A Memory for Goals Account for Priming in Confidence Judgments

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Abstract

Drift diffusion models of decision-making offer some of the most robust predictions of response time for a number of memory manipulations. Some drift diffusion models have been extended to explain confidence judgments. Many of these models assume that confidence judgments are independent and are not systematically related to other task items. In this paper the authors report a relationship between confidence judgments in procedural tasks and how the Memory for Goals model would explain this relationship.

Keywords: confidence, memory for goals, priming, sequential sampling models

Introduction

How are confidence judgments made? All theories of confidence suggest that there is a strong relationship between the target memory and the confidence judgment itself. Exactly what that relationship is and how the confidence judgment is made are what differentiates these theories. The models currently best able to explain how people make confidence judgments are drift diffusion models (2DSD, Poisson, RTCON2: Merkle & Van Zandt, 2006; Pleskac & Busemeyer, 2010; Ratcliff & Starns, 2009, 2013; Van Zandt & Maldonado-Molina, 2004).

Drift diffusion models assume that information accumulates continuously until one of n (typically two) pre-determined thresholds is hit and a memory retrieval is made (Laming, 1968; Link & Heath, 1975; Ratcliff, 1978; Stone, 1960). Confidence judgments are made by interrogating the same accumulated evidence that the memory judgment was made (Heath, 1984; Merkle & Van Zandt, 2006; Douglas Vickers, 2001, 2014, p. 1) or by allowing evidence to continue to accumulate and then making a judgment based on post-decision evidence (Pleskac & Busemeyer, 2010). Other models propose that confidence is measured as the difference between possible counters (Merkle & Van Zandt, 2006; Van Zandt & Maldonado-Molina, 2004; D. Vickers, 1970), but the basic process between all of the models is similar.

One interesting aspect of drift diffusion models of confidence is that confidence judgments are assumed to be independent of each other. The implication of this assumption is that confidence judgments should show no systematic relationship. In procedural tasks, items do have a systematic relationship where priming plays an important role in maintaining cognitive control. Some diffusion theorists have explained priming effects as a faster execution of the primed response—not part of the memory machinery per se, but a faster and more vigorous motor response (Voss, Rothermund, Gast, & Wentura, 2013).

Models with priming mechanisms (Anderson, 1983; Baddeley, 1997; Neath, 1998; Norman, 1968; Ratcliff & McKoon, 1988; Tulving & Schacter, 1990) can explain carry over effects. We are interested in memory and confidence judgments during procedural tasks (Reason, 1990), so we will focus here on Memory for Goals (MFG: Altmann & Trafton, 2002) which is written in the ACT-R cognitive architecture (Anderson, 1982).

Memory for Goals

MFG states that when a person retrieves a goal from memory, they retrieve the most active goal. Goal activation is determined by the frequency and recency that a goal is retrieved and when a goal is retrieved, activation is spread through associative links. These two constraints, in combination with the notion that memories decay over time, allows MFG to make strong predictions about goal activation and its effect on performance for procedural tasks.

Altmann & Trafton (2002) explain that cumulative priming facilitates cognitive control in procedural tasks. When a goal is retrieved it provides a small amount of activation to goals that are temporally or semantically linked. When tasks proceed in the same order, there is a cumulative priming effect. For example, if five steps are completed consistently in the same order, each of the previous steps will prime the sixth step to a small degree. At the time of the sixth step, activation should be high relative to distracters because of cumulative priming (B. Edwards & Gronlund, 1998).

Altmann & Trafton (2007) showed that when items are connected in memory they have a systematic relationship to each other. To demonstrate a systematic relationship, Altmann & Trafton (2007) investigated the effect of interruptions on resumption lag (Trafton, Altmann, Brock, & Mintz, 2003). Resumption lag measures the time taken to resume a task after a disruption ends. Participants were trained in a procedural task and, while completing the task, they were occasionally interrupted with a secondary task. Altmann & Trafton (2007) measured the resumption time on the primary task up to ten steps after an interruption.

MFG predicts that performance should suffer because the interruption cuts off priming from previous goals. As expected, the authors found a significant increase in resumption time for the step immediately after the interruption. Interestingly, the increase in resumption time persisted, producing a curvilinear pattern where resumption time slowly decreased until it reached an asymptote around step 10.

Altmann & Trafton (2007) interpret the curvilinear pattern as resumption of a cognitively complex process over time. Participants recovered as cumulative priming built up again from the retrieval of goals that were associatively linked.

