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RESEARCH****Research Report****Electrophysiological correlates of task conflicts in task-switching****Shulan Hsieh*, Hanjung Liu***Cognitive Electrophysiology Laboratory, Department of Psychology, National Chung Cheng University, Taiwan***ARTICLE INFO****Article history:**

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ABSTRACT

The current study investigated how stimulus-induced task conflicts influence task-switching, and how this effect modulates the post-stimulus switch-related event-related potentials (ERPs). In most task-switching paradigms, the stimulus display comprises a target and a distractor, which together can cause task conflicts when each is associated with a different task-set. To avoid performance interference due to task conflicts, it may be necessary to suppress inappropriately activated responses afforded by the irrelevant stimulus (Stimulus–Response (S–R) inhibition), or the entire irrelevant task-set (task-set inhibition) in response to contextual changes. The current study employed a pair-wise task-switching paradigm, in which task-switching and repeat trials were compared among three stimulus conditions—neutral, congruent, and incongruent—to distinguish the two types of inhibition. The results of the current study showed that both mean response time (RT) and the P3b effect were modulated by the stimulus condition, and reliably differed in both the congruent and incongruent stimulus conditions from the neutral stimulus conditions. Thus, the electrophysiological results of the current study suggest that the P3b component involves inhibitory processes to overcome stimulus-induced task conflicts at the level of the entire irrelevant task-set in task-switching.

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1. Introduction

People continuously shift among different tasks during daily life; whether and how shift operations incur performance costs has drawn the attention of researchers over the past 15 years. Switching tasks often involves longer reaction times and higher error rates (switch costs). The tasks used in a laboratory setting frequently refer to a set of processes linking the sensory analysis of a stimulus by categorizing or identifying the stimulus in relation to the choice of a response (e.g., Stimulus–Response (S–R) links). For instance, participants may be instructed to press a left (right) response key in the case of an odd (even) number (e.g.,

“odd/even” task-set) and a left (right) response key in the case of a vowel (consonant) (e.g., “vowel/consonant” task-set). Although seemingly trivial, shifting between these two simple task-sets (odd/even ↔ vowel/consonant) is consistently found to incur significant switch costs.

1.1. Task-switching and inhibition

Switch costs have been hypothesized to reflect the time required for active preparation for a forthcoming task (known as “active reconfiguration” theory; Meiran, 1996; Rogers and Monsell, 1995); “long-term memory retrieval” of the to-be-switched

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task rule (Mayr and Kliegl, 2003; Rubinstein et al., 2001); inhibition of the to-be-abandoned and previously relevant but now irrelevant task-set (known as “backward inhibition” theory; Mayr and Keele, 2000; Schuch and Koch, 2003); passive dissipation of the preceding task-set (known as “task-set inertia” or “proactive interference”; Allport et al., 1994); the involuntary stimulus-task binding effect (known as “interference” theory; Allport and Wylie, 2000; Koch and Allport, 2006; Waszak et al., 2003); or re-encoding of the task cue for switch trials (e.g., Arrington and Logan, 2004; Logan and Bundesen, 2003; Schneider and Logan, 2007).

Despite differences among the characteristics of switch costs as proposed by these theories, one consensus process underlying task-switching may be the inhibitory process. In most task-switching paradigms, stimulus displays containing relevant and irrelevant stimuli (or stimulus dimensions, known as “bivalent” stimulus) can induce task conflict, given that both types of stimuli are associated with different task-sets. More and more studies have provided empirical evidence suggesting a linkage between inhibition and task-switching, and some earlier studies have shown that performance in switch trials is poorer with bivalent stimuli than with univalent stimuli (Jersild, 1927; Spector and Biederman, 1976). Rogers and Monsell (1995) further showed that switch cost was larger with bivalent stimuli, indicating that bivalence had a stronger effect on switch trials than on repeat trials. Friedman and Miyake (2004), using structural equation modeling, suggested that task-switching ability is related to response-distractor inhibition. Derrfuss et al. (2005) employed a quantitative meta-analytic approach across published studies, showing that both Stroop and task-switching paradigms activated the inferior frontal junction, which was related to inhibitory cognitive control (Derrfuss et al., 2005) (see Aron et al. (2004) and Mayr et al. (2006) for different views about the brain area (e.g., the right prefrontal cortex) sub-serving the inhibitory process). These studies provide convergent evidence that task-switching involves the inhibitory process.

