Neuropsychologia 51 (2013) 1663–1672

Contents lists available at SciVerse ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

Cognitive and affective control in a flanker word task: Common and dissociable brain mechanisms

Sonia Alguacil, Pío Tudela, María Ruz *

Mind, Brain and Behavior Research Center, Universidad de Granada, Campus de Cartuja s/n, Spain

ARTICLE INFO

Article history:
Received 11 December 2012
Received in revised form
16 May 2013
Accepted 28 May 2013
Available online 5 June 2013

Keywords:
Control mechanisms
Emotion
P1
N170
N2
P3

ABSTRACT

In the present study we compared the nature of cognitive and affective conflict modulations at different stages of information processing using electroencephalographic recordings. Participants performed a *flanker task* in which they had to focus on a central word target and indicate its semantic category (cognitive version) or its valence (affective version). Targets were flanked by congruent or incongruent words in both versions. Although tasks were equivalent at the behavioral level, event-related potentials (ERPs) showed common and dissociable cognitive and emotional conflict modulations. At early stages of information processing, both tasks generated parallel sequential conflict effects in the P1 and N170 potentials. Later, the N2 and the first part of the P3 wave were exclusively modulated by cognitive conflict, whereas the last section of the P3 deflection/Late Positive Component (LPC) was only involved in affective current conflict processing. Therefore, the whole data set suggests the existence of early common mechanisms that are equivalent for cognitive and affective materials and later task-specific conflict processing.

1. Introduction

When performing a task, humans often have to focus their attention on stimuli that are relevant to the task at hand and overcome the influence of distracting, irrelevant information. These situations require the implementation of control processes, given that relevant and irrelevant stimuli often trigger opposite action tendencies (see Norman & Shallice, 1986; Posner & Fan, 2004). How we exert control and solve such conflicts is a key research question that has been studied for many years using stimulus-response compatibility (SRC) tasks (Kornblum, Hasbroucq, & Osman, 1990). In this type of settings, goal-relevant targets are surrounded by irrelevant stimuli that are associated with the same (congruent) or opposite (incongruent) action tendencies. The typical *conflict effect* (Eriksen & Eriksen, 1974) arises, as responses are faster and more accurate in congruent than in incongruent trials. On the other hand, the *conflict adaptation effect* (Gratton, Coles, & Donchin, 1992) is evaluated based on the interaction between the previous and current congruency in consecutive trials. Responses on trials following an incongruent trial show decreased conflict. This finding is supposed to reflect the heightened activation of control mechanisms, which seem to be more available for the resolution of new incongruences (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Egner, Etkin, Gale, & Hirsch, 2008). This effect seems to be domain-specific, as it does not transfer across different SRC tasks that are performed sequentially (Egner, 2008; Egner et al., 2008; Funes, Lupiáñez, & Humphreys, 2010).

In neural terms, according to the conflict-monitoring hypothesis, the anterior cingulate (ACC) and dorsolateral prefrontal (dlPFC) cortices are involved in monitoring conflictive situations and implementing control mechanisms, respectively, when required (Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999; Cohen, Botvinick, & Carter, 2000; MacDonald, Cohen, Stenger, & Carter, 2000). This hypothesis posits that the ACC monitors the occurrence of conflict online and the dlPFC holds task-relevant representations and amplifies cortical responses to reduce conflict. After that, the ACC is thought to provide feedback (Botvinick et al., 2001, 1999; Cohen et al., 2000; Egner & Hirsch, 2005).

Initially, research on emotional conflict used SRC paradigms such as the emotional counting Stroop task (Whalen et al., 1998) and other related tasks (Bush, Luu, & Posner, 2000) in which emotional information was a distractor but not a target, as targets were always cognitive. However, further developments were aimed at equating cognitive and affective types of conflict within a single task (Egner et al., 2008; Kanske & Kotz, 2010a) and using the same type of stimuli across conditions (Ochsner, Hughes, Robertson, Cooper, & Gabrieli, 2008).

For example, Egner et al. (2008) modified the classic Stroop task (Stroop, 1935) by displaying overlapping male and female faces (expressing fear or happiness) and words (referring to the

* Corresponding author. Tel.: +34 958246240.
E-mail address: mruz@ugr.es (M. Ruz).

0028-3932/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.neuropsychologia.2013.05.020

gender or the emotional expression of the faces). Participants had to respond to the gender of the faces in the cognitive version of the task and to the emotional expression of the faces in the affective version of the task. In both cases, participants had to ignore irrelevant superimposed verbal information. Thus, faces and words could be either congruent or incongruent in both cognitive and emotional tasks. Similarly, Ochsner et al. (2008) used a task in which a word (target) was presented at the center of the screen, flanked by another two words displayed above and below. Participants had to indicate the semantic category (fruits vs. metals) of the target in the cognitive version of the task and respond to the valence of the words (positive vs. negative) in the emotional version.

To date, several reports have jointly explored the neural substrate of cognitive and affective conflict. Results converge on the finding of common areas of activation for both types of tasks in the dorsal ACC. However, differences have also been found between cognitive and affective versions. Cognitive conflict seems to involve activity in the dorsolateral prefrontal cortex, whereas affective conflict seems to recruit the rostral medial prefrontal and ventral anterior cingulate cortices (Bush et al., 2000; Egner et al., 2008; Kanske & Kotz, 2010a; Ochsner et al., 2008). These results are mainly derived from functional magnetic resonance imaging (fMRI). This technique, however, is not appropriate to conduct analyses on how different types of conflict affect the various rapid stages of information processing that take place from stimulus onset to response execution. By contrast, electroencephalography (EEG) provides excellent temporal resolution that helps understand whether cognitive and emotional conflicts generate common or dissociable effects along the various stages of stimulus processing.

