Interruptions Reduce Performance across All Levels of Signal Detection When Estimations of Confidence are Highest

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When people are highly confident in their memory of a particular event, it is likely that the accuracy of that memory is also high. However, research has shown that the relationship between confidence and memory accuracy changes under certain circumstances. Interruptions, for instance, have been shown to change this relationship (Zish, Hassanzadeh, McMurry, & Trafton, 2015). The present study sought to determine the response behavior associated with this change. Results indicated that the change in the relationship between memory and confidence is characterized by a decrease in the rate of hits and an increase in the rate of false alarms. Thus, interruptions disrupt the relationship between memory and confidence by reducing sensitivity across all levels of signal detection.

INTRODUCTION

People determine whether or not they should trust what they remember by estimating their confidence in that particular memory (Roediger III & DeSoto, 2014). In everyday life, people assume that this process is an accurate way to determine whether a remembered event actually happened (Dunlosky & Metcalfe, 2008). For instance, you may be concerned about whether or not you turned the stove off before leaving the house. Typically, if you are highly confident that you remember turning off the stove, you likely did. Likewise, if you are unsure or doubtful that you remembered to turn the stove off, there is a good chance you forgot. Therefore, professionals and laypeople alike assume that the relationship between memory and confidence is positive (Roediger III & DeSoto, 2014).

Although the confidence-memory relationship is typically robust, evidence indicates that there are situations in which the relationship can weaken or even become negative. By manipulating confidence, for instance, studies have shown that the relationship between memory and confidence can change. For example, Brewer and Sampaio (2006) showed that deceptive items led to a negative relationship between confidence and memory. Similarly, Koriat (2008) demonstrated that the confidence-memory relationship is affected by the consensuality of an answer.

When memory is manipulated however, it is assumed to have no effect on the confidence-memory relationship (Roediger & Desoto, 2012). In a study by Zish, Hassanzadeh, McMurry, and Trafton (2015) however, researchers showed that participants who rated themselves highly confident in a memory after they were interrupted were significantly less accurate than participants who were not interrupted but expressed the same level of confidence. This finding suggests that manipulating memory through a brief interruption can, in fact, change the relationship between memory and confidence.

Interruptions are ubiquitous in most work environments. In healthcare for instance, interruptions are so pervasive that researchers have claimed that some departments suffer from a "culture of interruptions" (Knudsen, Herborg, Mortensen, Knudsen, & Hellebek, 2007). In error-intolerant industries like healthcare and aviation, an error resulting from an interruption can have deadly consequences (Westbrook, Woods, Rob, Dunsmuir, & Day, 2010). Considering that laypeople and professionals alike assume that confidence is a good indicator of memory accuracy, it is important to investigate how interruptions may disrupt this relationship.

Memory for Goals (MFG) provides a useful model for understanding why interruptions occasionally lead to errors (Altmann & Trafton, 2002). Built within the ACT-R framework (Anderson et al., 2004), MFG is an activation-based computational model of cognition. A primary assertion of MFG is that memories are selected based on their level of activation. In other words, the memory that presents the highest amount of activation at a particular time will be the memory retrieved. During an interruption, activation for memories decay. When activation for a correct memory decays, the likelihood increases that an incorrect memory will be retrieved due to random noise (Trafton, Altmann, & Ratwani, 2011; Trafton, Jacobs, & Harrison, 2012). When an incorrect memory is retrieved, an error occurs.

Zish et al. (2015) showed that interruptions changed the relationship between memory and confidence. The present study aimed to better understand the response behavior associated with this change. Specifically, the goal of this study was to determine whether the change in the confidence-memory relationship corresponded with a change over all levels of signal detection or if the change was confined to a single dimension.

Signal detection theory (SDT) provides a means to quantify and categorize response behavior. SDT breaks down the consequences of binary response actions into four discrete categories: hits, misses, false alarms, and correct rejections. Perfect performance is achieved when an operator commits no misses or false alarms. By using SDT we were able to determine the precise breakdown of response behavior after an interruption. Depending on how responses are distributed, different methods of remediation may be appropriate.

METHOD

Participants

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

Tasks

Primary task. The primary task required participants to complete a simulated stock order form (Figure 1). The order form was broken down into twelve widgets. Each widget called for a specific piece of information that could be found either in the stock information box in the center, or in the order ticker at the bottom. Before starting, participants determined which order they were working on by locating the highlighted stock in the order ticker. Once participants identified the order, they could begin completing the widgets by inputting the specified information.

A starting widget was randomly generated and indicated to the participants by a red arrow. To activate the widget, participants needed to select the start button to the left or right of the widget (depending on the widget). Once selected, the widget relocated to the bottom of the page. At this point, the drop-down menu was activated allowing participants to see their options and select their answer. Once participants selected the correct answer, the widget returned to its original position.

