The Effect of Interruption Modality on Primary Task Resumption

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

The majority of empirical papers investigating the effect of interruption modality on primary task resumption have been grounded in Multiple Resource theory; this theory stresses the benefits of cross-modal information presentation. Alternatively, Altmann and Trafton's (2002) Memory for Goals theory suggests that maintaining an association between the suspended primary task goal and relevant environmental cues is critical to the task resumption process. Using reaction time and eye movement measures, the theoretical predictions of these two frameworks were empirically examined to determine whether interruption modality influences primary task resumption.

INTRODUCTION

Attempting to complete a task in a busy office setting is nearly impossible without being interrupted. The sources of interruptions in work settings are abundant; interruptions can take the form of phone calls, emails, instant messages or a colleague stopping by your office, just to name a few possibilities. In fact, Mark and Gonzalez (2004) have suggested that workers are only able to spend an average of eleven and a half minutes in continuous work before being interrupted.

The majority of the literature investigating the impact of interruptions on primary task performance has shown that interruptions are generally disruptive (Adamcyzk & Bailey, 2004; Hodgetts & Jones 2006a,b; Monk, Boehm-Davis & Trafton, 2004). However, interruptions often occur in different modalities. For example, while working at a computer one might receive a phone call (auditory interruption) or one might receive an urgent email (visual interruption). How does the modality of an interruption impact the resumption process? Is one modality less disruptive than another?

Altmann and Trafton's (2002, 2007) Memory for Goals framework is a prominent activation based theory that has been applied to the interruptions paradigm (Hodgetts & Jones 2006a,b; Monk, et al, 2004). This theory suggests that the current most active goal directs behavior and the activation levels of goals decay over time. When interrupted, the current primary task goal is suspended and the activation level of this goal decays. Upon resumption, the time required to begin work on the primary task reflects the process of retrieving the suspended goal. The higher the activation level of the suspended goal, the more easily that goal can be retrieved. There are several constraints in this theory that determine the activation level of the suspended goal. First, the strengthening constraint suggests the history of the goal (i.e. frequency and recency of goal retrieval) impacts goal activation. Second, the priming constraint suggests that cues in the environmental context provide associative activation or priming to the associated goal in the primary task, and thus facilitate retrieval.

Although Memory for Goals does not make explicit predictions about interruption modality and the resumption process, the priming constraint can be leveraged to make these predictions. Specifically, based on the priming constraint, any interruption that allows for the associative link between the environmental cues and the target goal to be maintained should facilitate resumption. Thus, the interruption modality that allows for this associative link to be maintained will be less disruptive as compared to modalities that do not allow for this associative link.

Alternatively, Multiple Resource theory (Wickens, 1984; 2002) makes a different prediction. Multiple Resource theory would suggest that,all else being equal, cross modal interruptions (e.g. auditory interruption- visual primary task) will be less disruptive than interruptions that occur in the same modality as the primary task (e.g. visual interruption- visual primary task). There have been several empirical papers grounded in Multiple Resource theory that have investigated the effect of interruption modality (Ho, Nikolic, & Sarter, 2001; Ho, Nikolic, Waters, & Sater, 2004; Latorella, 1998); these papers have resulted in mixed support. Latorella found that there was no difference in cross-modality conditions in terms of time cost. However, when looking at error rates, there was some support for Multiple Resource theory. Ho, et al. found that participants sought to avoid interruptions that were intra-modal when they were both visual; they took this to be support for Multiple Resource Theory. Although there appears to be some support for the benefits of cross-modal information presentation, there is no direct evidence of a time cost benefit within an interruptions paradigm.

The purpose of this study was to examine whether there is a benefit to presenting an interruption in a different modality than that of the primary task and to distinguish between the Memory for Goals theory and Multiple Resource theory in their accounts for the effect of interruption modality. Specifically, we focus on resuming a computer based visual primary task following either an auditory or visual interruption. Given this focus, the

Memory for Goals theory would suggest that the auditory interruption would facilitate resumption to the degree that the interruption will allow for the maintenance of the environmental cues and the association to the suspended primary task goal. Multiple Resource theory would make the strong prediction that an auditory interruption would be less disruptive to a visual primary task than a visual interruption because of the cross modal benefit. An experimental paradigm was designed to tease apart these two theoretical predictions.

