
User Attention with Head-Worn Displays

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Abstract

Recently there has been a surge of interest in wearable devices both in industry and academia. This includes the introduction of head-worn devices into everyday life. Head-worn devices have the advantage of containing a screen that is easily seen by the wearer at all times, in contrast with other device screens, which can be hidden in pockets or simply easily ignored. However, during certain activities it can be difficult to get the wearer to notice messages even when presented through head-worn devices. For certain applications, it may be important that the user does not

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miss a particular notification or warning. Not much is known about which methods work best to attract the users' attention in such situations. We describe results from two user studies to determine the best method to catch the attention of a user with a head-worn display.

Author Keywords

Wearable notification cues, mobile attention, head-worn displays

ACM Classification Keywords

H.5.2 User Interfaces.

Introduction

With the increase in prevalence of wearable devices, there has been an introduction of head worn devices intended for everyday use (e.g. Google Glass Sony SmartEyeglass and Microsoft's Hololens). These devices provide a great platform to develop and test applications that require just-in-time information and interactions based on the user's current context [1]. While the opportunities for such applications in wellbeing, learning and decision-making are significant, such applications will only be effective if the user notices the feedback or intervention displayed on the device at the desired moment. Therefore, attracting the user's attention as close as possible to the moment of message delivery is pivotal. In our studies we attempt

to achieve bottom-up, or stimulus driven, attention as it is rapid and acts early [7].

Mobile devices have become increasingly efficient at diverting user attention and interrupting daily activities, so much so that many attempts have been made to make these devices more contextually aware [2][3]. In related work researchers have shown what methods are effective in grabbing user's attention on a mobile device [5]. This paper focuses on the form factor of head worn displays. We describe two user studies that prove a user engaged in certain tasks may miss messages that are presented. We then discuss experiments we conducted that test which method is most effective in attracting the user's attention in the context of head-worn displays.

STUDY DESCRIPTIONS

We conducted two studies - one to show that tasks exists that are sufficiently distracting to cause users to miss notifications on head-worn displays (study 1) and one to determine which types of interventions are better at refocusing user attentions on the notifications during these tasks (study 2).

Study 1

Ten users were asked to perform three activities. Each activity was meant to simulate a common task that a user may be engaged in (computer interaction, conversation and physical activity such as walking). Each task required visual, auditory, or spatial focus to complete the task. During each of these activities a word was displayed on the Google Glass screen accompanied by one of three interventions: (1) auditory cue, (2) visual cue (the screen flashes prior to displaying the message), or (3) no cue. The Google

Glass uses a high-resolution display equivalent of a 25-inch high definition screen seen from eight feet away [9]. However, the display is not directly in line of sight, but slightly above the right eye. Each of these three cues was tested during each of the three activities for each of the ten test subjects. Through this study, we evaluated which activities are the most distracting and what are the most effective and preferred methods when delivering the cues.

STUDY PROCEDURES

Each participant was asked to perform three activities. During each of the activities, three different words were displayed with a 15 second delay in between each word. The participants were not told the words ahead of time and nothing besides the words were presented on the display. Each word was displayed with or without a cue as described in the introduction.

For the first activity, each participant was introduced to a computer game called "FallDown". The game, which was played on a laptop, consists of using the arrow keys to guide a ball down the screen without being trapped as obstacles advance in the opposite direction. The game had no music or sound effects that could distract from the auditory cues used during the experiment. The participant was asked to continue playing until notified to stop by the prompter, which required participants to start a new game when they "died".

During the second activity, participants listened to a series of 8 numbers (single or 2-digit) read aloud and were asked to repeat the series backwards. This continued until all three words were presented.

| | None | Audio | Visual |
|-------|------|-------|--------|
| Task1 | 8 | 7 | 8 |
| Task2 | 5 | 8 | 6 |
| Task3 | 9 | 10 | 10 |

Table 1: Total number of participants able to recall the word given for each test scenario

The final task involved each participant walking back and forth while touching their nose with the hand opposite of the leg that is currently off the ground. The participant was asked to continue walking until enough time had passed for all three words to be presented.

After each activity, the participant was asked how many of the words they observed and could remember. They were also asked which of the cues they found most effective and how they would improve their cue of choice. Additionally, the participant was asked for any additional feedback they could give about the cues. Each participant was asked which method they preferred and if they would improve or change this method in any way.

