Biological Psychology 105 (2015) 115–123

Contents lists available at ScienceDirect

Biological Psychology

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

The late positive potential: A neural marker of the regulation of emotion-based approach-avoidance actions?

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ARTICLE INFO

Article history:
Received 3 March 2014
Received in revised form
14 December 2014
Accepted 14 January 2015
Available online 22 January 2015

Keywords:
Approach
Avoidance
Emotion regulation
Event-related potentials
Late positive potential

ABSTRACT

The ability to regulate our emotional responses is crucial to effective functioning in daily life. Whilst there has been extensive study of the brain potentials related to valenced stimuli, the neural basis of the ability to regulate actions elicited by these remains to be clarified. To address this, 40 volunteers undertook an approach-avoidance paradigm. In the congruent condition, participants approached pleasant and avoided unpleasant stimuli. In the incongruent condition, the opposite was the case, requiring the regulation of natural emotional response tendencies. Both behavioural and electrophysiological indices of emotional regulation were recorded. Congruency effects were observed at both the behavioural and electrophysiological level. Reaction times were faster and the LPP larger, when performing emotionally congruous relative to incongruous actions. Moreover, neural and behavioural effects were correlated. The current results suggest that the LPP congruency effect can be considered a neural marker of individual differences in emotion-driven action tendencies. We discuss whether this reflects emotion regulation, effort allocation, or correct mapping of stimulus response tendencies.

1. Introduction

An organism's safety and survival depends to some extent on the inbuilt tendency to approach positive (i.e. rewarding, safe, pleasant) and avoid negative (i.e. dangerous, threatening, unsafe) stimuli or events. On occasion, however, it is necessary to over-ride these tendencies if we are to act optimally and prosper in daily life. Without this ability to regulate our responses to these emotionally valenced stimuli, we cannot, on the one hand resist temptation, on the other be brave and face dangerous and difficult situations. An inability to do this (i.e. emotional dysregulation) is associated with a number of psychopathologies (Davidson, 1998, 2002; Phillips, Ladouceur, & Drevets, 2008a, 2008b). Despite the importance of this ability, most studies of emotion-related responses focus on the perception and classification of emotional stimuli, rather than the regulation involved in the preparation to complete an appropriate regulated action (Burgdorf & Panksepp, 2006; Calder, Lawrence, & Young, 2001; LeDoux, 2000).

The approach-avoidance (AA) concept and associated methodology has been developed to study the action stage in emotional responding and specifically to uncover how individuals can override their natural tendencies to respond to emotionally charged stimuli (Chen & Bargh, 1999; Solarz, 1960). The AA paradigm involves presenting participants with emotionally valenced stimuli on a computer screen and then requiring them to either "approach" or "avoid". Typically these studies involve a task where participants respond to valenced pictures from the standardized International Affective Picture System (IAPS) set (Lang, Bradley, & Cuthbert, 1999), or a standardized valenced word set (Fazio, Sanbonmatsu, Powell, & Kardes, 1986) by pulling or pushing a lever. More sophisticated tasks have also been used where either participants control a manikin on the screen which acts as a virtual self that is moved towards or away from stimuli, or simply experience a change in stimulus size which triggers approach or avoidance. In the congruent condition (CC), participants are prompted to perform "natural"

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http://dx.doi.org/10.1016/j.biopsycho.2015.01.009
0301-0511/

pleasant-approach/unpleasant-avoid actions. In the incongruent condition (IC), participants have to over-ride these natural tendencies by approaching unpleasant and avoiding pleasant stimuli. Participants have faster reaction times (RT) when performing congruent than performing incongruent actions. This confirms the automatic predisposition to approach pleasant and avoid unpleasant stimuli, and highlights the additional effort needed to regulate these tendencies when required (Bamford & Ward, 2008; Chen & Bargh, 1999; De Houwer, Crombez, Baeyens, & Hermans, 2001; Duckworth, Bargh, Garcia, & Chaiken, 2002; Krieglmeyer, De Houwer, & Deutsch, 2012; Neumann & Strack, 2000; Rotteveel & Phaf, 2004; Solarz, 1960; Wentura, Rothermund, & Bak, 2000). The difference in the speed of the response on congruent compared to the incongruent trials has been termed a congruency effect; for example a large congruency effect would be observed when comparing congruent trials with very fast responses to incongruent trials with very slow responses, whereas more similar response times for congruent and incongruent trials would represent a smaller congruency effect. The size of the congruency effect can therefore be used to index the difficulty individuals experience when asked to over-ride their normal AA response pattern and complete the incongruent action.

Surprisingly little is known about the underlying *neural* basis of emotion-related AA actions. Evidence from electroencephalographic (EEG) studies suggests a frontal asymmetry of approach-avoidance processing, with approach tendencies being lateralized to the left frontal region and avoid to the right (Davidson, Ekman, Saron, Senulis, & Friesen, 1990; Harmon-Jones & Allen, 1998). However, these studies typically used mood induction procedures to get the participant into a frame of mind ready to approach or avoid, rather than measuring brain potentials whilst *a response* is being prepared and executed and base their analysis on averaged EEG activity over an extended period of time (e.g. 6 min) whilst the participants are in these particular moods. Miller and Tomarken (2001) employed EEG in a monetary incentive delay task to look at frontal asymmetry when preparing responses to gain reward (approach) and avoid punishment (avoid), however the task included only congruent responses. Such studies therefore do not allow the examination of specific event-related brain activity associated with the preparatory phase of congruent and incongruent approach-avoidance actions. Further, Miller, Crocker, Spielberg, Infantolino, and Heller (2013) argued that we need to go beyond EEG activity related to broad brain areas and asymmetry, and search for specific neural markers of these crucial emotion-driven behaviours.

