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Relation between temporal perception and inhibitory control in the Go/No-Go task

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ABSTRACT

This research was designed to replicate and extend findings concerning bidirectional interference between concurrent timing and inhibition tasks reported previously. Subjects performed serial temporal production and Go/No-Go (GNG) tasks under single-task and dual-task conditions in two experiments. The degree of inhibitory control required in the GNG tasks was manipulated by varying the proportion of go and no-go stimuli (experiment 1) and by instructing subjects to devote different amounts of attention to the dual tasks (experiment 2). The dual-task conditions in both experiments showed a pattern of mutual interference in which each task interfered with the other. In experiment 1, concurrent timing interfered more strongly with performance on a high inhibitory-demand GNG task compared with a low inhibitory-demand GNG task. In experiment 2, concurrent timing and GNG performance displayed a reciprocity effect in which greater attentiveness to one task improved performance for that task but diminished performance for the other task, and vice versa. These results support the view that temporal processing and inhibitory control depend upon a common pool of attentional resources, and point to the GNG task as a reliable research tool for investigators studying the role of attentional processes in time perception.

1. Introduction

Temporal perception and inhibitory control are closely aligned processes. Most temporal behaviors involve some degree of inhibitory control. For example, a common method used to time short intervals is chronometric counting, in which one keeps a count of the number of elapsed seconds by trying to pace the counts at one-second intervals, as in "Mississippi—one, Mississippi—two," etc. (Grondin, Meilleur-Wells, & Lachance, 1999; Grondin, Ouellet, & Roussel, 2004; Hinton & Rao, 2004). Various collateral behaviors, such as tapping or other repetitive rhythmic responses, may also be employed to mark time (Michon, 1985; Richelle & Lejeune, 1980). All these strategies depend on inhibitory control to regulate the behaviors into constant-length temporal segments. However, inhibitory control may have a deeper relationship with timing beyond merely pacing self-generated counts. Inhibition is an essential executive cognitive function that enables one to resist distractions, block out irrelevant information, and suppress automatic responses (Friedman & Miyake, 2004; Hasher, Lustig, & Zacks, 2007). These processes, along with other executive functions such as attentional switching, memory updating, and reasoning serve to control and direct thought and behavior (Banich, 2009; Logan, 1985; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000; Stuss & Alexander, 2000). A growing body of work suggests that the attentional resources that sustain these executive functions are the same resources that support timing processes as well (see Brown, 2008, in press; Brown, Collier, & Night, 2013). The main line of evidence backing this view centers on interference patterns between concurrent timing and nontemporal distractor tasks. Typically, interference in timing performance is manifested as a shortening of perceived time and/or increased variability or error in time judgments (Brown, 2008). Distractor tasks emphasizing executive functioning tend to produce a pattern of bidirectional interference, in which each task interferes with the other (i.e., the distractor task interferes with timing performance and timing interferes with distractor performance). Mutual interference implies that the two tasks compete for the same attentional resources (Navon & Gopher, 1979, 1980; Wickens, 1984). In contrast, nonexecutive distractor tasks tend to interfere with timing but timing does not interfere with them (Brown & Merchant, 2007), which suggests only a partial overlap of resources.

One classical test of inhibitory control is the Go/No-Go (GNG) task, originally described by Donders, (1868/1969). In its basic form, the task involves the random presentation of a series of two different stimuli, such as the letters A and B. Subjects are instructed to respond with a button press to one stimulus (the go stimulus, e.g. A) and inhibit responding to the other stimulus (no-go, e.g. B). Typically, most stimuli in the sequence are go stimuli, which sets up a predisposition to respond most of the time. Inhibitory control is required to prevent responding to the no-go stimuli. In a recent study on the relation between time perception and inhibition, Brown, Johnson, Sohl, and

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Dumas (2015), exp. 3 combined the GNG task with a concurrent timing task. The experiment included both simple and complex versions of the GNG task (see Garavan, Ross, Murphy, Roche, & Stein, 2002; Langenecker, Zubieta, Young, Akil, & Nielson, 2007; Simmonds, Pekar, & Mostofsky, 2008). The simple version conformed to the standard GNG task, in which subjects responded to each appearance of a particular go stimulus letter and inhibited responses whenever a particular no-go stimulus letter appeared. The complex version of the task involved an alternating sequence of two letters. This version of the task entailed a context-based rule for deciding to respond or not. The rule was to treat each alternating letter as a go stimulus and any repeated letter as a no-go stimulus. The results showed that, compared with single-task conditions, the dual tasks produced a clear pattern of bidirectional interference between GNG performance and timing performance, which is consistent with the idea that a common pool of resources underlies timing and inhibitory control. Further, the complex GNG task interfered with timing to a greater degree compared with the simple GNG task. The interpretation of this last result, however, is uncertain. Is the stronger interference effect associated with the complex GNG task due to a greater involvement of inhibitory control resources, or is it because the complex task recruits additional executive functions beyond just inhibition? The complex GNG task may require a greater reliance on planning, memory maintenance processes, and memory updating, compared with the simple GNG task. Indeed, brain-imaging studies have demonstrated that the complex version of the task activates additional neural circuits beyond those activated by the simple version (Simmonds et al., 2008). A better approach to investigating the role of inhibition in time perception would be to employ a procedure that allows one to manipulate different degrees of inhibitory control while holding other cognitive processes relatively constant.

