A Spatial Memory Mechanism for Guiding Primary Task Resumption

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By

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

A SPATIAL MEMORY MECHANISM FOR GUIDING TASK RESUMPTION

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Theories accounting for the task resumption process following an interruption have primarily been memory based accounts (Altmann & Trafton, 2002, 2007; Oulasvirta & Sarrlilouma, 2004). The purpose of this study was to examine the resumption process at the perceptual level to determine whether spatial memory processes are used to resume and to determine whether these processes can be directly integrated with an activation-based theoretical framework of goal memory (Altmann & Trafton, 2002). Based on previous literature two plausible hypotheses, a retrace hypothesis and a spatial memory hypothesis, were examined to account for the perceptual processes used to resume an interrupted task. Six eye movement studies, using two different tasks that varied in task structure, were conducted to distinguish between these two hypotheses. In Experiments 1 and 4, the pattern of eye movements upon resumption was examined to distinguish between the retrace and spatial memory hypotheses. In Experiments 2 and 5, an interrupting task that required spatial working memory resources was shown to be more

disruptive than a non-spatial interrupting task. These results directly implicate spatial memory in the task resumption process. In Experiments 3 and 6, interruption length was manipulated to determine whether spatial memory remains intact over longer interruption lengths. Together, the results of these experiments provide strong support for a spatial memory mechanism of task resumption that can be directly integrated with the Altmann and Trafton (2002, 2007) memory for goals theory.

INTRODUCTION

In today's work environment, people are often bombarded with interruptions (Gonzalez & Mark, 2004); it is rare to be able to work on a single task without having your attention diverted towards something else. To begin to understand the effect of interruptions on a primary task, the timeline of this process can be examined using a task analytic approach (Trafton, Altmann, Brock, & Mintz, 2003), as shown in Figure 1. An interruption forces people to direct attention away from the primary task to the interrupting task. When resuming the primary task, there is often a time cost associated with the resumption process, termed the resumption lag (Altmann & Trafton, 2002, 2004). It takes people time to "gather their thoughts" to determine what they were doing before being interrupted. What cognitive and perceptual processes account for the resumption lag?

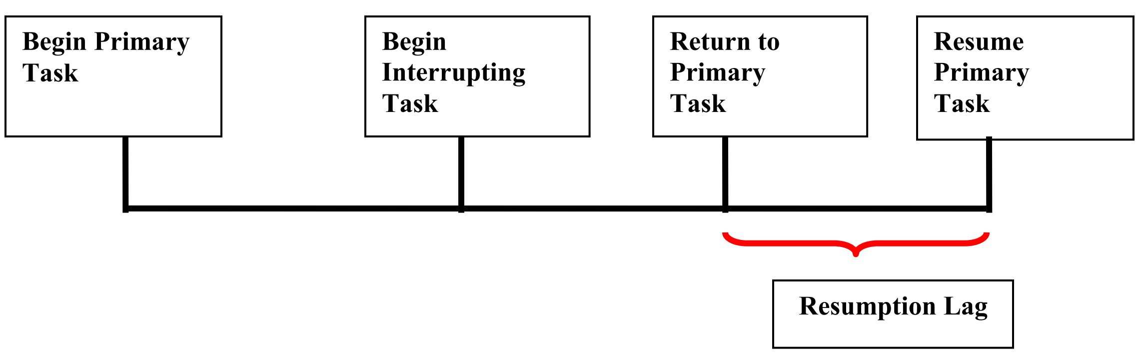


Figure 1. Illustration of the interruption and resumption process.

Memory-Based Accounts of the Resumption Lag

Several general memory theories have been applied as theoretical accounts of the interruption and resumption process (e.g., Long Term Working Memory, (Ericsson & Kintsch, 1995; Oulasvirta & Sarrlilouma, 2004)). These theories suggest that interruptions will be disruptive if they interfere with the transfer of information from short term working memory (STWM) to long term working memory (LTWM). The focus of these theories, however, is on determining when an interrupting task will be disruptive to primary task performance, not on the specific processes that take place to resume an interrupted task.

A prominent theoretical framework that has been applied to the interruptions domain to account for the resumption process is the memory for goals model (Altmann & Trafton, 2002, 2007). This activation-based theory suggests that the most active current goal directs behavior. When interrupted, the current primary task goal must be suspended and the activation level of this goal decays during the interruption. Upon resumption, the time required to actually begin work on the primary task reflects the process of retrieving the suspended goal; the resumption lag measure reflects this process. The higher the activation level of the suspended goal, the more quickly and easily that goal can be retrieved upon resumption.

Within the memory for goals theory there are two main constraints which determine the activation level of the suspended goal. First, the strengthening constraint suggests that the history of the goal (i.e. how frequently and recently the goal was retrieved) will impact goal activation. The primary task goal that has occurred most frequently and the primary task goal that was last worked on, prior to the interruption, will have the highest activation levels upon resumption. Second, the priming constraint suggests that cues may prime the suspended task goal by providing associative activation to the goal. These cues can either be in the mental or environmental context. In order for a retrieval cue to be effective it must be associatively linked to the target goal prior the interruption and the cue must be attended to upon resumption. Thus, when resuming the primary task these cues may provide associative activation to the suspended primary task. This boost in activation may facilitate the retrieval of this goal.

Several empirical studies have directly examined the predictions of the Altmann and Trafton (2002) framework. There has been support for the decay of the primary task goal over the length of the interruption (Hodgetts & Jones, 2006b; Monk, Trafton, & Boehm-Davis, under review). These studies have shown that as the length of the interruption increases, the time required to retrieve the suspended task goal upon resumption also increases. These effects have been shown at shorter interruption lengths (i.e. less than 30 seconds). There has also been explicit evidence for the strengthening (Trafton et al., 2003) and priming constraints (Hodgetts & Jones, 2006a; Trafton, Altmann, & Brock, 2005). Trafton et al. (2003) provided support for the strengthening constraint by showing that in order to prevent or slow down goal decay it is possible to rehearse the retrospective or prospective goal. Trafton et al. (2005) provided support for the priming constraint by showing that environmental cues facilitate goal retrieval upon resumption. Finally, Altmann and Trafton (2007) have shown that each task relevant goal in the goal hierarchy is associatively linked to future goals in the hierarchy. Thus, retrieval of one task goal provides priming for the next task goal. Together, the memory for goals framework and these empirical studies provide a broad understanding of the memory processes underlying primary task resumption.

Several things should be noted about the Altmann and Trafton (2002) theory and the empirical papers supporting this theory. The memory for goals theory (and others) make the assumption that resuming a task is, in large part, a matter of determining *what* had been done previously; the focus has been on *what* the goal was prior to the interruption and the memory processes used to retrieve this goal post-interruption. For many tasks (e.g., computer based interactions), however, determining *where* (i.e. spatial location) in the task or interface (Ehret, 2002) pre-interruption work had occurred is just as important as determining *what* had been done previously. Although the memory for goals theory suggests that environmental cues are important to the task resumption process because they provide associative activation to the suspended goal, the interaction between perceptual processes and environmental cues is currently unspecified. For example, it is unclear as to how one knows what cues to attend to. The overarching goal of this dissertation is to focus on the perceptual level to determine how people know where to resume and to understand if these processes can be integrated with the current constraints of the memory for goals theory.

Perceptual Explanations for the Resumption Lag

When resuming a computer based task, where do people look during the resumption lag and do these eye movements provide insight into the resumption process? By focusing on eye movements, inferences can be made about cognitive process (Just &

Carpenter, 1976; Rayner, 1998); thus, examining eye movements during the resumption lag may provide insight into the cognitive processes underlying task resumption. Studying eye movements during the resumption lag may also provide insight into the interaction between perception and memory processes. Although there have been no direct empirical papers examining resumption processes at the eye movement level, other researchers have proposed hypotheses about perceptual and spatial processes during resumption. The first hypothesis is that people may not remember where to resume in the primary task and will retrace their steps when resuming; this is based on research within the interruptions domain (Miller, 2002). An alternate hypothesis, based on research in the visual search domain (Lleras, Rensink, & Enns, 2005, 2007; Shen & Jiang, 2006), is that one may be able to maintain a spatial representation of the primary task during the interruption and use this spatial representation to resume the primary task.

Retracing behavior. A study by Miller (2002) provides direct support for the retrace hypothesis. Miller (2002) interrupted participants as they performed a complex radar operator decision making task. Through self-report measures, it was found that following the interruption, participants tended to start the primary task over again after the interruption as opposed to resuming at the point where the interruption had occurred. Miller (2002) suggested that participants may have adopted this strategy of restarting the primary task because it was easier than determining the specific resumption point. These results are also consistent with the interpretation that participants may not have remembered where to resume in the task and consequently may have retraced their steps from the beginning. Thus, in terms of eye movements, one might retrace his or her steps from the beginning of the task or from a point several steps prior to where the interruption occurred in the task hierarchy until the point where work was last completed is reached.

In addition to these self-report measures, there are empirical studies that have found that interruptions which occur early in the primary task are less disruptive (i.e. result in a shorter resumption lag) as compared to interruptions that occur in the middle of the primary task (Adamcyzk & Bailey, 2004; Czerwinski, Cutrell, & Horovitz, 2000a, 2000b; Monk, Boehm-Davis, & Trafton, 2002). These empirical findings are consistent with a retrace hypothesis. If people retrace their steps after being interrupted, interruptions occurring at the beginning of a primary task would not be as disruptive because less work will have occurred up to the point of the interruption. When an interruption occurs in the middle of a task, there would be more steps to retrace as compared to an early task interruption, possibly leading to a longer resumption lag following the middle task interruption. Thus, these empirical papers also provide some support for the retrace hypothesis.

Memory for spatial location. Another possible explanation for the processes taking place during the resumption lag is that spatial memory may be used to remember the general spatial location of where one was in the primary task. Memory for the spatial context of a display (Chun, 2000; Chun & Jiang, 1998) and memory for the spatial location of specific objects (Andrade & Meudell, 1993; Ellis, 1990; Hasher & Zacks, 1979) has been shown be encoded incidentally. Further, spatial memory has been shown to be quite durable, lasting for several minutes (Ellis, 1990) and even up to one week

(Chun & Jiang, 2003), whereas goal memory has been shown to decay quite rapidly (Altmann & Trafton, 2002). If spatial memory can be maintained during the interruption, upon resumption, spatial memory may guide one's attention to the physical location in the primary task interface where pre-interruption work last occurred. This suggests that people should not retrace their steps from the beginning of the primary task. However, one thing to note is that spatial memory may be slightly inaccurate resulting in a resumption point that is few steps behind the exact location of pre-interruption work. Thus, people may retrace their steps from this point until they reach the point of pre-interruption work. This partial retrace process still relies on spatial memory of the primary task and makes a different prediction from the full retrace hypothesis; the partial retrace process does not involve starting at the beginning of the task.

A body of literature in the visual search domain provides preliminary support for the ability to maintain spatial information of the primary task. In a visual search paradigm, it has been shown that memory for where an item is located, not the features of the item, are used during visual search (Beck, Peterson, & Vomela, 2006). This suggests that spatial location information is being stored and possibly used to direct attention. There have also been several studies demonstrating that people can maintain some kind of spatial representation of a visual search task over a delay (Lleras et al., 2005, 2007; Shen & Jiang, 2006; van Zoest, Lleras, Kingston, & Enns, 2007). Lleras et al. (2005) showed that resuming an interrupted visual search task was faster than initially beginning a visual search task. This suggests that some information about the visual search display is kept in memory upon resumption of the search task after the interruption. Shen and

Jiang (2006) also explored interruptions during visual search tasks. They found that unfilled temporal delays (up to 6 seconds) do not affect search performance, while short (4 second) delays filled with search tasks (i.e. a search task interrupting a search task) disrupted search performance and long (3 minute) delays filled with search tasks completely eradicated search memory. Shen and Jiang suggest that relative spatial location (spatial configuration) information is being retained during the interruption interval.

Further support for the role of spatial representations of the task environment directing attention comes from research examining eye movements while participants interact with real-world environments (Aivar, Hayhoe, Chizk, & Mruczek, 2005; Hayhoe, Shrivastava, Mruczek, & Pelz, 2003). These studies have shown that a spatial representation of the task environment is quickly built up over several fixations and this spatial representation is used to program eye movements and direct attention.

Together, the visual search studies and the real-world environment studies provide support for being able to maintain a spatial representation of a task environment over a short delay and for this spatial representation guiding attention. However, the visual search studies have primarily used general reaction time measures to illustrate that a spatial representation of the search display can be maintained over a delay. It is unclear whether this spatial representation of the primary task can actually direct attention to a specific location within the primary task. Further, it is unclear how spatial memory might facilitate task resumption in more complex tasks, especially during longer interruption intervals (i.e. greater than 6 seconds), and the relation between spatial memory and goal memory remains unspecified.

The Current Research

The purpose of this study was, first, to establish the role of spatial memory in the task resumption process. After showing that spatial memory is a component of the task resumption process, the aim was then to examine how spatial memory and goal memory interact. Six experiments, using two different types of primary tasks, were conducted to accomplish these two goals. These six experiments are divided in two chapters; Chapter 1 contains Experiments 1-3 and Chapter 2 contains Experiments 4-6.

