Working Memory-Based Action Control: An Interference Paradigm for Neuroimaging

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Introduction

Investigators have begun to examine the subjective urges that one may experience when performing tasks involving response interference and working memory.

In these kinds of experiments, it is often the case that, (*a*) subjects know which response to execute prior to being presented with the 'go' cue, (*b*) subjects know which information from the memoranda will be relevant to the current task at hand, and (*c*) the task is straightforward and requires little effort in deciphering the association between the retrieval cue and what part of the memoranda must be acted upon. In everyday life, working memory performance is often more challenging, lacking features *a*, *b*, and *c*. With this in mind, we developed a new task that mirrors to a greater extent the complexity of everyday working memory performance. Our primary aim was to measure if participants can do this task.

Participants were trained to press one of two buttons when presented with two action-related letters (the memoranda) but to refrain from responding until the cue appeared. To examine a potential methodological limitation, we introduced another condition in which the prompt was not a letter (a dot, Hubbard et al., 2013), but was associated with the spatial location of the target. All subjects underwent both the Letter and Dot conditions.

Method

Pilot

Subjects. San Francisco State University undergraduate students (n = 29) participated for course credit.

Stimuli. The stimuli for the memoranda consisted of two letters (A and B), which were separated by a horizontal bar and displayed in a vertical orientation, thereby resembling a fraction (e.g., A over B, or A/B).

Procedures. All instructions were presented on the computer screen. Participants were instructed to hold in mind the memoranda, and respond accordingly by pressing one of the two associated buttons once the cue appeared. In the Letter prompt condition, the letter appeared in the center of the screen. In the Dot prompt condition, a filled circle appeared either above or below a horizontal bar presented in the center of the screen. In the Congruent condition, the action corresponds to the presented cue; in the Incognruent condition, the action corresponds to the other letter in the memoranda. After each trial, participants rated their subjectively experienced urge to err.

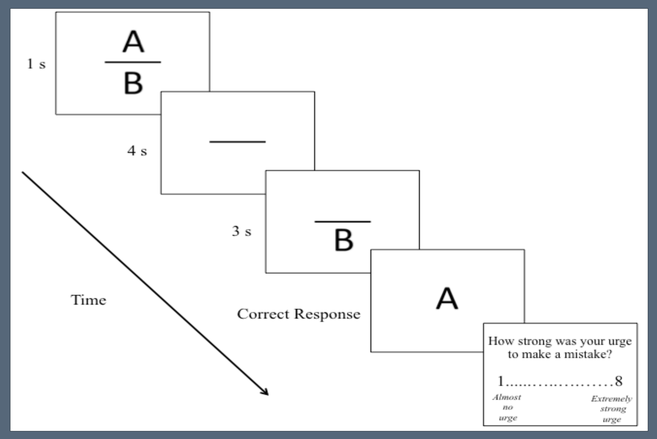
Experiment

Subjects. San Francisco State University undergraduate students (n = 64, 48 Females, M_{age} = 22.12, SD = 5.44) participated for course credit.

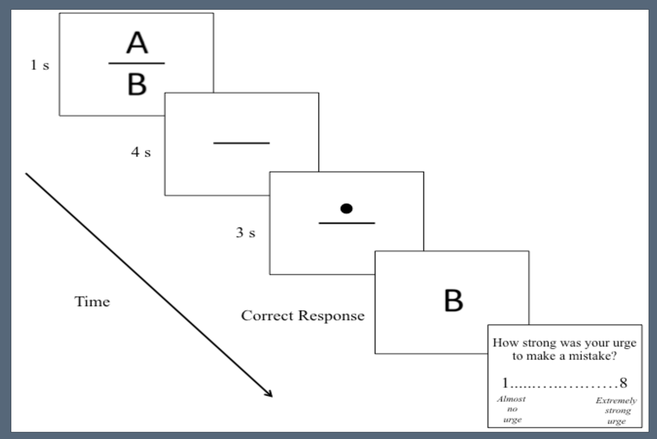
Stimuli. The stimuli for the memoranda consisted of two letters (A and B), which were separated by a horizontal bar and displayed in a vertical orientation, thereby resembling a fraction (e.g., A over B, or A/B).

Procedures. The procedures were identical to our pilot study except that the letter prompt appeared in the form of a fraction, similar to the Dot condition, rather than a single letter in the center of the screen. After each trial, participants rated their subjectively experienced urge to err.

Incongruent Letter Condition



Incongruent Dot Condition



Results

Urges to Err

There was a main effect of Congruence, $F(1, 63) = 25.99$, $p < .001$ ($\eta_p^2 = .29$), in which urges were stronger for the Incongruent than the Congruent conditions, and a main effect of Prompt, $F(1, 63) = 13.93$, $p < .001$ ($\eta_p^2 = .18$), in which urges were stronger for the dot prompt than the letter prompt.