The results of Altmann & Trafton (2007) are evidence of a priming mechanism for memory in procedural tasks. Given the strong relationship between target memory and confidence, and that MFG makes strong predictions about target memories in procedural tasks, a priming mechanism should be present for confidence judgments. If confidence has a priming mechanism we should see a systematic change over time following a memory manipulation such as an interruption. Already, Aguiar, Zish, McCurry, & Trafton (2016) and Zish, Hassanzadeh, McCurry, & Trafton (2015) demonstrated that confidence is sensitive to interruptions. Interruptions decrease confidence and the time to produce a confidence response. In this study we investigate a possible priming mechanism for confidence judgments. MFG makes a clear prediction: interruptions should decrease confidence in the target memory and confidence should slowly recover when the task is resumed. If there is no priming mechanism, as is left unexplained by current drift diffusion models, confidence should decrease after an interruption and immediately recover.

Methods

Participants

Fifty-five George Mason University undergraduates participated for course credit.

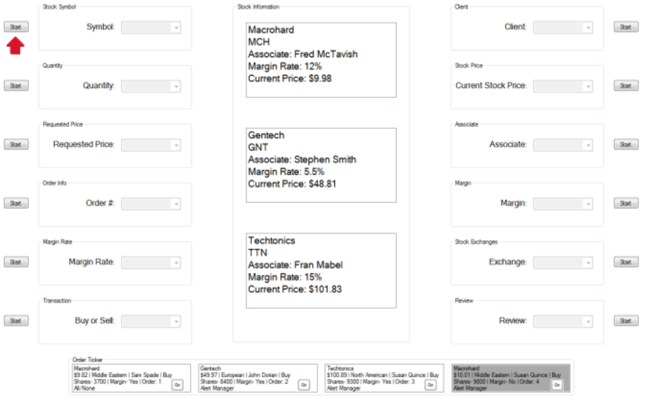
Tasks

Primary Task The primary task consisted of the financial management task (Ratwani & Trafton, 2011) where participants filled out Buy and Sell orders on a simulated stock exchange. Each order had 12 widgets that needed different information about the state of the stock market and the Buy or Sell request (e.g. Stock Symbol, Exchange, Transaction Type).

To begin, participants were presented with a Buy/Sell order at the bottom of the screen (colored gray) and a red arrow that randomly designated which of the 12 widgets required information first.

Participants located and selected a “Start” button on the side of the widget designated by the red arrow. Participants would use information from the gray-colored request and the stock market information along the middle of the screen to fill in the widget with the correct information (Figure 1). Participants repeated the process by finding information for the next widget. Following the first randomly selected widget, participants were instructed to complete the form in a left-to-right and top-down pattern.

A trial ended when another Buy/Sell order and randomly selected start widget appeared.



Macrohard
MCH
Associate: Fred McTavish
Margin Rate: 12%
Current Price: $9.98

Gentech
GNT
Associate: Stephen Smith
Margin Rate: 5.5%
Current Price: $48.81

Techtonics
TTN
Associate: Fran Mabel
Margin Rate: 15%
Current Price: $101.83

Macrohard
$9.82 | Middle Eastern | Sam Spade | Buy
Shares- 3700 | Margin- Yes | Order: 1
All/None

Gentech
$49.97 | European | John Dorian | Buy
Shares- 8400 | Margin- Yes | Order: 2
Alert Manager

Techtonics
$100.89 | North American | Susan Quince | Buy
Shares- 9300 | Margin- Yes | Order: 3
Alert Manager

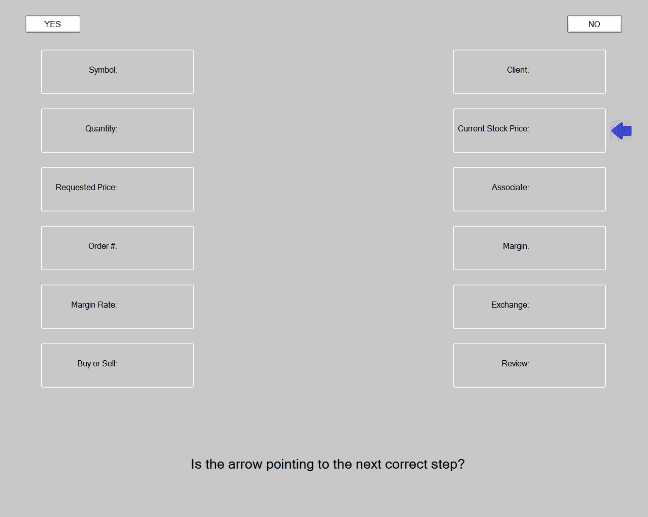
Macrohard
$10.01 | Middle Eastern | Susan Quince | Buy
Shares- 9800 | Margin- No | Order: 4
Alert Manager

Figure 1: Primary task with auto-selected order and widget.