EXPERIMENT

In order to distinguish between the Memory for Goals and Multiple Resource theories, two different interruption modalities (auditory and visual) were manipulated across three different conditions. In one condition an auditory interruption was presented while the primary task interface was still completely visible to the participant. In a second condition, an auditory interruption was presented, but a blank screen covered the primary task interface. In a third condition, a visual interruption was presented which completely occluded the primary task interface.

Given that the primary task is visual, Multiple Resource theory would suggest that resumption of the primary task following the visual interruption should be more difficult than resumption following either of the auditory conditions. The auditory interruptions leverage the benefits of cross-modal information presentation, while the visual interruption does not.

The Memory for Goals theory makes a slightly different prediction. Memory for Goals would suggest that the conditions in which participants can not explicitly maintain the associative link between the cue and goal will result in more difficult resumption as compared to the conditions in which this link can be maintained. The only condition where this link can be explicitly maintained is the auditory condition with the primary task interface visible. Thus, this auditory condition should result in faster resumption times than the auditory condition with a blank screen and the visual interruption condition. Further, since both the auditory interruption condition with a blank screen and the visual interruption condition do not allow for maintenance of the associative link, these interruptions should be equally disruptive.

In addition to collecting reaction time measures to differentiate between these two theories, eye movement data were collected as well. The eye movement data should provide explicit evidence as to whether participants are actually maintaining the relevant environmental cues as the Memory for Goals theory would suggest.

Method

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

Materials. The primary task was a complex production task based on Li et al (2006), 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. 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. The addition problems were either presented aurally or visually. The time required to present each addition problem was equal for all types of interruptions.

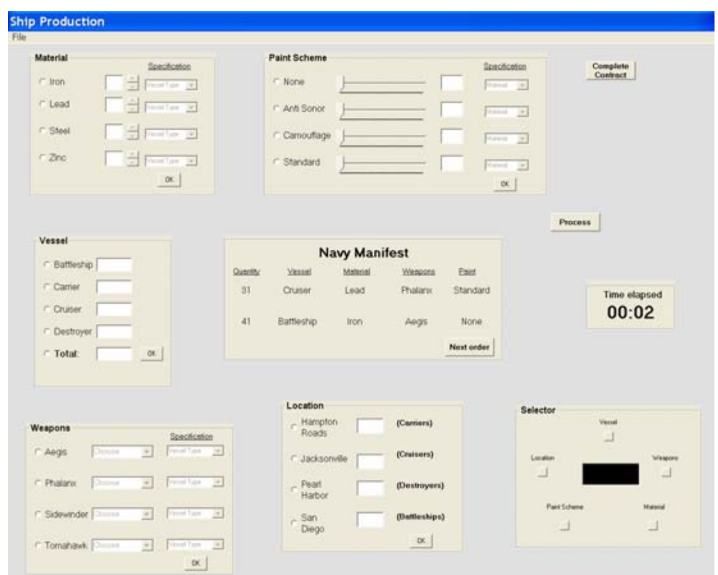

Figure 1. Screenshot of the primary task interface.

Design. Interruption modality was manipulated between participants. Although there were two different modalities (visual and aural), there were three interruption conditions: auditory interruption with full view of the primary task, auditory interruption with a blank screen covering the primary task for the duration of the interruption, and a visual interruption completely occluding the primary task. In no case could any actions be performed on the primary task during the interruption. To easily refer to these conditions the auditory condition with the primary task available will be called *auditory-visible*, the auditory condition with a blank screen will be called *auditory-blank* and the visual condition will be called *visual*. 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 randomly assigned to one of the three modality 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 click on the primary task interface. In the auditory-visible condition, a screen flash signified the end of the interruption. 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 (approximately 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.

