The Effect of Alert Type to an Interruption on Primary Task Resumption

Alyssa E. Andrews[1], Raj M. Ratwani[1,2], J. Gregory Trafton[2],
George Mason University[1], Naval Research Laboratory[2]

Interruptions are pervasive; rarely can one work for an extended period of time without being interrupted. One method for reducing the disruptiveness of interruptions is to present an alert prior to the interruption. Based on the Memory for Goals theory (Altmann and Trafton, 2002), this alert period provides an opportunity to maintain an associative link between the suspended primary task goal and relevant environmental cues which facilitates resumption. This theory does not, however, describe what types of alerts are most effective. Using reaction time and eye movement measures, three different types of alerts were examined to determine which alerts were the most effective and to determine which afforded the greatest opportunity to form an associative link between the suspended primary task goal and relevant environmental cues. Alert conditions resulted in faster resumption times than a no alert condition. There were no differences between the alert conditions themselves, despite eye movement differences reflecting cue association processes. The eye movement data suggest that one fixation is enough to form an associative link which reduces the disruptiveness of interruptions.

INTRODUCTION

Interruptions are a fact of work life. Rarely is it possible to maintain continuous workflow in a busy, dynamic work environment without some need to temporarily suspend a current action. Gonzalez and Mark (2004) showed that the office workers were interrupted every 11 and a half minutes. These interruptions come from numerous sources such as a phone call, a colleague coming to speak with you, software application pop-ups, and email. These interruptions are uprising events created outside of an individual's control, forcing him or her to attend to the interruption, at least momentarily (Speier, Vessey & Valacich, 2003). After completing an interrupting task, people then have to figure out how to return to or refocus on their original task.

Previous literature investigating the impact of interruptions on primary task performance has shown that interruptions are generally disruptive (Trafton, Altman, Brock, & Mintz, 2003; Monk, Boehm-Davis, & Trafton, 2004; Bailey, Konstan, & Carlis, 2000; Altmann & Trafton, 2004). The disruptiveness of interruptions has been explained by Altmann and Trafton's (2002, 2007) Memory for Goals framework. This framework is an activation based theory of goal memory that has been applied to the study of interruptions (Hodgetts & Jones 2006a, b; Monk, et al, 2006). According to this theory, the current most active goal directs behavior and the activation levels of goals decay over time. Thus, over the course of an interruption, the activation level of the suspended primary task goal will decay and it will be more difficult to retrieve this goal upon resumption of the primary task. The activation level of the goal is dependent on two constraints: strengthening and priming. The strengthening constraint suggests that the history of the goal (e.g. frequency and recency) influences activation. The priming constraint suggests that cues in the physical or mental environment influence activation by providing associative activation. Critically, an association between the cue and the suspended primary task goal must be established prior to the interruption.

One commonly used method for mitigating the disruptiveness of interruptions is to provide an alert of an imminent interruption (Trafton, Altmann, Brock, and Mintz, 2003). The memory for goals theory suggests that an alert provides for an opportunity to prepare for the upcoming interruption. The time between an alert and the pending interruption has been termed the interruption lag (Altmann & Trafton, 2002). During this interruption lag, people can either prospectively prepare for resumption by encoding specific goals they want to achieve upon return to the primary task (prospective goal encoding). Also, they can prepare retrospectively by rehearsing the goal they just completed prior to the interruption (retrospective rehearsal).

Empirical papers examining the effectiveness of alerts have shown that alerts can be beneficial by reducing the time to resume the primary task (Trafton, Altmann, Brock, and Mintz, 2003; Hodgett's and Jones, 2003). There are, however, several different methods for alerting users of an upcoming interruption. For example, some computer applications notify the user of an imminent interruption with a visual cue, while other applications use an auditory cue. How do these different types of alerts impact the resumption process?

Although the Memory for Goals theory does not make specific predictions as to which type of alert would be the most beneficial, the priming constraint can be leveraged to make these predictions. Specifically, an alert that allows for the greatest opportunity to establish an associative link between the environmental cues and the target goal should allow for faster resumption time since the suspended goal will have a higher activation level upon resumption. Thus, an alert that distracts the user by drawing their attention should be less effective than an alert that allows the user to establish an associative link.