Interruption Task For half of the trials, participants were given a secondary task that served as an interruption. The interruption lasted for 20-seconds after completing an order. The interruption consisted of a series of addition problems. Addition problems completely occluded the screen until the secondary task was complete. Participants were instructed to complete the addition problems as quickly and as accurately as possible.

Signal Position Question After a trial ended or after a trial and interruption ended, participants were presented with a facsimile of the stock order screen. A blue arrow pointed to one of the 12 widgets with the question: “Is the arrow pointing to the next correct step?” Participants would respond by clicking the word “Yes” in the top left corner or the word “No” in the top right corner (Figure 2). Once the participant made a selection, they were presented with the next order to complete with a new Buy or Sell request.

The blue arrow pointed to the correct step half of the time.



Is the arrow pointing to the next correct step?

Figure 2: Signal Position Question with a blue arrow pointing at a possible next correct step.

Confidence Question Once the signal detection question was complete, the screen was replaced with a question that asked: “How confident are you that the [widget name] was the next correct step?” The participant selected a button on the bottom of the screen that represented their confidence on a scale of 1 through 6 with 1 being “Not at all Confident” and 6 being “Entirely Confident.”

Design

The study was a 2 factor (interruption/non-interruption) repeated measures design.

Each participant had 32 interruptions across 64 trials. The order of screens participants saw was the primary task for 2-5 completed widgets, a 20-second secondary task after half of the trials, a signal position question, and a confidence question.

The 64 trials were equally divided between 2, 3, 4, and 5 completed widgets in length. The length of the trial was varied to reduce the likelihood that participants could prepare for an interruption and/or signal position question.

Each participant had half of the signal position arrows pointing to the next correct step.

Procedure

Participants filled out an approved IRB consent form as well as biographical information. Participants were seated approximately 47cm from the computer monitor. The task was first described using screenshots of the primary and secondary tasks as well as the signal position and confidence question.

Three practice trials were completed that were each 12 widgets long. This was to give the participant the opportunity to experience the order of the widgets before being given partial orders to fill. The experimenter provided the opportunity for participants to ask clarifying questions about the behavior of the task. Participants could begin once the experimenter left the room and were debriefed and dismissed once finished.

Measures

Behavioral data based on mouse clicks was collected for all participants in addition to screen recordings. Answer response time (RT) and confidence for identifying the next step in the task were calculated for correct responses up to seven trials after an interruption.

Results

Fifty-five participants completed the financial management task. Overall accuracy on the primary task was 90.7%. The Signal Position Question was answered correctly 3176 times. Answer RT and confidence RT responses greater than 3 standard deviations from the mean were removed leaving 3069 trials for analysis.

To assess the effects of trial position since the interruption on answer RT and confidence judgments, repeated-measures ANOVAs were performed. Performance was significantly different across trial position after the interruption for answer RT [$F(1,54) = 212.80$, $MSE = 67.08$, $p < .05$, $\eta^2 = .53$] and confidence [$F(1,54) = 97.84$, $MSE = 17.04$, $p < .05$, $\eta^2 = .37$]. Table 1 shows means for answer RT and confidence for each trial position since an interruption.

Table 1: Mean Performance by Trial Since Interruption

Trials Since Interruption	Answer RT (ms)	Confidence
1	4145.62	5.16
2	2718.04	5.89
3	2682.57	5.90
4	2471.10	5.92
5	2377.67	5.92
6	2265.53	6.00
7	2183.88	6.00

To detect any systematic relationship between trial position after an interruption and response time or confidence, polynomial contrasts were run for seven trials after an interruption. Thus, this analysis was trial position by one of two performance measures.

There was a significant linear and quadratic pattern for answer RT [Overall: $F(6,261) = 42.26$, $p < .05$; Linear: $t = -6.15$, $p < .05$; Quadratic: $t = 3.46$, $p < .05$]. Similar to Altmann & Trafton (2007), this curvilinear pattern is evidence of a systematic priming mechanism at work after resuming from an interruption in the financial management task. Figure 3 shows the pattern of answer RT.

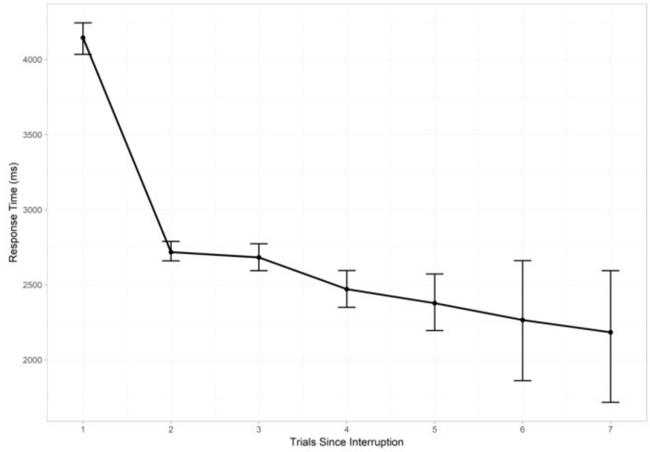


Figure 3: Mean answer response times in milliseconds up to seven trials after an interruption. Error bars are 95% confidence intervals.

