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# Stimulus ambiguity elicits response conflict

Arnaud Szmalec [a,*], Frederick Verbruggen [a], André Vandierendonck [a], Wouter De Baene [a,b], Tom Verguts [a], Wim Notebaert [a]

[a] *Department of Experimental Psychology, Ghent University, Henri Dunantlaan 2, B-9000 Ghent, Belgium*
[b] *Laboratorium voor Neuro-en Psychofysiologie, K.U. Leuven, Belgium*

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**Abstract**

Conflict monitoring theory [M.M. Botvinick, T. Braver, D. Barch, C. Carter, J.D. Cohen, Conflict monitoring and cognitive control, Psychol. Rev. 108 (2001) 625–652] assumes that perceptual ambiguity among choice stimuli elicits response conflict in choice reaction. It hence predicts that response conflict is also involved in elementary variants of choice reaction time (RT) tasks, i.e., those variants that, by contrast with the Stroop task or the Go/No-Go task for instance, are rarely associated with cognitive control. In order to test this prediction, an experiment was designed in which participants performed a simple RT task and a regular between-hand 2-choice RT task under three different levels of stimulus ambiguity. The data show that response conflict, as measured by the N2 component of the event-related brain potential (ERP), was elicited in the 2-choice RT task but not in the simple RT task and that the degree of response conflict in the 2-choice RT task was a function of stimulus ambiguity. These results show that response conflict is also present in a regular choice RT task which is traditionally not considered to be a measure of cognitive conflict.


*Keywords:* Choice reaction; Conflict monitoring theory; Response conflict; Stimulus ambiguity; ERP; N2

An important aspect of cognitive control is the detection of suboptimal information processing. As recently proposed in conflict monitoring theory (CMT; [1]), suboptimal information processing can be operationally defined as the occurrence of conflict, like the concurrent activation of two competing responses in a Stroop task, for example. The present study examines CMT's assumption that response conflict is elicited also in regular choice reactions which are, by contrast with other so-called conflict tasks like Stroop or Go/No-Go tasks, generally not related to conflict monitoring. The reason that neutral choice reactions are rarely associated with conflict is that a regular choice RT task does not involve competition between an erroneous response prepotency and an appropriate but less obvious response (e.g., word reading and color naming in a Stroop task). According to CMT however, response conflict does occur in a neutral choice reaction context because it is inherent in the requirement to select a response based on stimulus discrimination (e.g., [1]). The theory further predicts that the degree of response conflict is a function of perceptual ambiguity or discriminability among the choice stimuli. The aim of the present study is to test this prediction.

One strong asset of CMT is that it proposes a formal measure of response conflict which makes it possible to empirically test the predicted levels of conflict. In a network model of a 2-choice RT task for example, response conflict can be quantified as the product of the activations of the response alternatives

$$\text{response conflict} = z_i z_j \qquad (1)$$

where $z_i$ and $z_j$ are the activation values for the possible responses (see Ref. [1], p. 641, for a detailed description). Clearly discriminable stimuli are represented by a network input vector [0 1] or [1 0], indiscriminable stimuli by [0.5 0.5] and a possible input for ambiguous stimuli is [0.2 0.8]. This continuous measure predicts that response conflict increases with stimulus ambiguity (e.g., $z_1 z_2 = (0.9)(0.1) = 0.09$, $z_1 z_2 = (0.8)(0.2) = 0.16$ and $z_1 z_2 = (0.7)(0.3) = 0.21$ under conditions of easy, intermediate and hard discriminability, respectively), but not in a simple RT task that involves only one response alternative ($z_1 z_2 = (1)(0) = 0$).

The current electrophysiological study uses ERPs in order to test CMT's prediction that the degree of response conflict in a 2-

* Corresponding author. Tel.: +32 9 264 64 39; fax: +32 9 264 64 96.
*E-mail address:* arnaud.szmalec@UGent.be (A. Szmalec).