The focus of the experiments in Chapter 1 was to clearly distinguish between the retrace and spatial memory hypotheses by using a task that allowed for a clear measure of where participants first fixated when the task resumed. The primary task, called the odd numbers task, required participants to search a list of numbers and transcribe the odd numbers from this list. The key feature of this task is that it has a flat goal structure, which allowed for the focus to be on where in the physical task environment participants resumed as opposed to where in the task hierarchy participants resumed. A task with a flat goal structure, unlike a task with a hierarchical goal structure, does not have a series of nested subgoals. Thus, upon resumption, one does not have to remember the history of subgoals that were performed in order to accurately resume the task. A simple task analysis (Card, Moran, & Newell, 1983), as shown in Figure 2, illustrates the flat goal structure and the lack of subgoals in this task.

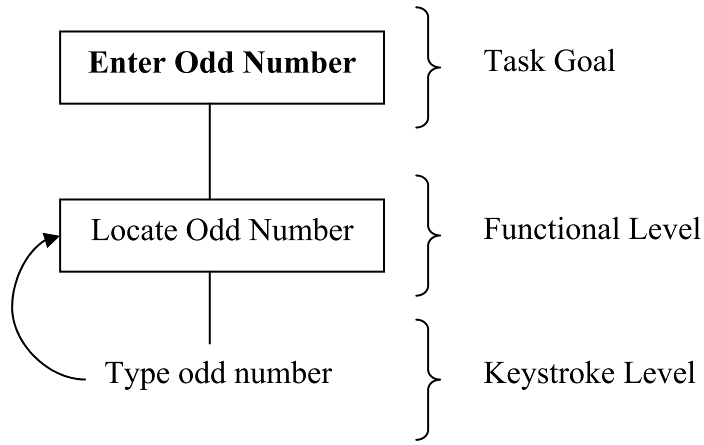


Figure 2. Simple task analysis of the odd numbers task.

In Chapter 2, a hierarchically structured task was used to replicate the findings from Chapter 1, with a more complex task, and to examine how spatial memory and goal memory interact. Many of the tasks used in the interruptions domain and many real-world tasks are hierarchically structured (e.g. making coffee (Botvinick & Bylsma, 2005)). Tasks with a hierarchical goal structure require several subgoals to be performed in order to accomplish the primary goal. Using a primary task with this type of structure provided an opportunity to investigate the interaction between goal and spatial memory, unlike the task used in Experiments 1-3. A task analysis (Card et al., 1983) of the task used in Experiments 4-6, called the sea vessel production task, is depicted in Figure 3. As can be seen in this figure, this task requires that one keep track of which subgoals have been performed in order to complete the main task goal.

When resuming the sea vessel production task following an interruption, one must remember the specific goal to be resumed (e.g. I need to enter ship material information) and one must remember the physical location of where to resume (e.g. I was last working in the upper left corner). The interaction of spatial and goal memory during the task resumption process is unclear. Specifically, does memory of the suspended primary task goal prime retrieval of the spatial location of where to resume or does spatial location of where to resume in the primary task interface facilitate retrieval of the suspended primary task goal? This distinction is important in order to determine how spatial memory might be integrated with the memory for goals model (Altmann & Trafton, 2002).

Currently, when specifying the memory for goals (Altmann & Trafton, 2002) account of the task resumption process within the ACT-R cognitive architecture (Anderson et al., 2004), the resumption process would consist of first retrieving the suspended task goal and then retrieving the spatial location of where to resume (Brudzinski, Ratwani, & Trafton, 2007); thus, retrieving the goal of what to do primes retrieval of the spatial location of where to resume or where to attend to. However, given the previous literature on the robustness of spatial memory and the role of environmental cues in the task resumption process (Altmann & Trafton, 2002); spatial memory may be a mechanism by which these environmental cues are attended to. Thus, spatial memory may prime goal memory by directing attention to the appropriate cues.

The experiments in Chapter 2 attempt to provide insight into the interaction between spatial and goal memory by examining the pattern of eye movements as participants fixate on the relevant environmental cues associated with the primary task goal. If spatial memory precedes goal memory and guides attention to the relevant environmental cues in the task interface, participants should fixate on these cues immediately upon resumption. However, if participants first retrieve goal memory participants will have to search around the task interface to find the relevant environmental cues. Thus, there should be a different pattern of eye movements depending on whether spatial memory primes goal memory or goal memory primes spatial memory.

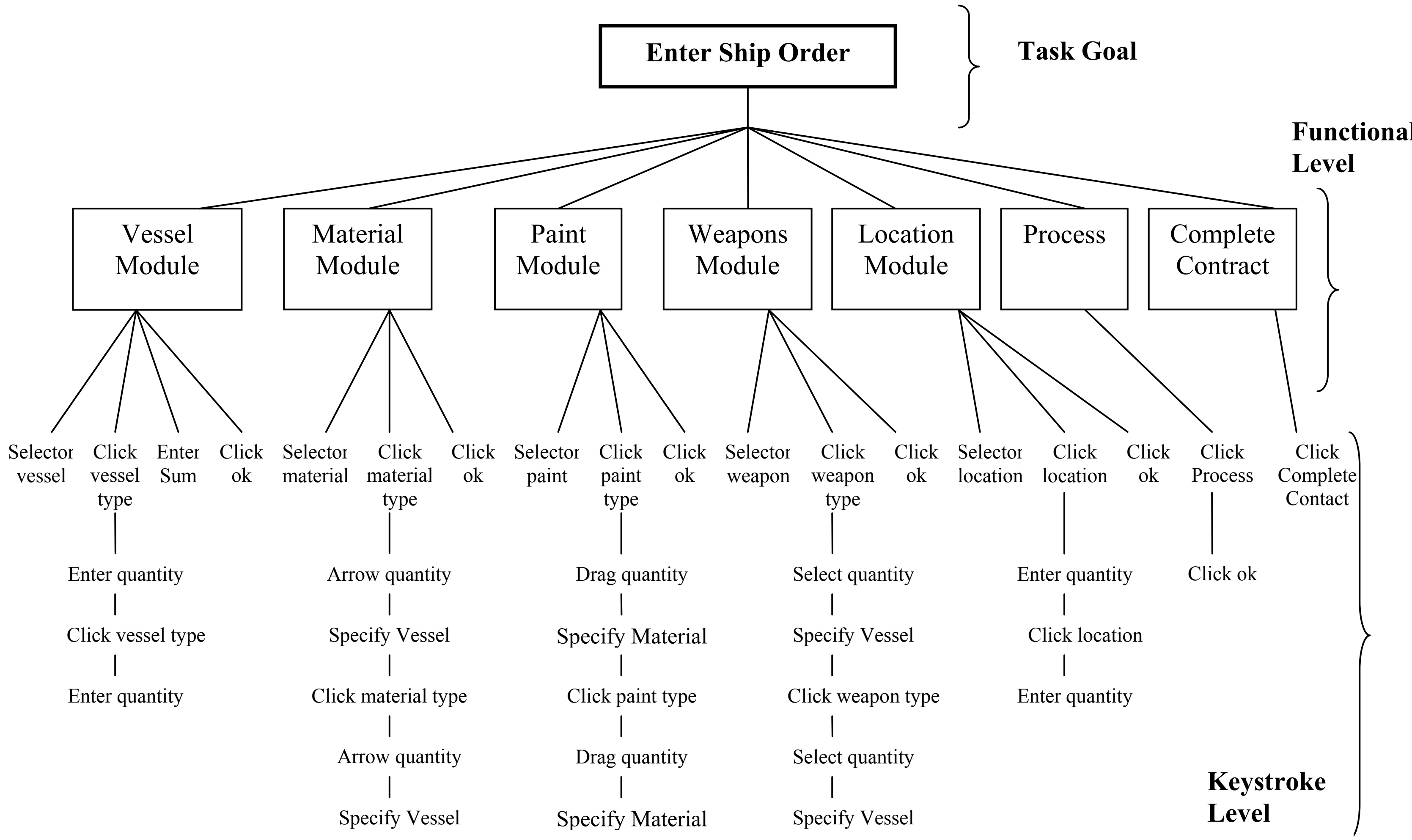


Figure 3. Simple task analysis of the sea vessel production task.

Although the primary tasks used in Chapters 1 and 2 were different, the manipulations across the three experiments in each chapter were consistent. In the first experiment of each chapter (Experiments 1 and 4), the focus was on describing the general pattern of eye fixations as people resumed. In the second experiment of each chapter (Experiment 2 and 5), the effects of a spatial interrupting task on resumption were compared to a non-spatial interrupting task. If spatial memory guides task resumption, a spatial interrupting task should disrupt the spatial representation of the primary task, resulting in slower and more inaccurate resumption of the primary task. In the final experiment of each chapter (Experiments 3 and 6), the length of the interruption was manipulated to examine whether spatial memory decays over longer interruption lengths, resulting in more imprecise spatial memory upon resumption. The interruption duration effect (Hodgetts & Jones, 2006b; Monk et al., under review) suggests that longer interruptions may result in longer resumption lags because of greater decay of the primary task goal over the longer interruptions; however, spatial memory has been shown be more durable and may persist over longer interruption lengths (Chun & Jiang, 2003; Ellis, 1990). Thus, there is a disconnect between these two bodies of literature in regard to spatial and goal memory decay; Experiments 3 and 6 explicitly examined this issue.

CHAPTER 1

The focus of the experiments in Chapter 1 was on determining whether spatial memory is a process used during task resumption. In order to distinguish between the retrace and spatial memory hypotheses, a primary task with a flat goal structure and a sequential order of operations was used. By measuring eye movements, the pre-interruption and post-interruption locations could be easily examined to determine whether participants were retracing their steps or using spatial memory to resume the task. Comparing pre- and post- interruption fixation location allowed a direct measure of the ability to return to where one was last working.

Experiment 1

The goal of this experiment was to examine where (i.e. spatial location) participants looked when resuming a primary task following interruption to determine whether participants were retracing their steps from the beginning of the task or using spatial memory to resume. The eye movement data should clearly disambiguate between these two accounts. If participants retrace their steps from the beginning of the task after being interrupted, their first fixation upon resumption should be biased towards the beginning (i.e. the first action) of the primary task. If participants use spatial memory to resume, participants should fixate close to where pre-interruption work last occurred prior to being interrupted.

Method

Participants. Thirteen George Mason University undergraduate students participated for course credit.

Materials. Each trial of the primary task consisted of a column of 11 three-digit numbers ranging from 100-999 (see Figure 4). In order to generate the trials fifteen unique templates containing slots specifying which numbers were to be even or odd and the location of these numbers were used to generate the actual columns of numbers used in the experiment; each template contained a minimum of five odd numbers. The distance between the odd numbers was varied in each template and ranged from zero (e.g. one odd number followed by another odd number) to four cells. Based on the templates, two sets of 15 columns of numbers were created for presentation; each column was one trial resulting in a total of 30 matched trials. The specific numbers that filled the slots in the template were randomly generated for each participant. Each number subtended .6º of visual angle, each cell subtended 2.9º and each number was separated by 2.3º of visual angle.

The interrupting task lasted 15 seconds and was a list of 9 addition problems each containing four single-digit addends ranging from 1-9. The addends were randomly generated.

Design. A within participants design was used; one set of 15 trials served as interruption trials and one set as control trials. Presentation order of the all the trials was randomized. Each interruption trial contained a single interruption which occurred equally among different positions in the primary task (early, middle, and late).

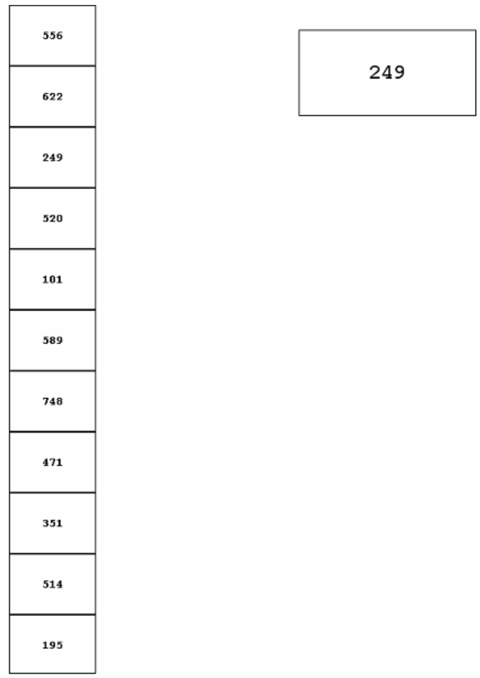


Figure 4. Screenshot of the primary task.

Procedure. Participants were seated approximately 47 cm from the monitor. Stimuli were presented using E-Prime (Schneider, Eschman, & Zuccolotto, 2002). The primary task required participants to type the odd numbers from the primary column (on the left) into a separate copy box (on the right; see Figure 4). Participants were instructed to start at the top of primary column and to work their way to the bottom. The participant pressed the space bar to move on to the next trial.

On the interruption trials, when an interruption occurred, the interrupting task immediately appeared and fully occluded the primary task screen. During the interruption, participants were instructed to answer as many addition problems correctly as possible. Upon resumption of the primary task, the odd number that was last entered in the copy box prior to the interruption was still displayed. In order to resume, a participant would have to remember the exact location of where the next correct odd number to enter is located or that participant could find the number last entered in the primary column and continue from that point.

