Mitigating the Effects of Interruptions and Task Switching using Blink-Based Interfaces

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Abstract

A popular topic in HCI research has been the desire to implement technologies that present users with the ability to manipulate and interact with UI elements without the use of their hands. Technologies such as voice commands have become a ubiquitous staple in current technologies, such as Apple's Siri and Microsoft's Cortana. Continuing on previous work, we will be using an EEG blink-based interface to present users with a "third hand" in order to manipulate UI elements by dismissing and recalling popups. We will benchmark this interface against traditional "mouse-and-click" interfaces.

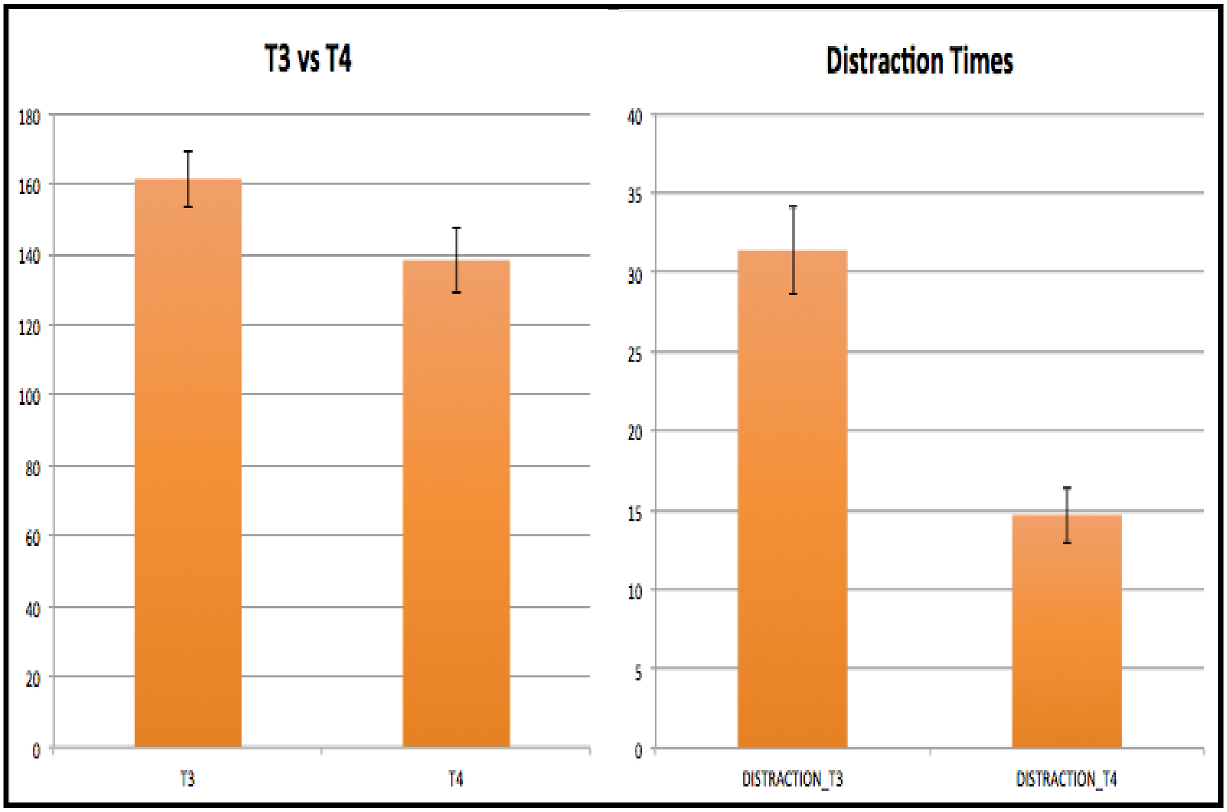

Fig. 1. The above charts show the relative performance between T3 (mouse-and-click interface) and T4 (blink-based interface) when performing a task that includes sorting quotes and attending to a popup notification.

Keywords: EEG, EOG, Third-Hand, Task Switching, Interruptions, Human-Computer Interactions (HCI)

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I. Introduction

A. Problem Statement

A well known issue in computing has been the intteruptive and distractive nature of popups and notifications. Notifications and popups stemmed from a desire to allow users to be alterted of events and information apart from the task at hand. This was widely regarded as a way to improve multitasking and overall awareness of secondary tasks. However today, these constructs have become more and more aggressive, resulting in popups that envokes actions rather than being passive informational popups. For instance, a popup that informs you that you have email is functionally different than an email that informs you of a specific email and then prompts you to respond to that email. The latter, more distractive type of popup is the user experience model we set out to improve.

