Interruptions as Multimodal Outputs: Which are the Less Disruptive?

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Abstract

This paper describes exploratory studies of interruption modalities and disruptiveness. Five interruption modalities were compared: Heat, Smell, Sound, Vibration, and Light. Much more notable than the differences between modalities was the differences between people. We found that subjects' sensitiveness depended on their previous life exposure to the modalities.

Individual differences greatly control the effect of interrupting stimuli .We show that is possible to build multimodal adaptive interruption interface, such interfaces would dynamically select the output interruption modality to use based on its effectiveness on a particular user.

Keywords

Interruption modalities, interface design, modalities of interaction, multimodal interfaces, self-adaptive interfaces.

1. Introduction

Even though past work provides evidence that there are substantial advantages in efficiency by using multimodal interfaces [1][9], its main focus is on combining input modalities – such as speech, pen, touch, hand gestures, eye gaze, and head and body movements– rather than using multimodal outputs. Furthermore, these interfaces are not taking advantage of the fact that humans have extraordinary sensing capabilities, which are in use all the time.

Traditional human computer interfaces found in desktop computers focus only on a small number of modalities to interact with users. Sound and visual are the most often used modalities for conveying information; generally ignoring important modalities such as olfactory, and tactile [5]. According to Srinivasan [11] from the touch lab at MIT, despite the progress made in the pass two decades in the area of haptic interfaces, these interfaces have not yet become widely used in human computer interfaces.

In order to demonstrate the benefits of using other perceptual channels into current computer interfaces, this work explores the use of ambient displays in the context of interruption. Computers gain the ability to communicate with users through additional channels by using multiple modality ambient displays. This ambient displays act as an external interruption generator designed to get users' attention away from their current task. Human computer interaction can be greatly improved by using multimodal outputs and its interruptions effectively.

1.1. Interruptions

The use of interruptions is a key issue in the design of human-computer interfaces. Observational studies in the workplace show that the recipient of an interruption benefits 64% of the time from being interrupted. However in 40% of the cases, the recipients of an interruption does not resume the task they were doing prior to the interruption [8]. Studies investigating the effect of interruptions in highly abstract processes, such as software development, show that interruptions significantly reduce a developers' efficiency [13]

People's work styles vary; some choose to work on one thing for a long time, while others cast around constantly. Interruptions affect everyone so that people that like to work on one thing for a long time will often choose a quiet calm venue to do it. We now know that interruptions are inherent in the way people work.

Advances in computer technologies have enabled the creation of systems that allow people to perform multiple activities at the same time. Interruptions are common to today's multitasking computing user interface experience. This kind of multitasking environment is useful and might seem natural, however it also introduces the side effect of causing people to be interrupted constantly. For instance,

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some researchers have examined interruptions by looking at when to interrupt users in a multitasking environment [6].

Timers have been available and useful for people as reminders or as alarms. Sound, light and vibration are commonly used as means for getting someone's attention. Today's thermostats allow the changing heat in people's houses to wake them up. However, smell and heat have rarely been used as modalities for interruption. Heat has several limitations, such as slow rate of appearance for some cases, and high-energy consumption. Smell is "noticed" with very different mechanisms than other modalities but has a better rate of appearance and a broader range of intensities than heat. Despite the disadvantages of smell, several companies have developed products that generate smell and hope to use it as a media for communication [5]. Currently, sound is the most frequently used interruption modality, disrupting everyone near by. Auditory interruptions have been tested extensively; whereas, heat and smell have not been tested as much.

Gillie et al [2] showed that the length of an interruption does not affect how disruptive it is. Their work allows us to compare five interruption modalities even though they are of different nature. Our goal is to find the modality that is the most effective while being the less disruptive, i.e. reducing the time a person needs to get back to the task she was doing.

1.2. Ambient Displays

In ambient displays information is moved off the screen in a way that makes use of the entire physical environment as an interface for information [15]. One example is the representation of activity by a pattern of illuminated patches projected onto a wall [4]. Ambient displays seek to present information in the modality and form that can be interpreted with minimal cognitive effort. In the presentation of ambient media, one of the key elements is the modality chosen to present information.

