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The locus of the emotional Stroop effect: A study with the PRP paradigm☆

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ABSTRACT

Stimuli that are clearly positive or negative (hence valence-laden stimuli) have the potential to interrupt unrelated task processing. A typical example is the emotional Stroop effect (ESE) in which responding to a certain task feature (e.g., color) is delayed by the presentation of task-irrelevant valent stimuli (e.g., negative pictures) compared to valence-neutral stimuli. Here we scrutinize which processes are slowed down by irrelevant but valent stimulation. In Experiment 1, participants performed in a Psychological Refractory Period (PRP) experiment with tone discrimination as Task 1 and color discrimination as Task 2. Importantly, colors in Task 2 were accompanied by valent or neutral pictures. Valent pictures delayed responding in Task 2 (thus an ESE) and this delay was additive to the time interval between tasks. In Experiment 2, task order was reversed and the ESE in Task 1 fully propagated to the Task 2 tone discrimination. These results imply that irrelevant valence-laden stimulation delays capacity-limited processes, and we suggest that this is a late perceptual process acting on stimulus categorization.

1. Introduction

First things first. First things for humans, such as threatening or attractive stimuli often possess affective connotations. They appear as very negative or positive. It has been suggested that such stimuli are processed with high priority and perhaps automatically (Bargh, 2006; Chen & Bargh, 1999; Dijksterhuis & Aarts, 2003; Eimer & Holmes, 2002; Pratto & John, 1991). This priority is signified by the potential of valent stimuli to disturb ongoing information processing in unrelated tasks (e.g., Bertels, Kolinsky, & Morais, 2010; Cohen, Henik, & Moyal, 2012; De Houwer & Tibboel, 2010; Gupta & Raymond, 2012; Kunde, Augst, & Kleinsorge, 2012; Melcher, Born, & Gruber, 2011; Pereira et al., 2006; Verbruggen & De Houwer, 2007).

A typical example for such disturbance of ongoing cognitive activity is illustrated with the emotional Stroop task. In the original version, participants are to name the color of positive, negative, and neutral words while the word meaning itself is irrelevant. However, responses are delayed when words are valent, especially negative, compared to when they are neutral — the emotional Stroop effect (ESE; cf. Mathews & MacLeod, 1985; Williams, Mathews, & MacLeod, 1996, for reviews). Recent studies used variations of this original task. For example, participants responded to the colors with key presses (e.g., McKenna & Sharma, 2004; Frings, Englert, Wentura, & Bermeitinger, 2010) or movements (e.g., Chajut, Mama, Levy, & Algom, 2010), pictures served as emotional stimuli while participants performed an unrelated categorization task (e.g., Erthal et al., 2005; Kleinsorge, 2007, 2009; Kunde & Mauer, 2008; Kunde, Augst et al., 2012; Murphy, Hill, Ramponi, Calder, & Barnard, 2010), or the emotional stimulation was presented prior to target onset (e.g., Cohen et al., 2012; Gupta & Raymond, 2012; Pereira et al., 2006). The crucial feature in all these studies is that valence-laden, especially negative, stimuli disturb ongoing information processing despite being irrelevant for task performance.

The present study aims at providing hints about the possible source for the ESE by using a well-established chronometric approach for pinpointing the particular stage of processing where a given experimental effect arises: the Psychological Refractory Period (PRP) paradigm. Before discussing what the available literature suggests about the source of the ESE, we introduce this paradigm in the next section.

1.1. The PRP paradigm and the localization of effects

The PRP paradigm is a dual-task paradigm, where two tasks are performed on each trial. The degree of their overlap is experimentally varied by manipulating the stimulus onset asynchrony (SOA), that is, the time from presentation of the Task 1 stimulus until presentation of the

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Task 2 stimulus. Typically, response times in Task 1 (RT1) do not depend on the SOA, but those in Task 2 (RT2) are slower the smaller the SOA is, the PRP effect (Telford, 1931; for a review of exceptions from the PRP effect, see Janczyk, Pfister, Wallmeier, & Kunde, 2014). One influential model to account for the PRP effect is the central bottleneck model (e.g., Pashler, 1994). This model assumes that (a) pre-central, perceptual as well as post-central, motor processes can run in parallel with all other processes, but that (b) only one central process can run at any given time, hence a bottleneck. Thus, at short SOAs, the central stage of Task 2 must await release from this bottleneck from Task 1, and this idle time – called the *cognitive slack* (Schweickert, 1978) – leads to the longer RT2s. At sufficiently long SOAs no such slack occurs, thus processing of Task 2 is not interrupted and RT2s are lower (see also Fig. 1).