An associative link is operationally defined as making a mental connection (association) between physical or mental cues and a task relevant goal (e.g., the current or next action).

Specifically, during an alert, people may look at areas of the interface that are relevant to resumption – the action they just completed or their next step. According to Memory for Goals, this encoding should facilitate resumption because it creates an association between the physical step and the mental goals.

The purpose of this study was to examine if there is a difference in effectiveness between different kinds of alerts (e.g. auditory, visual). Three different types of alerts were examined: a general visual alert (i.e. screen flash), a specific visual alert (i.e. a face appearing on the screen), and a general auditory alert (i.e. and auditory tone). The Memory for Goals theory would suggest that the general visual alert and the auditory alert would facilitate resumption the most because these alerts allow for the greatest opportunity to establish an associative link between the environmental cues and the suspended primary task goal. The specific visual alert would draw the users' attention and reduce the amount of time the user has to establish an associative link

EXPERIMENT

In order to determine if different alerts enable different mitigation strategies, alert type was manipulated across three conditions and compared to a control condition with no alert. The three alert types were an auditory tone, a screen flash, and a picture of a face that flashed in the upper right hand corner of the primary task. All of the alerts were presented 1500 msec before the onset of the interruption. In addition to collecting reaction time measures to differentiate between the three alerts and control condition, eye movement data were collected as well. The eye movement data should provide explicit evidence as to whether participants were making the associative link between the environmental cues and the suspended goals during the interruption lag as the Memory for Goals theory would suggest.

Based on the memory for goals theory, participants should resume more quickly in the alert conditions as compared to the no alert condition. The alert conditions allow for the opportunity to create an association between environmental cues and the to be suspended goal prior to the interruption. This association should facilitate retrieval upon resumption of the primary task by boosting activation of the goal and allowing for faster retrieval. The condition without an alert would not provide this opportunity, resulting in greater difficulty in retrieving the suspended goal.

There should be differences between the alert conditions as well. While an alert should capture attention to let the user know that an interruption is imminent, an alert that captures visual attention for too long may detract from the process of forming an associative link between environmental cues and the target goal. Thus, the visual face condition should be the least effective alert because it may be too distracting and prevent the process of forming an associative link. The visual flash and auditory tone alerts may be general enough and provide a greater opportunity to create an associative link. In addition to differences in resumption times between the alert conditions there should be corresponding differences in eye movements.

Fixations to the locations on the task interface where the most recent action was completed (retrospective) and where the next action needs to be completed (prospective) would suggest the creation of an associative link between cues and the target goal. The visual face alert condition should have fewer fixations to these important cues as compared to the other alert conditions.

Method

Participants. Forty-four George Mason University undergraduate students participated for course credit.

Materials. The primary task was a complex production task based on Li et al (2006) and Ratwani, Trafton, and McCurry (2008), called the sea vessel production task (see Figure 1). The goal of the task was to successfully fill orders for different types of navy sea vessels. At the beginning of each trial, an order sheet for two different types of navy sea vessels was presented in the center of the screen (see Figure 1). To fill the order, the participant had to specify information from this order in five different modules on the computer interface; the modules corresponded to the vessel name, material, paint scheme, weapons and location of delivery. There was a specific correct procedure for filling each order. After entering information in each of these modules the order was processed by clicking the process button and finally the order was completed by clicking the complete contract button. The interrupting task consisted of 3 addition problems and completely filled the screen; participants did not have visual access to the primary task during the interruption. Each problem required the participant to take the sum of two single digit addends ranging from 1-9. Each addition problem was presented serially and participants were given five seconds to answer each problem (this time included presentation time); thus, the total interruption duration was 15 seconds. The addends were randomly generated.