B. Motivation

As detailed in the problem statement, there are a class of UI elements, namely popups and notifications, that have evolved into task-generating entities. Popups are no longer simply informational, they present a bridge to a secondary task that supplants what the user is currently doing. Often users either respond immediately to the popup (because they believe that the popup will expire), or they ignore/dismiss the popup (resulting in the secondary task being lost indefinitely). As useful as these notifications may be, they present a serious distraction. Currently, most desktop OSes use traditional mouse-and-click methods to interact with popups. This results in a situation where, upon notification, the user has to disengage their main, primary task in order to attend to the task by moving the mouse if they choose not to ignore it completely.

For instance, Checkerplus is a chrome plugin that gives you Gmail notifications in the bottom right corner. However, the plugin beeps on each message and begins reading out the message as default behavior, resulting in a notifcation that actively envokes a secondary task.

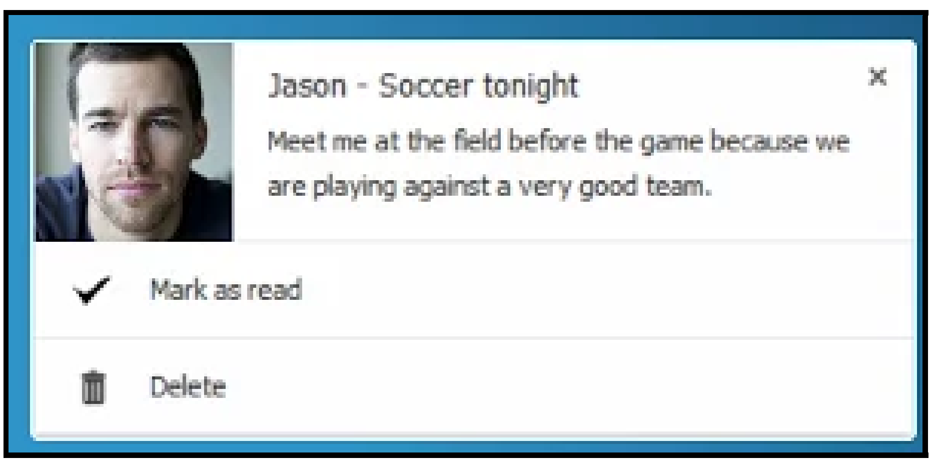


Fig. 2. Screenshot of Checkerplus notification. Note that, in order to dismiss the notification, you must select the “X”, “Mark as read”, or “Delete”. Image Courtesy: Checkerplus

Thus, we are motivated to develop hands-free methods to interact with computers that allow us to continue working on or minimally interrupt primary tasks.

C. Related Work

1) Czerwinski Studies:

In the early 2000s, Microsoft Research Labs took a close look at the effects of instant messaging interruptions on computing. Their studies found that when a person is interrupted during the "evaluation phase" of a task, the total completion time was significantly longer than in other phases.[1] They also found that interruptions that were irrelevant to the task being performed resulted in longer task resumption times.[1]

Boiled down, they found that humans are generally poor task switchers when they are in the middle of performing a task, as it requires the person to make a decision on how best to prioritize this new task, which results in a loss of place of the primary task. If the secondary task is significantly different than the task they are performing, they struggle returning to the primary task because they have flushed the working memory of the primary task in performing the secondary task.

Thus, in developing a "third-hand" tool, we must keep these findings in mind that whatever our tool may be, it must aid in task scheduling in a way that does not severely impact the user's working memory and allow the user to proceed to the secondary task when they deem fit or reach a natural pause.

In addition to distraction studies, there are a few interesting, relevant developments in the Human-Computer Interfaces (HCI) field that fall within the scope of our research. These state of the art inputs present methods to control computer interfaces without the use of a direct input, such as a mouse, keyboard, or touchscreen.

2) Skinput:

Skinput is a technology co-developed by the HCI Institute at Carnegie Mellon University and Microsoft Research Labs. Skinput uses the human body as an acoustic source which permits the skin to be used as an input surface. [2] By analyzing the vibrations that propagate through the body upon the tapping of fingers, they are able to provide an always-on input system.