Results and Discussion

Accuracy on the Interrupting Task. Accuracy on the interrupting task was compared between conditions to ensure that there were no differences in attention to this task. Participants were equally accurate at answering addition problems during the interruption in the auditory-visible (M = 89.1%), auditory-blank (M = 88.1%) and visual (M = 91.1%) conditions, $F(2, 45) = .41$, $MSE = 92.1$, $p=.7$.

Reaction Time Measures. The resumption lags from the interruption trials were compared to the interaction intervals from the control trials across all conditions to determine whether the interruption was disruptive to primary task performance. The resumption lag (M = 3523.1 msec) was significantly longer than the interaction interval (M = 2303.8 msec), F (1, 47) = 97.3, MSE = 366546.8, $p<.001$, suggesting that the interruption was disruptive. Thus, even when the primary task screen was available during the interruption, and participants could look directly at where they should resume, there was still a time cost due to the interruption itself.

Next, the resumption lags were compared between conditions to determine whether it was easier to resume following the auditory interruption conditions as compared to a visual interruption. The omnibus ANOVA was significant, F (2, 45) = 10.5, MSE = 781963.6, p<.001, suggesting that there was a difference between the three conditions. To examine differences between conditions, Tukey HSD post-hoc comparisons were used. The resumption lag following the auditory interruption with the primary task visible was significantly faster than the auditory condition with a blank screen ($p<.01$) and faster than the visual interruption ($p<.001$). The resumption lag following the auditory interruption with the blank screen was not significantly different from the visual interruption ($p = .3$). Figure 2 illustrates these results. There was no difference in the interaction intervals between conditions, $F(2, 45) = .6$, $MSE = 301839.9$, $p = .6$.

Could the faster resumption times in the auditory-visible condition be due to a speed-accuracy tradeoff? The fact that there was equal accuracy on the interrupting task between each of the conditions suggests that reaction time differences are not due to a speed-accuracy tradeoff.

These reaction time measures demonstrate that simply presenting the interruption in a different modality than the primary task is not sufficient to reduce the time cost of resuming; there was no general cross modality benefit as Multiple Resource theory would suggest. There was a benefit when the primary task interface was available during the interruption, as the Memory for Goals theory would suggest.

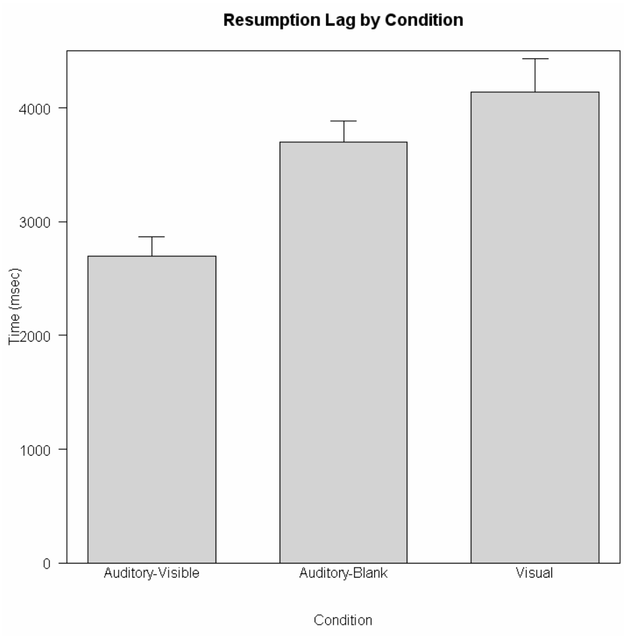

Figure 2. Mean resumption lag by condition.

Eye Track Measures. Were participants actually looking at the relevant environmental cues on the task interface in the auditory-visible condition as Memory for Goals would suggest? In order to answer this question, we examined participants' eye movements during the interruption itself to determine whether there were differences between the conditions. In particular the focus was on where participants fixated during the interruption interval. If participants were actively maintaining the association between the environmental cues and the primary task goal, they should be fixating on the location of where they had just completed work or where they should resume after the completion of the interruption.

In the auditory-visible condition, participants could fixate directly on the relevant environmental cues since the primary task interface was visible. In the auditory-blank condition, participants could have also looked at these general locations, however, the blank screen completely occlude the primary task interface. Yet, these general spatial locations could be maintained since the interruption did not demand the participants' visual attention.

