpreter may induce tunnel vision and overpower other changes in the classroom [17, 22], such as slide changes, incoming chat messages, and instructor actions. The resulting changeblindness may cause the student to miss other sources of information [19]. The student must decide, very consciously and carefully, when to look away from the interpreter to gather information from other sources. Consistent with research on dual-task effects, the need to prioritize information sources and choose one task at the expense of the others adds cognitive load [8] and results in on-going decision-making during class that for other hearing students is rather effortless.

In fact, these findings are consistent with Marschark et al. [13], studying visual attention of deaf students during instruction. While deaf students obviously spend as much time watching the interpreter as hearing students spend watching the instructor, they spend considerably less time looking at the course materials, such as slides. This may shed some light on the trend that hearing students gain more information from class time than their deaf peers [11, 12].

Based on the focus group, we implemented notifications in ClassInFocus to let students know of changes. The success of these notifications leverages years of research on visual and perceptual attention and techniques for interrupting users.

3. RELATED WORK

The ClassInFocus notification techniques were rooted in three research areas: (i) perceptual attention theory, (ii) interruption theory that supports focus on the current task, and (iii) technology for directing visual attention.

3.1 Perceptual Attention

The human eye only sees in high acuity foveal vision within 2 degrees of visual angle, but low-acuity peripheral vision may extend to 100-110 degrees from the point of fixation. To put those numbers in perspective, a 2 degree visual angle is about the size of a thumbnail at arm's length, whereas a standard laptop with a 15-inch screen placed 2 to 3 feet from the user occupies approximately 20 to 30 degrees of visual angle. Even though peripheral vision tends to be effective at detecting change and motion, our ability to see things at the edge of a computer screen may vary with our level of attention to the task we are performing.

Tunnel vision causes the focus of attention to narrow considerably, and can be induced by a combination of high foveal cognitive load, a focused attention strategy, and speed stress [17, 22]. One might expect these factors to be common in classroom learning, and, not surprisingly, students reported experiencing all three in our focus group and prototype test. Many also reported a narrow focus of attention while attending to sign language video and/or captions and, as a result, did not notice content changes in areas beyond their primary visual focus.

When visually searching for specific information, we tend to follow a "feature integration theory" [21]. This theory predicts an initial stage of pre-attentive search followed by secondary serial stage in which features identified in the first stage are investigated further. The initial stage finds low-level features, such as color or uniqueness, in parallel across the full field of view, while the secondary stage involves more attentive search. While the first stage is rather effortless and automatic, the second stage requires explicit effort on the part of the searcher.

Our ClassInFocus notifications were carefully designed to induce pre-attentive search strategies so that students will see changes almost effortlessly without employing the more explicit attentive search. For example, color contrast and movement will invoke pre-attentive search, whereas smaller changes and notifications that persist in order to show change overtime would require explicit attentive search.

Some research indicates that deaf observers have different, often enhanced, visual search strategies. For example, deaf observers appear to respond faster than hearing observers to targets flashed in the periphery [6]. Deaf people do not necessarily have advanced visual abilities: when the location of the target is predictable, deaf and hearing observers performed equally. Only when the location of the target is unpredictable do deaf observers outperform their hearing peers in target acquisition. Exposure to sign language is unlikely to account for this difference, as hearing native signers performed on par with hearing observers (non-signers). Neither group of hearing people were as quick as deaf observers. This suggests that hearing loss may result in better allocation of attention to the entire peripheral field, a result that could lead to added advantage for deaf students using ClassInFocus.

With multiple visual sources of content, deaf and hard of hearing students are presented with the challenge of deciding where to look at any given time. Their decisions are made on imperfect information of what they perceive to be the most important or richest source of information. By including visual notifications in the interface, ClassInFocus seeks to alleviate the added cognitive load of deciding where to look while reducing the chances of missing important changes to class materials.