Once completed, participants continued to the next widget. For this task, participants were required to follow a specific order of steps. The order followed a zig-zag pattern. This pattern was chosen to disrupt spatial memory.

Signal detection question. Occasionally after completing a widget, the stock order form was replaced with a screen that showed the names of the widgets without any of the financial information (Figure 2). A blue arrow was shown pointing to one of the 12 widgets and participants were asked whether the arrow pointed to the next correct step. Participants answered by selecting either "Yes" in the top left corner or "No" in the top right corner.

Confidence question. After the signal detection question, the screen was replaced with a question asking participants: "How confident are you that your choice was correct?" Participants were told to gauge their confidence in their choice by selecting a number on a six-point Likert scale at the bottom of the screen. Selecting a "1" indicated "Uncertain" and a "6" indicated "Certain." Once a confidence rating was provided, participants began a new stock order form.

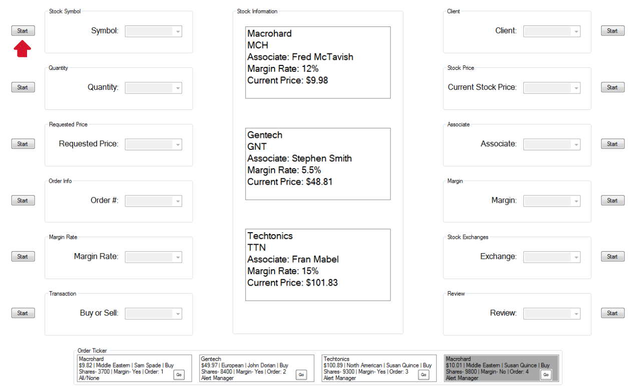

Figure 1. Screenshot of simulated stock order form

Secondary task. After half of the trials, participants were required to complete a secondary task. For the secondary task, participants completed a series of math problems. During these math problems, participants were not able to access or view the primary task. As such, the secondary task served as an interruption to the primary task. After performing the secondary task for 20 seconds, the screen was replaced with the signal detection question screen.

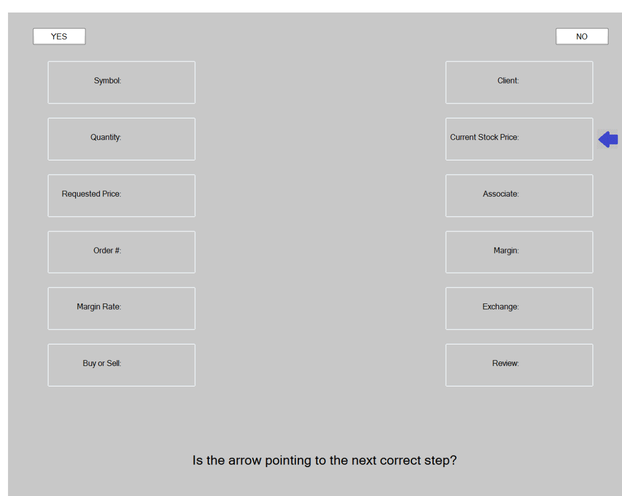

Figure 2. Screenshot of signal detection question

Design

A 2 (interruption/ no interruption) x2 (correct signal/ incorrect signal) repeated measures design was used for this study. When the blue arrow pointed to the correct next step during the signal detection question, it was defined as a correct signal. When the arrow pointed to any other widget than the correct next step, it was defined as an incorrect signal.

For each participant, the signal presented in the signal detection question was correct on 12 trials. For the other 48 trials in which an incorrect signal was provided, participants had 12 trials at the -2 step relative to the correct next step, 12 trials at the -1 step, 12 trials at the +1 step, and 12 trials at the +2 step.

Thirty-three participants completed a total of 60 trials, 30 of which were interruption trials. In order to prevent participants from preparing for interruptions and signal detection questions, the length of trials was made variable. Each trial was 2-6 widgets in length. Participants completed 12 trials of each trial length.

Procedure

Before beginning the study, participants read and signed an IRB approved consent form. After consenting to the study, biographical information was obtained from the participant. A researcher then explained all aspects of the primary and secondary tasks through the use of screenshots. Participants then completed a practice session with the researcher. During the practice session, the participant was encouraged to ask questions to ensure he or she comprehended all components of the task. The participant was then instructed to begin the main task as soon as the researcher left the room. When all trials of the main task were completed, the participant was debriefed and thanked.

Measures

Behavioral data was analyzed in this study. Behavior was measured as accuracy on the signal detection question.

