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Attentional constraints on semantic activation: Evidence from Stroop's paradigm☆

Darcy White *, Derek Besner

Psychology Department, University of Waterloo, Canada

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ABSTRACT

It is widely believed that semantic activation from print is automatic in the sense that it is capacity free. Two experiments addressed this issue in the context of the Psychological Refractory Period (PRP) paradigm. Participants identified whether a tone was high or low in pitch in Task 1, and named the color carried by an irrelevant word in Task 2. Tasks 1 and 2 were separated by a short or long SOA. In Experiment 1 incongruent color words and neutral words served as irrelevant distractors, whereas in Experiment 2 the distractors consisted of incongruent color associates (e.g., *tomato*) and the same set of neutral items. Additionally, the proportion of short and long SOAs between Task 1 and Task 2 varied across blocks, within subjects (e.g., 80:20), so as to determine whether the bottlenecking of semantic activation and response competition reported previously is best construed as structural, or subject to performance optimization. Replicating Miller, Ulrich, and Rolke (2009), SOA Proportion interacted with SOA in both experiments, consistent with performance optimization. In contrast, replicating Besner and Reynolds (2014), SOA and Congruency had additive effects on RT in both experiments, consistent with an account in which both response competition and semantic activation are bottlenecked. The best account to date is that (i) semantic processing and response competition are structurally bottlenecked (require some form of capacity), whereas (ii) other anonymous processes are subject to performance optimization.

1. Introduction

The dominant view in the reading literature is that semantic activation from print is automatic in a variety of senses (e.g., Augustinova & Ferrand, 2014; Brown, Gore, & Carr, 2002; Neely, 1977; Neely & Kahan, 2001; among many others). This automatic processing perspective posits that semantic activation is ballistic (once initiated it cannot be stopped), occurs without intention, occurs without conscious awareness, cannot be interfered with by other processes, and is capacity free (does not require any form of attentional resources). The present investigation focuses on the widespread conclusion that semantic activation from print is capacity free. As Neely and Kahan (2001) conclude:

> "…unless visual feature integration is impaired through misdirected spatial attention, SA [semantic activation] is indeed automatic in that it is unaffected by the intention for it to occur and by the amount and quality of attentional resources allocated to it" (p. 88).

The present experiments make use of the Stroop task (which uses color words, e.g., *blue*) as well as a variant in which semantic associates are employed (e.g., *sky* which is associated with the color blue). Standardly, participants in the Stroop task are required to name the color a word is presented in while ignoring the color carrier word. For both Stroop manipulations, participants are slower to respond on incongruent trials (trials on which the color carrying word does not match the color that it is presented in, or is not associated with the color that it is presented in) than on congruent trials (trials on which the color carrying word matches the color that it is presented in, or is associated with the color that it is presented in). These Stroop effects are often taken as strong evidence favoring automaticity (e.g., see MacLeod's, 1991 review). Indeed, Logan (1988, p. 511) asserts that "the major evidence for automatic processing comes from Stroop and priming studies, in which an irrelevant stimulus influences the processing of a relevant stimulus".

Although the automatic processing view is widely held, there is a small literature whose results conflict with the conclusion that semantic activation from print is automatic (e.g., Besner, 2001; Besner & Reynolds, 2014; Besner, Risko, & Sklair, 2005; Besner & Stolz, 1999; Fagot & Pashler, 1992; Labuschagne & Besner, 2015; Lachter, Forster, & Ruthruff, 2004; Lien, Ruthruff, Kouchi, & Lachter, 2010; Robidoux & Besner, 2015; Waechter, Besner, & Stolz, 2011, among others). Some of this evidence comes from research using the Psychological Refractory

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* Corresponding authors.
E-mail addresses: dwhite@uwaterloo.ca (D. White), dbesner@uwaterloo.ca (D. Besner).

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Period (PRP) paradigm. The PRP paradigm is useful in the present context because it can be used to determine whether a particular process is capacity demanding or not. We first briefly review this approach.

1.1. The PRP paradigm

In a typical PRP experiment (see Pashler's, 1994 review), participants respond to two stimuli presented sequentially, Stimulus 1 (S1) and Stimulus 2 (S2). Participants are instructed to respond to S1 before responding to S2. The stimulus onset asynchrony (SOA; the time between the onset of S1 and the onset of S2) is manipulated, as is a factor associated with Stimulus 2 processing.

When the SOA between Tasks 1 and 2 is long, processing associated with S1 can finish before S2 is presented. This condition mimics single task experiments, and the effect of the manipulated factor should be the same size as when the task is being performed in isolation. In contrast, when the SOA is short, processing associated with S1 is still taking place when S2 is presented, which can create a processing bottleneck whereby some processing of S2 must wait for some processing associated with S1 to finish.