Fig. 3. The Skinput uses an armband to collect its acoustic input. Image Courtesy: Microsoft Research

However, one of the limitations of the Skinput system is that it still requires tapping or touching. For instance, a user would need to tap a table, a wall, or their own body in order to make an input. However, since the user may already be engaging motor functions, such as typing or moving a mouse, in order to control the Skinput, they would need to disengage whatever typing they are doing on a physical input tool to provide input to the Skinput. This may not be the best third-hand tool for mitigating the effects of interruptions.

3) EMG Control:

The next interface we looked at was a Muscle-Computer Interface developed by the University of Washington, Microsoft Research Labs, and the University of Toronto. The system uses Electromyography (EMG) in order to classify finger gestures as a method of producing an always-on input. [3]The team developed six different grasps (spherical, cylindrical, palmar, tip, lateral, and hook), which allowed them to control a portable music device.

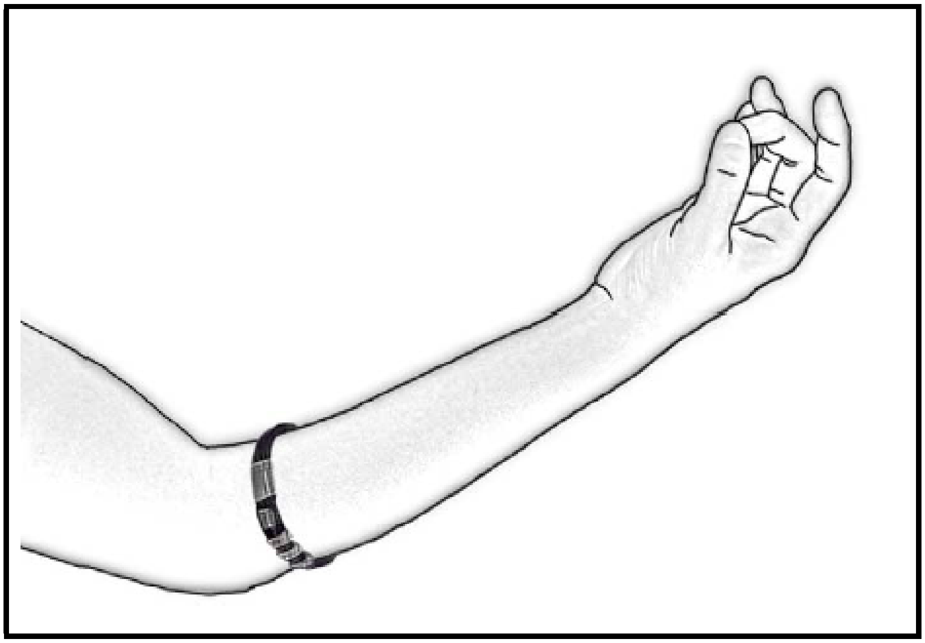


Fig. 4. This is an artist's rendering of the armband that would be used to collect EMG signals. Image Courtesy: Microsoft Research

However, one of the limitations of this system, as discussed in the paper, comes from this system developing its own ”Midas Touch” like issues. Scenarios, such as carrying groceries, may engage the system by triggering one of the classifications (hook in this case) and would provide a miscue to the device receiving input from this system. Since we desire a device that is robust to these unintentional inputs, the EMG method falls short. We do not want to invoke or dismiss popups accidentally in our system, as it would lead to greater distractions if the user had to fiddle with the device.

D. Potential Users

1) Users who wish to attend to secondary tasks without dismissing primary ones:

A potential user for this blink-based task scheduling system would be someone who is entirely focused on their primary task but still would like to attend to secondary tasks without having to disengage primary input methods from the primary task. For instance, if someone were to receive an email notification while typing in Microsoft Word, they would like to respond to the email with a macro, pre-written message, without moving their mouse and using their keyboard to issue such a command. A popup would listen in for a specific command, such as double blink for a standard, “I am busy right now” message.

2) Users who wish to enable a "snooze" function for notifications:

A second type of potential user would be someone who is interested in using a blink-based interface as a "snooze" button. This type of user is still interested in receiving notifications, but often times notifications come at the wrong time for this user. This user happens to also forget about their notifications after dismissal. Thus, an ideal situation for such a user is, upon notification, a blink initiates a snooze on the notification such that the notification returns when the user requests the notification back with another blink (or after a preset time).

II. METHODS

A. Participants

We had 16 (8 male, 8 female) intermediate to advanced users of Microsoft Office, ages 18-23 participate in the study. Participants were compensated in approximately 2-6 chocolate-chip cookies.