1.2. Level of inhibition

It is of theoretical importance to address which level of task representation is suppressed during task-switching. Some behavioral studies have suggested that the inappropriate response via a competing S–R link is inhibited (known as “S–R inhibition”, e.g., Aron et al., 2004; Meiran, 2000; Rogers and Monsell, 1995), while others have suggested that it is the entire irrelevant task-set that is inhibited (known as “task-set inhibition”, e.g., Aron et al., 2004; Koch and Allport, 2006; Koch et al., 2005; Mayr, 2002; Mayr and Keele, 2000; Rogers and Monsell, 1995; Rubin and Koch, 2006; Schuch and Koch, 2003; Steinhauser and Hübner, 2007). To date, the majority of behavioral evidence in the literature supporting S–R inhibition seems to come from studies examining switching between two tasks, whereas evidence for task-set inhibition seems to come from studies using three tasks and assessing $n-2$ task repetition cost (known as “backward inhibition”, developed by Mayr and Keele, 2000).¹ Recently, researchers have noted that the two types of inhibition may be distinct (e.g., Lien et al., 2006; Masson et al., 2003;

Table 1 – Mean reaction time (standard deviation) and error rate (standard deviation) of stimulus 2 for all conditions in the experiment

	Foreknowledge			Non-foreknowledge		
	Repeat	Switch	Cost	Repeat	Switch	Cost
<i>RT</i>						
Neutral	522.9 (42.3)	613.2 (94.2)	90.3	570.9 (50.7)	656.1 (79.5)	85.2
Congruent	550.2 (56.7)	669.2 (107.4)	119.0	611.6 (71.6)	732.7 (97.9)	121.2
Incongruent	549.2 (47.7)	705.1 (109.3)	155.9	614.3 (54.4)	762.2 (79.6)	147.9
<i>Error</i>						
Neutral	0.05 (0.03)	0.06 (0.05)	0.01	0.05 (0.04)	0.05 (0.03)	0.00
Congruent	0.04 (0.04)	0.06 (0.04)	0.02	0.04 (0.03)	0.06 (0.04)	0.02
Incongruent	0.05 (0.04)	0.12 (0.07)	0.07	0.07 (0.06)	0.12 (0.07)	0.05
RT = mean reaction time in milliseconds.						

Mayr et al., 2006);² therefore, it is both timely and important to cumulate more empirical evidence, to clarify whether the task-set inhibition is associated only with the backward inhibition paradigm. More importantly, a primary motive for the current study is to take advantage of the high temporal resolution of event-related potentials (ERP), to shed light on this issue.

In recent years, although there have emerged several ERP studies of task-switching that show switch-related P3b modulations (e.g., Barceló et al., 2002; Gehring et al., 2003; Hsieh and Chen, 2006; Karayanidis et al., 2003; Kieffaber and Hetrick, 2005; Wylie et al., 2003), few have directly examined the electrophysiological correlates of inhibitory processes underlying task-switching. To our knowledge, there may be only two ERP studies that are somewhat related to the electrophysiological correlates of the inhibitory process underlying task-switching — Poulsen et al. (2005) and Sinai et al. (2007). Nevertheless, the issue of inhibition level is not a main focus in either of these studies.

1.3. Objectives and hypotheses of the current study

Given the lack of sufficient ERP evidence directly elucidating the level of inhibition underlying task-switching, the current study aimed to extend the electrophysiological approach to other types of two-task switching paradigms in order to generalize the phenomenon. The current study adopted the pair-wise task-switching paradigm developed by Sohn and Carlson (2000). As its main interest, the current study compared the ERP components, focusing particularly on the P3b time-range component evoked

² The suppression process investigated in the two-task switching paradigm is associated with the irrelevant task and arises because of the need to resolve the task conflict evoked by a bivalent stimulus, whereas the suppression process investigated in the three-task switching paradigm refers to the extra time needed to overcome the inhibition of the just-abandoned task-set (e.g., when performing an A–B–A sequence, switching from task A to task B involves the inhibition of task A, and thus extra time is required to overcome the inhibition incurred by switching from task B back to task A).

¹ We wish to thank Iring Koch for commenting on this issue.

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