Huh, what was I doing? How people use environmental cues after an interruption

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We examine the effect of environmental cues on being interrupted while performing a task. We conducted an experiment in which participants, after an interruption, received either a blatant environmental cue of their previous action (a red arrow), a subtle environmental cue of their previous action (a cursor that was placed in the same location as their previous action), or no environmental cue at all. We found that participants in the blatant condition resumed their task faster than participants in the other two conditions. Furthermore, a subtle environmental cue was no better than no cue at all. The results support our model of memory for goals.

Introduction

Given the large amount of study that interruptions have recently garnered, it is a bit surprising that there are so few theories that are applicable to the study of interruptions. One approach uses the theory of long term working memory (Chase & Ericsson, 1981, 1982; Ericsson, 2003; Ericsson & Kintsch, 1995) and applies it to interruptions (Oulasvirta & Saariluoma, 2004). Other researchers have adapted event-based boundaries (Zacks & Tversky, 2001; Zacks *et al.*, 2001) to study interruptions (Adamczyk & Bailey, 2004). Our approach has been to build a computational cognitive model within ACT-R (Anderson *et al.*, 2004; Anderson & Lebiere, 1998) about memory for goals (Altmann & Trafton, 2002) and apply it the study of interruptions. This integrated theory has successfully allowed us to make both qualitative and quantitative predictions for a variety of tasks and interruption types (Altmann & Trafton, 2004; Monk *et al.*, 2004; Trafton *et al.*, 2003).

Our theory of interruptions starts with a general task analysis of interruptions and resumptions (shown in Figure 1). The primary task is ongoing when an alert occurs, indicating a pending interruption by a secondary task. The time between the alert and the start of the secondary task is the <u>interruption lag</u>. Eventually, after seconds, minutes, or longer of working on the secondary task, the operator completes it or suspends it and returns to the primary task. The time between leaving the secondary task and beginning the primary task is the <u>resumption lag</u>. (A more complete description of this task analysis can be found in Trafton et al., 2003).

Our theory makes three fundamental predictions about resuming a task after an interruption. First, goals decay relatively steadily (details of the equations that enter into this decay can be found in Altmann & Trafton, 2002 and Trafton et al., 2003). From our perspective, the goal of most interruption management tools is to slow down or reduce that decay in some manner. Our theory suggests that there are two primary ways of reducing or slowing down decay: rehearsal and using environmental cues (the two other components to the theory). Rehearsal can be either retrospective (e.g., “What was I doing?”) or prospective (e.g., “What was I about to do?”). Both retrospective and prospective rehearsal are important in the model, though both the model (Altmann & Trafton, 2002) and empirical data (Trafton et al., 2003) suggests that people perform more prospective rehearsal when given the chance.

Because our model is an activation-based model, priming is an important model component. Environmental cues come into play because contextual cues add activation to goals when those environmental cues are attended to. Thus, our model makes the strong prediction that highlighting what a user has previously done or what a user will do next will facilitate the resumption process. One of the strengths of our model is that it makes clear how and why environmental cues should facilitate interruption resumption: cues provide additional activation that primes a decaying goal, allowing that goal to be retrieved and resumed more easily. Interestingly, the proposal that environmental cues facilitate resumption has not received broad support in the literature.