3.2 Interrupting Users

The visual notifications in ClassInFocus are intended to help students decide where to look without causing extra distraction. Fortunately, interruptions have been shown to be less disruptive to effortful, cognitively-taxing tasks than to faster, stimulus-driven tasks [5]. Thus, if a class is especially interesting or cognitively taxing, we should expect visual notifications to have less of a negative, distracting effect from the ongoing task.

Similarly, interruptions that demand the users immediate attention are less effective for promoting learning and productivity than interruptions that notify the user of items that need their attention. Such negotiated interruptions [18] can be temporarily ignored and are less likely to be distracting. Interruptions that require a user's immediate attention may distract from the learning process and derail rather than support learning [16]. Furthermore, aligning the perceived visual urgency of interruptions with the utility or helpfulness of those interruptions can decrease annoyance and increase their perceived benefit [7]. Because our notifications are meant only as suggestions, we have chosen notifications that appear and then disappear quickly in a noticeable yet unobtrusive manner. Our notifications do not demand any action on the student's part.

Evidence also suggests that interruptions relevant to the primary task have less of a negative effect, and can even have a positive effect, on performance [20]. In our study, all notifications supported the ongoing lecture, but evidence such as this speaks to the importance of accuracy in future notification systems based on automatic change detection.

3.3 Directing Visual Attention

Changeblindness occurs when changes to a visual scene go unnoticed because they coincide with an eye movement, obscuration of the observed scene, or diverted attention during the change. Changeblindness may cause students to miss our visual notifications altogether. Regardless, many research efforts have successfully drawn the attention of their users (for example [1, 7, 9, 10, 18, 23]), giving us confidence that designing notifications to which users will respond is possible. We have designed ClassInFocus notifications drawing from lessons from this prior work, but we do not expect users to respond to all cues.

In contrast to most prior work, the cues themselves are part of the primary task. Often cues will suggest that users consider switching to a secondary task. Our cues require nothing from the user: they are merely suggestions to guide the learning process. For this reason, we have tested their effects on learning and user preferences, as well as the user's ability to notice, follow, and respond.

Research studying the "attention-getting" effects of animations on a computer screen has found that motion, especially when compared to color or shape, is an effective means of drawing attention [1]. However, certain types of motion may be found more annoying than others; specifically, Bartram et al. showed that moving animations were more distracting than anchored animations and users preferred a slow blinking technique that was still effective without being annoying [1]. The guidelines proposed in this work, specifically the frequency and transparency of visual cues, have guided the design decisions for ClassInFocus notifications.

Drawing attention is especially important for large displays and as a result has been studied extensively in that domain [1, 9]. One approach explored was to use trailing artifacts of motion to help improve task completion times for targets very far away from the initial fixation point (over 2000 pixels). Fade-in and fade-out techniques used to highlight targets were equally effective when targets were close. Because trailing motion adds complexity and distraction without improving effectiveness for close targets, we focused on anchored animations and fade-in and out techniques.

Obscuring the background material and leaving only the window of interest visually clear is another effective technique [1, 9, 23] that has been explored. This notification style works best when readability of the background material is no longer important. Because our visual directives are only suggestions, and should not obscure content necessary for classroom learning, we chose not to obscure any part of the screen for a long duration of time.

Based on the research and recommendations of years of work on interrupting users with visual notifications, we have chosen visual notifications that draw attention to salient aspects of a classroom without distracting from it. Our goal is to gracefully signal, not demand, student attention.

4. CLASSINFOCUS

ClassInFocus is implemented using Adobe's Flash Collaboration Services, a Flex framework facilitating real-time, social applications that run in a web browser using a Flash Player. For example, Connect, a popular online conferencing system was also built using this framework. We have expanded and modified some of the features of Adobe Connect to better suit the needs of deaf and hard of hearing students. For example, video streams will use a codec optimized for sign language video (MobileASL [2]). The flexibility of the Collaboration Services framework provides the opportunity to quickly iterate over designs. We can build features specific to ClassInFocus that Connect does not have, instrument these components with tracking mechanisms for quantitative data collection, and release to potential users via the web.

