Using Peripheral Processing and Spatial Memory to Facilitate Task Resumption

Raj M. Ratwani[1,2], Alyssa E. Andrews[2], Malcolm McCurry[1], J. Gregory Trafton[1,2], Matthew S. Peterson[2]

Naval Research Laboratory[1]
Washington, D.C.

George Mason University[2]
Fairfax, VA

Theories accounting for the process of primary task resumption following an interruption have focused on the suspension and retrieval of a specific goal (Altmann & Trafton, 2002). The ability to recall the spatial location of where in the task one was prior to being interrupted may also be important. We show that being able to maintain a spatial representation of the primary task facilitates task resumption. Participants were interrupted by an instant message window that either partially or fully occluded the primary task interface. Reaction time measures show that participants were faster at resuming in the partial occlusion condition. In addition, eye track data suggest that participants were more accurate at returning to where they left off, suggesting that they were able to maintain a spatial representation of the task and use this information to resume more quickly.

INTRODUCTION

Most studies examining the impact of interruptions on primary task performance have shown that interruptions can be detrimental to accomplishing the primary task (Altmann & Trafton, 2004; Czerwinski, Cutrell, & Horovitz, 2000; Monk, Boehm-Davis, & Trafton, 2004; Trafton, Altmann, Brock, & Mintz, 2003). Interruptions have increased the time required to accomplish the primary task, led to more errors, and elicited greater feelings of stress and anxiety.

Altmann and Trafton (2002) have applied an activation based memory for goals model to account for the process of resuming an interrupted task. The focus of their theory has been on *what* specific goal needs to be retrieved in order to resume the primary task. We have argued that in addition to memory for the specific goal that was suspended, memory for spatial location is an important component to the resumption process (Brudzinski, Ratwani & Trafton, in press; Ratwani & Trafton, 2006). Knowing *where* you are spatially in a task can guide you to where you left off and can provide the context required to resume the suspended goal. More specifically, in previous experiments we have shown that after an interruption, participants do not start the task over again, but rather are able to return to the general area where they left off. Thus, people have the ability to remember the general location of where they are in the task interface, information that can be used to guide resumption.

There has been support for the role of spatial memory in guiding task resumption in the visual search domain as well. First, it has been shown that the spatial representation of a task can be maintained over a delay (Lleras, Rensink & Enns, 2004, 2005). Further it has been suggested that spatial memory aids in resuming interrupted visual searches (Shen & Jiang, 2006).

The goal of the experiment presented here was to examine whether a more intact spatial representation of the primary task facilitated task resumption. If remembering where you are spatially in a task is important to resumption, then having a more intact spatial representation of the primary task upon resumption should serve to facilitate the resumption process.

In particular, an interrupting task that partially occluded the primary task screen was compared to one that completely occluded the primary task screen. A partially occluding interrupting task window allowed for peripheral access to the primary task screen and consequently may have resulted in a more intact spatial representation upon resumption of the primary task. If spatial memory is used to resume the task following an interruption, this more intact spatial representation should lead to faster resumption times.

EXPERIMENT

In the primary task, participants searched a column of numbers in a spreadsheet and transcribed only the odd numbers onto a separate list. While participants performed this task they were periodically interrupted by instant messages that either partially occluded the primary task screen or fully occluded the primary task screen. Reaction time and eye movement data were collected as participants performed the task.

We were first interested in examining whether the partial occlusion interruption led to faster resumption times as compared to the full occlusion interruptions. Second, we were interested in examining whether participants were able to resume more accurately in the partial occlusion case, suggesting a more intact spatial representation of the primary task.

Method

Participants. Thirty-three George Mason University undergraduate students participated for course credit.

Materials. Thirty Microsoft Excel spreadsheets were created; each sheet contained 10 three-digit numbers (see Figure 1 for an example). The numbers were randomly generated with the constraint that at least half of the numbers were odd. The numbers were listed in a single column on the left side of the spreadsheet in a random order. The distance between numbers was approximately 2.5° of visual angle.

Design. A mixed design was used where interruption vs. control trials were manipulated within subjects, while partial vs. full occlusion instant messages were a between subjects variable. Each spreadsheet served as a trial; half of the spreadsheets had no interruptions (control) and half had one interruption randomly occurring during that trial. Each trial was randomly assigned as a control or interruption condition. Participants were randomly assigned to either the partial or full occlusion group.

Procedure. The primary task required participants to type the odd numbers from the column on the left of the spreadsheet into a column labeled "odd numbers." They began at the top of the original column in the first spreadsheet and typed the odd numbers into the designated column without leaving spaces between the cells (see Figure 1). They performed the same task on each spreadsheet until all the spreadsheets had been completed; the experiment was self-paced.

The interrupting task was an instant message (IM) containing an addition problem with 5 whole-number addends. In the partial occlusion condition the IM occluded less than 25% of the primary task screen (see Figure 1). In the full occlusion condition the IM occluded 100% of the primary task screen. Once the IM was received the participant was forced to cease work on the primary task and to mentally add the five numbers as quickly and accurately as possible. The participant then typed the answer in the IM window, sent the message, closed the IM window and finally resumed their primary task. The interruption lasted approximately 10 seconds and occurred only after an entire three digit number was entered in the odd numbers column. A single control and interruption trial served as practice trials.

