International Journal of Psychophysiology 98 (2015) 612–623

Contents lists available at ScienceDirect

International Journal of Psychophysiology

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

Neurophysiological correlates of emotional directed-forgetting in persons with Schizophrenia: An event-related brain potential study☆

Regan E. Patrick [a,b,c], Michael Kiang [a,b,d], Bruce K. Christensen [a,b,c,*]

[a] McMaster University, Department of Psychiatry & Behavioural Neuroscience, 1280 Main St. W., Hamilton, ON L8S 4 L8, Canada
[b] McMaster University, McMaster Integrative Neuroscience Discovery & Study (MiNDS), 1280 Main St. W., Hamilton, ON L8S 4 L8, Canada
[c] McMaster University, Department of Psychology, Neuroscience, & Behaviour, 1280 Main St. W., Hamilton, ON L8S 4 L8, Canada
[d] University of Toronto, Department of Psychiatry, 172 St. George St., Toronto, ON M5R 0A3, Canada

ARTICLE INFO

Article history:
Received 30 May 2014
Received in revised form 10 January 2015
Accepted 16 January 2015
Available online 22 January 2015

Keywords:
Emotion
Directed-forgetting
Schizophrenia
ERP
Inhibition
Selective-rehearsal

ABSTRACT

Background: Recent research has shown that patients with schizophrenia (SCZ) exhibit reduced directed forgetting (DF) for negative words, suggesting impaired ability to instantiate goal-directed inhibition in order to suppress a competing, emotion-driven responses (i.e., emotional memory enhancement). However, disrupted inhibition is not the only possible mechanism by which patients could manifest reduced emotional DF. Therefore, the primary objective of the current study was to use event-related brain potential (ERP) recordings to investigate alternative hypotheses.
Methods: ERPs were recorded while patients and controls completed an item-method DF paradigm using negative and neutral words. The N2 indexed goal-directed inhibition of to-be-forgotten items. The late positive potential (LPP) indexed emotional memory enhancement for negative study items. The P300 indexed selective rehearsal of to-be-remembered items.
Results: The SCZ group exhibited a reduced DF effect overall, but this was not modulated by emotion. N2 amplitude at anterior sites was larger for forget versus remember cues in the control group only, but this effect was not modulated by emotion. LPP amplitude was greater for negative versus neutral words in both groups, independent of region. P300 amplitude at posterior sites was greater for remember versus forget cues in the control group only.
Discussion: These data suggest that reduced DF in SCZ may be due, in part, to both diminished goal-directed inhibition of to-be-forgotten items and reduced selective rehearsal of to-be-remembered items. However, these data do not support the hypothesis that goal-directed, inhibitory processes are disrupted by competing, emotion-driven processes in SCZ. Patients' ERP data also suggested that they did not exhibit disproportionately heightened encoding of emotional stimuli, nor did they have deficient selective rehearsal of to-be-remembered emotional items.

1. Introduction

Schizophrenia (SCZ) is characterized by abnormalities in both emotional and cognitive processing. However, the interactive contribution of these domains to SCZ psychopathology has not been well-delineated. To date, investigations of emotion-cognition interactions in SCZ have primarily focused on the effects of extraneous emotional distraction on primary cognitive processing. This literature has yielded inconsistent results, with behavioral and neuroimaging research suggesting *both* increased vulnerability (e.g., Bentall and Kaney, 1989; Dichter et al., 2010; Mohanty et al., 2005; Park et al., 2008; Strauss et al., 2008) and normal susceptibility to emotional interference (Anticevic et al., 2011, 2012; Demily et al., 2010; Diaz et al., 2011; Gopin et al., 2011). These apparently discrepant findings may stem from variability in methodology and sample characteristics across studies. They may also result from the fact that previous studies have failed to employ tasks that maximize the antagonistic relationship between cognitive and emotional determinants of behavior. Such antagonism frequently typifies cognition-emotion interactions in real-world settings (e.g., Metcalfe and Mischel, 1999; Bickel et al., 2007) and may potentiate the likelihood that one will impact the other (Anticevic et al., 2012). That is, patients with SCZ may have difficulty prioritizing cognitive or contextual response cues as determinants of goal-directed behavior in the face of countermanding emotional cues that impel an alternative response.

☆ Author note: The authors would like to thank Iulia Patriciu, Katie Herdman, Carolyn Roy, and Roshi Wagley for their contributions toward participant recruitment, data collection, and data management.