B. Equipment and Setup

1) Data Acquisition Devices:

Data acquisition for these experiments was done by a Neurosky MindWave Mobile. The MindWave Mobile's active electrode was wiped before each trial to ensure proper contact. Since we are using a dry electrode, participants were not required to use a moistened paper towel to clean their forehead prior to wearing the device. A 1.5V AAA lithium-ion battery was used to power the device. The battery was checked prior to each experiment trial to ensure the device provides proper readings.

2) Data Acquisition Software:

Data acquisition for these experiments was done via the OpenVibe platform. The OpenVibe Acquisition Server was configured to use the Neurosky Mindwave Mobile via Bluetooth and the device was set to a sampling rate of 512Hz. The Acquisition Server was also configured to include a 2ms drift correction.

3) Data Processing Software:

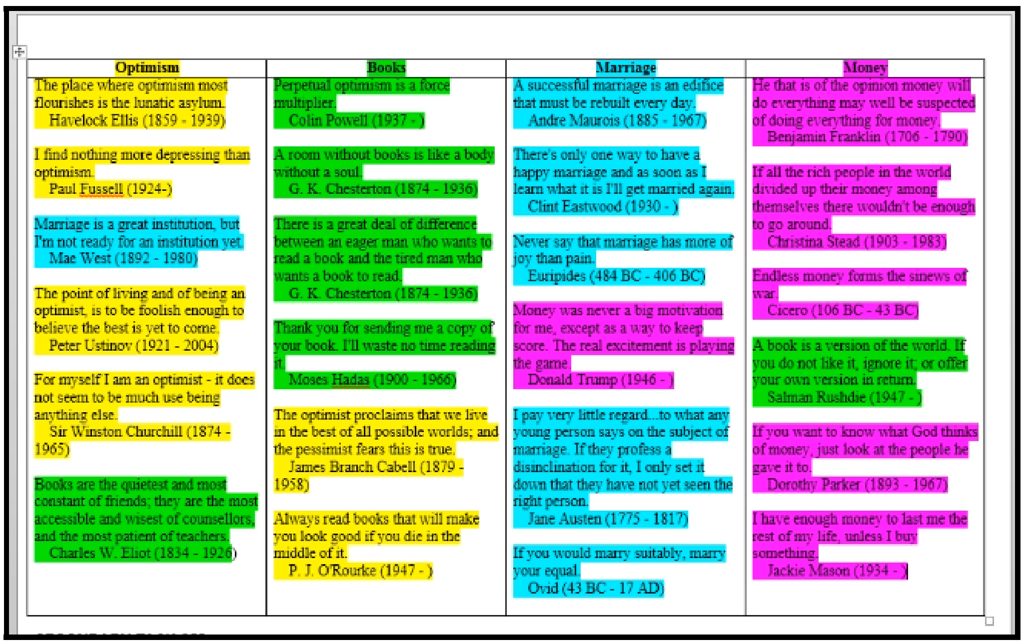
The data processing was done in both the OpenVibe 17.0 Design Studio and MatLab 2013b 64-bit. OpenVibe 17.0 needed to be run in compatibility mode within Windows 7 64-bit in order to run properly.

4) *Data Processing Hardware:*

Data processing was performed on a Lenovo ThinkPad W520 running Windows 7 64-bit equipped with a Quad-core Intel Core i7, 20GB of DDR3 RAM, and a 128GB SSD. CPU utilization was primarily single-threaded and required 100% utilization of a single core while using both OpenVibe Design Studio and MatLab. Memory usage hovered around 0.4GB during acquisition and processing. Hard-disk utilization was around 400KB for 35 seconds of data recording per stream. A 4GB RAMDISK was created to speed up CSV I/O between OpenVibe and MatLab.

C. Procedure

The study was comprised of 4 distinct tasks. Each task included a quote sorting task as a primary task, which involved a list of quotes that needed to be sorted into one of four categories via highlighting in Microsoft Word 2013. Some tasks (3 and 4) included a secondary task delivered via popup with different methods of interaction.