4.1 Visual Notifications

We have extended ClassInFocus components to automatically notify students when changes occur, letting students focus more on the course content and less on their interaction with it. The notifications direct students' attention to two types of changes automatically: slide changes and changes in speaker references in the captions (captioners typically indicate a new speaker by typing that person's name or position in large uppercase letters). Future versions of the system will also detect the transition from not-signing to signing of the interpreter or other students using motion vectors in the video [4] and the transition from not-talking to talking if the lecturer begins speaking after a break.

Based on perceptual attention literature, research on visual interruptions, and our specific classroom scenario, we designed our notifications using the following guidelines, which the authors believe may be useful to anyone designing visual notifications for deaf or head of hearing students:

Directly Indicate Content Changes
Notifications placed on or near the area of interest have been shown to be equally effective and less annoying [1, 9] and we believe more efficient. For example, a central directive that throws arrows in the direction of the window of interest would require an extra step to look at the arrow, then look where the arrow is pointing. For this reason, our notifications affect the window to which we hope to draw attention.

Avoid Superfluous Animation
Animated trails can effectively guide users to far away targets in large screen displays, but cues shown within or near the target are equally effective for closer targets [9]. We chose anchored animations that only appear on or near the target window itself to reinforce the message that our notifications are merely suggestions and do not demand immediate attention.

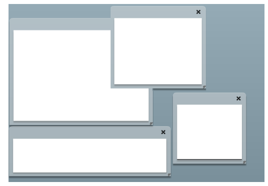
Avoid Changing Window Layout
Changing the window layout would be disorienting and may destroy the grounding established by students and members of the online classroom. For example, rotating the interface so that the window of interest is brought to the forefront

may seem like a nice solution, but is likely overly disruptive, especially for false positives, i.e. the automatic change detector incorrectly chooses to notify.

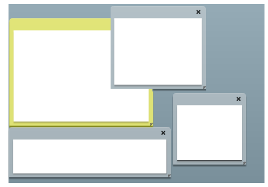
Avoid Additional Hardware
One might think that visual directives could adversely add to the cognitive load of managing visual information on the screen and a different modality altogether, such as haptics, would be more appropriate. This may in fact be the case, but due to extra hardware requirements, limited channels for haptic information, and a potential learning curve to map haptic information onto visual information, we have chosen to focus on visual directives. Furthermore, we believe that adding appropriate directives to the visual modality will actually have positive effects on the cognitive and visual load of students by relieving some of the visual search for changes and reducing information loss.

Do Not Distract From the Current Focus
We want to avoid distracting users from their current focus. For instance, using masking effects would overly obscure background material and other on-screen information. Our notifications are only suggestions of where to look, and should not obscure any window that the user may be attending to, or use any other technique that demands rather than suggests attention.

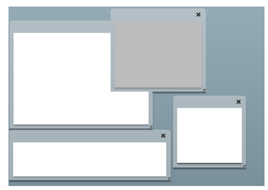
Using these guidelines, we chose three notification techniques for evaluation (see Figure 2). Each technique represents a specific type of anchored animation: illumination, darkening/brightening, and motion. To give users enough time to see the notification and to make sure the duration was consistent for each, all lasted 1500 ms (1.5 seconds).



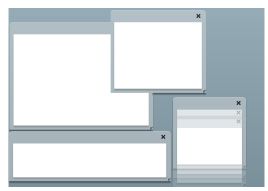
None: The lecture is shown in ClassInFocus with no special visual notifications.



Border: The border around a window of interest quickly turns yellow in the first 100 ms, remains yellow for 800 ms, then fades back to the blue color of ClassInFocus windows during the last 600 ms.



Lightswitch: The entire window of interest “turns off the lights” by dimming the window by 75% in the first 300 ms, then fades back to normal opacity within 1200 ms.



Wiggle: The window bounces twice. Each bounce is 750 ms, with 200 ms for 20 pixels of upward motion, then 550 ms for downward motion back to the original position.