Measures. Based on the reaction time data, an inter-action interval for control trials and a resumption lag for interruption trials (Altmann & Trafton, 2004) were calculated. The inter-action interval was the average amount of time between actions (i.e. the average amount of time in between entering odd numbers). The resumption lag was the time from the completion of the interrupting task to the first action back on the primary task (i.e. entering an odd number). Eye track data were collected using a Tobii 1750 operating at 60hz. A fixation was defined as a minimum of five eye samples within 10 pixels (approx 2° of visual angle) of each other, calculated in Euclidian distance. Each of the cells in the primary column and the copy box were defined as areas of interest. For descriptive purposes, the cells in the primary column were numbered sequentially from 1 to 11.

Results

Incorrect actions were removed from all analyses; this accounted for less than 3% of the data. An incorrect action was defined as entering an incorrect number in the copy box.

Performance on the Interrupting Task. Participants answered an average of 2.7 addition problems during each 15 second interruption with an average accuracy of 88.1%.

None of the participants answered all nine of the addition problems during any of the interruptions.

Reaction Time Data. The reaction time data were examined to determine whether the interruption was disruptive to primary task performance. The resumption lag (M = 4511.4 msec, SD = 1024.5) was significantly longer than the inter-action interval (M = 1893.6 msec, SD = 534.3), $F(1, 12) = 167.1$, $MSE = 366495.9$, $p<.001$. Participants took more than twice as long to enter an odd number following an interruption as compared to the average time in between entering odd numbers in the control condition.

Eye Movement Data. Upon resumption of the primary task, 99% of participant's first fixations were to the copy cell. In order to determine how accurate participants were at returning to the point in the primary task where pre-interruption work last occurred, the analyses focused on fixations to the primary column, not the copy cell. If participants were retracing their steps from the beginning of the task, participants' first fixation on the primary column should have been to the first cell. Thus, the average first fixation location should be approximately "one" reflecting a fixation to this top cell. The post-interruption first fixation location (M = 4.01, SD = 2.1) was statistically different from one, $t(12) = 5.1$, $p<.001$. This suggests that participants were not resuming the primary task by starting over.

To determine whether participants were using spatial memory to resume the primary task, participants' pre- and post- interruption fixation locations in the primary column were compared. A difference score was calculated between the two cell values that corresponded to where the pre- and post- fixations landed as a gauge of how far away participants returned from the point of pre-interruption work. For example, if a participant was fixating on cell 5 prior to being interrupted and then returned to cell 4 immediately after the interruption, this difference of -1 would indicate that the participant returned 1 cell back from where he or she last was in the primary column. A value of 0 would indicate perfect spatial memory.

Figure 5 shows the distribution of difference scores. The mean difference score was -1.9 and the distribution is centered on -2 indicating that participants were slightly more conservative in where they resumed. The majority of the time (~60%) participants were able to return within 3 cells of where pre-interruption work last occurred. To statistically determine whether there was a bias to returning within 3 cells, the resumption fixations were binned as falling within 3 cells of where participants left off or outside of 3 cells from where participants left off. Participants fixated within 3 cells of the pre-interruption point significantly more often than outside of 3 cells, $F(1, 12) = 4.7$, $MSE = 9927.1$, $p<.05$.

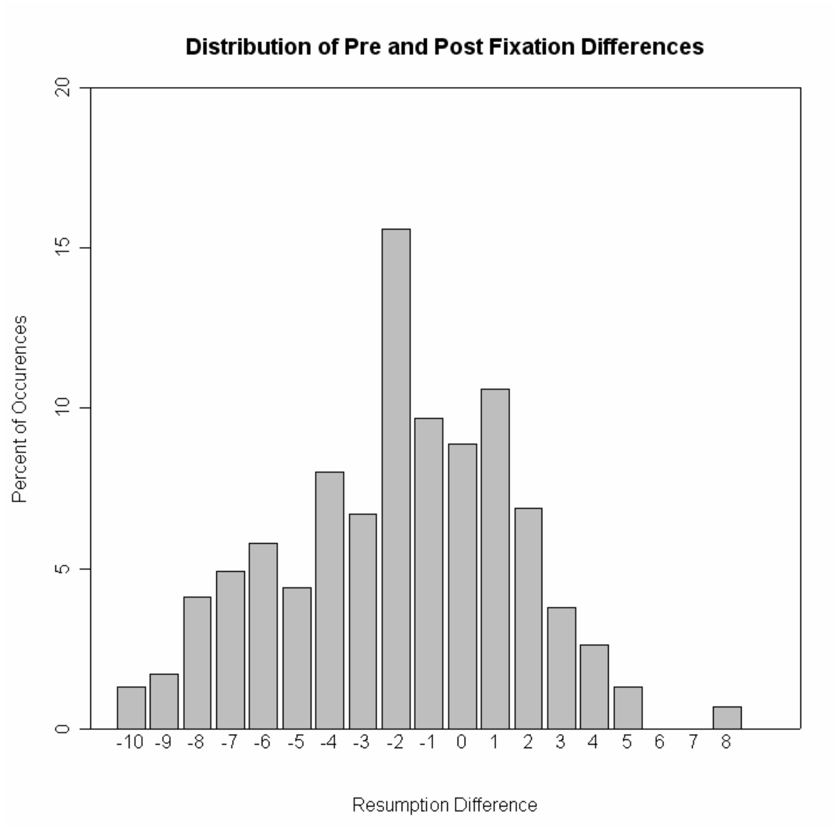


Figure 5. Distribution of difference scores.

Discussion

The reaction time measures showed that the interruption was disruptive to primary task performance; this finding is in agreement with several other studies showing the immediate disruptive effects of interruptions (Hodgetts & Jones, 2006a, 2006b; Monk, Boehm-Davis, & Trafton, 2004; Monk et al., under review). The eye movement data showed that participants were not retracing their steps from the beginning of the task; participants did not fixate to the top of the primary column upon resumption.

The distribution of difference scores provides some preliminary support for the role of spatial memory in the task resumption process. Participants did not have perfect spatial memory for where to resume, but participants were able to return relatively close to where they left of prior to the interruption. This suggests that participants were able to maintain some kind of spatial representation of the primary task, consistent with findings in the visual search domain (Lleras et al., 2005, 2007; Shen & Jiang, 2006). Further, these results suggest that the participant's spatial representation can be used to guide one close to where pre-interruption work last occurred (i.e. a specific spatial location).

One thing to note about the resumption distribution is that it is centered on -2, suggesting that participants often returned two cells back from where pre-interruption work occurred. The skew of the distribution can be taken as preliminary support for a partial retrace process. Perhaps participants were not retracing their steps from the beginning of the task, but rather retracing a few steps back from where pre-interruption work last occurred (i.e. partial retrace). A partial retrace process still suggests spatial memory is being used during task resumption since participants were remembering the general spatial location of where to resume. Although the eye movement patterns from this experiment provide general support for the role of spatial memory in the task resumption process, the goal of Experiment 2 was to directly manipulate spatial memory to clearly distinguish between the retrace and spatial memory hypotheses.

Experiment 2

The purpose of this experiment was to find direct evidence that spatial memory is involved in the task resumption process by attempting to disrupt participant's spatial memory for where to resume. In order to do this, a mental rotation task was introduced as an interruption task which required spatial working memory resources (Baddeley, 1986; Logie, 1995). If spatial memory is used to maintain a representation of the primary task during the interruption and this spatial representation guides resumption of the primary task, disrupting spatial memory should result in a less intact spatial representation of the primary task and should negatively impact the resumption process. If spatial memory is used to resume a task, the spatial interruption should affect resumption in two ways. First, the resumption lags following a spatial interruption should be longer than a non-spatial interruption. Second, participants should fixate further away from the point of pre-interruption work following the spatial interruption because of interference (i.e. there should be a larger fixation difference score in the spatial condition).

Method

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

Materials. The primary task materials were the same as Experiment 1. There were two types of interruption tasks: non-spatial and spatial. The non-spatial interruption was the same interruption addition task that was used in Experiment 1. The spatial interruption was a mental rotation task (Cooper & Shepard, 1973). Participants were presented with pairs of letters (R's) or numbers (2's) that were either upright or mirror reversed and rotated in one of six orientations (see Figure 6). For each pair the participant had to determine whether the presented stimuli were both the same orientation (i.e. either upright or both mirror reversed) or whether they were of different orientations (i.e. one mirror reversed and one upright). Participants were presented with 10 pairs of randomly generated stimuli during each interruption; each interruption lasted 15 seconds.

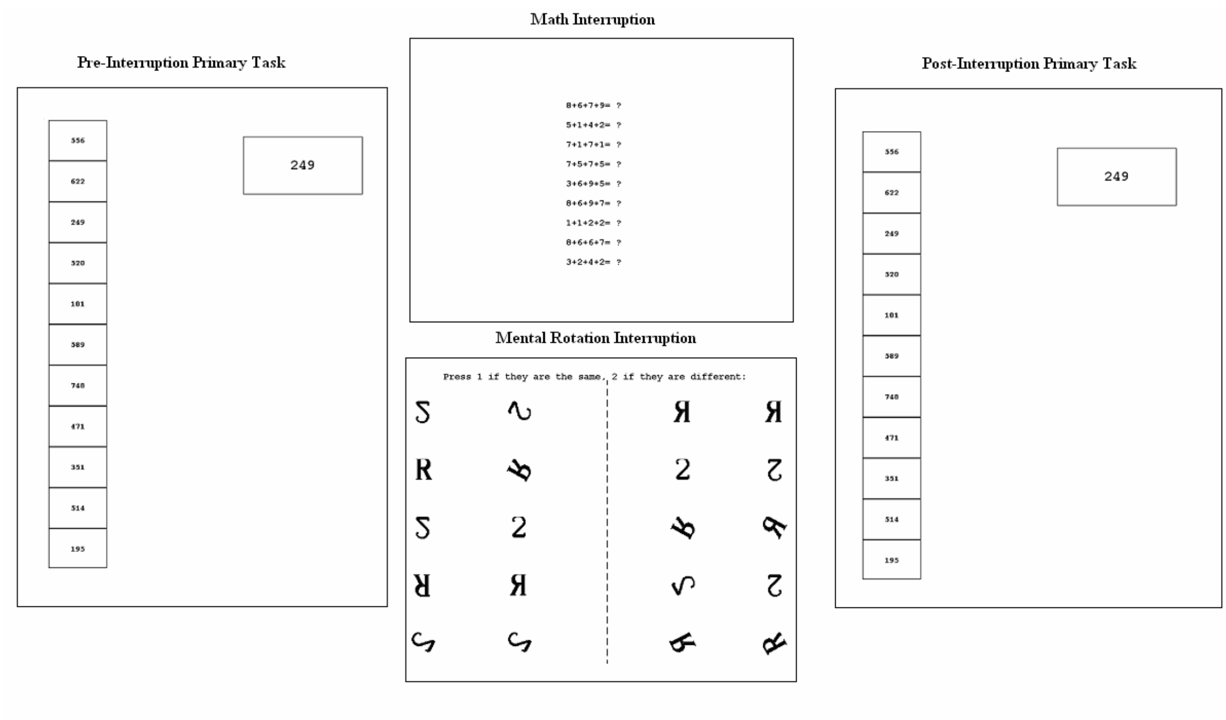


Figure 6. Screenshots of the primary and interrupting tasks.

Design. The type of interrupting task (non-spatial vs. spatial) was manipulated between participants. There were 18 participants in each condition; participants were randomly assigned to either condition. For each participant, one set of 15 trials contained interruptions and one set served as control trials for a total of 30 trials, just as in Experiment 1. Presentation order of the trials was randomized. Each interruption trial contained a single interruption which occurred equally across different positions in the task (early, middle, and late).

Procedure. The procedure for the primary task was the same as Experiment 1. During the 15 second interruption, participants were instructed to answer as many addition problems or mental rotation problems as possible. For each pair of stimuli in the spatial condition, participants responded by entering 1 if the stimuli were in the same orientation and 2 if the stimuli were in different orientations.

Measures. The measures were the same as Experiment 1.

Results

Resumption lag and inter-action intervals that were incorrect actions were removed from all analyses; this accounted for less than 3% of the data.

Performance on the Interrupting Task. Participants answered more mental rotation (M = 6.8, SD = 1.4) problems than math problems during the interruption (M = 3, SD = .9), $F(1,34)$ = 84.2, MSE = 1.2, p<.001. There was no difference in accuracy on the spatial (M = 91.9%, SD = 3.7) and non-spatial (M = 91.2%, SD = 7) interruptions, $F(1, 34)$ = .14, MSE = 31.24, p = .7. None of the participants answered all of the problems during any of the interruptions in either condition.

Reaction Time Data. The resumption lags from the interruption trials were compared to the inter-action intervals from the control trials in each respective condition to determine whether the interruption was disruptive to primary task performance. In the spatial condition, the resumption lag (M = 4505 msec, SD = 881.8) was significantly longer than the inter-action interval (*M* = 1828.1, *SD* = 451.2), *F*(1, 17) = 270.8, *MSE* = 238181.5, *p*<.001. In the non-spatial condition the resumption lag (*M* = 3982.2 msec, *SD* = 485.2) was significantly longer than the inter-action interval as well, (*M* = 1679 msec, *SD* = 382.7), *F*(1, 17) = 454.6, *MSE* = 105030, *p*<.001. Importantly, as Figure 7 shows, the spatial condition resumption lag (*M* = 4505 msec) was longer than the non-spatial resumption lag (*M* = 3982.2 msec), *F*(1, 34) = 4.9, MSE = 506480.1, *p*<.05. The inter-action intervals were not significantly different between conditions, *F*(1,34) = 1.1, *MSE* = 175020.3, *p* =.3.

