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An ERP study of target competition: Individual differences in functional impulsive behavior

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ABSTRACT

The present event-related potential (ERP) study aimed at investigating the specific behavioral and electrophysiological correlates of target competition, and their relationships to individual differences in functional impulsivity. Twenty-two participants performed a modified XO task with two conditions. Target competition displays included one up to three identical targets and no distractor, whereas distractor competition displays always included one target among one up to three distractors. On every trial, (one of) the target(s) had to be localized. Behavioral data revealed response time (RT) increases with increasing number of stimuli in both conditions. P2, N2, and P3 components were specifically responsive to target competition. High functional impulsives showed larger P2 for multiple- compared to single-target displays, but no effects on N2, P3, and RT. By contrast, in low functional impulsives target competition led to N2 increase, P3 decrease, and RT increase, while P2 effects were absent. Findings suggest that functional impulsives are better able to adapt to task requirements; in the present task they avoided conflict from multiple-target displays through better target discrimination at early stages of processing.

1. Introduction

In the experimental psychology literature, among other tasks, visual target detection has been used in the investigation of the processing of multiple targets. Visual detection tasks are typically composed of single- and multiple-target displays consisting of either two identical targets or two up to three different targets (see Ben-David and Algom, 2009, for review). The participants are instructed to press a button as soon as they detect a target at the screen. In this type of task usually a redundant target effect (RTE) has been found, being reflected in response time (RT) decrease for double-target displays compared to single-target displays (e.g., Iacoboni et al., 2000; Miller, 1986; Miniussi et al., 1998). Some studies, however, demonstrated that redundant targets can also produce RT cost (i.e., a "reversed RTE"; Grice et al., 1984a; see also Grice et al., 1984b; Grice and Reed, 1992), that was considerably smaller than the effect of an irrelevant distractor, but still significant. Schulte et al. (2006) confirmed these early findings. In their fMRI study, the authors differentiated between posterior perception-related activation associated to response facilitation for double-target displays, and anterior activation related to RTE attenuation. The anterior activation accompanying RTE attenuation was suggested to reflect response selection and preparation processes (Schulte et al., 2006).

The present study investigates behavioral and event-related potential (ERP) effects of multiple targets in a novel 4-choice RT task. Instead of a simple target *detection* task, a modified XO localization task was applied to introduce an element of choice. Within this task, simultaneously appearing multiple targets are mapped to *different* responses as they were presented in different locations. Potential multiple-target costs may then reflect response conflict resulting from competition between multiple correct responses for resources. In contrast, multiple targets in traditional detection tasks all favor the same response; target redundancy costs can then only emerge at the level of (competition for) perceptual resources. Thus, such a choice-RT task models many situations in daily life where flexible adaptation (or, attentional shielding) is necessary in the face of many potential target stimuli of which, however, only one at a time can get control over behavior.

1.1. Modified 4-choice XO localization task

Our modified XO localization task represents a more static arrangement of stimuli, but should still evoke conflict from multiple targets. During the experimental trials, participants have to localize *one target* in the presence of other *identical targets* or in the presence

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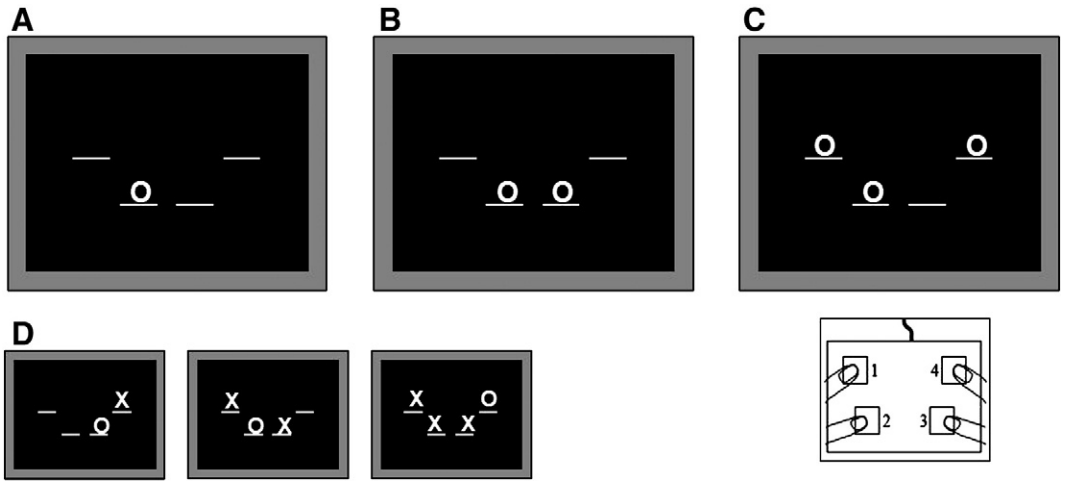

Fig. 1. Experimental setting. A: single-target display, B: double-target display, C: triple-target display; A–C constituted the target competition condition; D: types of displays in the distractor competition condition; keyboard arrangement.

of *identical distractors* different from the target. Up to four stimuli are simultaneously presented at four fixed screen locations (see Fig. 1). At least one of the stimuli is a target O; up to three targets can be present within one display. Zero up to three stimuli are distractors X.