All four classes of signal detection were calculated for each participant. When the participant correctly identified that the signal arrow was pointing at the next correct step during the signal detection question, their response was categorized as a "Hit." When an incorrect signal was provided and the participant selected "No" it was categorized as a "Correct Rejection." When the participant was provided a correct signal but responded with a "No," it was categorized as a "Miss." Finally, when the participant was provided an incorrect signal but responded with a "Yes" it was categorized as a "False Alarm."

We considered the rate of hits, misses, false alarms and correct rejections as defined by the opportunity for each type depending on whether or not the correct signal was presented.

RESULTS

From 33 participants, 1,980 trials were observed. Of these, 175 trials (8.3%) resulted in an error.

A one-way repeated measures ANOVA was conducted to compare the effect of interruption condition (interruption/ no interruption) on response accuracy. As expected, participants were less accurate during interruption trials (M = 82.92%) than during no interruption trials (M = 99.39%), $F(1,32) = 96.18$, $MSE = 54.85$, $p < .05$, $\eta 2 = .59$. The high accuracy rates in both interruption conditions suggest that the participants knew the task well.

Of the 33 total participants in this study, 27 reported a "6" at least once in every condition resulting in a total of 1,180 trials. When participants rated themselves highly confident (responded with a "6"), accuracy rates were lower after an interruption (M = 91.75%) than when participants were not interrupted (M = 99.45%), $F(1,26) = 9.00$, $MSE = 176$, $p < .05$, $\eta 2 = .35$ (Figure 3). These results support the Zish et al. (2015) finding that interruptions change the relationship between memory and confidence, particularly at the highest bounds of confidence estimation. As such, we will focus the remainder of our analysis on trials where participants rated themselves highly confident.

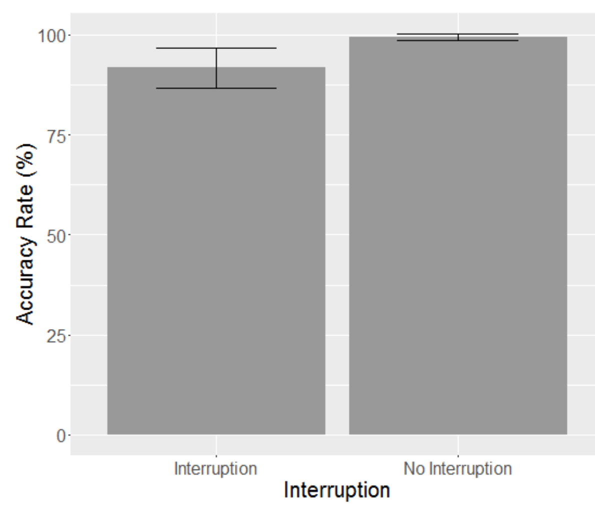

Figure 3. The accuracy rate for interrupted and non-interrupted widgets when participants were certain of their choice. Error bars are 95% confidence intervals.

Sensitivity on a signal detection task is represented by *d'*. Because *d'* is calculated by finding the difference between the z-scores of hits and false alarms, we chose to focus our analysis on these two rates.

To determine participants' rate of hits, a one-way ANOVA was conducted to compare the effect of interruption condition (interruption/ no interruption) on accuracy rates when a correct signal was provided and participants rated themselves highly confident. When participants were interrupted, they had a lower rate of hits (M = 88.02%) than when they were not interrupted (M = 99.07%), $F(1,26) = 4.74$, $MSE = 348$, $p < .05$, $\eta 2 = .15$ (Figure 4).

Next, we calculated error rates for both correct and incorrect signal conditions for trials where participants rated themselves highly confident. To determine participants' rate of false alarms, a one-way ANOVA was conducted to compare the effect of interruption condition on error rates when an incorrect signal was provided. When interrupted, participants had a higher rate of false alarms (M = 4.43%) than when they were not interrupted (M = 0.15%), $F(1,26) = 10.40$, $MSE = 23.69$, $p < .05$, $\eta 2 = .29$ (Figure 5).

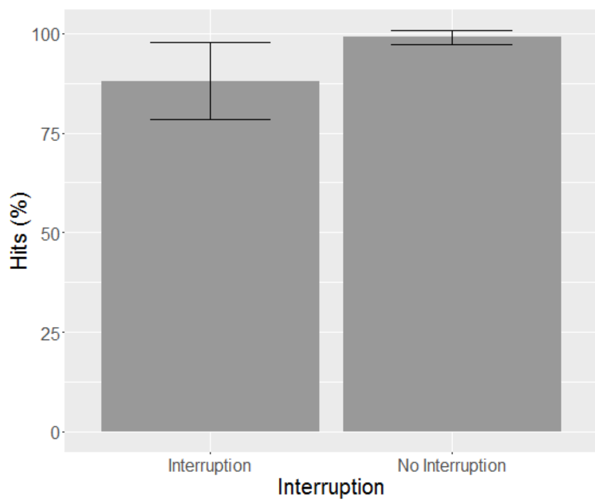

Figure 4. Rate of hits between interruption conditions when participants rated themselves highly confident. Error bars are 95% confidence intervals.