Optimism	Books	Marriage	Money
The place where optimism most flourishes is the lunatic asylum. Havelock Ellis (1859 - 1939)	Perpetual optimism is a force multiplier. Colin Powell (1937 -)	A successful marriage is an edifice that must be rebuilt every day. Andre Maurois (1885 - 1967)	He that is of the opinion money will do everything may well be suspected of doing everything for money. Benjamin Franklin (1706 - 1790)
I find nothing more depressing than optimism. Paul Fussell (1924-)	A room without books is like a body without a soul. G. K. Chesterton (1874 - 1936)	There's only one way to have a happy marriage and as soon as I learn what it is I'll get married again. Clint Eastwood (1930 -)	If all the rich people in the world divided up their money among themselves there wouldn't be enough to go around. Christina Stead (1903 - 1983)
Marriage is a great institution, but I'm not ready for an institution yet. Mae West (1892 - 1980)	There is a great deal of difference between an eager man who wants to read a book and the tired man who wants a book to read. G. K. Chesterton (1874 - 1936)	Never say that marriage has more of joy than pain. Euripides (484 BC - 406 BC)	Endless money forms the sinews of war. Cicero (106 BC - 43 BC)
The point of living and of being an optimist, is to be foolish enough to believe the best is yet to come. Peter Ustinov (1921 - 2004)	Thank you for sending me a copy of your book. I'll waste no time reading it. Moses Hadas (1900 - 1966)	Money was never a big motivation for me, except as a way to keep score. The real excitement is playing the game. Donald Trump (1946 -)	A book is a version of the world. If you do not like it, ignore it; or offer your own version in return. Salman Rushdie (1947 -)
For myself I am an optimist - it does not seem to be much use being anything else. Sir Winston Churchill (1874 - 1965)	The optimist proclaims that we live in the best of all possible worlds; and the pessimist fears this is true. James Branch Cabell (1879 - 1958)	I pay very little regard...to what any young person says on the subject of marriage. If they profess a disinclination for it, I only set it down that they have not yet seen the right person. Jane Austen (1775 - 1817)	If you want to know what God thinks of money, just look at the people he gave it to. Dorothy Parker (1893 - 1967)
Books are the quietest and most constant of friends; they are the most accessible and wisest of counsellors, and the most patient of teachers. Charles W. Eliot (1834 - 1926)	Always read books that will make you look good if you die in the middle of it. P. J. O'Rourke (1947 -)	If you would marry suitably, marry your equal. Ovid (43 BC - 17 AD)	I have enough money to last me the rest of my life, unless I buy something. Jackie Mason (1934 -)

Fig. 5. Above is a screenshot of an example quote set after being solved via highlighting. Each optimism-related quote is highlighted in yellow, each books-related quote in green, etc.

1) *Task 1:*

Task 1 was a practice trial to get the users more familiar with the task. In particular, users may not be intimately familiar with the Microsoft Office platform, especially Word 2013. Additionally, it became immediately clear that Mac users were particularly uncomfortable using a Lenovo ThinkPad trackpad, which may have hindered initial performance. Task 1 only included quote sorting. It did not include any secondary tasks.

2) Task 2:

Task 2 was another practice trial in order to establish a baseline speed after the task was performed an initial time. Additionally, Task 2 allowed users to develop strategies in sorting quotes and gain a larger sense of comfort with the laptop they were using to perform the experiment. Task 2 only included quote sorting (although the participant was given a different set of quotes and categories). Task 2 did not include any secondary tasks.