This study explores the use of ambient displays in the context of interruption. Looking to demonstrate the benefits of using other output channels into current computer interfaces. An interface of this kind communicates with users through several channels by using multiple ambient displays as external interruptions. These interruptions are presented in the form of heat, light, smell, sound and vibration. Ambient displays will serve a purpose other than the mere presentation of information—they will serve as a media for interruptions.

2. Experiment Description

This exploratory experiment measures the performance of subjects in a task interrupted with five modalities of interruptions: heat, light, smell, sound, and vibration. The test is run without interruptions in order to have a comparison basis. The task used in the experiment combined reading passages and counting backwards. Performance was defined as a combination of the ability to answer comprehension questions and reading speed. The experiment exploits the fact that people have selective memory relative to interruption: users are able to recall details of an interrupted task better than the details of an uninterrupted task [12]. It uses a dual-task that provokes the kind of human errors associated when being interrupted.

2.1. Method

Participants performed a mentally demanding task for approximately twenty-five minutes and were interrupted by five modalities in a random sequence. The order of interruptions varied randomly for each subject. "No interruption" periods were also randomly introduced when performing the task. Performance in the complex task without interruptions served as the baseline to compare to the reading performance with interruptions condition. After the end of each section, memorability was measured by a comprehension test about the section read. Two dependent measures were collected for each participant: 1) number of correct responses in the comprehension test, 2) reading speed. Performance was defined as a combination of this two measure and effectiveness was defined as the time taken by the user to acknowledge an interruption, also identified as reaction time. Disruptiveness was defined as a subjective measure of interruptibility caused by a modality in a current task.

2.2. Participants

Twelve native English speaking graduate students from MIT Media Lab (eight males and four females with ages ranging from 22 to 34 years) were tested. Subjects with similar performance were selected after a reading and comprehension pre-test.

2.3. Materials

A Windows application running on a desktop computer, that interactively displayed text from Jules Verne's novel; Around the World in 80 Days, and allowed participants to start and finish whenever they wanted, see *Figure 1*. The text at each section consisted of about 300

words. Devices used to generate the interruption for each modality, see *Figure 2*:

Heat – Ceramic infrared heat lamp aimed at the user's hand; controlled by the computer using x10 technology.

Smell – An atomizer and air absorber directed from behind a wall towards the subject used to deliver scents to the user. Elmer's glue and soy sauce were used as odors.

Sound – A phone ring sound file played by the computer.

Vibration – A vibrating device placed under the chair on which the subjects sat. The experimenter controlled the device using a potentiometer.

Light – Three spotlights also controlled by a potentiometer direct light to the back of the screen on both sides of the participant.

2.4. Procedure

Research has shown that interruptions that are similar to the primary task are very disruptive during the first trials, but are significantly less disruptive by the third session [3]. Therefore the experiment compensated for users' habituation by asking participants to perform two practice exercises to make them familiar with the task. Subjects were blinded to the hypothesis and goals of the study. They were told that they would be tested about their reading performance in order to force them to read carefully. The first practice part was done without interruptions and the second one used all the interruptions modalities to make subjects acquainted with all the interruptions they could expect.

Subjects were instructed to acknowledge each interruption by double-clicking on an icon on the screen. At the end of each section, subjects were asked multiple-choice reading comprehension questions about the text they read. Testing software recorded reading speed and answers to the questions. After the experiment ended, subjects were asked to rank all interruption modalities by their disruptive level from a most to least order.