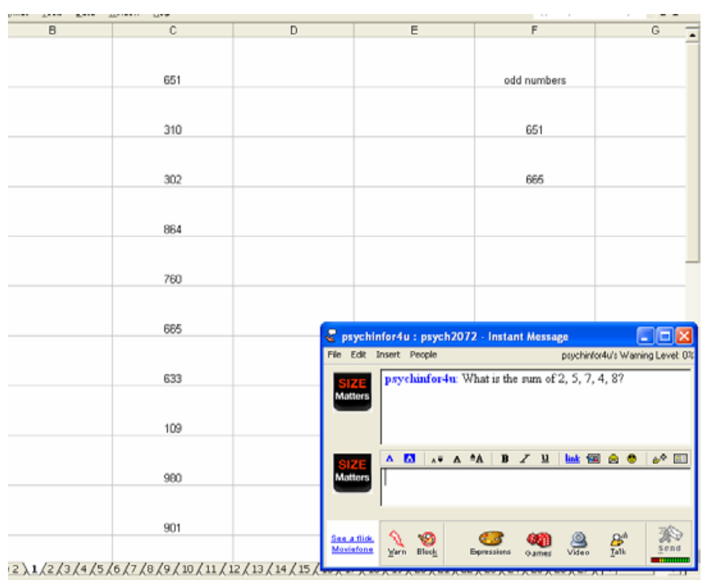

Figure 1. Primary task with partial occlusion IM.

Measures. The reaction time (RT) data were analyzed by computing the inter-action interval for the control trials and comparing this to the resumption lags from the interruption trials. The inter-action interval was the average time between entering numbers into the "odd numbers" column on the spreadsheet. The resumption lag was the average time from the end of the interrupting secondary task (closing the IM window) to the first action back on the primary task (entering an odd number).

The eye track data were analyzed using ProtoMatch software (Myers & Scholles, 2005). ProtoMatch defines fixations as a minimum of 6 samples within a default 2°- of visual-angle window resolution. Each cell in the left hand column and the "odd numbers" column was defined as an area of interest for categorizing the location of fixations.

RESULTS AND DISCUSSION

Reaction Time Data

We first sought to determine whether the interruptions were disruptive to primary task performance and whether this difference was influenced by the partial vs. full occlusion manipulation. The inter-action intervals from the control trials were compared to the resumption lags from the interruption trials for both the partial and full occlusion conditions. As Figure 2 suggests, the resumption lags (M = 2.7 sec) were significantly longer than the inter-action intervals (M = 1.2 sec), $F(1,31) = 168.9$, $MSE = .23$, $p<.001$. The main effect of partial vs. full occlusion was non-significant; however, there was a significant interaction, $F(1,31) = 7.1$, MSE = .23, $p<.05$. Tukey HSD post-hoc comparisons were performed to explore this interaction. There was no difference in the inter-action intervals for the partial (M = 1.2 sec) vs. full occlusion (M = 1.1 sec) conditions. However, the resumption lags in the partial occlusion condition (M = 2.5 sec) were significantly shorter than the resumption lags in the full occlusion condition (M = 2.9 sec), $p<.05$.

As expected, the reaction time measures show that the interruptions were disruptive to primary task performance. Further, the interruptions were more disruptive to primary task performance when delivered by the full occlusion IM as compared to the partial occlusion IM as evidenced by the difference in resumption lags. One explanation for this finding might be that participants spent less time on the interruption in the partial occlusion case allowing them to resume faster. We examined the amount of time spent on the interruption (i.e. the interruption duration) and there was no statistical difference between the partial (M = 9.9 sec) and full occlusion conditions (M = 10.7 sec), $F(1,31) = 1.4$, $p = .25$. Participants spent the same amount of time on the interrupting task in both conditions.

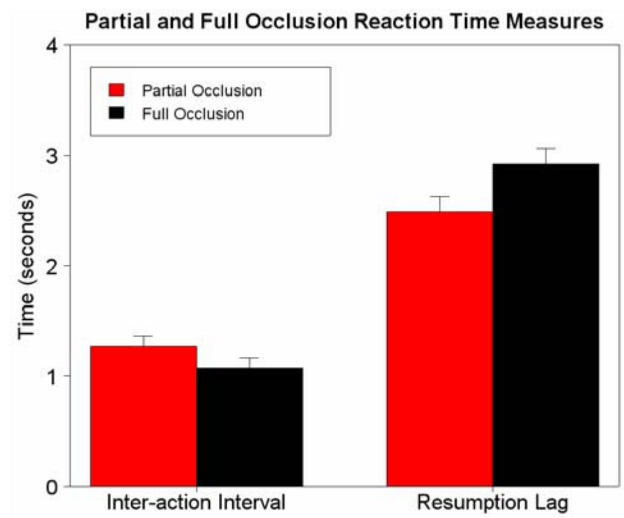

Figure 2. Reaction time measures.