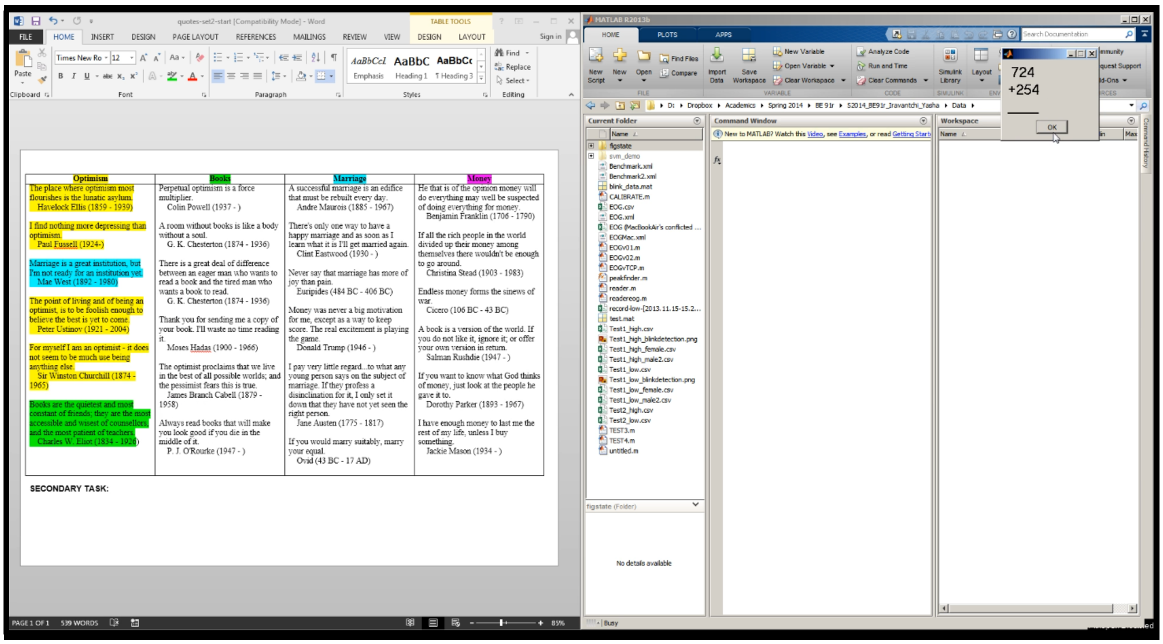


Fig. 6. Above is a screenshot of when a secondary task pops up in Task 3/Task 4. In Task 3, the user must interact with the popup solely via mouse-and-click. In Task 4, the user may choose to minimize/dismiss the popup via blinks.

3) Task 3:

Task 3 was a session in which, similar to Task 1 and Task 2, the participant was given a quotes sorting task. However, in Task 3, the participant was presented with an interruption. The interruption was presented using a popup generated by MatLab. The popup included a math problem (the addition of two three-digit numbers). This popup could be dismissed and retrieved using standard Windows conventions. The popup also included an “OK” button, which was to be pressed after the math problem was solved.

However, in order to ensure that this popup was attended to, participants were informed that from the moment the popup appeared, they had 10 seconds to either minimize the popup or solve the math question. If they failed to attend to the popup, they were greeted with a buzzing alarm sound. Additionally, in order to deter participants from hitting the “snooze” button and continually dismissing the task, the task would “expire” after 30 seconds after the initial popup, resulting in a buzzing alarm sound.

4) Task 4:

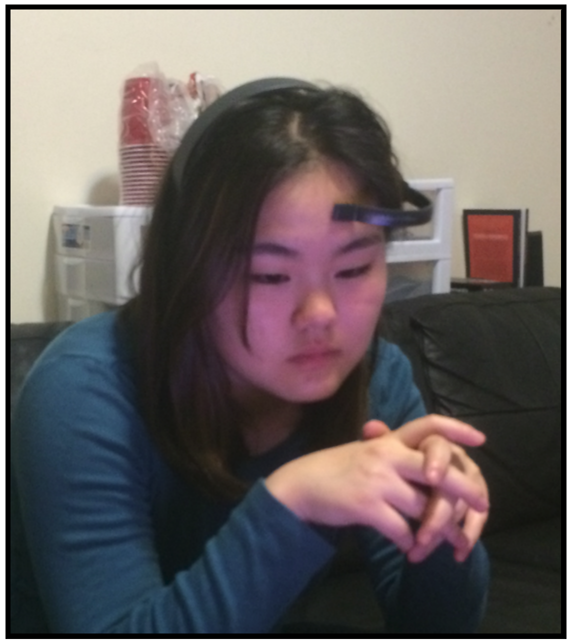


Fig. 7. In Task 4, the participant wears a Neurosky Mindwave Mobile to register blinks.

Task 4 was functionally similar to Task 3, with the exception that the popup was able to be interacted with with a blink-based interface developed in a previous 91r project. Prior to the start of Task 4, participants were asked to wear a Neurosky Mindwave Mobile. The Mindwave Mobile was connected to the laptop via a bluetooth connection, and the data was acquired using OpenVibe and processed by MatLab. The participant was asked to look forward for 25 seconds and blink freely. After 25 seconds, the participant was asked to make intentional blinks. This step calibrated the blink-based system to the participant. The user was then informed that a popup with similar behavior to the one in Task 3 would appear in Task 4. However, in Task 4, if the user made an intentional blink, the popup could be dismissed or retrieved. If the user has decided to solve, the user would still have to press the "OK" button. The user was presented with the same set of deterrents.

It is important to note that Task 3 and Task 4 were interchanged such that 50% of participants were presented with Task 3 first and the other 50% were presented with Task 4 first. In addition, the quote sets were distributed randomly among all the participants such that the order of the sets were not preserved between subjects.