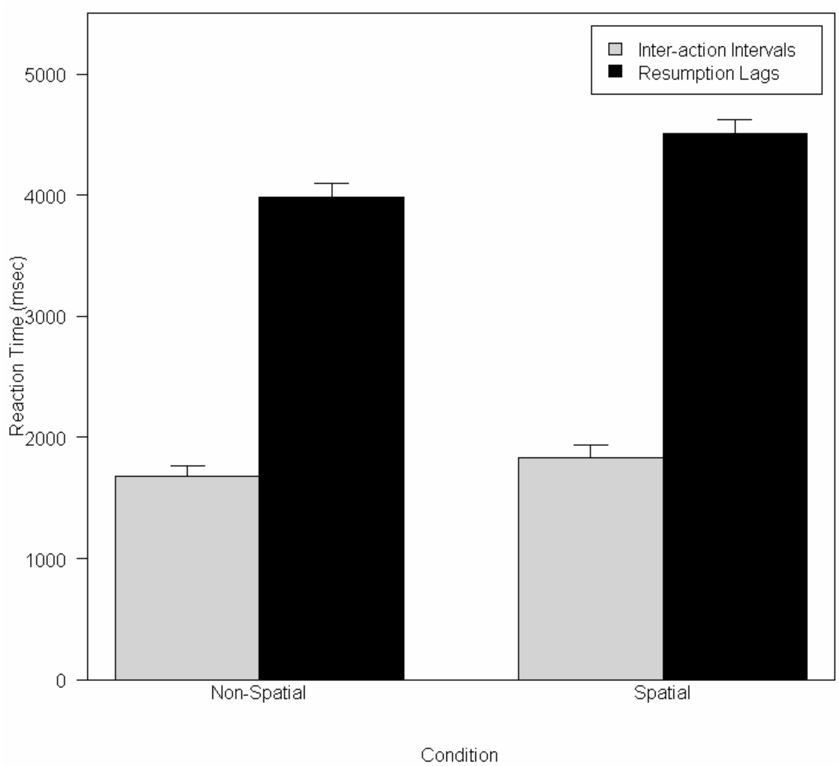


Figure 7. Experiment 2 inter-action interval and resumption lag data by condition.

Eye Movement Data. In order to determine whether the spatial interruption directly influenced participants' spatial memory, participants' pre- and post- interruption fixation locations were examined. Similar to Experiment 1, resumption location deviations were examined by calculating a difference score between the cell numbers that corresponded to the pre- and post- interruption fixation locations. The absolute values of the difference scores were examined to directly compare resumption deviation across conditions. Consistent with the spatial memory hypothesis, participants returned further from the point of pre-interruption work in the spatial condition (M = 3.5 cells, SD = 1.1) as compared to the non-spatial condition (M= 2.6 cells, SD = .71), $F(1, 34) = 10.1$, MSE = .8, $p<.01$.

Discussion

When the interrupting task required spatial working memory resources primary task resumption was disrupted. The spatial interruption not only resulted in longer resumption lags but also larger differences scores when comparing pre-interruption and post-interruption fixation locations. Note that the differences in resumption lag were not due to the mental rotation task being more difficult than the addition task because there was equal accuracy on the different interrupting tasks and participants answered more mental rotation problems than addition problems. Thus, interruption task difficulty is not a likely explanation for these resumption lag differences. These resumption lag differences suggest that memory for spatial location is an important component of task resumption and that disrupting spatial memory negatively influences primary task resumption.

Experiment 3

Experiments 1 and 2 suggest that spatial memory is a mechanism used to resume following an interruption. In those experiments, the interruption length was fifteen seconds. The goal of this experiment was to examine whether spatial memory persists over longer interruption intervals and to determine how this influences resumption. The interruption duration effect (Altmann & Trafton, 2002; Hodgetts & Jones, 2006b; Monk, et al., under review) suggests that longer interruptions lead to a longer resumption lag because of greater decay of the suspended task goal as the interruption duration increases. However, memory for spatial location is thought to be much more durable and thus may not decay as the memory for a specific goal does (Chun, 2000; Chun & Jiang, 1998, 2003; Ellis, 1990; Landsdale, Oliff, & Baguley, 2005).

In this experiment, interruption length was manipulated (15 seconds vs. 45 seconds) to determine whether spatial memory decays as goal memory does. If spatial memory is as durable as the previous literature suggests, the resumption location difference scores should be equal for the short and long interruptions. If longer interruption lengths lead to greater goal decay, as the interruptions literature suggests, it should take participants longer to resume following the longer interruption. Thus, there should be an observable disconnect between spatial memory and goal memory in terms of eye movements during the resumption lag. Participants should be able to maintain a spatial representation of the primary task equally well following the short and long interruptions, but there should be differences at the eye movement level to account for the longer resumption lag time following the longer interruption.

Method

Participants. Eighteen George Mason University undergraduate students participated for course credit.

Materials. The same primary task templates used in Experiment 1 were used in this experiment as well. Based on the templates three sets of 15 trials of numbers were created for presentation.

The interrupting task was the same as Experiment 1 with the exception that 12 addition problems were presented instead of 9 addition problems. This was done to ensure that participants were presented with enough addition problems to fill the 45 second interruption interval.

Design. The length of the interrupting task (15seconds vs. 45 seconds) was manipulated within participants. Participants performed 45 trials. One set of 15 trials contained interruptions with 15 second intervals, one set of trials contained interruptions with 45 second intervals, and one set of 15 trials served as control trials with no interruptions. Presentation order of the trials was randomized. Each interruption trial contained a single interruption which occurred equally across different positions in the task (early, middle, and late).

Procedure. The procedure for the primary and interruption tasks was the same as Experiment 1. During the interruption, the participants were instructed to answer as many addition problems as possible.

Measures. The measures were the same as Experiment 1.

Results

Resumption lag and inter-action intervals that were incorrect actions were removed from all analyses; this accounted for less than 3% of the data.

Performance on the Interrupting Task. Participants answered significantly more addition problems during the long interruption ($M = 6.2$, $SD = .8$) than the short interruption ($M = 2.3$, $SD = .6$), $F(1,17) = 866.7$, $MSE = .156$, $p<.001$. There was no difference in accuracy between the long ($M = 91.1\%$, $SD = 5.6$) and short interruptions ($M = 86.7\%$, $SD = 9.3$), $F(1, 17) = 2.8$, $MSE = .005$, $p = .11$. None of the participants answered all of the problems during any of the interruptions in either condition.

Reaction Time Data. An omnibus ANOVA testing differences between the short and long interruption resumption lags and the inter-action interval from the control trials was significant, $F(2, 34) = 207.7$, $MSE = 141286.5$, $p<.001$. Tukey HSD post-hoc comparisons show that the resumption lags following the long interruption ($M = 4324.6$ msec, $SD = 932.8$) were significantly longer than the inter-action intervals (M = 2094.6, SD = 397), $p<.001$. Likewise, the resumption lags following the short interruption ($M = 4387.5$, $SD = 664.2$) were significantly longer than the inter-action intervals, $p<.001$. Figure 8 illustrates the inter-action interval and resumption lag data. These results show that the interruption was disruptive to primary task performance. However, post-hoc comparisons reveal that there was no significant difference between the short and long interruption resumption lags, $p = .3$.

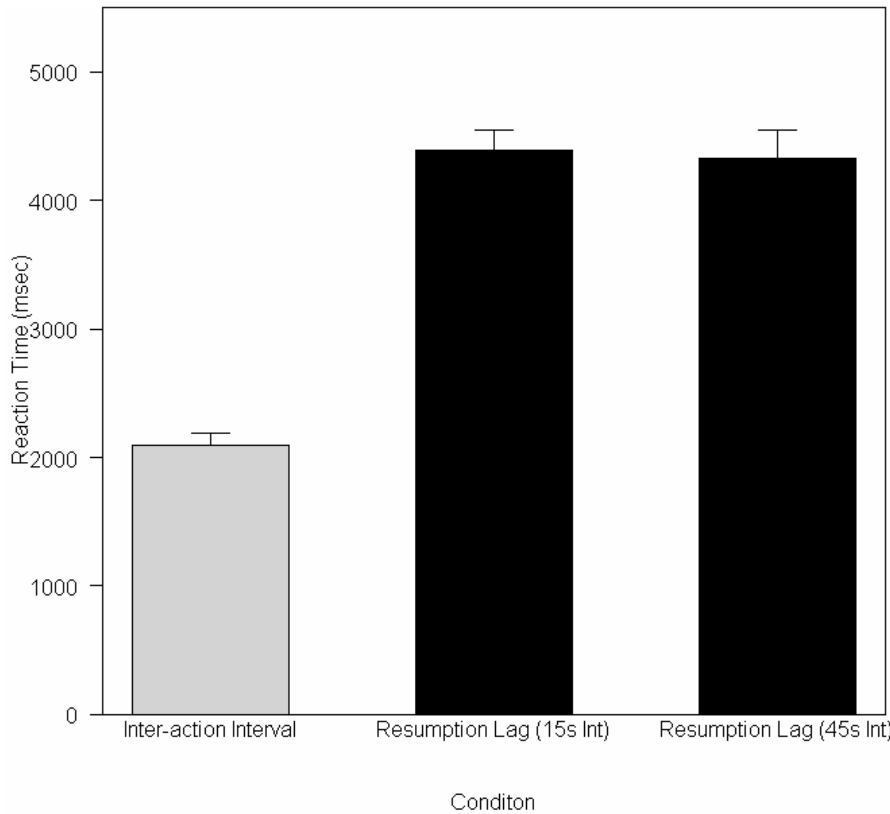


Figure 8. Experiment 3 inter-action interval and resumption lag data.

Eye Movement Data. In order to determine how the length of the interruption influenced participants' spatial memory, participants' pre- and post- interruption fixation locations were examined. Resumption location deviation was calculated as a difference score between the cell numbers that corresponded to the pre- and post- interruption fixation locations. The absolute values of the difference scores were examined to directly compare across conditions, similar to Experiment 2. There was no difference in the resumption difference scores between the long interruptions (*M* = 3.3 cells, *SD* = .87) and short interruptions (*M*= 3.1 cells, *SD* = .79), $F(1, 17) = 1.6$, *MSE* = .4, p=.23.

Discussion

There was no difference in resumption lags between the short and long interruption lengths. The failure to replicate the interruption duration effect (Monk et al., under review) prevented any examination of different decay rates between goal and spatial memory. There are three possible reasons for this failure to replicate the interruption duration effect. First, the interruption duration effect may be dependent on task structure. The primary task used in this experiment had a flat goal structure, whereas the empirical papers that have demonstrated the interruption duration effect have used hierarchically structured tasks (Hodgetts & Jones, 2006b; Monk et al., under review). Task structure may be important to the interruption duration effect because previous subgoals associated with the primary task may provide greater interference over longer interruption lengths resulting in longer resumption lags. In a task with a flat goal structure, because there are no nested subgoals, there may not be as much interference resulting in no difference in resumption lags between short and long interruptions. This explanation was explicitly examined in Experiment 6.

The second possible explanation for the failure to replicate the interruption duration effect is that both the 15 second and 45 second interruption lengths were too long. It is possible that these interruption lengths resulted in substantial decay of the primary task goal such that there were minimal differences in the time required to retrieve the goal. The manipulation of interruption length and its effect on resumption lag has been shown to be more sensitive at shorter time periods (Monk et al., under review). The largest differences in resumption lag are detected at interruption lengths that are less than fifteen seconds (Monk et al., under review).

The third possible explanation for the failure to replicate the interruption duration effect is that spatial memory was maintained equally well over the short and long interruptions and this memory for where to resume in the primary task resulted in equal resumption lags. This view is supported by that fact that there was no difference in resumption difference scores between the short and long interruptions. Thus, goal memory may have decayed as the interruption duration effect suggests, but spatial memory may have primed retrieval of the goal resulting in equal resumption times. This was further explored in Chapter 2.

Summary

The goal of Experiments 1-3 was to distinguish between the retrace and spatial memory hypotheses and to illustrate that spatial memory is used in the task resumption process. Table 1 summarizes the reaction time results from these experiments. In Experiment 1, the pattern of fixations upon resumption suggested that participants were not retracing their steps from the beginning of the task upon resumption. Rather, participants' fixations mostly landed within three cells of where the participant left off prior to the interruption, providing preliminary evidence for the role of spatial memory in the task resumption process. Experiment 2 more clearly demonstrated that spatial memory is a component of the task resumption process by showing that resumption lags were longer and resumption locations were further from the point of pre-interruption work following a spatial interruption as compared to a non-spatial interruption. In Experiment 3, by manipulating interruption length, it was found that resumption location difference scores were equal for short and long interruptions. This result suggests that spatial memory may remain intact even over longer interruption durations.

Table 1. Summary of results from Experiments 1-3; numbers in parentheses are standard deviations.