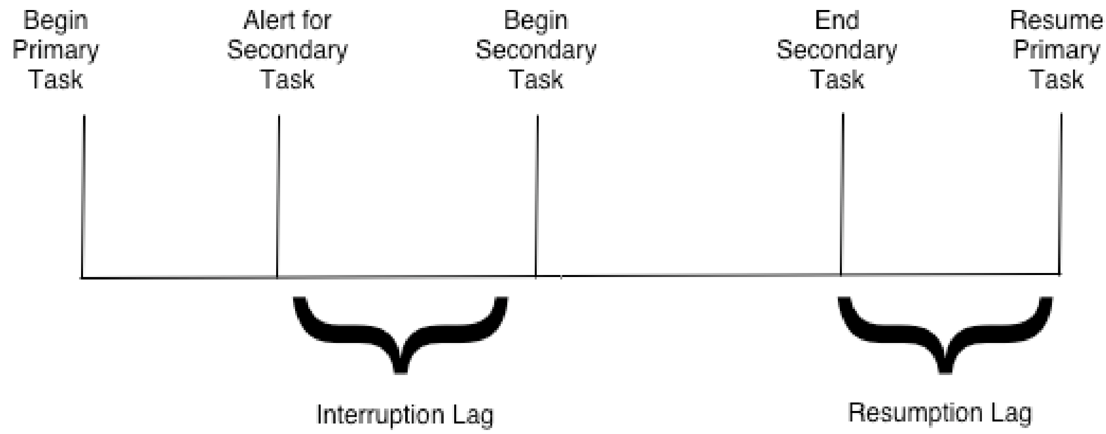

Figure 1: The interruption and resumption process, involving a primary (interrupted) and a secondary (interrupting) task.

Several other researchers have used environmental cues to attempt to facilitate tasks that had an interruption. Some researchers have found evidence that an external cue (e.g., a blue dot) can serve as a mnemonic to take a particular action (McDaniel *et al.*, 2004). In contrast, the work by Czerwinski and her colleagues has shown and replicated the finding that displaying an explicit visible marker does not facilitate task resumption (Cutrell *et al.*, 2001; Czerwinski *et al.*, 2000). In fact, Cutrell et al. (2001) say "…we confirmed our earlier assessment that there is little to no benefit of having a marker present after a notification was received" (p. 268). There were, of course, multiple differences between the experiments: McDaniel et al. used an external environmental cue explicitly as a reminder to accomplish a prospective memory task in the future, so it could be that environmental cues are not useful in problem solving situations. We should be clear, however, that our model makes a strong prediction that environmental cues will be useful for task resumption, especially in problem solving contexts. Our experiment thus explores different types of environmental cues within a complex problem solving environment.

Experiment

Our goal with this experiment was to manipulate different types of environmental cues, and then to measure the effects of those cues on resumption after an interruption. We were interested in two different types of environmental cues: subtle (a cursor marking the location of the last action performed) and blatant (a red arrow pointing to the location of the last action performed). All environmental cues were provided after an interruption occurred – participants worked on a primary task, were occasionally interrupted, and when they resumed the primary task, we showed them a subtle environmental cue, a blatant environmental cue, or no cue at all.

Method

Participants

Participants were 44 George Mason University students who enrolled for class credit; all were randomly enrolled in one of three conditions. Fourteen participants were in the no-cue condition, fifteen participants were in the subtle-cue (cursor) condition, and fifteen participants were in the blatant-cue (red-arrow) condition.

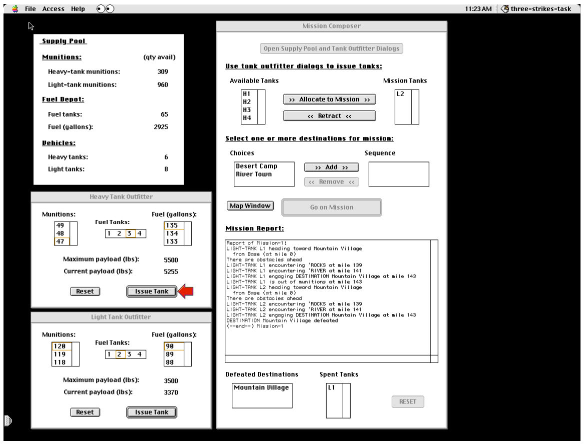

Figure 2: The primary tank task used in the experiment. This screen snapshot shows the status of the task immediately after an interruption in the blatant cue condition. Notice the cursor location (upper-left corner) and the red arrow pointing to the participant's last action

Task and materials

The primary task was a complex resource-allocation task (Brock & Trafton, 1999) that we will refer to as the tank task. Resources in this task are a set of tanks (heavy and light) and their associated munitions, fuel, and fuel tanks. Participants are assigned a mission to use these tanks to attack and destroy three destinations, or locales. The operator's interface uses a standard point-and-click paradigm and is composed of several dialog-box style windows in which the operator can review and select destinations, equip and allocate tanks, and subsequently evaluate the success or failure of a mission. The operator also has access to a map showing the location of each destination. Figure 2 shows a screen snapshot of the tank task.