III. RESULTS

In the study, we measured the total times for Tasks 1, 2, 3, and 4. In addition, in Tasks 3 and 4, we used a screen capture software (CamStudio) to record the participant performing the tasks. In those studies, we recorded the total time the participant spent on the primary task in addition to the the number of times the participant dismissed the popup and whether they were able to complete the secondary task correctly. We then were able to calculate the amount of time the participant was "distracted" by subtracting the time that was spent on the primary task from the total time.

We began by first determining the mean, standard deviation, and standard error for the total times of Task 1, Task 2, Task 3, and Task 4. It seems that, judging strictly by the mean, there

TABLE I
THE FOLLOWING TABLE SHOWS RELEVANT STATISTICS FOR T1,T2,T3, AND T4.

Statistic	**T1 (s)**	**T2 (s)**	**T3 (s)**	**T4 (s)**
Mean	169.25	139.94	161.40	138.3
Standard Deviation	53.91	58.71	32.52	37.31
Standard Error	13.48	14.68	8.13	9.33

is about a 23 second improvement of Task 4 (EEG) over Task 3 (mouse-and-click).

Using the screen capture videos, we were able to determine the total time spent on the primary task. We define this by only counting the time in which the mouse is in motion over the left half of the screen, as seen in Figure 6. We then define distraction time as the total time minus the time spent on the primary task. This includes the time spent on the secondary task in addition to any overhead resulting in the mouse not active over the left half of the screen. We also used the screen capture to record the number of times the popup was dismissed.

TABLE II
THE FOLLOWING TABLE SHOWS RELEVANT STATISTICS FOR THE PRIMARY TASK (PT) TIMES AND DISTRACTION TIMES FOR T3 AND T4, INCLUDING DISMISSES.

Statistic	**T3 PT (s)**	**T3 Distraction (s)**	**T3 Dismissal (no. of times)**	**T4 PT (s)**	**T4 Distraction (s)**	**T4 Dismissal (no. of times)**
Mean	130.00	31.38	0.38	123.63	14.69	1.88
Standard Deviation	37.54	10.97	0.60	40.24	6.94	0.93
Standard Error	9.39	2.74	0.15	10.06	1.74	0.23

It is interesting to see that the distraction times in Task 3 are almost 17 seconds greater, and the average number of dismissals in T3 was 0.38 compared to 1.88. This suggests that it may require less effort to dismiss using the EEG interface, resulting in more dismissals with better timing.

Lastly, we performed a Paired T-Test on both the total times and distraction times in addition to performing a Wilcoxon Test on the number of dismissals.

TABLE III
THE FOLLOWING TABLE SHOWS THE RESULTS OF STATISTICAL ANALYSIS DONE ON T3 VS T4 AND THEIR DISTRACTIONS AND DISMISSALS.

Statistic	**T3 vs T4 Total Time**	**T3 Distraction vs T4 Distraction**	**T3 Dismissals vs T4 Dismissals**
Paired T-Test (2 Tails)	$1.27 * 10^{-5}$	$1.39 * 10^{-4}$	N/A
Wilcoxon Test	N/A	N/A	0.01

With values less than 0.01 for each test, we reject the null hypothesis and determine that there is a significant difference between mouse-and-click methods and EEG blink-based methods.

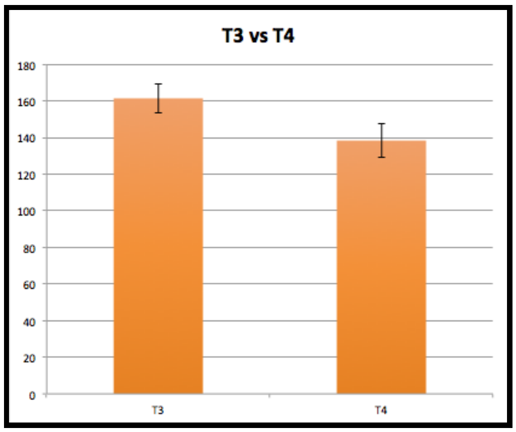


Fig. 8. This chart shows the mean total time required to perform Task 3 vs Task 4.

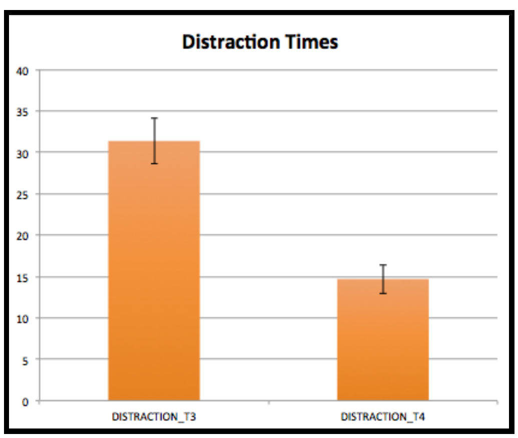


Fig. 9. This chart shows the mean distraction time when performing Task 3 vs Task 4.