Several event-related potentials (ERPs) are sensitive to conflict modulation across different stages of information processing. First, the P1 and N170 are early potentials that reflect perceptual processing in visual cortices (Hillyard, 2009; Luck, Woodman, & Vogel, 2000). The amplitude of the P1 is also heightened by selective attention to spatial positions and stimulus features (Hillyard, 2009; Luck, 2005), and seems to reflect the amplification of relevant information (Hillyard, Vogel, & Luck, 1998). According to research conducted by Meeren, Van Heijnsbergen, and Gelder (2005), the P1 displays larger amplitudes for congruent than for incongruent face-body emotional expressions. Similarly, Scerif, Worden, Davidson, Seiger, and Casey (2006) used a classic flanker paradigm and found conflict adaptation effects in the P1 potential. At that stage, incongruent trials preceded by trials of the same type had larger amplitude than the other combinations of previous and current congruency in a sequence of trials. Together, these results suggest that conflict and its previous congruency context can influence the processing of perceptual information at a very early stage.

The N170 potential is associated with perceptual discrimination and object categorization processes (Hillyard, 2009; Luck et al., 2000) and can be modulated by attention (see Aranda, Madrid, Tudela, & Ruz, 2010; Ruz & Nobre, 2008a). In two recent parallel experiments, Zhu, Zhang, Wu, Luo, and Luo (2010) used a Stroop face-word manipulation in which participants had to indicate the emotional category of the target stimulus (the *face* in Experiment 1 and the *word* in the Experiment 2) while ignoring the distractor element (similar to Egner et al., 2008). In Experiment 1 (in which participants responded to the face), the N170 potential had larger amplitude in the incongruent condition than in the congruent condition. In Experiment 2 (in which the word was the target), the amplitude pattern was reversed. Thus, the amplitude of this potential was enhanced by task-relevant information during emotional conflict processing (Zhu et al., 2010). Altogether, this evidence from the P1 and N170 potentials shows that cognitive and emotional conflict can modulate the perceptual processes reflected in these potentials and — at least in the P1 potential — reflects the control of cognitive conflict according to its previous congruency context.

The term ‘N2’ includes several waves that have generally been related to the allocation of attention to target stimuli and the suppression of irrelevant stimuli (Luck, 2005). The N2 that is most strongly associated with cognitive control is a negative deflection that takes place around 200 ms after stimulus onset with a fronto-central topography (Heil, Osman, Wiegelmann, Rolke, & Hennighausen, 2000; Kopp, Rist, & Mattler, 1996). Using a classic flanker task, Kopp et al. (1996) found that the amplitude of the N2 was larger in incongruent trials than in congruent trials (Kopp et al., 1996; Van Veen & Carter, 2002). This result, which seems to reflect the implementation of control mechanisms (Folstein & Van Petten, 2008), has since been replicated several times (Folstein & Van Petten, 2008; Van Veen & Carter, 2002). With the help of computer simulations, Yeung et al. (Yeung, Botvinick, & Cohen, 2004) proposed that the N2 potential reflects conflict monitoring in correct responses prior to response execution. In fact, the N2 potential seems to reflect a process of detection of potential future errors that takes place before response execution (Yeung et al., 2004).

Regarding emotions, Kanske and Kotz (2010b, 2011a,b) have used various paradigms to study the influence of emotional and neutral materials during the resolution of cognitive conflict. In their tasks (Kanske & Kotz, 2010b, 2011a,b), however, the valence of the stimuli is not relevant for performance, and therefore the response never concerns this dimension. In two of their studies, for example, Kanske and Kotz (2010b, 2011b) used a flanker task composed of affective and neutral words. In each trial, three stimuli (a target word flanked by two additional words) were displayed in the same (congruent condition) or different colors (incongruent condition). Participants were required to indicate the color of the target but the meaning of the words was irrelevant. The presence of irrelevant affective material generated an N2 of larger amplitude compared to irrelevant words with neutral meaning. This effect was accompanied by a decrease of the conflict effect for affective materials. The authors therefore concluded that the emotional nature of irrelevant stimuli speeds up conflict resolution.

Finally, the P3 potential has been associated with stimulus selection and categorization and with the implementation of the required response (Luck, 2005). Polich (2006) posited that the P3 would be modulated by inhibitory processes involved in avoiding ‘extraneous’ information and in focusing attentional resources on the relevant elements of the task. Thus, the harder it was to inhibit ‘extraneous’ elements, the lower the amplitude of the P3. In addition, studies using SRC paradigms have reported larger amplitudes of this potential for congruent than for incongruent conditions (Neuhaus et al., 2010; Valle-Inclán, 1996a). Although few experiments have explored the susceptibility of the P3 to emotional conflict, a study using words in a modified Go/NoGo task found larger P3 amplitudes in NoGo trials but only for affective and non-neutral words (Chiu, Holmes, & Pizzagalli, 2008).

In summary, previous studies comparing cognitive and emotional conflict resolution have mainly used fMRI methods, and those recording EEG have not compared both types of material using the same type of stimuli and equating task demands. Therefore, in this study we explored the temporal dynamics of cognitive and emotional conflict resolution using the same kind of materials and task settings across conditions. To this end, we adapted the paradigm developed by Ochsner et al. (2008) and recorded EEG while participants assessed the semantic category or affective valence of words flanked by congruent or incongruent stimuli in different blocks. We focused on the P1, N170, N2 and P3 potentials as markers of different stages of information processing and studied how current and previous trial congruency factors