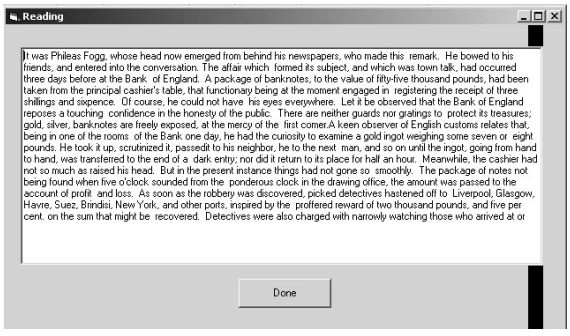

Figure 1. Easy to use interface allows subjects to read text in experiment

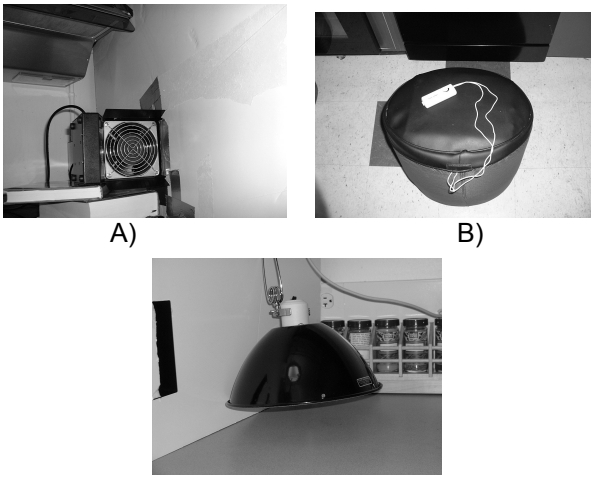

Figure 2. Devices used to generate interruptions. A) Air absorber for smell interruption. B) Vibrator placed under the seat for vibrating interruption. C) Infrared heating lamp for heat interruption.

2.5. Results

Interesting data came from the survey applied to users, which indicates the modalities ranking according to subject's preferences. The graph on *Figure 3* shows the number of times a modality was ranked either as the most disruptive or second most disruptive, in some cases the same subject ranked smell and vibration as most disruptive and second most disruptive. The graph shows that the least used modalities in computer interfaces have bigger disruptive effects, probably because of their novelty, some perhaps because of the appearance rate.

After collecting the data, we carried out an analysis of variance (ANOVA) in order to determine statistical significance. A within factors ANOVA test $F(5,45)$ resulted in a p-value of 1.256 with an alpha level of 0.28, which indicated no statistical significance for differences in performance for every interruption modality. Not enough subjects were evaluated as to have enough power for valid statistical analysis.

Research shows that human senses differ in both, precision and speed [14]. Results from this study show that subjects were affected differently by each of the modalities. Previous personal experience played a key factor in their reaction to interruption modalities. For example, subjects who had extensive experience in the field of television broadcasting reacted strongly to light; light changes always represent a crucial event in their business. Some subjects didn't notice smell but others insisted on trying to think and identify them each time

they were present. While another subject was very involved in homemaking and kitchens reacted much more to odors than others.

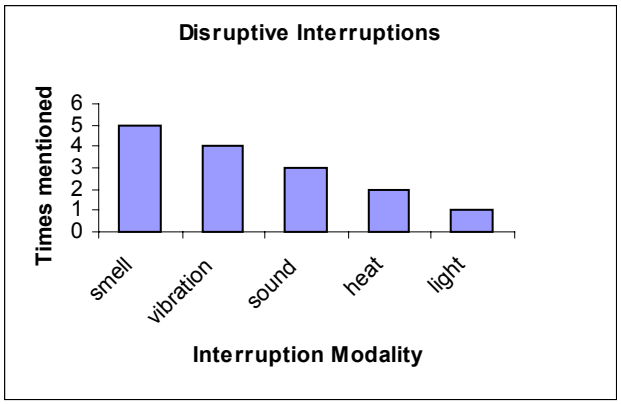

Figure 3. Interruptions ranked as the most disruptive.

These strong individual differences were striking and suggest that people's backgrounds and worldview may possibly be the strongest factor in the effectiveness of various modalities for interruption. Taking these results and applying them to user interface design we could be able to maximize the effectiveness of an interruption through optimal modality selection.

3. Discussion And Future Work

Even though work has been done on the area of adaptive user interfaces [10] [7], they do not consider adapting the output modality itself. Our results suggest that could be possible to build a multimodal interface that will employ the results generated from this study by dynamically selecting the interruption modality based on the effectiveness of it on a particular user. Thus it is conceivable to maximize the effectiveness of an interruption through proper modality selection and configuration.

This interface will ubiquitously collect data regarding both, user's performance and the perceived effect of each of the modalities. Performance data will include writing speed, spelling errors, surfing windows speed, perception thresholds and reaction times after being interrupted by one of five different modalities (heat, light, smell, sound, vibration). The interface will then analyze how users react to each interruption modality, dynamically selecting and adapting the interruption modality.

Future systems will then become multimodal self-adaptive interfaces, receiving physiological feedback about disruptive effects of an interruption modality and using this feedback to adapt output modalities themselves.

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