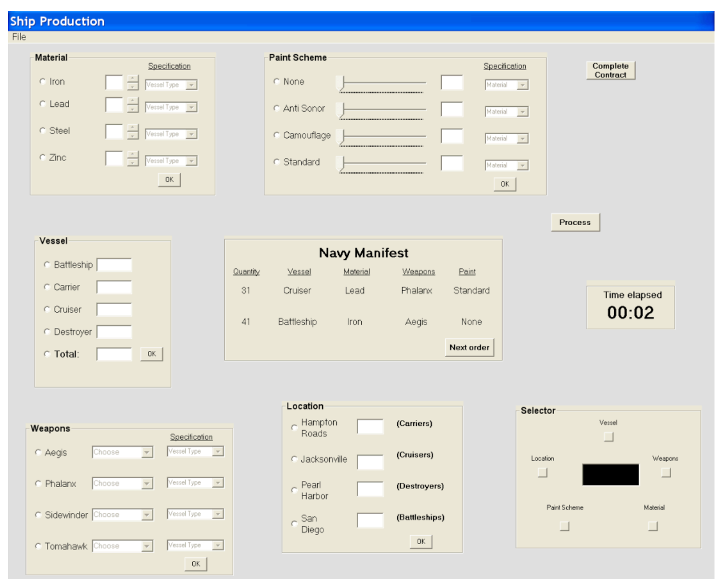

Figure 1. Screenshot of the primary task interface.

Design. Alert modality was manipulated between participants. Although there were two different modalities (visual and aural) used for the alerts, there were three alert conditions: an auditory alert where the participants heard a tone and had full view of the primary task during the alert (auditory), a visual alert where the screen flashed three times (flash), and a second visual alert where a cartoon face flashed three times on the right side of the screen (face) with the primary task present. A fourth condition without an alert served as the control (no-alert). In each alert condition, the alert lasted 1500 msec.

Each condition contained a visual interruption. In no case could any actions be performed on the primary task during the alert or interruption. Control and interruption trials were manipulated within participants. Filling in one order on the primary task served as a trial. Participants completed a total of 12 trials; half were interruption trials with two interruptions, and half were control trials with no interruptions. The assignment of interruption and control trials was randomized, and participants were assigned to one of the four conditions. The interruptions occurred either after filling information in on one of the five modules or after clicking the process button. Thus, there were a total of 6 possible interruption points; the interruptions occurred equally among these 6 positions.

Procedure. Participants were seated approximately 47cm from the monitor. After the experimenter explained the primary and interrupting tasks to the participants, the participants performed two practice trials, the first with no interruptions and the second with two interruptions. After successfully completing these trials, the participant began the actual experiment. Each participant was instructed to work at his/her own pace. After completing six trials the participant was offered a break. When performing the interrupting task, participants were instructed to answer the addition problems as soon as they knew the solution by typing in the numeric response using the keypad. Upon resumption of the primary task there was no information on the primary task screen to indicate where the participant should resume.

Measures. Keystroke and mouse data were collected for each participant. The primary reaction time measures were the resumption lag and inter-action intervals. The resumption lag was the time from the onset of the primary task screen following the interruption until the first action on the primary task interface. The inter-action interval was the time between clicking between modules and clicking between the process and complete contract buttons. Eye track data were collected using a Tobii 1750 operating at 60hz. A fixation was defined as a minimum of five eye samples within 30 pixels (approx 2° of visual angle) of each other, calculated in Euclidian distance. Several areas of interest were defined in order to analyze the eye track data. These areas of interest included each of the five modules and the process and complete contract buttons. Each area of interest was separated by at least 2.5° of visual angle. Each of the modules subtended an area greater than 3°, the process and complete contract buttons subtended an area of 2°, and the selector buttons each subtended an area of .75°. Reaction times that were more than three standard deviations from the mean were removed from all analyses. The corresponding eye movement data were removed as well.

Results and Discussion

Accuracy on the Interrupting and Primary Tasks. There was no difference in accuracy on the primary task, $F(3, 40) = .78$, $MSE = 3.06$, $p = .51$. Additionally, participants were equally accurate at answering addition problems during the interruption in the auditory ($M = 91.1\%$), face ($M = 90.0\%$), flash ($M = 92.6\%$) and visual ($M = 92.4\%$) conditions, $F(3, 40) = .23$, $MSE = 15.76$, $\rho = .88$.