The purpose of the present research is to (a) replicate the basic finding of bidirectional interference between timing and GNG performance as reported by Brown et al. (2015), and (b) test whether procedures designed to increase the degree of inhibitory control needed in the GNG task would enhance dual-task interference effects. If these manipulations altered bidirectional interference, then the proposition that timing is related to inhibitory control would be strengthened. Here we report two experiments in which subjects performed timing and GNG tasks separately and concurrently. We manipulated the degree of inhibitory control required by varying the numbers of go and no-go stimuli (exp. 1) and by varying attentional allocation to the concurrent tasks via instructions to participants (exp. 2). The prediction is that the concurrent task conditions would produce a pattern of bidirectional interference, and that conditions designed to increase inhibitory demands would produce stronger interference effects.

2. Experiment 1

Inhibitory demands of the GNG task were manipulated in experiment 1 by altering the proportionality of the go and no-go stimuli. The rationale is that different proportions of go and no-go items induce different degrees of inhibitory control because they influence the strength of the prepotency of responding (Nyberg, Brocki, Tillman, & Bohlin, 2009; Wagner et al., 2005). Fewer numbers of go stimuli produce a weaker prepotency to respond, and so are associated with relatively low inhibitory demands; greater numbers of go stimuli produce a stronger prepotency to respond, and so are associated with relatively high inhibitory demands for the occasional no-go stimuli that do appear. Subjects performed a timing task concurrently with either a low-demand or a high-demand version of the GNG task. We anticipated that, insofar as timing and inhibition are related, the two tasks would produce a pattern of mutual interference. Further, the high-demand version of the GNG task should be associated with more interference compared with the low-demand version. That is, we expected that concurrent timing would interfere more with the high-demand version of the task and/or the high-demand version would interfere more with timing. This pattern would provide further support for the idea that timing and inhibitory control share the same set of attentional resources.

2.1. Methods

2.1.1. Subjects

Eighteen students (3 men, 15 women) enrolled in General Psychology classes participated in the experiment in return for extra course credit. The average age of the students was 21.7 years.

2.1.2. Apparatus and stimuli

A desktop PC equipped with a 5-button Serial Response Box (Model 200A; Psychology Software Tools, Inc.) was used to present stimuli and record responses. Programming for the experiment utilized E-Prime V2.0 software (Psychology Software Tools, Inc.). The stimuli consisted of the following letter pairs: A-U, T-Q, X-B, and C-H. The first letter in each pair served as a "go" stimulus and the second letter was the "no-go" stimulus. These letter pairs were assigned to different experimental conditions to control for practice effects and to prevent the development of automatic response inhibition (Verbruggen & Logan, 2008). The letter pairs were selected for their distinctiveness; based on an interletter confusion matrix reported by van der Heijden, Malhaus, and van den RooVaart (1984), the proportion of times each letter in a pair was confused with the other was 0.001. The letters appeared on the screen in an 18-point bold Times New Roman font. The letters were white and were presented against a black background.

2.1.3. Design and procedure

Subjects were tested individually. Watches were removed prior to testing. The subjects participated in five 3-minute trials. There were three single-task trials performed in a random order, followed by two dual-task trials that were also performed in a random order. The single-task trials were timing alone, low-demand GNG, and high-demand GNG. The timing task was serial temporal production, in which subjects pressed a button on the response box with their non-dominant hand at a rate that they judged to be one response every 5 s. The low-demand GNG task involved the letters A and U. These letters were presented one at a time in a sequential fashion in the center of the screen. Each letter was presented for 850 m s, with a blank 150 m s inter-stimulus interval (ISI) separating the letters. Thus, 180 letters appeared during the 3-min trial. Subjects were instructed to respond to each occurrence of an A by pressing the spacebar on the computer keyboard with their dominant hand (go), and to withhold responses for each occurrence of the letter U (no-go). The order of the letters was selected randomly by the program, with the constraint that 25% of the letters ($n = 45$) were A's (go) and 75% ($n = 135$) were U′s (no-go). For the high-demand GNG task, the letters were T (go) and Q (no-go). In this instance, 75% of the letters ($n = 135$) were go stimuli and 25% ($n = 35$) were no-go stimuli. In the dual-task trials, subjects performed the timing and GNG tasks concurrently, with the instruction that they were to devote equal amounts of attention to each task. The timing + low-demand GNG condition involved the letters X (go stimuli, comprising 25% of letters) and B (no-go stimuli, comprising 75% of the letters). In the timing + high-demand GNG task, the corresponding letters were C (go, 75% of the total) and H (no-go, 25% of the total).

2.2. Results and discussion

2.2.1. Timing task performance

Overall, subjects made 2206 temporal production responses. These data were converted into two standard summary measures of timing performance. The mean inter-response interval (IRI) corresponds to the mean temporal production, a measure that reflects the accuracy and directional error in time judgments. The coefficient of variation