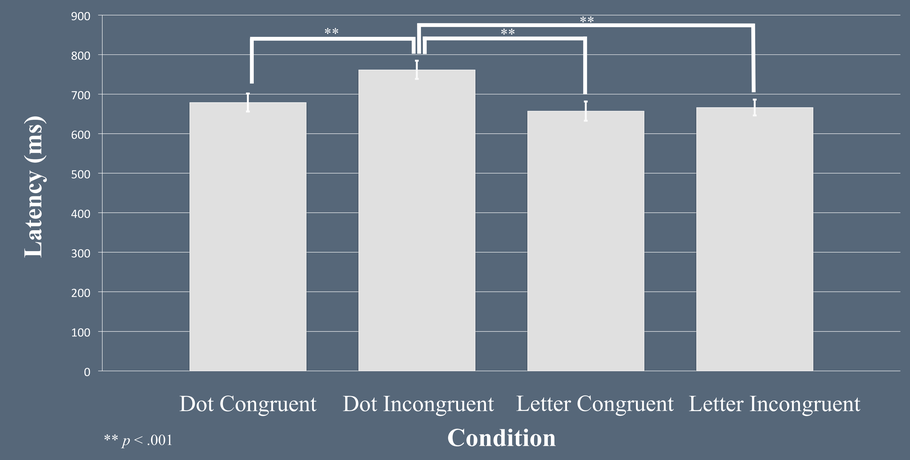
Error Rates

In a fully within-subjects ANOVA with Congruence as one factor and Prompt (dot versus letter) as the other factor, there was a main effect of Congruence, $F(1, 63) = 22.88$, $p < .001$ ($\eta_p^2 = .27$), and a main effect of Prompt, $F(1, 63) = 11.76$, $p = .001$ ($\eta_p^2 = .16$).

Response Times

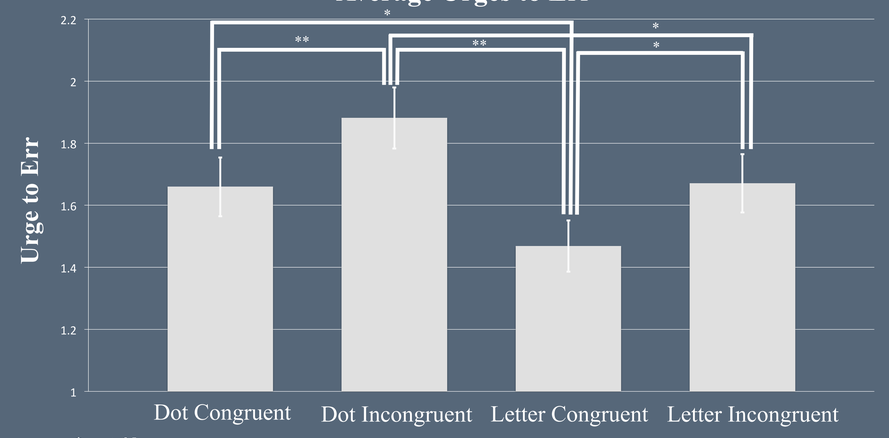
In a fully within-subjects ANOVA with Congruence as one factor and Prompt as the other factor, there was a main effect of Congruence, $F(1, 63) = 30.80$, $p < .001$ ($\eta_p^2 = .33$), in which RTs were longer for the Incongruent than the Congruent conditions, and a main effect of Prompt, $F(1, 63) = 32.61$, $p < .001$ ($\eta_p^2 = .34$), in which RTs were longer for the dot prompt than the letter prompt.

Latency of Responses



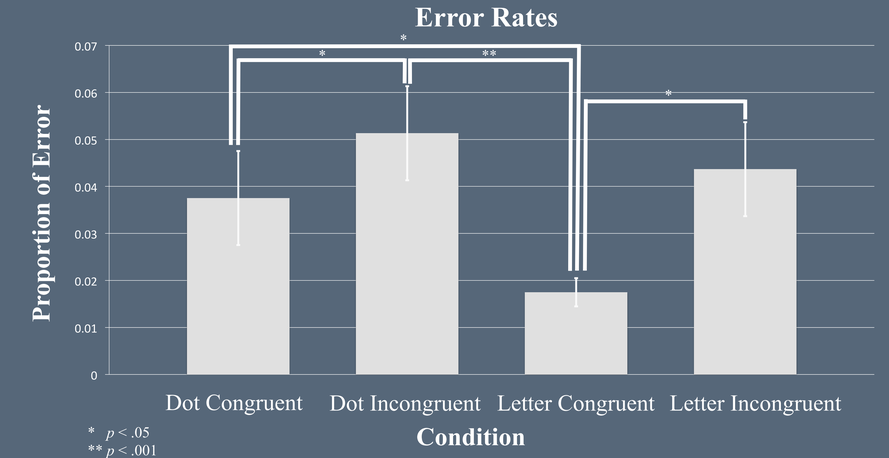
** $p < .001$

Average Urges to Err



* $p < .05$
** $p < .001$

Error Rates



* $p < .05$
** $p < .001$

Discussion

This study reveals that subjects are able to successfully perform the task (accuracy > 90%) even though (a) they do not know which response to make before the cue is presented, (b) they do not know which letter in the memoranda is action relevant, and that (c) the task requires effort in deciphering the association between the retrieval cue and the part of the memoranda that must be acted upon. The subjective data add to a literature demonstrating that subjective effects are systematic, reliable, and capable of being predicted by theoretical frameworks. This experiment can be utilized to further understand the relationship between working memory performance and consciousness. Additionally, this paradigm can be coupled with neuroimaging techniques to illuminate the neural correlates of the subjective effects associated with working memory performance.