The secondary task is a simulated tactical assessment task that has been used extensively in other studies (Ballas *et al.*, 1999; Brock *et al.*, 2002a; Brock *et al.*, 2002b). In the tactical assessment task, approaching objects (or "tracks") must be classified as hostile or neutral based on a set of rules for their behavior. Figure 3 shows a screen snapshot of the tactical assessment task.

Either the primary (tank task) or secondary (tactical assessment task) was displayed on the screen at one time. At no time were both tasks displayed concurrently.

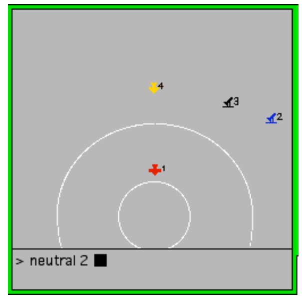

Figure 3: The tactical assessment task. Participants had to identify whether each icon was neutral or hostile. The original is in color.

Design and procedure

Participants were trained for approximately one hour on how to perform the two tasks singly and in combination. There was one between-participants factor (no-cue, subtle-cue, blatant-cue) and one within-participants factor (Session). In all conditions, when an interruption occurred, participants were immediately taken to the secondary task.

Within the experimental testing period, there were three sessions of approximately 20 minutes each. Sessions ended after participants had spent 20 minutes on the tank task. The time spent on interruptions was not part of this 20 minutes.

During each session, a participant was given ten interruptions randomly distributed throughout the 20 minutes. Each interruption occurred immediately after a mouse-click.

During an interruption, participants performed the tactical assessment task for about 30 seconds. After the interruption, they were immediately returned to the tank task. Upon resumption, all windows were deactivated (or back-grounded) so that during resumption the operator would not be able to infer from perceptual cues which window he or she had been working in. In the no-cue condition, the cursor was placed in the upper left-hand corner of the screen upon resumption. Note that our goal was not to eliminate the use of all environmental cues, but only those that could be exploited by the operator to direct his or her attention to a particular region of the interface during resumption. The subtle-cue condition was exactly the same as the no-cue condition except that upon resumption, the cursor was placed in the location that the operator had left it on the primary task. Thus, if the participant clicked on the "Issue heavy tank" button and then got interrupted, upon resumption, the cursor would be placed over the "Issue heavy tank" button. In the blatant-cue condition, upon resumption the cursor was again placed in the upper left-hand corner of the screen, but a bright red arrow pointed to the last action performed by the operator. We provided no explicit instructions for how to resume their task nor pointed out the environmental cues (or lack thereof). Note that a pure Fitts' Law explanation would suggest that the cursor condition would be fastest throughout.

Measures

Keystroke and mouse-click data were recorded for every participant. The primary measure of interest was how fast people were able to resume the primary task after being interrupted by the secondary task. To measure this quantity, we computed resumption lag as the interval from the moment the tank task interface was restored following the interruption to the first mouse click or key press a participant made to resume the primary task. However, we also computed a derived measure of time to resume the primary task. Previous studies (Trafton et al., 2003) showed that individual differences in time to perform the task were quite large. To reduce these individual differences as a source of variance, we first determined the average inter-click lag, or time between actions in the tank task. The inter-click lag was calculated by taking the average time elapsed between mouse clicks/keyboard actions over all mouse clicks/keyboard actions in a session. Inter-click lags were quite variable between participants, but were reasonably stable within participants. We then computed a disruption score by subtracting the average inter-click lag of each participant from the average resumption lag for that participant. Thus, each session for each participant had a resumption lag, an inter-click lag, and a disruption score. We will use the disruption score as our primary dependent variable for this analysis.