Reaction Time Measures. The resumption lags from the interruption trials were compared to the inter-action intervals from the control trials using a mixed design ANOVA to determine whether the interruption was disruptive to primary task performance. There was a significant main effect for resumption lag versus inter-action interval, $F(3, 40) = 3.65$, $MSE = 1116637.92$, $\rho < .01$. There was a significant main effect of condition, $F(3, 40) = 3.65$, $MSE = 1116637.92$, $\rho < .01$. The interaction was significant, $F(3, 40) = 2.20$, $MSE = 893311.63$, $\rho < .01$.

Tukey HSD post-hoc comparisons were conducted to explore the interaction. The resumption lags were not significantly longer than their respective inter-action intervals in any of the alert conditions (all p's>.05). However, the resumption lag was significantly longer than the inter-action interval for the no alert condition, $t(11) = 6.17$, $\rho < .05$. Thus, any kind of alert eliminated the time cost of the interruption.

Next, the resumption lags were compared between conditions to determine whether a particular type of alert resulted in faster resumption times. As figure 2 suggests, the omnibus ANOVA was significant, $F(3, 40) = 3.13$, $MSE = 1984817.2$, $\rho < .05$, suggesting that there was a difference between the four conditions. To examine differences between conditions, Tukey HSD post-hoc comparisons were used. There was no difference between any of the alert conditions (all ρ's>.05). Further, each of the alert conditions was faster than the no-alert condition (all ρ's <.05). Thus, all of the alerts were equally effective.

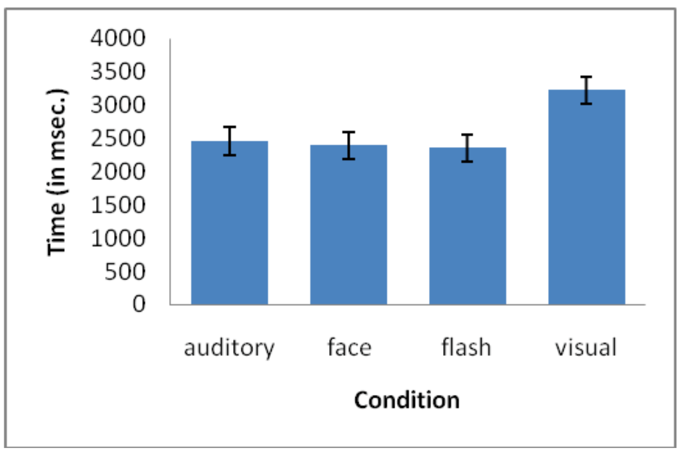

Figure 2. Mean resumption lag by condition.

One possible explanation for the differences in resumption lags between the four conditions is that participants in the alert conditions are generally faster at the primary task. There was no difference in the inter-action intervals between conditions, $F(3, 40) = .3$, $MSE = 25132.4$, $\rho = .8$, suggesting that this is not a likely explanation. Another possible explanation for the resumption lag differences is that participants are trading speed for accuracy in the alert conditions. Given that participants were equally accurate on both the primary and interrupting tasks in all conditions suggests that this is not a likely explanation either.

The reaction time measures did not entirely support our predictions. While the alert conditions were faster than the no-alert condition as predicted, the face alert condition was no different than any of the other alert conditions. These reaction time measures demonstrate that presenting any kind of alert is equally beneficial to resumption time. The alert conditions resulted in no time cost from the interruption. Based on the reaction time data alone, however, it is unclear whether participants used the interruption lag to create an associative link as memory for goals would suggest. To determine whether participants were actively forming an associative link we examined the eye movement data.

Eye Track Measures. Were participants actually looking at task-relevant areas on the primary task interface during the alert as Memory for Goals would suggest? In order to answer this question, we examined participants' eye movements during the alert. In particular the focus was on where participants fixated during the alert. If participants attempted to make an association between the environmental cues and the primary task goal, they should fixate on the location of where they had just completed work or where they should resume after the completion of the interruption.