Figure 2: Visual Notifications of Content Changes.

5. EVALUATION

To evaluate the effects of our visual notifications, we recruited deaf and hard of hearing students to watch a prerecorded lecture using ClassInFocus. We measured (i) user preferences using Likert scale and open-ended questions, (ii) eye movements of the students using a Tobii eyetracking system, and (iii) effects on learning through carefully designed questions covering the lecture content. Using these three measures, we investigate whether students perceive the notifications as beneficial, whether students look at the notifications, and whether the notifications affect learning.

5.1 Study Design

For the study, we used a pre-recorded lecture from a university course on Information and Communication Technologies for the Developing World, specifically a Microsoft initiative called Unlimited Potential. Even though the prerecorded nature of the course meant that our study participants could not interact with the lecturer or the other students as they might when using ClassInFocus in their own classes, we intentionally chose an actual course lecture in order to test the relevance of our techniques in a natural setting. And because the live course was both in-person and remotely taught, archives with slides were available and included some student interaction.

We divided the lecture into eight segments so that each of our visual notification techniques could be shown exactly twice in a balanced, repeated measures design. Aside from a 25-second introduction video that allowed students to get comfortable with the system before the lecture began, the segments ranged in duration from 1.5 minutes to 3.1 minutes with an average of 2.1 minutes. The segments were shown to each participant in the order that they actually occurred in the live lecture, only the order of the notification techniques was varied.

Both interpretation and real time captioning for the recorded class were provided as one of the windows in the ClassInFocus interface. We recorded a professional sign language interpreter who has eight years of experience, all at the university level, is certified with the Registry of Interpreters for the Deaf (RID), and regularly interprets for University of Washington courses, often computer science courses. In order to eliminate any confounding factors in the study, we wanted to create an interpretation of the lecture that was as error-free as possible. Thus the interpreter was given time to watch the lecture, practice his interpretation before the recording session, and retake any part of the interpretation he felt could have been better. Similarly, the captions were created by the first author, checked to eliminate errors, and timed with the lecture to appear as if they were real-time.

After completing a short demographic questionnaire, then calibrating to the eyetracker, participants began the study by configuring the windows of ClassInFocus as they saw fit. One of the hallmarks of ClassInFocus in enabling students to independently configure their own classroom environment to best suite their individual needs. For the study, ClassInFocus opened as a blank screen and the students were asked to open each of the four windows (instructor, slides, interpreter, and captions) and place them in any size or position on the screen that they felt was best for them. They were permitted to close a window if they so chose. They then watched a short class introduction, and were given a second opportunity to change their window configuration before proceeding with the rest of the study. They then watched the eight lecture segments with varying notification techniques and were asked 3 to 5 content questions at the end of each segment. Finally, a post-study questionnaire asked them to subjectively rate the notification techniques and asked for feedback on the project as a whole.

6. RESULTS

We recruited six deaf and hard of hearing students and one instructor to participate in the study (5 male, 2 female). All were either pursuing or had already obtained a bachelor's degree, some were pursuing an advanced degree. Three of the participants regularly request sign language interpreters for classes, 3 request an interpreter or a real-time captioner depending on the circumstances or course content, and 1 does not typically request any accommodation, preferring to sit up front, lip read, and utilize an amplification system. Participants represented a diverse range of academic interests: Visual Design, Dance, Business, Biochemistry, Psychology, Applied Technology, Ecology, and American Sign Language Instruction. All participants were relatively technically savvy, reporting an average 20.6 hours per week using a computer or accessing the Internet ($SD = 14.2$): all reported using email and instant messaging, 6 use social networking (such as facebook and myspace), 5 use video conferencing, and 2 reported blogging, 1 in video blogging (vlogging).

