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The hierarchy of task decision and response selection: A task-switching event related potentials study

Ami Braverman *, Andrea Berger, Nachshon Meiran

Ben-Gurion University of the Negev, Be'er Sheva, Israel

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ABSTRACT

According to "hierarchical" multi-step theories, response selection is preceded by a decision regarding which task rule should be executed. Other theories assume a "flat" single-step architecture in which task information and stimulus information are simultaneously considered. Using task switching, the authors independently manipulated two kinds of conflict: task conflict (with information that potentially triggers the relevant or the competing task rule/identity) and response conflict (with information that potentially triggers the relevant or the competing response code/motor response). Event related potentials indicated that the task conflict effect began before the response conflict effect and carried on in parallel with it. These results are more in line with the hierarchical view.

1. Introduction

The architecture of the response selection mechanism is hotly debated. Some theories suggest a multi-step ("hierarchical") architecture in which the context, or task rule is first identified, and only then a motor response to the target stimulus is selected (e.g., Biederman, 1972; Haggard, 2008; Meiran, Kessler, & Adi-Japha, 2008; Rogers & Monsell, 1995; Rubinstein, Meyer, & Evans, 2001; Sohn & Anderson, 2001). An everyday example of such hierarchical processing is, when about to turn, a driver first decides whether to use the blinker or not ("task decision") and then signals 'left' or 'right' ("response selection"). According to the alternative view, the context information (e.g., task) and the target stimulus information are jointly considered in a single-step ("flat") response selection process (Mayr, Kuhns, & Rieter, 2013). Perhaps the clearest example of a flat model is Logan and Bundesen's (2003; cf. Schneider & Logan, 2005) in which the task information and the target stimulus provide a compound cue for response retrieval. Parallel Distributed Processing models could also be regarded as "flat" in some regards because, in these models task decision occurs in parallel with response selection and imposes constraints on the latter (e.g., Cohen, Dunbar, & McClelland, 1990; Gilbert & Shallice, 2002; Verguts & Notebaert, 2008). In these models, response selection is a time consuming process, whereas task decision is only considered with regards to how it affects the response selection latency (Verguts & Notebaert, 2008). Nonetheless, these models do enable proactive activation of task representation, meaning that they could technically operate either in a single step or in two steps. The task switching paradigm (e.g., Kiesel et al., 2010; Meiran, 2010; Monsell, 2003; Vandierendonck, Liefooghe, & Verbruggen, 2010) provides a suitable platform to address the question of hierarchy since it explicitly separates between task identity information (provided for example by a task cue) and response relevant information (provided by the target stimulus).

The aforementioned dispute mostly concerns *when* each type of processing takes place. Thus, perhaps the most direct means to decide between the models, hierarchical or flat, is to examine the unfolding of events during the course of an experimental trial (e.g., Mayr et al., 2013, who examined eye movements). In the present study, we adopted event related potentials (ERPs, e.g., see Karayanidis et al., 2010; Kieffaber & Hetrick, 2005; Travers & West, 2008), which have proven to be very useful in testing the latency events within a trial. To detect when task information and response information are processed, we manipulated task conflict and response conflict, separately, as explained below. Our assumption was that a given conflict is influential only when the related information (task or response) is being processed. Thus, the time window in which the conflict influences the ERPs represents the time window in which the respective decision is being made.

* Corresponding author. Address: Department of Psychology, Ben-Gurion University of the Negev, Be'er Sheva 84105, Israel. Fax: +972 8 6428348.

E-mail address: amibr@bgu.ac.il (A. Braverman).

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1.1. Task conflict and response conflict

One way to study selection processes is by manipulating selection-related conflicts (e.g., Kornblum, Hasbroucq, & Osman, 1990). Most of this work concerns response conflict, however, there has been some work on task conflict (e.g. Brass & von Cramon, 2004; Goldfarb & Henik, 2007; Kalanthroff, Goldfarb, & Henik, 2013; Rubin & Meiran, 2005; Steinhauser & Hubner, 2009). Braverman and Meiran's (2010) study, which used a task switching paradigm is most relevant here. These authors noted that response conflict and task conflict were often confounded in previous studies. Accordingly, their research strategy was to manipulate a given conflict in conditions in which the other conflict was absent.

The task switching paradigm is especially suitable to meet this requirement. In this paradigm, participants switch (usually randomly) between two or more tasks. Very often, the target stimuli afford two tasks and the identity of the task that is required in the current trial is cued by an informative cue that usually appears prior to target appearance. Braverman and Meiran's strategy was to first let the participants form a strong association between the cues and the tasks which they cued. Secondly, these authors used these stimuli as distractors which could either point to the same task as the required task ("task congruent") or to the alternative task ("task incongruent"). Specifically, these previously relevant (and now irrelevant) cues appeared as distractors together with new valid cues (Experiment 2 & 3) or they appeared together with a target stimulus that afforded only one task (Experiment 1). A significant TCE was found in all three experiments. Importantly in the present context, the stimuli used in the second phase of the experiments were ones which could only prompt one response, and thus did not involve any response conflict manipulation.