Results and Discussion

We examined the effects of the cue manipulation on task resumption. Figure 4 shows the disruption score separated by condition and by session. As Figure 4 suggests, there is a main effect of session, $F(2, 82) = 3.4$, $MSE=1.9$, $p < 0.05$. Session two seemed to have a particularly long disruption score. We have no explanation for this finding, and have not seen it before. However, this "blip" on session 2 shows the same overall pattern as the rest of the data, so we will not focus on it further.

Critically, there is also a main effect of condition, $F(2, 41) = 3.8$, $MSE=4.3$, $p < 0.05$. Condition and session did not, however, interact, $F(4, 82) = 1.2$, $MSE=1.9$, n.s. To further explore the condition effect, we performed Tukey post-hoc comparisons between the conditions. We found that participants in the blatant-cue condition were faster at resuming the main task than participants in either the no-cue or the subtle-cue conditions, $p < 0.05$, while there was no difference between no-cue and subtle-cue.

During problem solving, a perceptually salient, non-subtle cue seems to greatly facilitate resumption after an interruption. The cue used in this experiment was a red arrow that pointed to the last action that the participant had performed before the interruption. It is not completely surprising that this type of explicit, blatant cue is far better than no cue at all. However, it is a bit surprising that an explicit cue is better than a more subtle cue. It could be that the cursor cue is simply not really encoded as a cue of past action because the cursor is typically used for action (clicking) rather than marking a place (pointing).

These data also strongly support our theoretical model. Environmental cues of past actions clearly facilitate getting people back on track after an interruption. What's more, these data suggest that it is not just any environmental cue that is useful, but one that can be easily tied to previous (or future) goals.

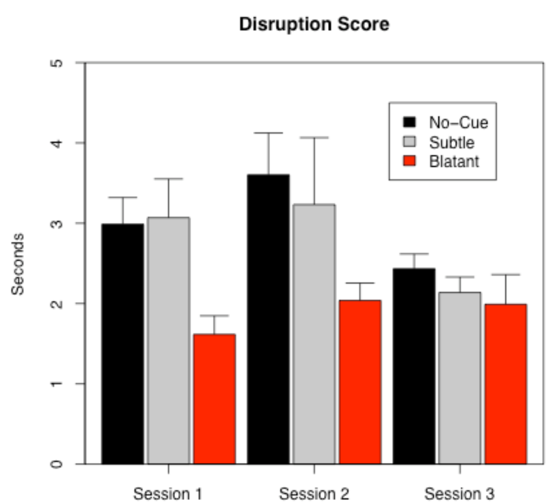

Figure 4: Figure of the disruption score across condition and session. Error bars are standard error of the mean.

Why did we find an effect of environmental cues when Czerwinski and colleagues did not? There are at least two possibilities for resolving this discrepancy. First, we focused our analysis on resumption lag, a theoretically derived variable, while Czerwinski et al. (2000) and Cutrell et al. (2001) focused on larger scale measures (e.g., overall time on task). Large-scale measures are likely to be less sensitive to the disruptive effects of an interruption partially because time on task (sans interruption) may be more variable than the effect of the interruption. Second, the environmental cue they used (a highlighted cursor to mark position), while blatant, may have been more of an interface action rather than a perceptual environmental cue. For example, the highlighting cursor that Czerwinski et al. (2000) and Cutrell et al. (2001) used could have been simply a way to page to the next set of information, rather than a marker of where participants' attention was. This is particularly possible, since saccades and reading speed can be extremely quick (Rayner, 1998), while scrolling a highlighted cursor is much slower.

From a purely practical point of view, it seems that providing a blatant (though unobtrusive) environmental cue marking the last action a person takes can greatly facilitate task resumption after an interruption.

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