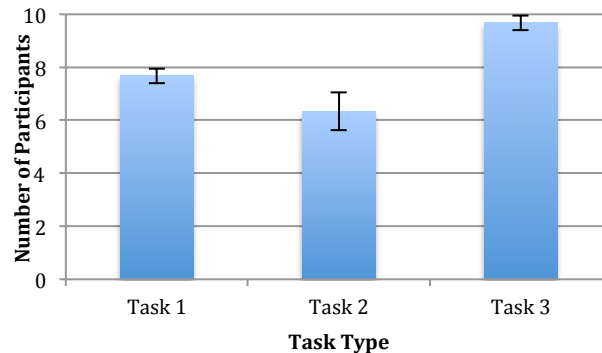


Figure 1: Average number of participants able to recall the given words regardless of cue type

STUDY RESULTS

Figure 1 shows the average number of participants that were successful with word recall regardless of the cue type. We can see that participants had a significant lower recall rate when performing task 2. This led us to use task 2 as the distraction task in the second study.

Figure 2 shows the effect of cue type regardless of the task. While not significant, the data suggests that audio cues are more effective at grabbing attention.

Table 1 summarizes the results from study 1. The conversation activity was the most distracting situation for our participants. During this task, the auditory cue was most effective at regaining the participant's attention. The walking task was the least distracting and had equivalent performance across all cue types. The visual task, task 1, was also not very distracting and participants had similar performance regardless of cue type. Although the tasks were presented in the same order for each participant, we do not feel the high performance during the walking task could be attributed to learned effect or there would be upward trend across the three tasks.

Generally, the auditory cue outperformed not using a cue by 73% and the visual cue by 3%. However, the performance between visual and auditory cues was starker when user preference was taken into account.

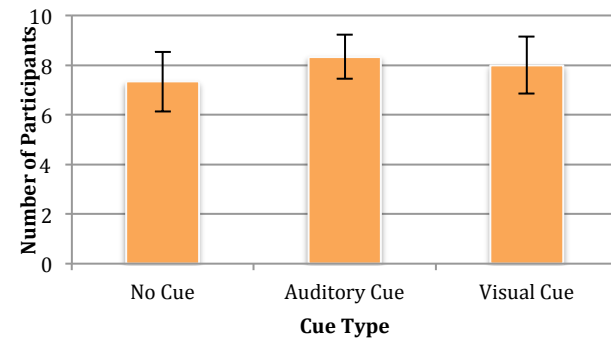


Figure 2: Average number of participants able to recall the given words by cue type regardless of activity type.

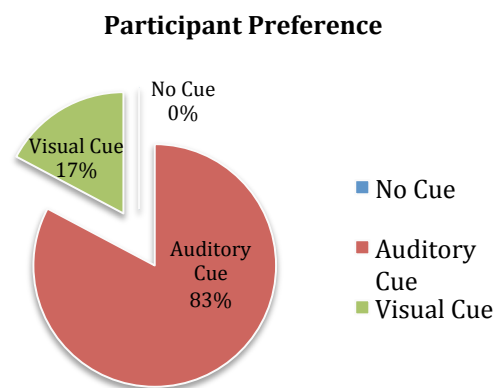


Figure 3: Cue preference

Figure 3 illustrates the overall preferred cue method. Participants, at a drastically higher rate than any other cue or no-cue method, preferred auditory cues.

STUDY DISCUSSION

The information in Figure 1 and Figure 2 indicates that auditory cues may be preferable for displaying just-in-time messages on head-worn displays. Intuitively, visual cues would be assumed to be more effective at grabbing the attention of wearers of head-worn displays. Visual cueing creates a spotlight, which should guide attention faster to the exact location where information will be presented. However, during particularly distracting tasks, wearers tend to look in off screen directions. This could help explain why auditory cues work better in these situations.

Participants also found the visual cues to be “jarring”, producing a jerking pull to attention. This initially goes

against the proven guidelines for cues used on mobile devices where “auditory cues are more public and intrusive in nature while tactile and visual cues may be more subtle and private” [5]. However, the same principle may hold for users of head worn display. In this case audio cues are more private and visual cues are more distracting. The most common complaint of auditory cues was the inability to be heard in noisy surroundings. In these situations it may be better to use a visual cue, however this study focused on normal activities and situations.

Each of the tasks given to the participants were given with limited outside stimuli. All participants were familiar with the environment the study took place in and there were no noticeable visual or auditory cues besides the ones given. We would assume, due to the limited stimuli, that all of the intentional cues given during the study would be perceived and be processed [8]. The low performance during the second tasks suggests that effective cueing is necessary for some task to ensure just-in-time messages are processed.