To determine how often participants were looking at the location of where they had just completed work or where they should resume in the task interface, the frequency of fixations to these locations were counted. The frequencies were converted to a percentage of the total number of fixations during the interruption since the total number of fixations during the interruption itself varied. Figure 3 shows the mean percent of fixations that landed on the part of the interface where work was just completed or on the part of the interface where the participant should resume. An omnibus ANOVA showed that there was a significant difference among these means, $F(2, 45) = 37.9$, $MSE = 36.7$, $p<.001$. To examine differences between conditions, Tukey HSD post-hoc comparisons were used. Participants in the auditory-visible condition fixated on these locations significantly more than the auditory-blank condition ($p<.05$) and the visual condition ($p<.001$). Participants in the auditory-blank condition fixated on these locations significantly more than the visual condition ($p<.001$) as well.

These results suggest that participants were in fact looking at relevant environmental cues more often in the auditory-visible condition as compared to the other conditions. This is in direct support of the Memory for Goals model. Interestingly, in the auditory-blank condition, participants looked at the relevant environmental cues more than the visual condition. However, these fixations did not amount to reaction time differences as evidenced by the resumption lag data.

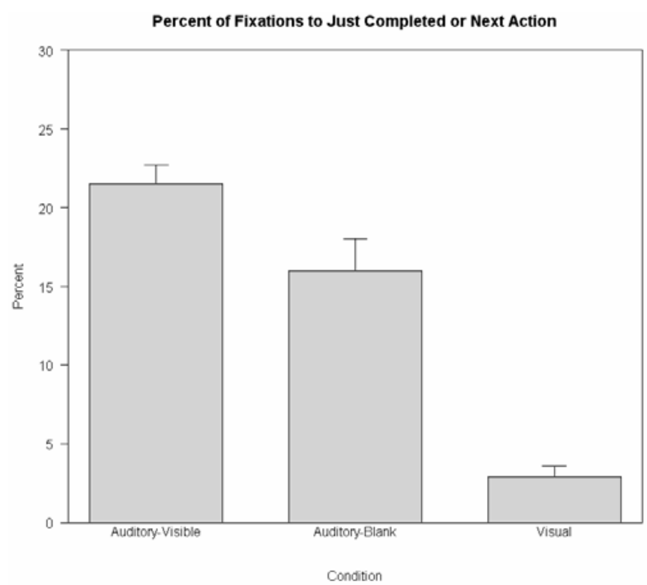

Figure 3. Percent of fixations to the just completed or next action.

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. The results of this study show that when interruptions allow for this associative link to be maintained, resumption of the primary task is faster as compared to conditions where this link cannot be maintained. The eye movement data from the auditory-visible condition clearly demonstrated that participants were actively fixating on the relevant environmental context during the interruption, presumably to maintain association with the suspended task goal. Thus, there is not a general cross modality benefit as Multiple

Resource theory would suggest. Rather, there is a cross modality benefit to the extent that the associative link between the environmental context and the target goal can be maintained.

The eye movement data from this study raise interesting questions about the perceptual processes involved in task resumption. Several papers have highlighted the importance and benefit of being able to maintain a spatial representation of the primary task when interrupted (Brudzinski, Ratwani & Trafton, 2007; Ratwani & Trafton, under review; Ratwani & Trafton, 2006; Ratwani et al., 2007). Yet, in the auditory-blank condition, while the eye movement data showed that participants were fixating on the location of where they should resume significantly more than the visual condition, these eye movement differences did not amount to differences in the time to resume. This finding points towards an interesting interaction between goal memory and spatial memory which will require further investigation.

From an applied perspective the findings from this study suggest that when designing systems to be resistant to interruptions, one should pay careful attention to preserving the maintenance of the associative link between goal memory and the environmental context. Simply using the heuristic of a cross-modality benefit may not be enough, as was illustrated here. In a computing environment, interruptions should be designed such that they allow users to have visual access to the primary task interface. Aurally presented interruptions will facilitate resumption to the extent that the user can still associate the suspended goal with an environmental cue.

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