6.1 Interface Layout

All participants except one opened all four windows (teacher, slides, interpreter, and captions). P-02, who typically does not request any accommodation, minimized the interpreter window so that only the instructor, slides, and captions were visible. Figure 3 shows the participant layout choices, showing a great deal of personal preference. Nearly all participants volunteered that they liked the ability to move and position windows to best configure their classroom, and took great care to find optimal placements: average time spent adjusting windows was initially 3.3 minutes, with an addition 1.1 minutes after watching the introductory video. Six of the seven said they wished they could have moved the windows *during* the lecture as they saw the class proceed.

6.2 Participant Preferences

Some participants liked the notification techniques and felt they helped during the lecture (see Figure 4). When asked "What did you think of the automatic change notifications?" with answer choices ranging from "1-I didn't like it at all" to "5-I like it a lot," P-01, P-03, P-04, P-05, P-07 had strong preferences toward a favorite (typically either the Border or the Wiggle) and responded with an average high rating of 4.8 ($SD = 0.4$), ($\chi^2 = 12.14$, $N = 20$, $df = 4$, $p < .05$), whereas P-02 and P-06 did not like them as well and did not rate any of them higher than a "3-I didn't mind it". Similarly, when asked "Did the automatic change notifications help during the lecture?" the former group rated their favorite notifier with an average of 4.6 ($SD = 0.5$), ($\chi^2 = 11.10$, $N = 20$, $df = 4$, $p < .05$), whereas the latter group did not feel they helped, rating a "3-Didn't make a difference." These two groups, divided in their opinion of

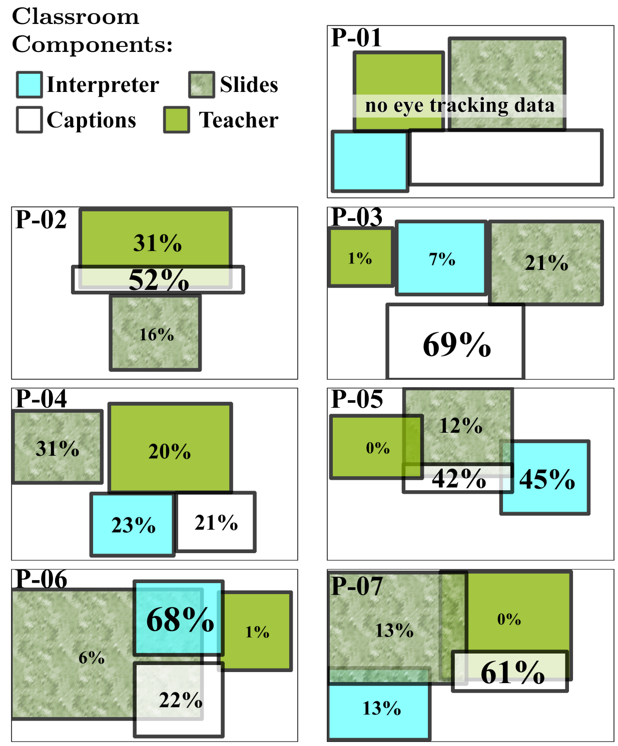


Figure 3: Participant-designed layouts showing percent gaze time on classroom components overlayed. Note: eyetracking data is not consistently available.

the notification techniques, turned out to be quite different both in their response to the notification techniques and their general approach to observing the lecture.

6.3 Eyetracking

We limited analysis of eyetracking results to fixations (rather than all gaze points) because a pause is required for information absorption. We define a fixation here as 100 milliseconds within a 30-pixel radius.

We noticed very different strategies of where the students chose to distribute their visual attention during class. Individual gaze strategies can be seen in Figure 3. As we expect, the majority of time was spent on either the interpreter or the captions and rarely on the teacher or slides. This supports prior work tracking eye movements of deaf students in a live classroom: our participants spent on average 12.2% on the teacher and 18.1% on the slides compared to 16% and 22% reported by Marschark *et al.* [13].