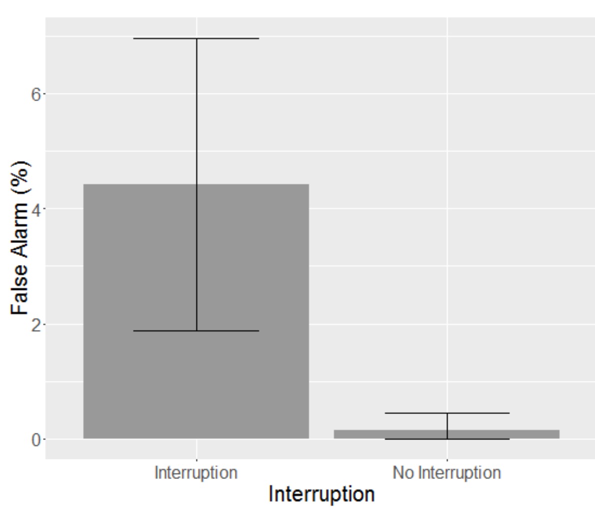

Figure 5. Rate of false alarms between interruption conditions when participants were highly confident. Error bars are 95% confidence intervals

DISCUSSION

Typically, confidence and memory accuracy are positively correlated (Brewer & Sampaio, 2012; Nelson, 1988). Although changes in this relationship have been observed when researchers manipulate confidence (Brewer & Sampaio, 2006; Koriat, 2008), the expectation is that interruptions should not affect this robust relationship. This means that when people rate themselves highly confident in the reliability of a memory, they should be equally accurate regardless of whether or not they were interrupted.

Zish et al. (2015) however, showed that interruptions changed the relationship between confidence and memory accuracy. The strongest evidence for this was when participants rated themselves highly confident. Replicating the results from the previous study, we found that compared to no interruption trials, when participants rated themselves highly confident after an interruption, their accuracy decreased by over 7%. This finding suggests the perceived meaning of "highly confident" changes after an interruption.

The goal for this study was to better understand the response behavior that characterizes the change in the relationship between memory and confidence after an interruption. Our results indicate that interruptions led to a lower rate of hits and a higher rate of false alarms. This finding demonstrates that interruptions lead to a decrease in operator sensitivity. Thus, the change in the relationship between memory and confidence is characterized by poorer performance across all levels of signal detection.

Theoretical

Although the findings of this study explain the response behavior that characterizes the change in the relationship between memory and confidence after an interruption, the results do not address how confidence estimations are generated. Memory for Goals (MFG) however, can provide a theoretical explanation for why interruptions affect the relationship between memory and confidence estimation. When completing a procedural task like the simulated stock order form, MFG posits that each step has some level of activation at all times. During an interruption, attention is diverted from the current task to an alternative goal. When activation is left to decay during an interruption, the difference between the heights of competing activation peaks is reduced. When the difference between activation peaks is small, the likelihood increases that random noise will cause an incorrect step to generate more activation than the correct step (Trafton, Altmann, & Ratwani, 2011).

Our findings suggest that estimations of confidence are determined by calculating the relative difference between the height of the highest activation peak and the height of the second highest activation peak. This would explain our finding that interruptions not only lead to an increase in errors but also lead to less sensitive confidence estimations. A future study will test the hypothesis that confidence judgements are based on relative as opposed to absolute differences in peak activation.

Applied

Our results indicate that people are less sensitive in calibrating their confidence to accuracy after an interruption. This means that when people experience an interruption they are not only more prone to make errors, but also less likely to know they are making them.

These findings suggest that—whenever possible—users should not be required to rely solely on memory confidence to complete high-risk tasks. Instead, systems should be designed to aid interruption recovery. One way to accomplish this is through the use of environmental cues.

Many real-world procedural tasks provide environmental cues that signal information about the state of the world. For example, take the routine task of making coffee. If interrupted during the task, the user can easily determine whether or not the step of adding milk to the coffee has been accomplished by simply examining the color of the coffee. The user does not need to rely on their memory confidence to determine whether this step was accomplished. Instead, the environment provides a visual cue that aids in the resumption of the task. Designing systems that place task-relevant information in the environment may help improve the reduced operator sensitivity identified in this study.

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