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choice RT task is a function of perceptual ambiguity among the choice stimuli. The N2 component of the ERP will be used as an index of response conflict. The N2 is a negative deflection of the stimulus-locked ERP with a frontocentral topography. This ERP component was initially seen as a marker of response inhibition [e.g., 4,10]. More recently however, a number of studies demonstrated that the N2 is not elicited by the inhibition that is required to withhold the erroneous response, but by the detection of a conflict between the correct and the incorrect response [3,9,13]. Donkers and van Boxtel [3] for example, used a Go/GO task in which participants were required to provide a normal response on Go trials and to press harder on GO trials. They observed an increased N2 amplitude on infrequent GO trials. Analogously, in a Go/No-Go task with 80% No-Go trials, Nieuwenhuis et al. [9] found an N2 amplification on the infrequent Go trials. Since both studies show a stronger N2 deflection when – in contrast to the regular Go/No-Go task – the infrequent alternative is to respond instead of to withhold, these findings cannot be explained by a response inhibition account. Therefore, the N2 is now an established marker of conflict between response representations which occurs prior to a response in situations that are characterized by high response conflict, such as the Eriksen flanker [13] and Go/No-Go tasks [9]. Another question that stands orthogonal to the inhibition/conflict issue is whether the N2 reflects stimulus conflict or response conflict. Earlier studies showed a selective sensitivity of the ERP component to response conflict. Van Veen and Carter [11], for example, used a flanker task with four stimuli mapped on two responses (i.e., two stimuli mapped onto each response). Such a flanker task introduces three types of flanker-target combinations. One type of trial consists of flankers identical to the target, another type consists of flankers that differ from the target but that are mapped on the same response (stimulus incongruent but not response incongruent), and finally, there is a type of trial where flankers differ from the target but are mapped on a different response (response incongruent). In this paradigm, N2 is enhanced on response incongruent trials, but it is not amplified by stimulus incongruent trials (see also Ref. [12], for a review). Accordingly, the sensitivity of N2 amplitude to response conflict and its insensitivity to stimulus conflict makes it an appropriate measure for investigating whether perceptual ambiguity elicits response conflict. Note that, in contrast to the definition of stimulus conflict, our definition of stimulus ambiguity does not necessarily exclude response conflict.

In order to investigate the effects of stimulus ambiguity on N2 amplitude in a regular between-hand 2-choice RT task, we designed an experiment in which participants performed a simple RT task and a regular 2-choice RT task under three different levels of discriminability (hard, intermediate, and easy discriminability), using auditory signals. It is important to mention that an auditory signal is a single-attribute stimulus, and that ambiguity is by consequence manipulated within the same dimension. This means that response conflict elicited by the ambiguous stimulus cannot be achieved by a competing dimension, like in an incongruent Stroop stimulus for example. Based on CMT, we anticipated N2 amplitude to reflect the response conflict measures as described above for the different conditions. More specifically, two predictions were made. First, we predicted an N2 deflection in the choice RT task, but not in the simple RT task, because in the latter task all stimuli lead towards the same response, thus no response conflict can occur. Second, given that response conflict is a function of perceptual ambiguity among choice stimuli, we predicted that the amplitude of the N2 marker of response conflict will increase with the level of stimulus ambiguity in the 2-choice RT task.

Thirteen right-handed participants (6 females) between the age of 19 and 26 years (mean = 22.50 years) were paid €35 for taking part in the study. All participants had normal hearing and they reported being free from neurological or psychiatric problems.

Participants were subjected to a 2 (task: simple RT task vs. choice RT task) × 3 (stimulus ambiguity: hard vs. intermediate vs. easy discriminability) within-subject design. The stimuli for the choice RT task depended on the degree of stimulus discriminability: in the condition with hard discriminability, the first sound was 262 Hz and the second sound 262 Hz + the just notable difference (JND) (in Hz), assessed at individual level. In the easy condition, participants performed choice reactions between sounds of 262 and 524 Hz (difference of one octave). In the condition with intermediate discriminability, sounds of 262 and 376 Hz were presented, where the latter frequency is the logarithmic midpoint between 262 and 524 Hz (discriminability is a logarithmic function of the frequency difference). All sounds were 150 ms sinusoidal tones, binaurally presented through a headphone (Sennheiser HD 265-1 closed headphones) at approximately 60 dB SPL. Data were collected in a sound-attenuated and electrically shielded room.

Prior to the main experiment, we determined the JND at 262 Hz for each participant individually, by using the psychophysical method of constant stimuli [5]. Piloting work suggested that, for the audio parameters and apparatus used in the present study, perfect discriminability for normal hearing and musically untrained subjects could be obtained within a range of 28 Hz from the 262 Hz base sound. Accordingly, stimulus pairs were constructed which consisted of the 262 Hz base sound and a deviant up to 290 Hz (262 + 28) in steps of 2 Hz. This resulted in a set of 14 sound pairs, which were each presented 20 times in a random order. Participants were asked to judge whether they heard a difference between the two sounds in the pair. Then, the JND for this study was determined as the difference in frequency which was recognized in 90% of the trials. A lower percentage would probably produce too many errors and consequently too important a loss of EEG epochs.

After the JND assessment, participants rested for 20 min, during which they were prepared for the EEG recording. Then, they went through the six counterbalanced conditions of the experimental design. In each condition, three blocks of 120 sounds were presented, which makes a total of 360 sounds per condition. Stimulus ambiguity was manipulated between blocks. This means that in the choice RT task condition with easy discriminability, participants indicated for each tone whether it was the 262 or the 524 Hz tone. In the choice RT task condition with intermediate discriminability, they had to discriminate between the 262 and the 376 Hz tone. In the hard discriminability condi-