If the process associated with the manipulated factor in Task 2 is capacity limited, then we should see additivity of the manipulated factor and SOA on RT (i.e., the effect should be the same size on short and long SOA trials). This pattern of results would imply that some processing of S2 was put on hold until processing of S1 is complete (it is standardly argued that such processing of S2 is *structurally* bottlenecked, resulting in serial processing as in Fig. 1a). In contrast, if the manipulated factor indexes a process that is capacity free, then we should see under-additivity of our manipulated factor and decreasing SOA (i.e., the size of the effect should decrease as SOA decreases). This pattern of results is typically taken to imply that processing associated with S2 was absorbed into the time taken to process S1 (i.e., that the two stimuli were processed in parallel, see Fig. 1b). In other words, the effect of the manipulated factor in Task 2 is absorbed into the cognitive slack that results from waiting for Task 1 bottleneck processing to finish. That said, this is an oversimplification, because such under-additivity depends on prior processes also being capacity free. Thus, additivity of some factor and SOA may only mean that some prior process was bottlenecked. These constraints have not been widely recognized (see also Besner et al., 2009 for a case in which under-additivity was taken to imply both capacity free processing coupled with release from competition).

Investigations of the standard Stroop effect in the context of PRP have yielded additivity of Congruency and SOA, consistent with the inference that semantic activation from print is capacity limited (Fagot & Pashler, 1992; Magen & Cohen, 2002, 2010). However, one problem with this interpretation is that the standard Stroop effect does not

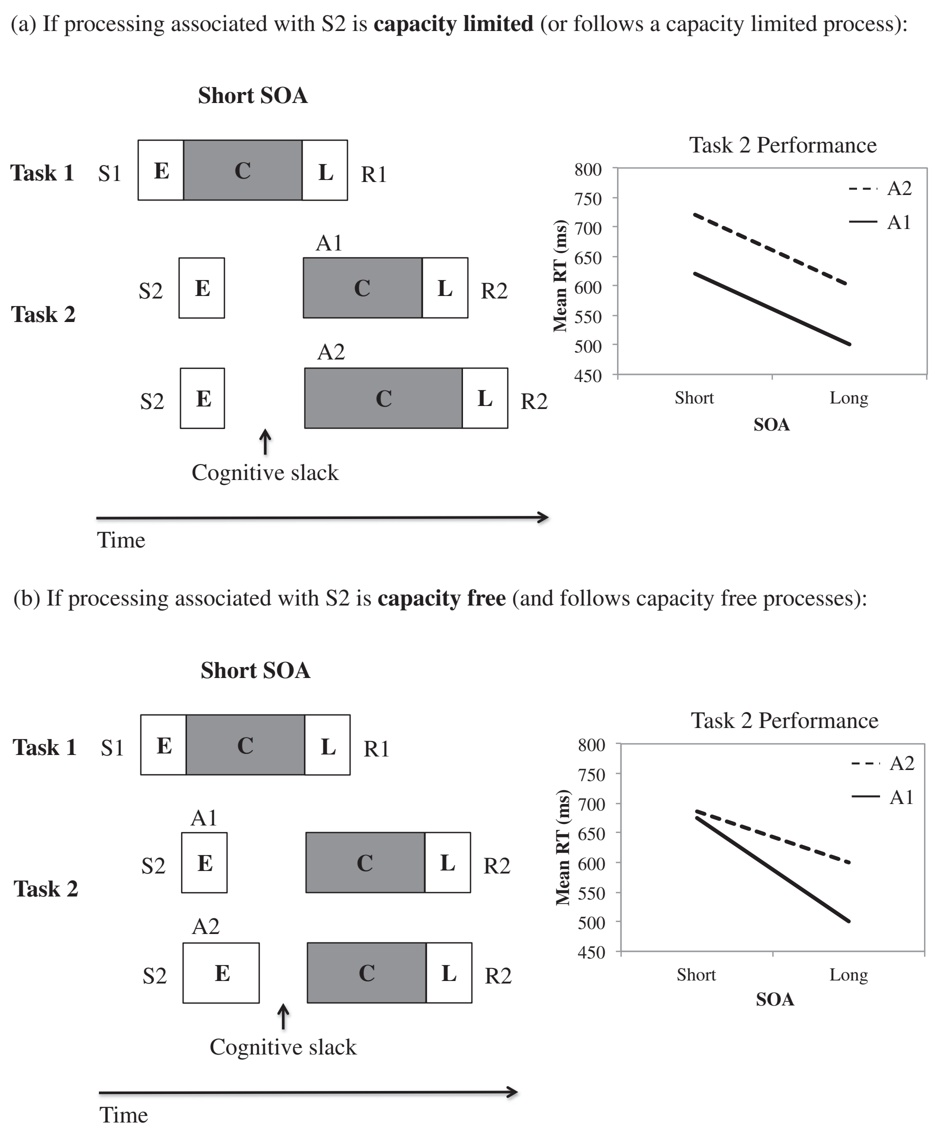

Fig. 1. A depiction of (a) additivity in PRP, and (b) under-additivity in PRP. "E" represents early processes, "C" represents central processes, and "L" represents late processes.

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