Experiment	*N*	Interruption Manipulation	Resumption Lag	Inter-action Interval (control)	Interruption problems attempted	Interruption accuracy
1 (within)	13	15 sec addition	4511.4 (1024.5)	1893.6 (534.3)	2.7 (1.1)	88.1% (10.6)
2 (between)	18	15 sec spatial	4505 (881.8)	1828.1 (451.2)	6.8 (1.4)	91.9% (3.7)
	18	15 sec addition	3982.2 (485.2)	1679 (382.7)	3 (.9)	91.2% (7)
3 (within)	18	15 sec addition	4387.5 (664.2)	2094.6 (397)	2.3 (.6)	86.7% (9.3)
		45 sec addition	4324.6 (932.8)		6.2 (.8)	91.1% (5.6)

The results of these experiments clearly demonstrate that spatial memory is a component of the resumption process. These results show that participants were able to maintain a spatial representation of the primary task over varying lengths and use this representation to return to a specific location in the primary task. These results suggest that a spatial memory component should be added to the Altmann and Trafton (2002) framework for a more complete account of the resumption process. However, in order to begin to understand how this spatial memory mechanism might be integrated with the

Altmann and Trafton (2002) framework the interaction between spatial and goal memory must be understood.

CHAPTER 2

In this chapter, a more complex hierarchical task was used to replicate the findings from Chapter 1 and to examine how spatial and goal memory interact. In order to integrate spatial memory with the memory for goals theory (Altmann & Trafton, 2002, 2007) it is important to determine whether spatial memory precedes goal memory or whether goal memory precedes spatial memory. This distinction will shed light on the functional role of spatial memory within the memory for goals theory.

The sea vessel production task used in this chapter has several subgoals which must be accomplished in order fulfill the high level primary task goal. Upon resumption of the primary task, one must remember which previous subgoals were accomplished in order to accurately resume the task. Thus, goal memory will play a larger role in the resumption process allowing for spatial and goal memory to be directly examined.

Experiment 4

Similar to Experiment 1, the focus of this experiment was on comparing the location of the initial fixation immediately upon resumption to the last fixation on the primary task prior to interruption. However, this experiment goes beyond distinguishing between the retrace and spatial memory hypotheses. Because a hierarchical task was used in this experiment, the pattern of fixations provide insight as to whether goal memory primes spatial memory or whether spatial memory primes goal memory.

Currently, in the ACT-R cognitive architecture the process of task resumption as specified by Altmann and Trafton (2002) would be instantiated as follows: retrieve the specific suspended task goal, retrieve the visual (spatial) location of where to resume, and go to that location to begin work (Brudzinski et al., 2007). This process is one in which goal memory primes spatial memory. Based on Almann and Trafton's (2002) priming constraint, one would attend to different areas of the task interface to find relevant environmental cues which will prime retrieval of the suspended goal.

Alternatively, spatial memory may be the mechanism that allows one to return to the physical spatial location in the task interface where pre-interruption work had last occurred. Attending to this location may provide the necessary environmental cues to boost activation of the suspended task goal allowing for the retrieval of the suspended task goal. Thus, spatial memory may direct one's attention to the necessary environmental cues; in this case, it is spatial memory that primes retrieval of goal memory.

The process of how participants initially fixate on the relevant environmental cues in the task interface may provide insight as to whether goal memory primes spatial memory or vice versa. The environmental cues on the primary task interface are likely to be specific areas of the task interface that are associated with the subgoals of the task (i.e. the material module for the subgoal of entering material information) since these areas would provide priming of the specific subgoal. General environmental context information would not provide priming of the specific subgoal in this hierarchical task. Thus, if goal memory primes spatial memory, participants should explicitly be looking around the task interface to find the specific relevant environmental cues. At the eye movement level, participants should be examining several different areas of the interface until the relevant cues are found. When examining the distribution of resumption fixation points, this process should manifest itself as an equal distribution. Participants should be equally likely to fixate on any particular area of the task interface since the participant would essentially be "searching" for relevant cues to facilitate retrieval of the suspended task goal.

Alternatively, if spatial memory directs attention to the relevant environmental cues (i.e. spatial memory primes goal memory) upon resumption, the relevant task cues should be fixated on rather quickly and participants should be able to return to the point where pre-interruption work last occurred or to the next correct action. This process should manifest itself in the resumption point distribution as a concentration of fixations on the action that was last made on the task interface and next correct action on the task interface.

Method

Participants. Twenty George Mason University undergraduate students participated for course credit.

Materials. The primary task was a complex production task (Li, Cox, Blandford, Cairns, & Abeles, 2006), called the sea vessel production task. 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 9). 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. Finally the order was completed by clicking the *complete contract* button.

The interrupting task consisted of addition problems that contained five single digit addends ranging from 1-9; each addition problem was presented serially and the interrupting task completely occluded the primary task screen. The addends were randomly generated.

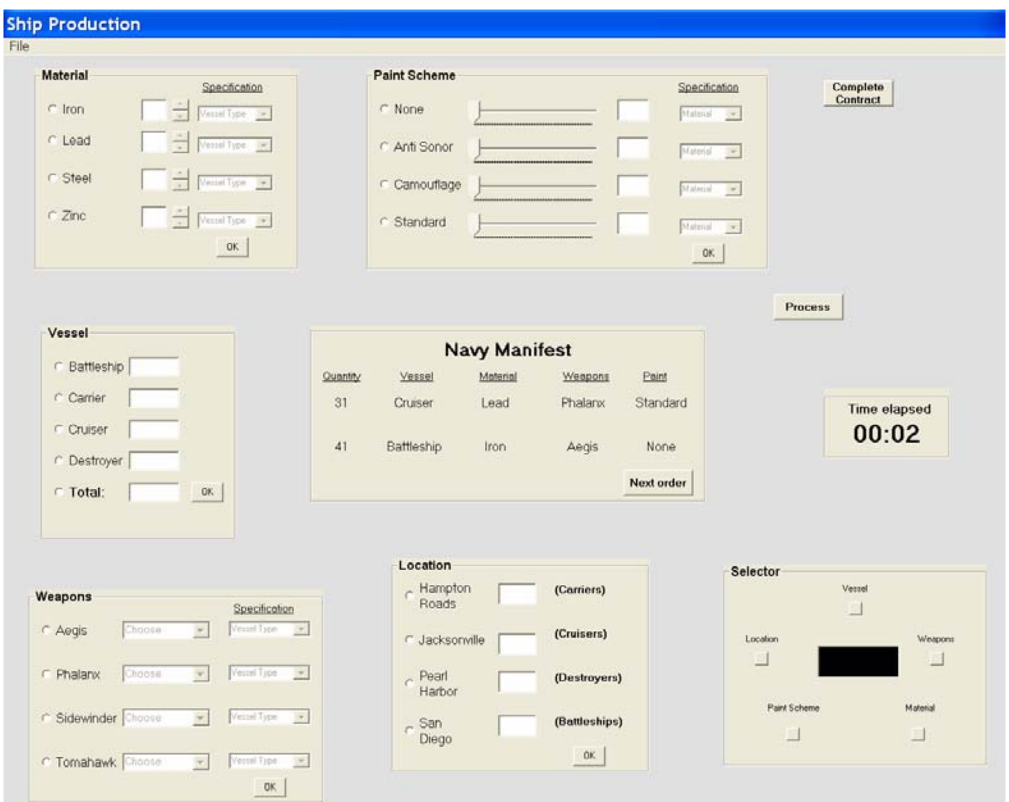


Figure 9. Screenshot of the task used in Experiments 4-6.

Design. A within-participants design was used. Each order 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. 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. The primary and interrupting tasks were first explained to the participants on paper (the complete task instructions can be found in Appendix A). Participants were then asked to perform 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. Participants were instructed to answer as many addition problems as possible during the interruption. Upon resumption of the primary task, there was no information on the primary task screen to indicate where the participant should resume. This was done to ensure that there were no explicit visual cues indicating where to resume. There was a specific correct action to be performed upon resumption. If participants attempted to perform an action on the primary task that was incorrect, the computer emitted a beep signifying that this action was an error. The participant then had to perform the correct action in order to continue on with the task.

Measures. Keystroke and mouse data were collected for each participant. Similar to the previous set of experiments, 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. The inter-action interval was calculated for control trials and was the time interval between clicks to the different 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 10 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. For the purposes of analyzing the eye track data, each of the five modules and the *process* and *complete contract* buttons were numbered sequentially from 1-7 based on the procedure of completing an order. This allowed for the analysis of where in the task procedure participants resumed. Immediately upon resumption, the task was setup such that participants fixated on the order sheet in the center of the screen since that was the same location as where the interrupting addition problems were presented during the interruption. The fixations to the order sheet were not counted in the analyses examining the location of fixations. The analyses that examined the location of fixations focused on the seven relevant parts of the task interface: the five modules and the *process* and *complete contract* buttons.

Results

Resumption lags and inter-action intervals that were incorrect responses were not analyzed; this amounted to less than 7% of the data.

Performance on the Interrupting Task. On average participants answered 1.9 addition problems during each 15 second interruption and average accuracy was 85.2%.

Reaction Time Data. The resumption lag (M = 4157.8 msec, SD = 1057.6) was significantly longer than the inter-action interval (M = 2162 msec, SD = 601.4), $F(1,19)$ = 63.9. MSE = 62898.1. $p<.001$. This suggests the interruption was disruptive to primary task performance.

Eye Movement Data. If participants were retracing their steps from the beginning of the task, their first fixation upon resumption of the primary task should have been to the first module on the task interface. Thus, the average location of the first fixation after the interruption should have been approximately "one". The post-interruption first fixation location (M = 3.3, SD = .8) was statistically different from one, $t(19)$ = 12.4, $p<.001$. This suggests that participants were not resuming the primary task by retracing their steps from the beginning of the task.

To determine whether participants were using spatial memory to resume the primary task and whether spatial memory precedes goal memory, the participants' initial post-interruption fixation location was compared to the last fixation on the primary task interface prior to the interruption. A difference score was calculated between the pre-interruption fixation location and the post-interruption fixation location. For example, if a participant had just completed working on the paint scheme module (step 3 coded as location 3) prior to being interrupted and then returned to the vessel module upon resumption (step 1 coded as location 1), this difference was calculated as -2 suggesting that the participant returned 2 steps behind where they should have returned. A score of zero suggests that participants returned to where they were last working, while a score of 1 suggests that they moved to the next correct step in the procedure.

Figure 10 shows the distribution of difference scores. This distribution is centered on 0 indicating that participants were quite accurate at returning to where they left off. Nearly 70% of the time, participants either returned to where they had just completed work or to the next correct step in the task interface. To statistically examine this distribution, the resumption differences were binned, similar to Experiment 1. Participants returned immediately back to where pre-interruption work last occurred or to the next correct action (i.e. 0 or 1) significantly more often than to any other place in the task interface, $F(1, 19) = 201.4$, $MSE = 46.4$, $p<.001$.

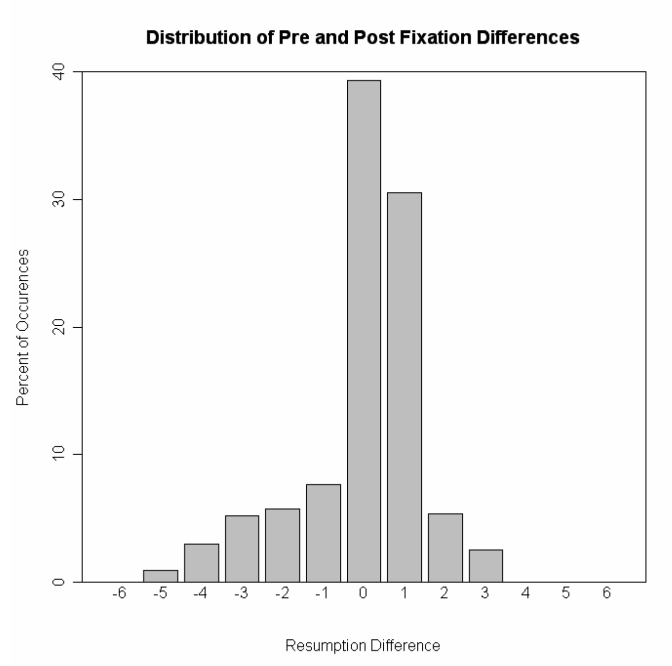


Figure 10. Distribution of pre- and post- interruption fixation locations.

Discussion

The reaction time measures showed that the interruption was disruptive to primary task performance, as expected. The eye track data suggest that upon resumption, participants were not retracing their steps from the beginning of the task. The distribution of post-interruption locations suggests that participants were using spatial memory to resume, returning to where they were last working or where they should work next in the task interface over 70% of the time. One thing to note is that participants were much more accurate at resuming in this task as compared to the odd numbers task from Chapter 1. One reason for this may be that the spatial layout of the sea vessel production is very distinct with several different potential landmarks that do not change from trial to trial. These landmarks may influence spatial memory and guide attention (Peterson, Boot, Kramer, & McCarley, 2004) resulting in a strong spatial representation of the primary task interface. In the odd numbers task there were few, if any, landmarks which could be used to facilitate spatial memory.