In the auditory condition, participants could fixate directly on the relevant environmental cues since the primary task interface was fully visible without any visual distraction. In the flash condition, participants could have also looked at these general locations. In the face condition, however, visual attention may be captured away from these general locations by the alert cue itself. When an object differs in shape or color, it can draw attention away from where it was previously focused (Turatto & Galfano, 2000).

To determine how often participants looked at task-relevant cues, the frequency of fixations to both retrospective (just completed) and prospective (next-action) locations were examined. Figure 3 shows the mean number of fixations that landed on task-relevant areas. An omnibus ANOVA showed that there was a significant difference among these means, $F(2, 29) = 7.12$, $MSE = 3.32$, $\rho < .01$. To examine differences between conditions, Tukey HSD post-hoc comparisons were used. Participants in the auditory condition fixated on task-relevant locations significantly more than the face condition ($\rho < .05$) but not the flash condition ($\rho = .09$). Participants in the flash condition fixated on task-relevant locations significantly more than the face ($p < .05$) as well.

The results show that participants were making more fixations to task-relevant cues in the auditory and flash alert conditions as compared to the face alert condition. Thus, the face alert did seem to capture visual attention away from task-relevant areas. However, these fixations did not amount to reaction time differences as shown by the resumption lag data. This suggests that even one fixation during an alert allows for encoding important environmental cues that can aid in task resumption.

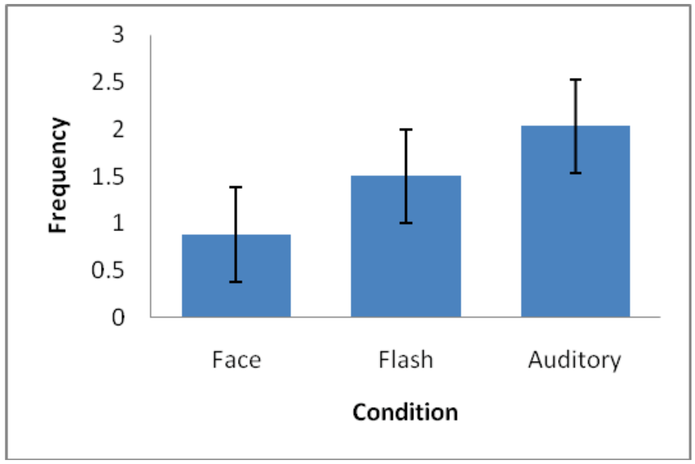

Figure 3. Frequency of fixations to the just completed or next action.

GENERAL DISCUSSION

The priming constraint of the Memory for Goals model suggests that upon resumption of the primary task, environmental cues that were associatively linked to the primary task goal prior to the interruption will boost activation of the suspended task goal upon resumption. A goal can be prepared for suspension during an interruption lag by allowing for the time to associatively link the primary task goal to the environmental cues. The results of this study show that when an interruption lag is provided, resumption of the primary task is faster as compared to a condition with no interruption lag. The eye movement data from the alert conditions clearly demonstrated that participants were actively fixating on the relevant environmental cues during the alert, presumably to make the association with the suspended task goal. These results suggest that it is not the type of alert that matters in facilitating goal resumption. Rather, it is whether the duration of the alert provides enough time to encode the target goal. In this study, one fixation was enough to establish the association.

The reaction time data from this study are particularly interesting because the disruptive effect of the interruption was eradicated in the alert conditions. Other papers investigating the effect of alerts on resumption have shown that alerts allow for resuming the primary task more quickly (Hodgetts &Jones, 2003; Trafton, Altmann, Brock, & Mintz, 2003), but the interruption has still had a disruptive effect. It is not entirely clear why our study resulted in no interruption cost at all. It should be noted that this study used a rather easy and brief interruption, which may have contributed to this finding.

From an applied perspective, the findings from this study suggest that when designing systems to be resistant to the time cost of interruptions, alerts can be an effective method. This study suggests that an alert of any modality can be useful in providing an opportunity for people to prepare to stop where they are working in a primary task and to think ahead to where they need to resume following the interruption as long as the alert provides some opportunity to create an associative link. Salient and distinct environmental cues should also be implemented in visual displays so that people can easily link these cues to their task goal during an alert.

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