Perhaps more important than *where* students look during a lecture, do they look when ClassInFocus notified them of a change? Again, we see two groups of students (see Figure 5). Those who said they liked the notifications (right) were more likely to look at one or more notifications (57.9% of the time) than they were for a change without notification (30.8% of the time) ($F_{1,3} = 15.19$, $p < .05$). In contrast, students who said they did not like the notifications (left) did not tend to use them; this group looked at notifications 16.7% of the time and looked at changes without notifications 20.0% of the time, an insignificant difference. This supports participants' subjective ratings: students who made use of the notifications also liked them and found them helpful.

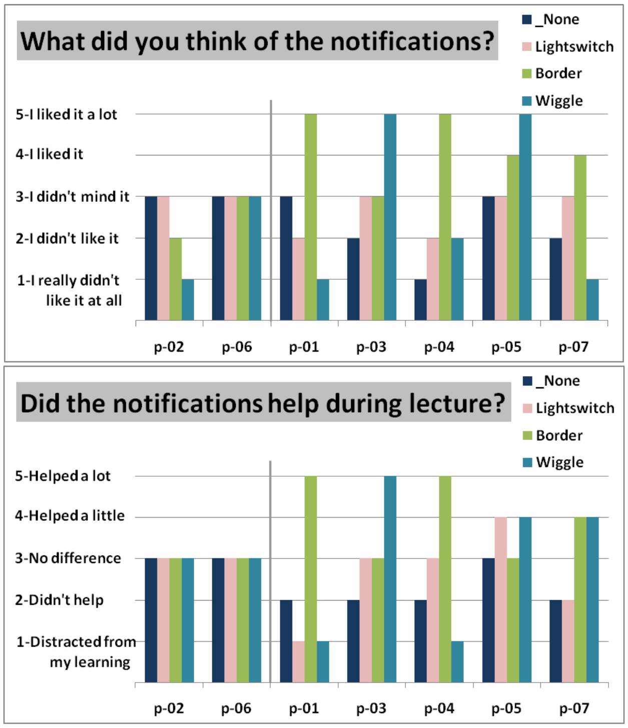


Figure 4: Subjective ratings produced two groups: those who liked the notifications and found them helpful (right), and those who did not (left). Border was liked best, people felt strongly for or against Wiggle.

6.4 Content Questions

Participants also varied in their ability to correctly answer our content questions, ranging from 44.1% to 88.2% and averaging 72.9%. Interestingly, students who said they liked the notifications were more likely to benefit from them. For these students, notifications had a positive affect on correctness ($F_{1,3} = 85.62$, $p = .07$) (see Figure 5).

In terms of the different strategies that students use for distributing their visual attention, we observed that students who gathered information from multiple sources tended to do better on the content questions. For instance, the frequency that the students looked at the slides had a positive effect on their score ($t(5) = 9.97$, $p < .0001$). This is especially interesting considering that only 2 of the 39 total questions contained information found only on the slides.

6.5 Discussion

Reactions to ClassInFocus were very positive. The statement "ClassInFocus would be a valuable tool in the classroom" received an average rating of 4.7 ($SD = 0.5$) between "4-Agree" and "5-Strongly Agree" and "ClassInFocus would be a valuable study tool after class" received an average rating of 4.4 ($SD = 0.8$). All participants liked the layout flexibility and some commented on the benefits of having both sign language and captions. For example, one participant offered "It has high potential for use, especially in information-heavy courses, such as science and engineering."

Our participants had different visual strategies, some appear to be more successful than others. We noticed a correlation between looking strategies and preference for our visual notifications. We also noticed a correlation between these strategies, preferences, and ability to answer content questions. Students who liked the notifications and thought they were helpful were also more likely to take advantage of them during the lecture. In fact, these students did consistently better on test questions when notifications were provided.