Thus, three display types are target-only displays: single-target displays, double-target displays and triple-target displays. In the latter two types of displays, one can expect mainly two types of processes taking place. One process may lead to performance increase as reflected in RTE, and another to performance decrease as reflected in RTE reversal. Regarding the first, with increasing number of targets in a display, localizing one of them may become easier due to higher probability of *correct guesses*. Consequently, one would expect response facilitation as reflected in RT decrease. Regarding the second, multiple targets may compete for the same attentional and control processing resources, because the selection of a response to one target may interfere with the selection of the response to another target. This is because once a target has been selected, the corresponding response may have to be shielded from an actually correct, but now distracting tendency to localize another identical target. This would constitute a situation of *target–target competition* that should involve processing conflict, particularly response conflict, and hence may result in response slowing (i.e., RT increase).

1.2. Potential ERP correlates of target–target competition

As mentioned above, Schulte et al. (2006) found evidence that frontal brain activity is associated with RTE attenuation. The present ERP approach can provide brain indices of the processing of multiple targets, at excellent temporal resolution. Specifically, ERP correlates of attentional and cognitive controls, originating in medial frontal brain structures, should distinguish between facilitatory and/or conflict-inducing effects of multiple targets. An ERP correlate of a potential facilitatory effect could be the P2a or P2(00) component. A second ERP component that may represent a correlate of a potential conflict-inducing effect could be N2(00). A third, more parietally located, indicator of effortful information processing of target–target competition may be the P3(00b) component.

The *P2* is a positive going ERP component with fronto-central scalp distribution peaking at around 150-to-300 ms, depending on modality. Different ideas about the functional significance of P2 have been proposed, however a definite consensus is still missing. Some studies relate the P2 to attentional selection and attentional control processes such as the evaluation of task relevance of the stimuli and, possibly, the initiation of decision making (e.g., Martin and Potts, 2004; Potts et al., 1996, 2004). These authors found larger P2 amplitude for task-relevant stimuli than for not task- relevant stimuli. Recent studies suggested that P2 might also reflect early conflict detection (Nikolaev et al., 2008) and showed that it is one of the first conflict-sensitive components (Gajewski et al., 2008).

The *fronto-central N2* is a negative deflection peaking about 200–350 ms after stimulus onset. It has been linked to cognitive control, specifically to conflict monitoring processes and response inhibition (e.g., Botvinick et al., 2001; Falkenstein et al., 1999; Kopp et al., 1996; van Veen and Carter, 2002; Yeung et al., 2004). N2 amplitude is larger in trials consisting of highly conflicting task-relevant stimuli compared to low-conflict trials (e.g., Kopp et al., 1996; Yeung et al., 2004). Karch et al. (2010) found N2-like activity in medial frontal brain areas for both, trials on which participants were free to respond (as opposed to not to respond at all) and trials requiring a response to conflicting stimuli. The fact that both, voluntary responding and multiple targets imply an element of choice suggests that target competition may be linked to N2-related cognitive control.

The P3(b) is a positive deflection with parietal scalp distribution, peaking between 250 and 650 ms after stimulus onset, depending on modality and task. Numerous studies have linked the P3 to cognitive processes. For example, Johnson (1986) suggested that P3 decreases with decision uncertainty. This is in line with Kok's (2001) view who argued that P3 reduction reflects effortful processing in trials where decision making is difficult, which may also hold for multiple-target displays.

1.3. Individual differences in functional impulsivity

Several studies reported individual differences in information processing that were reflected in different behavioral and electrophysiological parameters, particularly in those tapping cognitive control processes such as attentional control and conflict monitoring (e.g., Falkenstein et al., 1999; Fritzsche et al., 2010; Pailing et al., 2002; Stahl and Gibbons, 2007). Regarding the present multiple-target arrangement, individuals with efficient attentional control should better be able to minimize the potential conflict from multiple targets than individuals with less efficient attentional control, resulting in superior multiple-target performance in the first group. Functional impulsivity (FI; Dickman, 1990) is characterized by this type of flexible adaptation. In fact, high functional impulsivity is defined in terms of efficient behavioral control, leading to positive consequences in ambiguous