To-date three studies have looked more specifically at these brain processes by examining event-related potentials (ERPs) in AA tasks in healthy volunteers. All three measured neural responses at the P3, which is thought to reflect the allocation of attention towards task-relevant and emotionally salient stimuli (Keil et al., 2002; Polich, 2007), and have produced inconsistent findings. Two of these studies focused on the influence of personality traits on AA responses. Van Peer et al. (2007) found differences at the P3 component only in participants who had high scores on the Behavioural Inhibition Scale (Carver & White, 1994), and who had also been given cortisol (as compared to a within subjects placebo condition). These differences manifested as enhanced P3 amplitude to unpleasant (congruent) compared to pleasant (incongruent) trials in the avoid condition. Ernst, Weidner, Ehlis, and Fallgatter (2012) focused on the relation between Behavioural Activation Scale scores (Carver & White, 1994), P3 amplitudes, and AA behaviours. They found an overall behavioural congruency effect but no corresponding P3 congruency effect. The paper most relevant to our question was authored by Ernst et al. (2013) who investigated AA responses more generally without focus on personality traits. They discovered a congruency effect at the early components, N1 and N2, for positive stimuli (larger amplitudes for approach than avoid) but no congruency effects were seen at the P3 component. Results from these studies therefore are mixed for the P3 component but also indicate that early components such as the N1 and N2 may be involved. Previous literature has shown differentiation at these components between emotional and neutral stimuli (Foti, Hajcak, & Dien, 2009; Keil et al., 2002), with larger amplitudes for emotional stimuli. It is therefore possible that an action-based differentiation could occur in relation to these components too.

Another component that might be especially important in the preparation of regulated actions is the LPP. Whilst the P3 is thought to reflect the allocation of attention towards task-relevant and emotionally salient stimuli (Keil et al., 2002; Polich, 2007), the late positive potential (LPP), extending outside the latency of P3 well beyond 1000 ms, reflects continued emotion stimulus processing. Research investigating the LPP in this context illustrates its sensitivity to emotional content, with larger amplitudes to emotional than neutral stimuli (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Hajcak, Dunning, & Foti, 2009; Hajcak, MacNamara, & Olvet, 2010; Hajcak & Olvet, 2008; Schupp et al., 2000; Schupp, Junghöfer, Weike, & Hamm, 2004).

Crucially, the LPP is also found to be sensitive to the active regulation of emotional responses, where a reduction in LPP amplitude is observed following reappraisal (Hajcak & Nieuwenhuis, 2006; MacNamara, Foti, & Hajcak, 2009), and suppression (Moser, Hajcak, Bukay, & Simons, 2006). The P3 and the LPP may index different aspects of emotional processing with the P3 and early LPP sensitive to intrinsic factors (whether the stimuli is emotional or neutral) and the late LPP more sensitive to extrinsic factors (one's interpretation or regulation of that stimuli; MacNamara et al., 2009). Despite all this supporting evidence for its role in emotion regulation no study has focused specifically on this component as a marker for the regulation of emotion-based AA actions.

It is important to note that there is some overlap between P3 and LPP components, leading to a lack of clarity between studies given the different temporal definitions of LPP employed (see Weinberg and Hajcak (2010) for a review of the different time windows). To address this Hajcak et al. (2010) recommend dividing the P3/LPP in multiple time windows following stimulus presentation. We have adopted this recommendation in the current study.

Our goal in the current study was to examine whether the LPP is a neural marker for the regulation of AA actions to emotional stimuli. In doing so we hoped to specify more precisely the neural underpinnings of congruent (automatic) and incongruent (regulated) actions during AA, and investigate further the functional significance of the LPP. Our predictions are based on the existing emotion regulation literature in the neural and the behavioural domains. On the neural level, LPP amplitudes are smaller for effectively regulated responses (Hajcak & Nieuwenhuis, 2006; MacNamara et al., 2009; Moser et al., 2006). We would therefore predict that a regulated (incongruent) response would have a comparatively smaller amplitude than an unregulated more automatic (congruent) one and so it follows that the more regulated a response, the larger the difference between the incongruent and congruent amplitudes and the larger the LPP congruency effect. In contrast, at the behavioural level, an individual who can effectively regulate responses should be able to execute an incongruent response with little additional effort compared to a congruent response leading to similar response times for both conditions producing a small congruency effect.

Our specific predictions were: (i) a congruency effect for the LPP component with a larger LPP for congruent and a smaller LPP for incongruent trials, (ii) that this effect would be negatively correlated with a RT congruency effect—a larger LPP congruency effect (suggesting more efficient emotion regulation in the incongruent condition) would be associated with a smaller RT congruency effect.