The distribution of difference scores also provides support for the view that spatial memory primes goal memory. The distribution was concentrated on 0 and 1 suggesting that participants were directing their attention immediately to the action that was just completed or the next correct action. This suggests that participants were using spatial memory to return to the relevant environmental cues; participants were not searching the primary task interface for relevant cues. These data support spatial memory as a mechanism for directing attention to the relevant environmental context and support spatial memory priming goal memory.

Experiment 5

The purpose of this experiment was to explicitly disrupt spatial memory of the primary task during the interruption to clearly demonstrate that spatial memory is a component of task resumption. In order to disrupt spatial memory, a mental rotation task (Baddeley, 1986; Logie, 1995) which demands spatial working memory resources was used as an interrupting task. The resumption lags from the spatial interruption condition were compared to a non-spatial interruption (i.e. addition problems) condition. If spatial memory is used to resume in this more complex task, the spatial interruption should result in longer resumption lags.

In addition to reaction time differences, there should be differences in eye movements as well. The difference between the post-interruption and pre-interruption fixation locations was examined just as it was in Experiment 2. Although there was a difference in this measure between the spatial and non-spatial conditions in Experiment 2, given the resumption difference score data from Experiment 4 which suggests that participants were able to maintain a strong spatial representation of the sea vessel production task, it is not clear that this measure will be as informative for this particular task. Thus, two additional measures were examined. First, the number of fixations until the participant returned to the next correct action was calculated since each participant had to perform this action in order to complete the task. If the spatial interrupting task negatively impacts resumption by disrupting the spatial representation of the primary task, it should take participants more fixations to get to the next correct action. Participants may spend more time looking at the navy manifest as they determine where they should resume or participants may look at other areas of the primary task interface.

Second, the percentage of times the participants went directly to the next correct action without looking at where they were last working was examined in each condition. If the spatial interrupting task negatively impacts resumption by disrupting the spatial representation of the primary task, participants should go directly to this next correct action less frequently than the non-spatial condition.

Method

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

Materials. The primary task materials were the same as Experiment 4. There were two types of interrupting tasks, a non-spatial task and a spatial task. The non-spatial interrupting task was the math task that was used in Experiment 4. The spatial interrupting task was the mental rotation task that was used in Experiment 2. The interrupting tasks lasted 15 seconds each and consisted of either math or mental rotation problems being presented serially for the duration of the interruption.

Design. The non-spatial and spatial interrupting tasks were manipulated between participants. Half of the participants were assigned to the non-spatial interruption condition and half to the spatial interruption condition; participants were randomly assigned to either condition.

Each ship order served as a trial. Participants completed a total of 12 trials, 10 trials were interruption trials with two interruptions and 2 trials were control trials with no interruptions. The number of interruption trials was increased in this experiment, as compared to the previous experiment, in order to collect more stable data. Pilot testing showed that the spatial manipulation resulted in a large amount of variability in the resumption lag data, thus, with more interruption trials per participant more stable data could be captured. The assignment of interruption and control trials was randomized. The interruptions occurred after filling information in on one of the five modules. Thus, there were a total of five possible interruption points; the interruptions occurred equally among these five positions.

Procedure. The procedure was the same as Experiment 4. During the interrupting task, participants were instructed to answer as many math or mental rotation problems as possible.

Measures. The same measures used in Experiment 4 were used here. There were two additional eye track measures as well. First, a count of the total number of fixations from the end of the interruption until the first fixation on the next correct action was calculated. Second, the percent of times participants went directly to the next correct action without looking back to where they had just completed work prior to being interrupted was calculated for each participant.

Results

Resumption lags and inter-action intervals that were incorrect responses were not analyzed; this amounted to less than 3% of the data. The error rate in this experiment is lower than Experiment 4, presumably because participants had more interruption trials and had more practice resuming the primary task.

Performance on the Interrupting Task. Participants answered more mental rotation (M = 9.6, SD = 1.9) problems than math problems during the interruption (M = 3.1, SD = .6), $F(1,34)$ = 188.3, MSE = 2.1, $p<.001$. There was no difference in accuracy on the spatial (M = 93.8%, SD = 7.5) and non-spatial (M = 89.9%, SD = 9.2) interruptions, $F(1, 34)$ = 2.5, MSE = 54, p = .12.

Reaction Time Data. The resumption lag from the interruption trials was compared to the inter-action interval from the controls in each respective condition to determine whether the interruption was disruptive to primary task performance. Any data points that were more then three standard deviations above or below the condition mean were removed from all analyses; this amounted to less than 4% of the data.

In the non-spatial condition, the resumption lag (*M* = 3761 msec, *S*D = 340.1) was significantly longer than the inter-action interval (*M* = 2117.1 msec, *SD* = 336.9), $F(1,17) = 358.8$, *MSE* = 67852.3, $p<.001$. The resumption lag in the spatial condition (*M* = 4312.3, *SD* = 807.2) was also longer than the respective inter-action interval (*M* = 2218.9, *SD* = 585.1), $F(1,17) = 199.5$, *MSE* = 197721.9, $p<.001$. Critically, the spatial resumption lag (*M* = 4312.3, *SD* = 807.2) was longer than the non-spatial resumption lag (*M* = 3761 msec, *SD* = 340.1), $F(1,34) = 7.1$, *MSE* = 383656, $p<.05$, as Figure 11 shows. The inter-action intervals were not significantly different between conditions, $F(1,34) = .41$, *MSE* = 227916.6, $p = .5$.

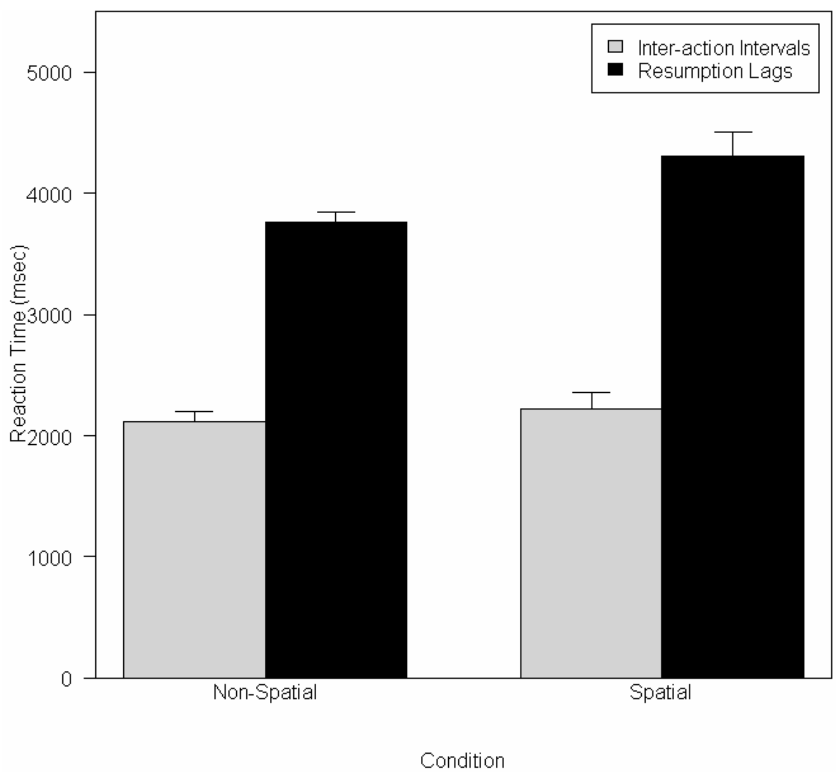


Figure 11. Experiment 5 inter-action interval and resumption lag data by condition.

Eye Movement Data. In order to determine whether the spatial interruption directly influenced participant's spatial memory for where to resume in the primary task resumption difference scores were examined, just as it was in Experiment 2. This was calculated by taking the difference score between where the participant last fixated prior to being interrupted and where the participant returned after the interruption (other than the manifest box). The absolute values of the difference scores were examined to directly compare between the conditions. There was no significant difference in resumption difference scores following a spatial interruption (M = .90, SD = .25) and a non-spatial interruption (M = .85, SD = .17), F (1, 34) = .65, MSE = .047, p = .43. One possible explanation for the null effect in resumption difference scores is that the sea vessel production task has several distinct areas which may serve as landmarks. These landmarks may have been strong enough to guide attention directly to the point of pre-interruption work regardless of the type of interrupting task.

In addition to examining resumption differences scores, the number of fixations until participants returned to the next correct action in the primary task was examined by condition for all interruption points. For example, participants may have had several fixations on the navy manifest before returning to the module where post-interruption work should occur. It took participants in the spatial interruption condition (M = 6.9, SD = 1.04) more fixations to return to the next correct action as compared to the non-spatial condition (M = 5.6, SD = 1.6), F (1, 34) = 7.9, MSE = 1.9, p<.01. Lastly, the percentage of times participants went directly to the next correct action without ever looking at where they were last working was examined by condition. Participants in the spatial condition went directly to the next correct action less frequently (M = 13.8, SD = 14.9) than the non-spatial condition (M = 28.1, SD = 17.3), F (1,34) = 7.1, MSE = 261.1, p < .05.

Discussion

The reaction time data show participants were slower to resume the primary task following the spatial mental rotation interruption as compared to the non-spatial math interruption. There was no difference between conditions when examining the resumption difference scores. However, participants in the non-spatial condition returned to the next correct action in fewer fixations and went directly to the next correct action more often. These results suggest that the spatial interruption disrupted the spatial representation of the primary task resulting in these reaction time and eye movement differences. With a less intact spatial representation of the primary task upon resumption, participants had greater difficulty in resuming, suggesting that spatial memory was a critical process in resumption even in a more complex task. The equal accuracy on the interrupting task and the fact that participants answered more mental rotation problems than addition problems suggest that these resumption lag differences were not due to differences in interruption task difficulty.

Do these results support the results of Experiment 4, which suggest that spatial memory primes goal memory? The results of this experiment do not distinguish between goal memory priming spatial memory and spatial memory priming goal memory. Although the eye movement measures demonstrated that the spatial interruption disrupts resumption, a spatial interruption should have the same effect on spatial memory regardless of whether goal memory primes spatial memory or whether spatial memory primes goal memory. If a participant first retrieves the suspended primary task goal and then uses spatial memory to return to where he or she was last working or if spatial memory primes retrieval of the primary task goal, a spatial interruption would result in a less intact spatial representation and differences in reaction time and eye movements.

Experiment 6

The purpose of this experiment was to distinguish between robust spatial memory (Chun & Jiang, 1998, 2003; Ellis, 1990) and the decay of goal memory over longer interruption lengths (Altmann & Trafton, 2002). The same interruption length manipulation that was used in Experiment 2 was used in this experiment as well. In Experiment 2, while there was evidence for the spatial representation of the primary task being maintained equally well following a short and long interruption, there was no evidence for the interruption duration effect. One explanation for the failure to replicate the interruption duration effect was that the task used in Experiment 2 had a flat goal task structure whereas other empirical papers examining the interruption duration effect have used hierarchically structured tasks (Hodgetts & Jones, 2006b; Monk et al., under review). This experiment directly examined this possibility.

Participants were interrupted by 15 second or 45 second interruptions. Based on the interruption duration effect, there should be longer resumption lags following a long interruption as compared to a short interruption. As was found in Experiment 2, participants should be able to maintain their spatial representation of the primary task over both short and long interruption lengths. Thus, if the interruption duration effect can be replicated, there should be a separation between goal memory and spatial memory and this separation should be evident in the eye movement data.

Method.

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

Materials. The primary and interrupting tasks were the same as Experiment 4.

Design. Interruption length was manipulated between participants. Half of the participants received short interruptions (lasting 15 seconds) and half of the participants received long interruptions (lasting 45 seconds). Participants were randomly assigned to the short or long interruption condition. The number of trials and the location of interruptions were the same as Experiment 4.

Procedure. The procedure was the same as Experiment 4.

Measures. The measures were the same as Experiment 4.

Results.

Resumption lags and inter-action intervals that were incorrect responses were not analyzed; this amounted to less than 8% of the data. The error rate from this experiment is similar to Experiment 4, presumably because the number of control and interruption trials was the same in both experiments.

Performance on the Interrupting Task. Participants answered significantly more addition problems during the long interruption (M = 5.9, SD= 1.9) than the short interruption (M = 1.8, SD = .5), $F(1, 38) = 83.5$, $MSE = 2$, $p<.001$. There was no difference in accuracy between the long interruptions ($M = 92.3\%$, $SD = 5$) and short interruptions ($M = 89.9\%$, $SD = 10.3$), $F(1, 38) = .81$, $MSE = .007$, $p = .37$.

Reaction Time Data. The resumption lags from the interruption trials were compared to the inter-action intervals from the controls in each respective condition to determine whether the interruption was disruptive to primary task performance. The resumption lags in the long interruption condition ($M = 4701.8$, $SD = 902.6$) were significantly longer than their respective inter-action intervals ($M = 2099.1$, $SD = 351.1$), $F(1, 19) = 161.9$, $MSE = 418449.3$, $p<.001$. Likewise, the resumption lags in the short interruption condition ($M = 4867.6$, $SD = 1175.8$) were significantly longer than their respective inter-action intervals ($M= 2169.9$, $SD = 391.6$), $F(1, 19) = 111.3$, $MSE = 654116.2$, $p<.001$.