Eye Track Data

We examined the eye track data to determine how participants were able to resume more quickly in the partial occlusion interruption condition. The eye track data showed that only one participant fixated on the primary task during the interruption, and that this only occurred on a few of the trials; this amounted to less than 2% of the all the interruption trials for all the participants. Thus, the majority of participants were not making explicit fixations to the primary task during the interruption, suggesting that having peripheral access to the primary task may be influencing participants' ability to resume faster.

If having peripheral access to the primary task during the interruption facilitates memory for spatial location and consequently resumption of the primary task, there are several straightforward predictions at the perceptual level. First, participants should be more accurate at returning to where they left off in the primary task following the interruption in the partial occlusion condition. Second, because participants should have a more intact spatial representation and can return closer to where they left off after the interruption, they should be able to resume by making fewer fixations during the resumption lag.

In order to examine spatial accuracy when resuming the primary task, we focused on where the participant was prior to being interrupted and compared this location to where they initially returned after completing the interrupting task. We calculated the Euclidean distance in pixels between the location of the pre-interruption fixation and the post-interruption fixation and compared this distance for the partial occlusion and full occlusion conditions. We found that participants were more accurate at returning to where they left off in the partial occlusion condition (M = 109.8 pixels) as compared to the full occlusion condition (M = 131.7 pixels), $F(1,31) = 5.6$, $p<.05$ (see Figure 3). Thus, the partial occlusion IM allowed participants to return more closely to where they left off as compared to full occlusion IM.

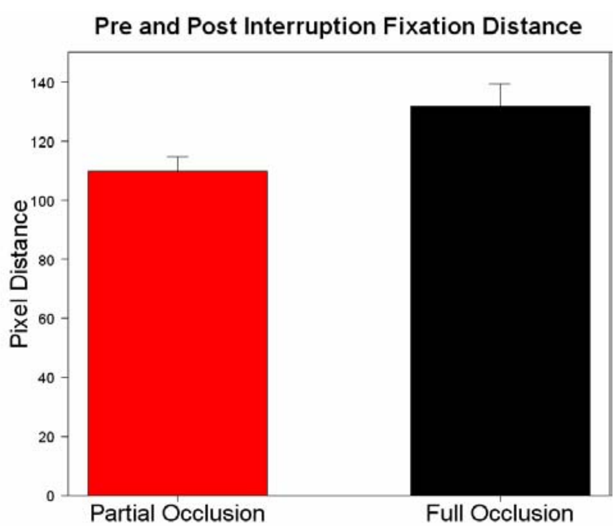

Figure 3.Distance between fixation points.

Next, we examined the number of fixations during the resumption lag. If participants were more accurate at returning to where they left off following the partial occlusion interruption they should be able to resume the task with fewer fixations. We found that participants made fewer fixations during the resumption lag following a partial occlusion IM (M = 5.8) as compared to a full occlusion IM (M = 7.3), $F(1,31) = 6.2$, $p<.05$, as Figure 4 suggests.

The eye track data showed the partial occlusion IMs allowed for participants to be more accurate at returning to where they were in the primary task following the interruption and that participants were able to resume with fewer fixations. Importantly, participants were not explicitly fixating on the primary task during the interruption, and there was no difference in the amount of time spent on the interrupting task.

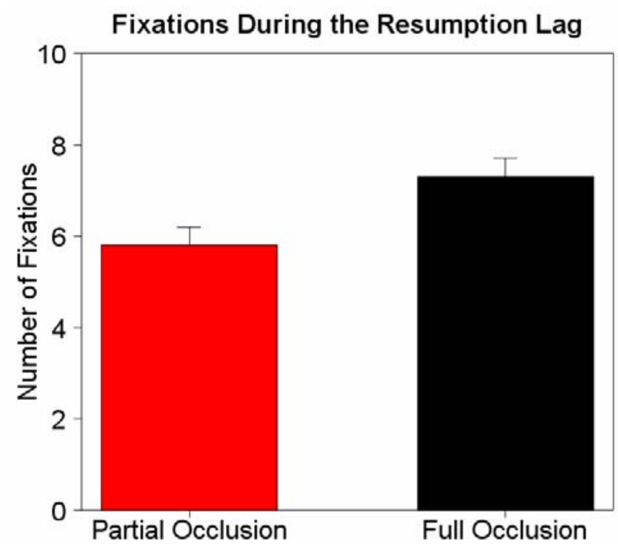

Figure 4. Number of fixations during the RL.

GENERAL DISCUSSION

Most theories that attempt to account for the resumption process following an interruption focus on the specific goal that was being worked on in the primary task. We have focused on spatial memory and knowing *where* in the task one was prior to being interrupted. In the experiment presented here, we have shown that by allowing for peripheral access to the primary task interface during an interruption, a more intact spatial representation can be maintained. This spatial representation can facilitate resumption of the primary task upon completion of the interruption by allowing one to return more closely to where he or she was prior to the interruption. These results show that not only is spatial memory important to the resumption process, but also that maintaining a spatial representation of the primary task is possible using peripheral vision, and this does not increase the amount of time required to handle the interrupting task.

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