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Research report

Subliminally and consciously induced cognitive conflicts interact at several processing levels

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ABSTRACT

Controlled behavior is susceptible to conflicts that can emerge from subliminal or consciously processed information. While research suggests that both sources of conflicting information may interact in their modulation of controlled behavior, it has remained unclear which cognitive sub-processes involved in controlled behavior are affected by this interaction; i.e., at which processing level subliminally and consciously induced response conflicts interact in modulating controlled behavior. Moreover, we investigated whether this interaction of subliminally and consciously induced response conflicts was due to a nexus between the two types of conflict like a common cognitive process or factor. For this, $n = 38$ healthy young subjects completed a paradigm which combines subliminal primes and consciously perceived flankers while an electroencephalography (EEG) was recorded. We show that the interaction of subliminal and conscious sources of conflict is not restricted to the response selection level (N2) but can already be shown at the earliest stages of perceptual and attentional processing (P1). While the degree of early attentional processing of subliminal information seems to depend on the absence of consciously perceived response conflicts, conflicts during the stage of response selection may be either reduced or enhanced by subliminal priming. Moreover, the results showed that even though the two different sources of conflict interact at the response selection level, they clearly originate from two distinct processes that interact before they detrimentally affect cognitive control.

1. Introduction

Exerting volitional control over one's behavior is essential for goal-directed actions. It allows us to ignore distractions when working on certain tasks, resist temptations, or pick the correct response among several available options. Yet, volitional action control is both effortful and prone to error as automatic processes can often not be completely shielded or suppressed

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by task-relevant control processes, so that automatic processes may impinge on cognitive control including response selection (e.g., Eimer & Schlaghecken, 2003; Ulrich, Schröter, Leuthold, & Birngruber, 2015). To understand why task goal shielding is error-prone, it helps to look at the balance between task goal shielding and shifting maintained by healthy individuals: Even though a very strict top-down shielding of task goals would minimize distractor-triggered conflicts, it would also prevent us from adapting our strategy in case more beneficial task sets/response strategies are available. Hence, it is actually advantageous to stay a little susceptible to stimulus input which is not part of a task set, so that we can shift our strategy, whenever beneficial (Goschke & Dreisbach, 2008). If the non-task relevant input however triggers strong conflicts, healthy individuals will increase their task goals shielding (Goschke & Dreisbach, 2008). While such conflicts increase error rates, the effortful task goal shielding often delays our responses.

To investigate such response conflicts in experimental settings, response-relevant targets are often combined with response-irrelevant distractors assumed to trigger response tendencies which are either compatible or incompatible with the required correct response (for review see Diamond, 2013; Leuthold, 2011). While the distractors used in such tasks are usually consciously perceived and processed, it has been pointed out that response conflicts may also arise from masked subliminal primes that are not consciously perceived, as evidenced by the positive and negative compatibility effects (i.e., PCE and NCE) (McBride, Boy, Husain, & Sumner, 2012). In fact, unconscious information processing has repeatedly been reported to affect or modulate consciously controlled behavior, especially in case the subliminal input matches currently active task sets (Parkinson & Haggard, 2014; Schlaghecken & Eimer, 2004). Unlike consciously perceived distractors, such subliminal input can however not be subject to top-down volitional control (Boy, Husain, & Sumner, 2010). It has therefore been argued that subliminal and consciously perceived distractors evoke different kinds of response conflicts. Yet, recent research suggests that these kinds of conflict may indeed interact and conjointly modulate volitionally controlled behavior (Boy et al., 2010). Boy et al. (2010) demonstrated this by combining a spatial flanker task with preceding subliminal primes. Their results suggest that response conflicts induced by primes and flankers do not simply add up in their modulation of controlled behavior (Boy et al., 2010). Instead, those conflicts may "potentiate" their effects by aggravating incompatibility/incongruency effects once the respectively other kind of conflict is present. The processing stages at which this interaction takes place have however not yet been identified. Furthermore, it has remained unclear whether the subliminally and consciously induced conflicts simply affect the same cognitive function (i.e., cognitive control), or whether they interact in a shared process *before* conjointly affecting cognitive control. If the latter was the case, there should be a nexus between the magnitude of the subliminally induced conflicts and that of consciously induced ones. If there was however no common/shared process, there should be no nexus between the magnitudes of subliminally and consciously induced conflicts. Based on this logic, contrasting subjects with large and small PCEs allows to investigate whether the degree of interaction between prime and flanker effects on cognitive control is modulated by a common process or independent thereof: In case conscious and subliminal interference are distinct processes which nevertheless interact, one would expect the degree of interaction between prime and flanker effects to be independent from PCE group in both behavior and neurophysiological measures. If, however, priming and flanker were based on the same underlying mechanism, the individual magnitude of the PCE should heavily influence the magnitude of the flanker effect.

As the study by Boy et al. (2010) was purely behavioral, their conclusions are based on only a small number of selected behavioral measures. Hence, their conclusions are limited to rather specific configurations and may require amendments in case they reflect more general principles. Even more importantly, the neurophysiological basis underlying the interaction on subliminally and consciously induced conflicts has remained elusive. To tackle this issue, we set out to analyze the entire information processing cascade from early attentional stimulus processing to the stages of response selection and motor processes. Most importantly, this allows to assess our main question, namely at which processing stages the interaction of subliminal and conscious control processes unfolds.

In the current study, we use event-related potentials (ERPs) to identify cognitive sub-processes and their neurophysiological correlates that are modulated by the interaction. We focus on the PCE of subliminal priming because the associated activation of prime-compatible responses is subject to less temporal variability (Kiesel, Berner, & Kunde, 2008; Schlaghecken, Birak, & Maylor, 2012) than the inhibition of prime-compatible responses in the negative compatibility effect (NCE). Also, the PCE has been shown to clearly influence response latencies while the NCE effects are less clear and might instead have a stronger influence on the way response choices are made (Parkinson & Haggard, 2014). Hence, investigation of the PCE should provide more reliable neurophysiological data. Based on the fact that cognitive control mechanisms are assumed to mainly unfold at the level of response selection (e.g., Bocanegra & Hommel, 2014; Botvinick, Braver, Barch, Carter, & Cohen, 2001; Ulrich et al., 2015), effects of subliminal priming and its interaction with flanker interference should mainly occur at this level. However, it cannot be ruled out that "earlier" perceptual and attentional selection processes are affected as well. Therefore, we analyze P1 and N1 ERPs (e.g., Luck, Woodman, & Vogel, 2000), as they may be influenced by priming (e.g., Bernat, Bunce, & Shevrin, 2001; Gibbons, Rammsayer, & Stahl, 2006; Kathmann, Bogdahn, & Endrass, 2006; Nativ, Lazarus, Nativ, & Joseph, 1992). Since conflicting stimulus input may increase P1 and N1 amplitudes (e.g., Ernst et al., 2013), we would expect larger P1 and N1 ERPs whenever flankers and/or the target are not compatible with the initially presented prime (in case subliminal priming interacts with the early attentional processing of flanker and/or target information). Response selection, conflict, and cognitive effort have been shown to be reflected by N2 amplitude modulations (overview: Beste, Baune, Falkenstein, & Konrad, 2010; Botvinick, Cohen, & Carter, 2004; Chmielewski, Mückschel, Dippel, & Beste, 2015;