Next, the resumption lags from the long and short interruption conditions were compared to each other to determine whether the long interruption was more disruptive than the short interruption. There was no difference between the resumption lags in the long interruption condition ($M = 4701.8$, $SD = 902.6$) and the short interruption condition ($M = 4867.6$, $SD = 1175.8$), $F(1, 38) = .3$, $MSE = 1098531.1$, $p= .6$, as Figure 12 shows. There was no difference in the inter-action intervals between the long ($M = 2099.1$, $SD = 351.1$) and short ($M= 2169.9$, $SD = 391.6$) conditions as well, $F(1, 38) = .4$, $MSE = 138306.3$, $p = .6$.

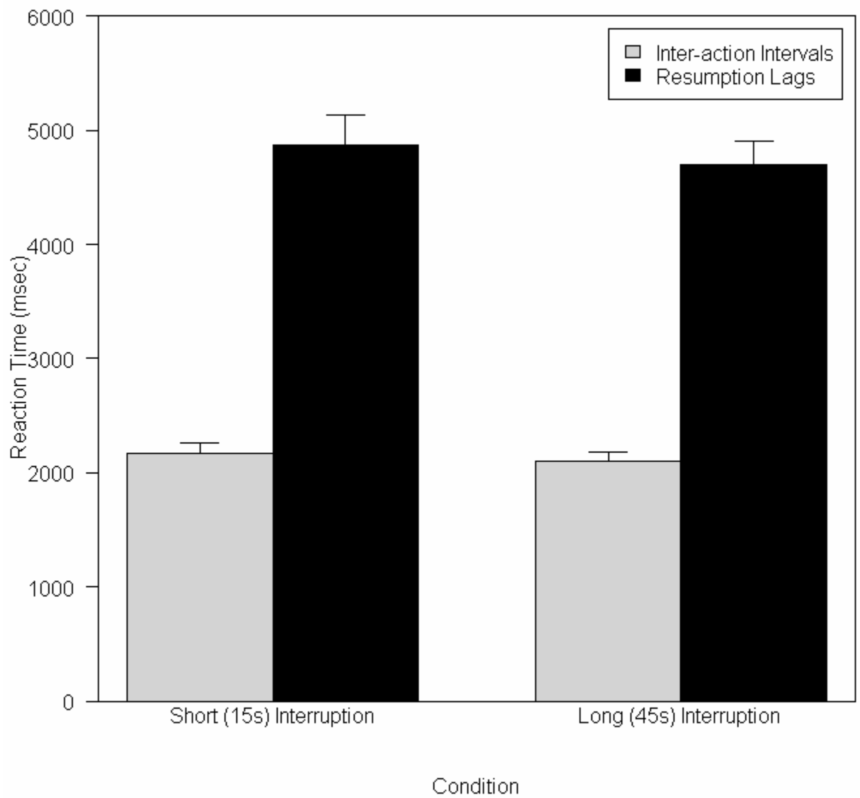


Figure 12. Experiment 6 inter-action interval and resumption lag data.

Eye Movement Data. First, the resumption difference scores were examined for each condition. There was no significant difference in the resumption difference scores between the long interruption (M = 1.2, SD = .4) and short interruption conditions (M = 1.1, SD = .3), $F(1,38) = 2.5$, MSE = .1, p = .12. Next, the number of fixations until fixation on the next correct action was calculated. There was no difference between the long interruption (M = 7.1, SD = 2.9) and short interruption conditions (M = 8.1, SD = 3.1), $F(1, 38) = 1.1$, MSE = 8.9, p=.3. Finally, the percent of times that participants went directly to the next correct action button without looking at where they were last working was examined. There was no difference between the long interruption (M = 25.1, SD =

18.9) and short interruption conditions (M = 29.3, SD = 22.6), $F(1, 38) = .4$, MSE = 433.02, $p = .5$.

Discussion

Memory for goals (Altmann & Trafton, 2002) proposes that the resumption lag, driven by the strength of activation of the suspended primary task goal, should be longer following long interruptions as compared to short interruptions. The reaction time data from this experiment failed to replicate the interruption duration effect (Monk et al., under review) suggesting that there is no difference in the amount of goal decay between the short and long interruptions. In conjunction with the results from Experiment 3, task structure is not the likely cause of this failure. One of the other possible explanations for both Experiments 3 and 6 is that the interruption lengths examined (i.e. 15 and 45 seconds) were both too long. At these interruption lengths, the suspended task goal may have already substantially decayed to a point where the retrieval times were equivalent (Monk et al., under review). If the 15 second and 45 second interruption lengths both caused the goal to decay to the point where the activation level of the goal was at this asymptote, there would be no significant difference in retrieval times.

There was no difference in any of the eye movement measures between the long and short interruption conditions. This finding is consistent with Experiment 3. The eye movement measures suggest that spatial memory may be robust enough to remain intact even over the longer interruption durations. Further, if it is assumed that goal memory did decay more over the longer interruption lengths (although there is no explicit evidence of goal memory decay), these results are consistent with the view that spatial memory primes goal memory. Spatial memory may be maintained equally well over the short and long interruption lengths and may prime retrieval of the suspended primary task goal, regardless of how much the goal may have decayed, resulting in no resumption lag differences between conditions.

Summary

The results from the experiments in this chapter extend the findings from Chapter 1 to a more complex hierarchical task. Table 2 summarizes the results of Experiments 4-6. Experiment 4 showed that in this more complex task, spatial memory is a component of the resumption process; the distribution of fixations upon resumption suggests that spatial memory primes goal memory. The results of Experiment 5 provided direct evidence for a spatial memory component in the task resumption process. A spatial interrupting task disrupted spatial memory of the primary task, resulting in longer resumption lags and differences in eye movements as well. The results of Experiment 6 provided some evidence that spatial memory of the primary task remains intact over longer interruption lengths (up to 45 seconds), based on the eye movement data. Unfortunately, the interaction of spatial memory and goal memory could not be examined because of the failure to replicate the interruption duration effect.

Table 2. Summary of results from Experiment 4-6; numbers in parentheses are standard deviations.

Experiment	*N*	Interruption	Resumption Lag	Inter-action Interval (control)	Interruption problems attempted	Interruption accuracy
4 (within)	20	15 sec addition	4157.8 (1057.6)	2162 (601.4)	1.9 (.75)	85.2% (13.9)
5 (between)	18	15 sec spatial	4312.3 (807.2)	2218.9 (585.1)	9.6 (1.9)	93.8% (7.5)
	18	15 sec addition	3761 (340.1)	2117.1 (336.9)	3.1 (.6)	89.9% (9.2)
6 (between)	20	15 sec addition	4867.6 (1175.8)	2169.9 (391.6)	1.8 (.5)	89.9% (10.3)
	20	45 sec addition	4701.8 (902.6)	2099.1 (351.1)	5.9 (1.9)	92.3% (5)

GENERAL DISCUSSION

The purpose of the six experiments in this study was to investigate the role of perception in the process of how people resume an interrupted task and to examine whether these processes can be integrated with the Altmann and Trafton (2002) memory for goals theory. Two plausible hypotheses about how perception works to aid resumption, a retrace hypothesis and a spatial memory hypothesis, were explored based on previous literature from the interruptions domain and the visual search domain. The results of these experiments provide strong support for a spatial memory mechanism: task resumption is not only about *what* specific task goal was suspended, it is also depends on knowledge of *where* in the task to resume. This spatial memory mechanism was demonstrated in two different task types which varied in complexity and structure, suggesting that this spatial memory mechanism is quite robust.

Although the manipulations in Experiments 1-3 were consistent with Experiments 4-6, the consistency of the results given the different primary tasks was remarkably surprising. Experiments 1 and 4 both clearly demonstrated that participants were not retracing their steps from the beginning of the task; rather, participants were able to return close to where pre-interruption work last occurred, providing preliminary evidence for a spatial memory mechanism. In Experiments 2 and 5 a spatial interruption was more disruptive to primary task resumption than a non-spatial interruption. These results provide evidence for a spatial memory component in the task resumption process. Resumption lags following the spatial interruption were longer than the non-spatial interruption. Further, these resumption lag differences were manifested in the eye movement data. Experiments 3 and 6 both demonstrated that spatial memory of the primary task is quite robust; participants were equally accurate at resuming the primary task following short and long interruptions.

The results of Experiments 3 and 6 were also consistent in that the resumption lags following the long interruption were the same as the resumption lags following the short interruption. These results are contrary to the interruption duration effect. One possible explanation for this failure to replicate the interruption duration effect is that the interruption lengths that were used in Experiments 3 and 6 were both too long to show resumption lag differences; the largest differences in resumption lags are found for interruption lengths under fifteen seconds (Monk et al., under review). The suspended task goal may have already decayed to such a degree that there were minimal differences in the time required to retrieve the goal. The failure to replicate the interruption duration effect prevented any direct examination of the possible interactions between spatial memory and goal memory at different interruption lengths. In order to more clearly investigate the interaction between spatial and goal memory, the length of the short interruption should be under 10 seconds and the long interruption should be over 30 seconds. These interruption intervals should be more sensitive to the interruption duration effect base on Monk et al. (under review).

Together, the results of these experiments demonstrate that spatial memory is a mechanism used upon resumption. The spatial processes during the resumption lag were evident in both reaction time measures and eye movement measures. When spatial memory was disrupted, participants were less accurate at returning to the point where pre-interruption work last occurred (Experiment 2) and made more fixations before returning to the next correct action (Experiment 5). These differences in eye movements translated directly into reaction time differences (i.e. differences in resumption lags). This spatial memory mechanism has both theoretical and applied implications. Theoretically, these results have implications for the memory for goals model (Altmann & Trafton, 2002) and several visual search studies (Lleras et al., 2005; Shen & Jiang, 2006). In regards to application, these results provide insight as to how to reduce the disruptive effects of interruptions for computer based tasks.

Integrating Spatial Memory with the Memory for Goals Model. Although the results of these experiments implicate spatial memory as a mechanism for task resumption, how might this mechanism be integrated with the memory for goals theory? The priming constraint of the memory for goals theory suggests the suspended task goal may be primed by an associated cue in the environment. Priming of the suspended goal boosts its activation, making it more likely that this goal is retrieved to direct behavior; thus, priming from environmental cues is important to goal retrieval. However, the memory for goals theory does not specify how these environmental cues are attended to. One way spatial memory might be integrated with the memory for goals theory is that, upon task resumption, spatial memory may play the functional role of guiding attention to the relevant environmental cues.

This mechanism can be directly integrated with the priming constraint of the memory for goals theory. The priming constraint stresses the associative link between the target goal and environmental cues. Spatial memory may be the component that actually directs one's attention to these environmental cues upon resumption. A spatial representation of the primary task may be built up over several fixations. During an interruption, this spatial representation of the primary task is maintained (unless it is explicitly disrupted by a spatial interruption), while memory for the specific goal decays. Upon resumption, this spatial representation, may be available to guide attention to the areas of the interface where pre-interruption work last occurred. These areas may serve as environmental cues, and once attended to these cues may boost activation of the suspended primary task goal. This primary task goal is then retrieved and primary task work can begin again. Thus, spatial memory plays the functional role of constraining the "search space" for relevant environmental cues and through this process spatial memory primes goal memory. This spatial memory mechanism is a process for finding the relevant environmental cues in the task environment that can be directly added to the Altmann and Trafton (2002) framework.

If spatial memory is a mechanism that directs attention to relevant environmental cues, this suggests that spatial memory primes goal memory. Currently, within the ACT-R framework, the task resumption process has been modeled as first retrieving the specific subgoal that was suspended and then retrieving the visual location of where to resume (Brudzinski et al. 2007); thus, goal memory primes the visual location of where to begin work. However, the results of Experiment 4 provide preliminary evidence for spatial memory priming goal memory. In Experiment 4, participants were able to return to the relevant environmental cues in the task interface immediately upon resumption of the primary task; participants did not search around the task interface to find the relevant environmental cues. This suggests that spatial memory precedes goal memory and spatial memory may direct attention to the environmental cues in the task interface. This conclusion, however, hinges on the assumption that the environmental cues that prime retrieval of the suspended task goal are specific objects or areas in the task interface. It is possible that the appearance of the primary task interface itself provides enough general environmental context to prime retrieval of the suspended primary task goal. Although, it is more likely that general priming from the environmental context primes the high-level main task goal (e.g. filling orders for ships) and not the specific subgoal within the task hierarchy.

The results of Experiments 3 and 6 suggest that spatial memory is quite robust over long interruption intervals, participants were equally accurate at returning to where pre-interruption work had occurred following a long (45 second) and short (15 second) interruption. These results support several other findings on the robustness of spatial memory (Chun, 2000; Chun & Jiang, 1998, 2003; Ellis, 1990; Landsdale et al., 2005). The results of Experiments 3 and 6 can also be construed as support for spatial memory priming goal memory if it is assumed that goal memory actually decayed more over the long interruption as compared to the short interruption. In Experiment 6, upon resumption of the primary task, spatial memory may have directed participant's attention to the relevant environmental cues following both a short and long interruption and this may have primed retrieval of the suspended primary task goal. Despite the fact that the goal may have decayed more during the long interruption, the priming provided by the environmental cues may have boosted activation enough to result in equal resumption times in both conditions. In order to more clearly examine whether spatial memory primes goal memory, interruption intervals that are more sensitive to the interruption duration effect should be examined.