Two procedures exploit the PRP paradigm in order to localize experimental effects: the *locus-of-slack* and the *effect-propagation logic* (for applications, see Janczyk, 2013; Janczyk, Dambacher, Bieleke, & Gollwitzer, 2014; Kunde, Pfister, & Janczyk, 2012; Miller & Reynolds, 2003; Schweickert, 1978). The locus-of-slack logic distinguishes a pre-central, perceptual cause from later causes. Here, the manipulation of interest, *M*, is implemented in Task 2. If *M* affects and prolongs the pre-central, perceptual stage (Fig. 1a), the additional processing time stretches into the slack at a short SOA, and only at long SOAs the RT difference becomes observable (thus an underadditive combination of *M* and the SOA manipulation). In contrast, if *M* affects a later stage (Fig. 1b), the RT difference is equivalent across all SOA levels (thus an additive combination of *M* and SOA). Because it remains unclear whether *M* affects the central or the post-central stage in this latter case, the effect-propagation logic can be used subsequently for distinguishing the motor stage from earlier stages as the source for the RT effect. Here, *M* is implemented in Task 1. If *M* prolongs a stage prior to the post-central one, it delays the beginning of the central stage of Task 2 as well. In other words, at least at a short SOA, the RT difference should be observed in Task 1 and in Task 2: the effect propagates to Task 2 (Fig. 2a). If instead *M* affects the post-central stage, this only prolongs RT1, but not RT2 (Fig. 2b).

To avoid misunderstandings here, the particular SOA values used in a given experiment must not be understood as, for example, ‘tapping into the perceptual or central stage’. Rather, the critical result for the locus-of-slack logic relates to the pattern of interaction between the effect under investigation and the SOA. The only requirement is that one SOA is short enough and another one is long enough to allow the cognitive slack to emerge at short SOAs.

Manipulations such as stimulus brightness or contrast, traditionally seen to affect early perceptual processes, in fact interacted underadditively with the SOA manipulation in several studies (e.g., Pashler, 1984; Pashler & Johnston, 1989). The nature of the “central

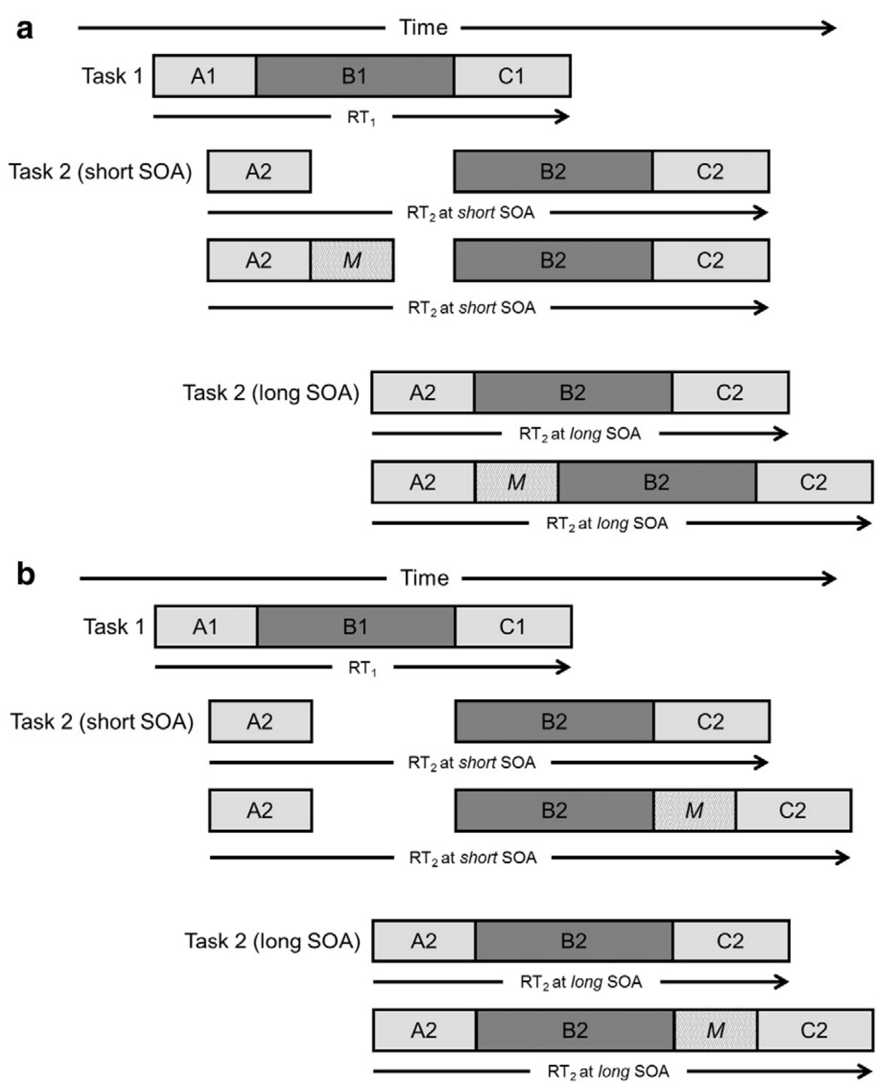

Fig. 1. Illustration of the locus-of-slack logic. (a) A manipulation *M* affecting the pre-central stage of Task 2 (A2) does not prolong RT2 at the short SOA, but does so at the long SOA. (b) *M* affects a later processing stage and prolongs RT2 at both the short and the long SOA (SOA = stimulus onset asynchrony, A1/A2 = pre-central, perceptual stage of Tasks 1 and 2, B1/B2 = central stages, C1/C2 = post-central, motor stages).