In the present work, we also examined the response conflict effect (RCE) in a similar fashion. Specifically, after associating stimuli with given responses, we used these stimuli as distractors that could prompt the correct response ("response congruent") or the incorrect response ("response incongruent"). Note that switching cost (the difference between a task switch trial and a task repeat trial) and other effects associated with task switching were not measured since they were not the scope of the study. Although there have been claims that switching cost is influenced by task conflict (e.g., Allport & Wylie, 2000, who argued that the stimulus prompts the competing task), the studies found significant switch costs even in conditions that did not prompt the competing task suggesting that task conflict is one of several component processes which give rise to switch costs. Moreover, the studies were done in conditions in which response conflict could have also contributed to the observed effects. For these reasons, switch costs were not suitable to answer our core questions.

1.2. Previous relevant studies

Previous TCE results already provide some tentative support for hierarchical models by showing that the effect diminishes as a result of task preparation that takes place within the trial, something that presumably indicates that task decision is performed separately from response selection (e.g. Braverman & Meiran, 2010; Goldfarb & Henik, 2007; cf. David et al., 2011). A problem with this evidence is that in some of these studies, an informative task cue was given before target appearance. Thus, task identity was cued prior to response identity and could have imposed a strategy of first processing task-identity information. A similar criticism applies to other studies that supported the hierarchical approach (e.g., Mayr et al., 2013). The present design overcomes this problem by presenting all the information simultaneously (see Biederman, 1972). Specifically, task identity information, and response identity information were provided simultaneously with the interfering information (prompting the in/correct task or response). Thus, the current setup did not impose a specific ordering of processes and if such ordering is found, it would reflect a true phenomenon.

Some functional MRI studies provide evidence for separate systems that are involved in task decision and response selection (e.g., Brass & von Cramon, 2004; Desmet, Fias, Hartstra, & Brass, 2011; Egner & Hirsch, 2005; Milham et al., 2001). Yet, given the poor temporal resolution of functional MRI, these studies cannot answer our core question, which was a temporal one. A more suitable tool would therefore be ERP. This imaging tool puts a much higher emphasis on temporal resolution than on spatial resolution. A number of ERP studies using task switching paradigms suggest the existence of processes that occur prior to response selection. Specifically, in the cued task-switching paradigm, the task cue, which conveys task-identity information, is presented ahead of the target stimulus, which enables response selection. Thus, the ERPs following the cue event (cue-locked ERPs) presumably indicate the processing of task-identity information and not response selection, since this measurement occurs prior to target appearance. West, Langley, and Bailey (2011) found that a frontal-central cue-locked ERP component (FCz) was sensitive to task transition at P2 (about 200 ms). Another cue-locked ERP component has been referred to as working memory updating of task-identity information. This component appears around 300 ms following cue appearance, at frontal (Fz), central (Cz) and parietal (Pz) midline sites (Jost, Mayr, & Rosler, 2008; cf. Travers & West, 2008). Nicholson, Karayanidis, Bumak, Poboka, and Michie (2006; cf. Karayanidis et al., 2011; Kieffaber & Hetrick, 2005) differentiated between cue processing and task switching effects and found a task-transition effect that began after 400 ms in parietal midline sites that was not associated with cue processing. They attributed this difference wave to a task reconfiguration process.

These studies do not fully address the current question because, as mentioned, what was measured was the cue-locked activity when task cues were presented ahead of the target stimulus, meaning that serial resolution of task conflict (first) and response conflict (second) may have been imposed by the design. As such, the studies mentioned did not (and could not) compare the dynamics of task selection and response selection when serial conflict resolution was not imposed. They could only suggest that preparation processes (triggered by the cue) <u>can</u> occur prior to response selection. Finally, none of these studies directly measured the processing of *conflicting* task-identity information, which is what TCE is about. For these reasons, in order to compare the dynamics of these two processes we allowed both processes, task preparation and response selection, to occur simultaneously and then measured their dynamics, separately. Assuming that RCE affects response selection and that TCE affects the processing of task-identity information, one could measure each effect separately whilst *allowing* task selection and response selection to begin at the same time. To our knowledge, there has yet been any ERP study that manipulated task conflict and response conflict separately whilst holding all other variables constant.

Another relevant set of ERP studies are those that focused on the cost of performing in a situation involving task switching, termed "global costs" (Mayr, 2001) or "mixing costs" (Fagot, 1994; Rubin & Meiran, 2005). These studies are relevant because what is being compared is a situation in which there are two (or more) potential tasks to a situation with only a single potential task. As such, the studies tap the management of task conflict/uncertainty. Moreover, these studies measured target-locked activity and could thus tap response conflict. Indeed, Ruge, Stoet, and Newman (2006) suggested that performing in blocks with task switching involves a process of task decision. These authors found that the cost of mixing tasks affected the N2pc component (starting