IV. Discussion

There are two possible explanations, or a combination of the two, as to why blink-based methods outperform traditional mouse-and-click methods. The first of which relies upon the amount of effort involved, as effort involved to initiate a blink is trivial compared to that of moving a mouse over to the correct spot, then pressing click. The second involves whether working memory is engaged or disengaged by the secondary task.

A. Effort Involved

If simply the effort involved is what governs the speed at which a person can schedule tasks, it reduces the problem to a trivial one where the interface that requires the least amount of effort wins. However, we know this is not the case. For instance, although touch screens require much less effort to manipulate UI elements compared to mice, unless the UI is specifically geared towards touch interfaces, a mouse would still be faster in completing tasks by being a more accurate method. Thus, although effort plays a factor in the speed to which a user can interact and dismiss tasks, it does not paint the whole story.

B. Working Memory

It may be also that, by using a blink-based interface, the user does not disengage their working memory dedicated to the primary task in order to attend to the secondary task. It may also be that their working memory is dedicated to performing a specific motor skill. For instance, if a popup was displayed and a touch interface was present, the user would have to lift a hand to dismiss the task. Although this may be faster than a mouse, it would not be faster than a blink-based interface because the participant does not have to stop their manual task in order to attend to the secondary task. Thus, possibility could be that by using a blink based interface, the user does not have to disengage their primary task unlike other interfaces.

V. Significant Challenges and Pitfalls

A. Google Glass XE16.1 Update

Originally, we intended on deploying notifications via Google Glass. It seems like a general trend in computing is moving towards wearables, such as smart watches and smart glasses, so it made sense to see the effects of notifications, especially since these devices require hand gestures when voice commands cannot be used, such as in a crowded room. However, Google pushed an update, XE16.1, which bricked our Glass device.[4] Thus, we were unable to receive a replacement device in time to perform the studies for this paper.

B. Realtime CSV Read

Mentioned in a previous paper, we use the OpenVibe software package to interface our EEG headset with MatLab. However, their TCP package is in alpha and is unstable, so we opted to use CSV file output for MatLab to parse. A significant challenge arose when we wanted to decrease the latency between blinks and UI manipulation. When using a SATA3 SSD, the latency between blink and action was about 1 second.

Using a computer with large amounts of RAM, we were able to create a ramdisk in which OpenVibe could write to and MatLab could read from. However, this led to another challenge in that previously, since standard hard disk operations are read over write (ROW), we were reaching the end of the file in MatLab faster than OpenVibe was able to write out the data. Thus, we had to artificially slow down MatLab's read by first reading the size of the CSV, then only reading in everything but the last 2 rows (giving the system .002 seconds extra time). We decreased the latency between a blink and an operation to less than a tenth of a second.

C. CamStudio Codecs

When we first began recording videos for Task 3 and Task 4, we were using the default Microsoft Video codec. However, these codecs were lossless codecs that resulted in 20GB+ worth of videos for each participant. Thus, for the first 14 subjects, we had to overwrite the videos for each session.

However, we later were able to find a compatible H.264 codec that would work (in realtime) with CamStudio, resulting in much smaller filesizes.

VI. Future Work

We would like to further the work developed by pairing a EEG blink-based interface to an eye-tracker interface. Currently, eye-trackers have challenges regarding blink differentiation, but they do provide greater functionality as they can determine if the user is looking on screen and where they are looking. A combination of dwell and blink may have interesting possibilities.

VII. Conclusion

In conclusion, in this semester-long 91r project, we were able to produce a blink-based interface that surpassed current mouse-and-click methods. Our study demonstrated both a compelling application developed in a previous 91r project in addition to its usefulness as a future method for UI manipulation. We conclude that, for simple tasks such as dismissal and retrieval, blink-based interfaces are superior to mouse based interfaces as they seem to have less negative impact when it comes to distraction.

VIII. Acknowledgements

We would like to thank Professor Krzysztof Gajos for his advice and guidance. We also would like to thank the Harvard School of Engineering and Applied Sciences Undergraduate Teaching Labs for provisioning the Olimex OpenEEG device.

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