Study 2

Analysis of the results from study 1 showed that the number series reversal task was the most distracting, and suggested that the auditory cue type is better at getting the user’s attention than the visual cue type or using no cue. To test this further we ran a second study to assess if auditory cues are significantly better than visual cues at grabbing user attention by using a larger participant pool.

Study Procedures

In the second study, 30 subjects were asked to perform the number series reversal task while wearing Glass. During the activity five words were presented, each preceded by either a visual or auditory cue (identical to the cues from the first study), where each subject was only exposed to one type of cue – assigned randomly. After all five words were displayed the user was asked how many words they think were displayed in total and which words they could recall.

STUDY RESULTS

Based on the results from study 1, we wanted to verify that auditory cues would be more effective in situations that required focused attention, since these tasks incur a higher chance of displayed messages not being noticed. In figure 4 we can see that when using an auditory cue, significantly more words are remembered than when visual cues are used $p = .043$. Subjects belonging to the auditory cue group notice nearly twice as many words on average.

It is also interesting to note the difference in performance when participants were asked the number of words they thought were presented. The average number of words, from the 5 presented, that students thought were presented, regardless of whether if they could remember each word was 3.23 for participants given audio cues versus 2.4 for participants given visual cues.

STUDY DISCUSSION

From Figure 4 it is clear those participants who received the audio cues outperformed or did as well as participants given the visual cue. Figure 5 shows that auditory cues also outperformed visual cues when participants were asked how many words they thought

they saw. While this result was not statistically significant it shows that participants saw more words than they could remember. This suggests that audio cues outperform visual cues when attempting to break attention and shift focus.

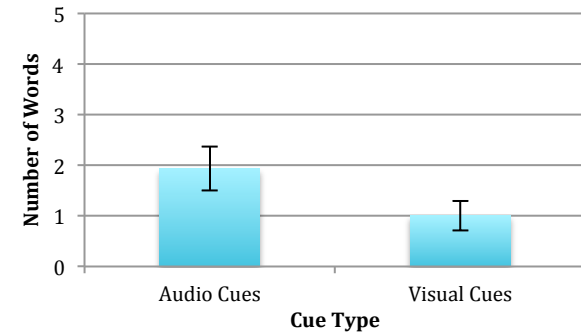


Figure 4: Average number of words remembered by participants by cue type.

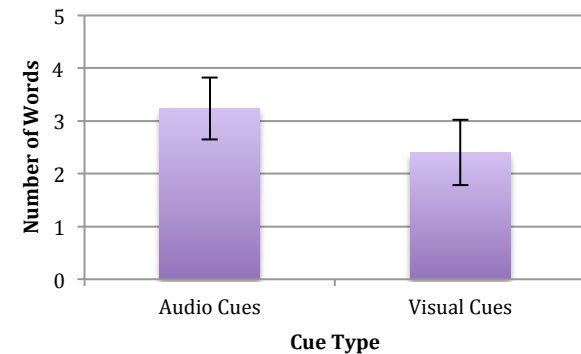


Figure 5: Average number of words participants thought they saw by cue type

Discussion

Development for this study was done using Wearsript [6]. The software causes a slight flash of the screen from black to white when cards are added. This flash is significantly shorter than the intentional flash and only occurs once. If this effect aided in attention grabbing we would not expect a significant increase in performance when using the auditory cue that we observed.

Future work could investigate the use of multi-modal cues. As [2] notes, for mobile cues it is advantageous "to avoid social misinterpretations as well as the problem of attention overload, it is desirable to design notification cues which combine the qualities of being subtle and public" [2]. Other future work could dynamically vary the cue used based on the task of the user as well as the context. For example, in a noisy context, a visual cue could be chosen.

Conclusion

In this study we evaluated different ways to attract the attention of a user of a head-worn display. As head worn displays become more common for work and everyday activities, it becomes necessary to find the most effective ways to display just-in-time messages to users. For wrist or waist worn wearables, it makes sense to duplicate the methods used for mobile devices. However for head-worn displays, visual cues may be assumed to be a more logical choice due to the location of the screen. This study has shown that auditory cues are actually a more effective and preferred design choice in distracting situations. Further work can be done to determine the best way to use both cue methods and when to switch between visual

and auditory cues to ensure fluid interactions for the user without producing harsh alerts.

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