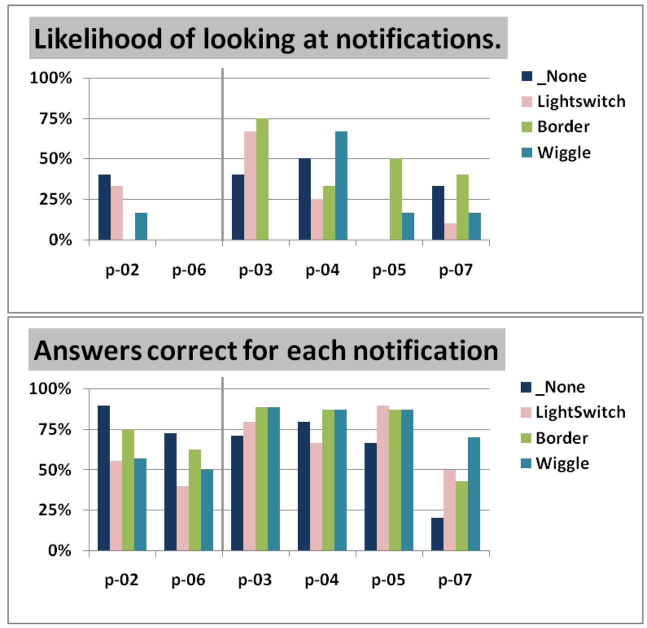


Figure 5: Participants who liked notifications were more likely to notice them (top) and were more likely to benefit from them (bottom).

For some participants, the notifications also appeared to lighten the cognitive load of deciding where to look. One participant commented, "The Border [condition] significantly reduced worry that I would miss a slide change; when 'no changes' for slides was selected, I would worry that I would miss a slide change."

As for which notification was best, there was no clear winner both in terms of preference and helpfulness. Some participants hated the Wiggle, but for some Wiggle was their favorite. The Lightswitch did not appear to be noticeable enough whereas the Border was rated most favorably. We did not see any significant negative effects of the notification techniques, students either used them or didn't, and students tended to either like them or not mind them.

Based on this study, it appears that gathering information from multiple sources, including slides, improves performance. The notification techniques helped students better distribute their visual attention. Perhaps a longer term use of ClassInFocus would encourage students who are accustomed to primarily focusing on one source to be more aware of classroom changes and improve their visual strategies.

7. CONCLUSIONS AND FUTURE WORK

Deaf and hard of hearing students manage all sources of classroom information visually, an inherently serial process. In juggling the various sources of visual information (instructor, slides, interpreter/captions, classmates, and notes), there are numerous opportunities for missed information when students look at the wrong place at the wrong time.

ClassInFocus reduces visual dispersion by bringing classroom components into one digital screen (while also opening opportunities for remote accommodation, better classroom interaction, and classroom capture). However, simply placing components on one screen is not enough, the visual and cognitive resources required to attend to language-rich information like signing and captions make it difficult to notice changes outside of the current focus of attention. To help better guide students' visual attention, ClassInFocus automatically detects important changes in the classroom and visually notifies students of those changes.

In our study, gathering information from multiple sources resulted in improved student performance on content questions. Not everyone liked the notifications and not everyone benefited from them. But we believe that the correlation between using our notifications and improved performance indicates that notifying students of classroom changes can help them better manage their visual attention during class.

Just as participants exhibited diverse visual strategies, no one notification technique resulted in a preference or performance increase across the board. ClassInFocus addresses this by enabling students to choose which notification technique to use and to set the size and location of classroom components. Personalization is a key approach to best accommodate this diverse group.

Our study was designed to prevent notifications from conflicting with one another; however in live classrooms, multiple notifications could be triggered at the same time. Future versions of ClassInFocus will employ probabilistic techniques for determining when changes should be shown and which should be given priority.

Notifying students of on-screen classroom changes is just one important aspect of a much larger project improving access to mainstream university-level classes for deaf and hard of hearing students. ClassInFocus offers many opportunities for future work. Tools could be developed through collaborative design that better support remote interpreting and captioning, student-driven classroom capture, and peer interaction.

Classroom technology has the potential to improve visual strategies to enable better access to modern classrooms; ClassInFocus represents an important point in this space for deaf and hard of hearing students.

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