Recall the predictions from MFG and drift diffusion models for confidence. MFG predicts that there should be a systematic relationship between steps of a procedural task. As a result, confidence should be worse after an interruption and should slowly recover as cumulative priming for later steps of the task builds. Alternatively, drift diffusion models of confidence leave priming unexplained. Drift diffusion models would predict that confidence is worse after an interruption but immediately recovers.

Figure 4 shows the results of confidence. Confidence decreases after an interruption and then demonstrates a pattern of recovery [Overall: F(6,261) = 29.55, $p < .05$; Linear: $t = 4.28$, $p < .05$; Quadratic: $t = -3.29$, $p < .05$). The recovery of confidence suggests that confidence judgments are sensitive to the systematic priming mechanism inherent in procedural tasks.

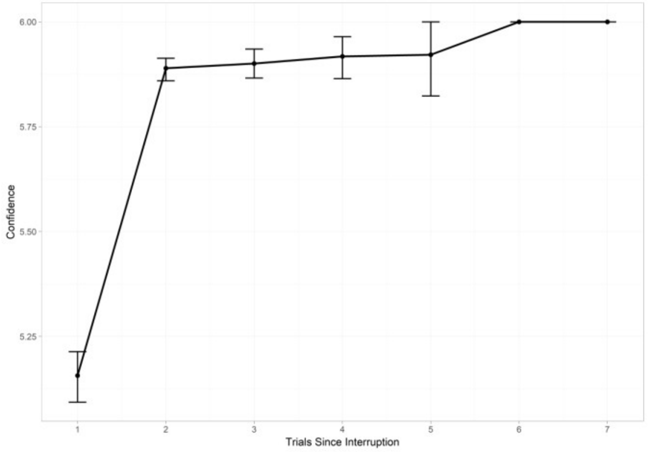


Figure 4: Mean confidence score up to seven trials after an interruption. Error bars are 95% confidence intervals.

Discussion

Participants completed a procedure on the financial management task. The goal of this study was to investigate priming in confidence judgments.

We were able to replicate the time course recovery of Altmann & Trafton (2007) for RT on a different task. For complex procedural tasks, activation for subsequent steps slowly builds the more time the task is left uninterrupted. An interruption cuts off cumulative priming to subsequent steps in the task resulting in an increase in RT immediately after an interruption. Task performance recovers after the task is resumed because of cumulative priming.

A similar pattern can be found for confidence judgments where interruptions are disruptive but performance improves over time. As predicted by MFG confidence judgments are influenced by systematic priming. To the authors' knowledge, this is the first study that demonstrates a priming mechanism for confidence in procedural tasks.

Could drift diffusion models account for priming effects like those found in Altmann & Trafton (2007) and in this report? Yap, Balota, & Tan (2013) suggested that semantic priming effects could be modeled by increasing the drift rate (the speed and direction of information accumulation), so adding in a priming component would be theoretically possible. However, the priming component itself (drift in this case) would presumably be identical to the formulation in Altmann & Trafton (2007), making the theories more difficult to differentiate.

Drift diffusion models are some of the strongest models of how confidence judgments are made and at explaining the relationship between confidence, accuracy, and response time. Many memory effects, such as reduced performance after an interruption, can be explained by a change in the drift rate. However, drift diffusion models of confidence assume a unitary process often found in visual discrimination and list learning tasks that are popular with cognitive psychologists that study confidence judgments (Baranski & Petrusic, 1998; Carroll & Petrusic, 2008; DeSoto & Roediger, 2014; Dunlosky & Metcalfe, 2008; Petrusic & Baranski, 2003).

Other models of memory, such as MFG have a ready explanation for why confidence recovers after an interruption in a procedural task: cumulative priming from previous steps increases activation. An open question is how models of memory, such as MFG would instantiate the calculation of confidence. MFG was not designed nor readily provides an explanation for how confidence judgments are made, just how they should behave.

Using goal activation, ACT-R has successfully predicted performance measures such as RT (Anderson et al., 2004). Altmann & Trafton (2007) were able to use the formulation from Anderson et al. (2004) to accurately determine the mean RT for any trial position after an interruption. Future work may determine how goal activation can be used to calculate confidence judgments for participants in procedural tasks.

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