It is also possible that the relationship between spatial and goal memory is bidirectional (i.e. spatial may prime goal and goal may prime spatial). Given the results of the current set of experiments, it is difficult to completely rule out this possibility. Although, in Experiments 2 and 5, when spatial memory for the primary task was disrupted using a spatial interrupting task, there were differences in resumption lag when compared to a non-spatial interrupting task. This suggests that goal memory cannot overcome the deficits in spatial memory. However, in Experiments 3 and 6, if we assume that there was greater goal decay following the longer interruption intervals, the results of these experiments suggest that spatial memory may have primed goal memory to overcome this decay. Thus, there is some preliminary support suggesting that spatial and goal memory is not equally bidirectional. However, further experiments will have to be conducted to completely understand the interaction of spatial and goal memory.

Implications for the Visual Search Domain. The results from Experiments 1-3 have direct implications for the visual search domain as well. First, these experiments demonstrate that spatial working memory processes are critical for the rapid resumption of visual search tasks. Shen and Jiang (2006) found that unfilled temporal delays and passive viewing tasks did not affect search performance, while short (4s) search tasks disrupted search performance and long (3min) search tasks completely eradicated search memory. The results of Experiment 2 show that if you engage spatial working memory processes during the interruption, memory for spatial location on the primary task will be disrupted. These results support other research examining visual search and spatial memory (Oh & Kim, 2004) and may account for the Shen and Jiang's results. The unfilled temporal delays and passive viewing tasks did not require spatial working memory; consequently, this did not affect search performance. However, the interrupting visual search task certainly required spatial memory resources and consequently search performance was disrupted.

Second, these results extend the previous interrupted visual search literature by providing insight as to how the spatial representation that is maintained during the interruption is used to resume. The interrupted visual search literature has mostly used reaction time measures to demonstrate the maintenance of a spatial representation (Lleras et al., 2005; Shen & Jiang, 2006). From these measures alone, it is not clear how the spatial representation actually facilitates resumption. For example, does the spatial representation provide a general encoding benefit upon resumption or does the spatial representation allow one to return to a specific location within the primary task? The task used in Chapter 1 had characteristics of a search task, but because there was a sequential ordering to the search, it allowed for the explicit examination of resumption position within the task. In traditional visual search tasks it is more difficult to determine where the correct resumption position might be. The resumption difference score measure showed that participants were able to return quite close to the point where the interruption occurred in the primary task. This eye movement measure suggests that participants are able to use their spatial representation of the primary task to return to a specific location within the task. Thus, the spatial representation may be used to guide attention to specific locations. This finding is in agreement with visual search memory studies that have shown that memory for spatial location may guide attention (Beck et al., 2006).

Practical Applications. The spatial memory component of task resumption has important practical applications that can be used to reduce the disruptiveness of interruptions in computer-based tasks. First, the results of this study (and others) suggest that a spatial representation of the primary task is maintained during the interruption and facilitates task resumption. Consequently, computer systems should be designed such that the spatial layout of the primary task interface is kept constant across the length of the interruption. If the layout of the primary task interface is different upon resumption, this may result in the user being spatially disoriented. This spatial disorientation may lead to severe resumption costs. Thus, the task interface should be the same as it was prior to being interrupted in order to leverage the spatial memory mechanism.

The spatial memory mechanism of task resumption may also be heavily influenced by landmarks. Landmarks in the primary task interface may allow for a stronger spatial representation of the primary task because the interface may be more distinct. A stronger, more intact, spatial representation may be more robust to interruption and may facilitate resumption. Within the visual search domain, there is evidence for landmarks guiding attention (Peterson et al., 2004). Landmarks in the spatial representation of the primary task may play a similar role in guiding attention upon resumption. The results of this study provide some support for this view. The odd numbers task used in Chapter 1 had few, if any, landmarks. By comparison, the sea vessel production task used in Chapter 2 had several landmarks and the interface was quite distinct. Comparing the resumption accuracies in Experiments 1 and 4 reveal stark differences in how close participants were able to return to where pre-interruption work last occurred. Participants were much more accurate at resuming the sea vessel production task. Thus, as a design guideline, interfaces should include landmarks or other distinguishing features that help segment the task interface. This may result in a more robust spatial representation that may facilitate task resumption.

Appendix A

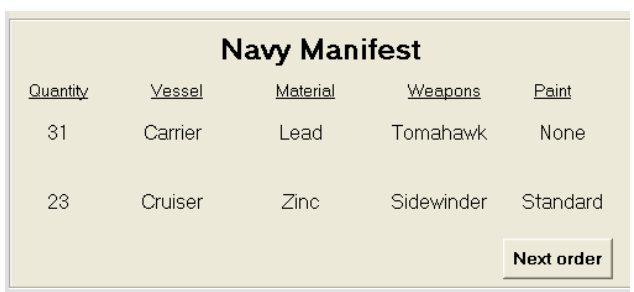
Ship Production Task Instructions

Ship Production Task Instructions

You run a ship production plant and you are in charge of filling orders from the Navy. The goal of this task is to successfully complete each order in a timely fashion. Each order will be for two different types of sea vessels. To complete an order you will need to specify several details based on the order manifest (the order sheet). Once these details are complete you must “process” the order, validate the information, and finally “complete” the contract.

You will begin the task by clicking the “next order” button. This will bring the current order into the Navy Manifest box. The Navy manifest will specify the Quantity, the Vessel Type, the Material used to build the ship, the Paint Scheme for the ship, and the Weapons system the ship will be equipped with. After filling in these details you will determine the location of the ship. Then you will process the order, validate the order, and finally complete the order. You will be asked to fill several orders.

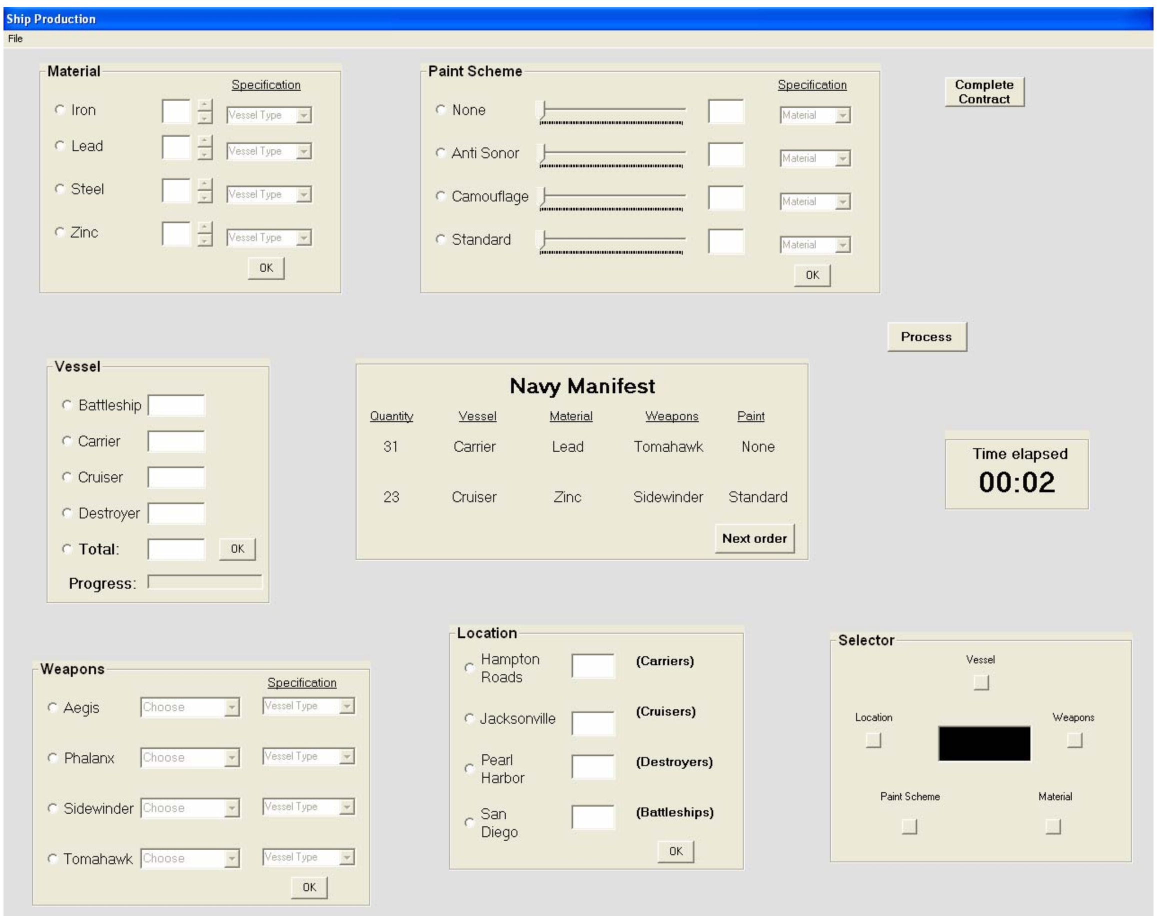
As stated earlier, each order will be for two different types of ships. You will be specifying the details for both ship types at the same time. For example, an order may look like this:



It is critical that you specify the details for each order in a very specific way. The details must be specified as follows in their respective boxes:

1. **Vessel**: Specify the number of each type of vessel ordered.
2. **Material**: The material used for each vessel must be specified.
3. **Pain Scheme**: The type of paint scheme requested must be stated.
4. **Weapons**: The weapon system requested must be specified.
5. **Location**: The location must be specified based on the type of ship that was ordered.
6. You must **process the order**.
7. Finally, you must **complete the contract**.

If you think about this order, it makes perfect sense! Of course, you have to specify the type of vessel first since people have to know what they are building. You then need to state the material that people should use; the material is the foundation of the ship. Next, you paint the ship. Only after you paint should you equip the ship with weapons, we don’t want any innocent painters being hurt by malfunctioning weapons. Finally, you specify where the ship needs to go. Then don’t forget to process the order and complete the contract.

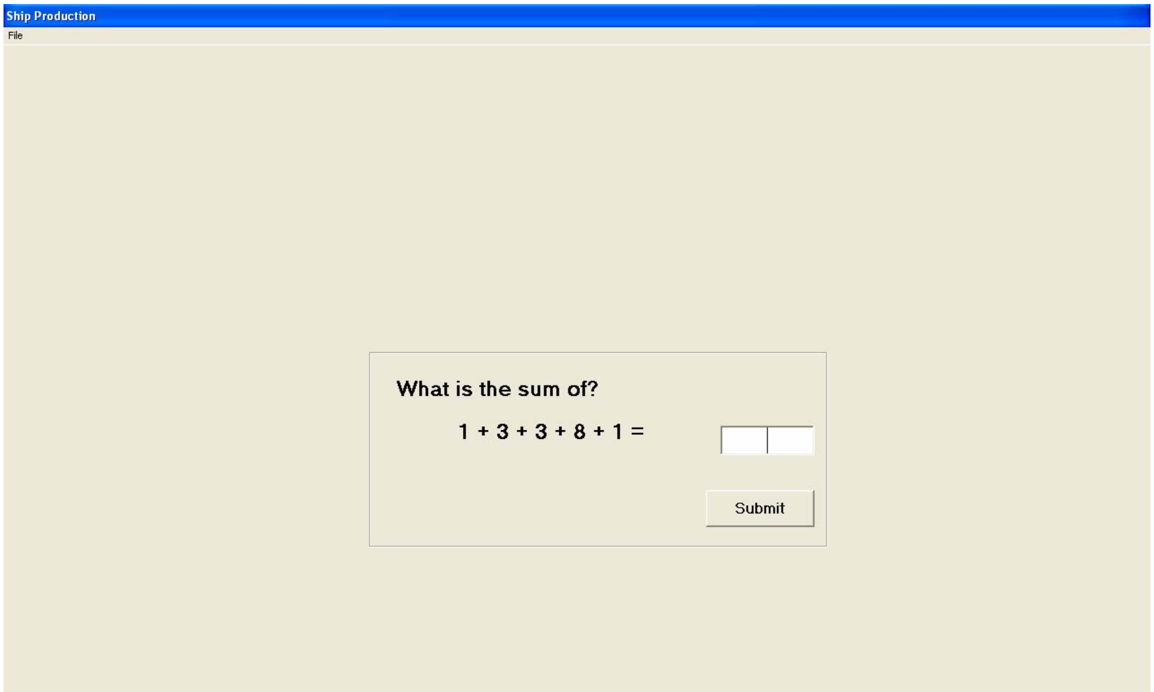


There will be a separate box to specify each of the details listed above. Before entering each detail, you must first activate the respective box by clicking the selector button for that box.

For example, before entering the vessel type you must first activate the vessel box by clicking on the vessel button in the selector box. This will then allow you to enter the necessary details. After completely entering the details for the two ships you will then click ok, and then activate the Materials box and so forth. YOU MUST ACTIVATE EACH BOX BEFRE ENTERING THE DETAILS AND YOU MUST CLICK OK AFTER ENTERING THE DETAILS. Once click ok, you cannot go back and make changes. That information is saved and is no longer available to you. After completing 1-5 above:

To get the next order you simply click “Next Order” and repeat the process again.

While performing the ship production task you may also be asked to answer simple addition problems. The addition problems will ask you to take the sum of five single digit numbers. Once you type in your response YOU MUST CLICK THE SUBMIT BUTTON. You should attempt to answer as many addition problems as possible.



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