* Corresponding author at: Department of Psychiatry and Behavioural Neuroscience, McMaster University, 100 West 5th Street, Hamilton, ON L8N 3K7, Canada. Tel.: +1 905 522 1155x36239.
E-mail address: bruce.christensen@mcmaster.ca (B.K. Christensen).

http://dx.doi.org/10.1016/j.ijpsycho.2015.01.006
0167-8760/

Patrick and Christensen (2013) recently investigated this assertion using an emotional, directed-forgetting (DF) paradigm. On this task, a goal-directed behavior (cue-induced, intentional forgetting) must override a competing, automatic emotional behavior (emotional memory enhancement[1]) for successful task completion. The authors observed that patients with SCZ were less able to intentionally forget negative words relative to healthy controls (HC) and, to a lesser extent, relative to positive and neutral words. These results suggest a deficit in SCZ patients' ability to instantiate a task-relevant, goal-directed behavior (memory inhibition of to-be-forgotten words) in service of overriding an opposing, automatic emotional response (memory enhancement for emotionally negative material). That is, SCZ patients displayed dysregulated emotion–cognition antagonism.

These data are consistent with recent neurobiological models of SCZ suggesting anomalous regulation of the neural circuits governing emotional reactions versus those governing task-relevant cognitive processing (Anticevic et al., 2012; Christensen and Bilder, 2000; Giaccio, 2006; Grace, 2003). However, these data are also clearly behavioral and, at best, offer a strictly inferential window into the functional neurobiology underlying these effects. Elucidating the associated neural dynamics is particularly relevant in the context of emotional DF as previous research in healthy controls suggests there are several putative mechanisms by which patients with SCZ could demonstrate a reduced emotional DF effect. First, patients with SCZ may be deficient in applying strategic inhibitory mechanisms on to-be-forgotten (TBF) emotional material, as suggested by Patrick and Christensen (2013). If so, this would provide support for their assertion that patients with SCZ have difficulty implementing goal-directed, cognitive behaviors in the face of competing emotion-laden response cues. Second, patients may attend to and encode emotional material more strongly. This would presumably lead to greater emotional memory enhancement and, by extension, reduced emotional DF. Third, patients with SCZ could exhibit decreased selective rehearsal of to-be-remembered (TBR) emotional items. The selective rehearsal account of DF posits that, upon seeing a remember cue, participants engage in more active, controlled rehearsal of TBR items, thereby enhancing recognition relative to TBF items. Thus, patients may have difficulty implementing targeted, strategic encoding processes (selective rehearsal) to aid subsequent memory performance for TBR emotional content. Indeed, strong arguments have been put forth suggesting the DF effect primarily reflects increased rehearsal of to-be-remembered items and *not* forget cue-induced strategic inhibition (e.g., Sheard and MacLeod, 2005; Benjamin, 2006).

These separate mechanisms are not necessarily mutually exclusive to one another as each one could influence emotional DF either alone or in concert with one another. Therefore, investigating all three mechanisms concurrently would provide the most comprehensive explanation of the neurocognitive basis for abnormal emotional DF in SCZ. Adjudicating between these alternative mechanisms has been complicated at the behavioral level. In contrast, several studies have identified specific neurophysiological correlates of memory inhibition, emotional memory enhancement, and selective rehearsal processes in healthy volunteers (reviewed below). In the context of DF, these experiments have primarily utilized the *item-method* variant as it is more adaptable to event-related potential (ERP) techniques. In this variant, participants are shown a series of study items one-at-a-time and are cued to remember or forget each item immediately after it is presented. The typical finding is that subsequent recognition memory for TBR items is better than for TBF items. With this in mind, the primary objective of the current study was to directly examine the alternative mechanisms described above by applying ERP methodology to an item-method, emotional DF task. In doing so, we sought to characterize the relative contributions of each mechanism toward abnormal emotional DF in SCZ and, in turn, better understand the neurocognitive basis for dysregulated emotion–cognition antagonism in this patient population.

1.1. ERP Correlates of Forget Cue-Induced Memory Inhibition

Results from several ERP studies support the hypothesis that cue-induced, goal-directed inhibition contributes to the DF effect. Yang et al. (2012) observed a larger anterior ERP negativity (200–300 ms) for forget cues associated with successfully forgotten items (i.e., TBF-miss) (Yang et al., 2012). This aligns with several other DF studies that have observed distinct electrophysiological activity associated with forget cues at anterior sites (Brandt et al., 2013; Cheng et al., 2012; Hauswald et al., 2010; Paz-Caballero et al., 2004; van Hoof and Ford, 2011). The latency range and scalp topography of the negativity observed by Yang et al. corresponds to the N2 component. This is notable as substantial research suggests the N2 is an index of inhibitory or executive control processes (see Folstein and van Petten, 2008 for review). For example, go/no-go, think/no-think, stop signal, and Erikson flanker tasks all elicit a more pronounced N2 on trials necessitating greater response inhibition (Folstein and van Petten, 2008; Huster et al., 2013). EEG inverse modeling and simultaneous EEG-fMRI analysis indicates that the anterior N2 is generated in medial and/or lateral prefrontal cortices (Huster et al., 2013). This is consistent with fMRI studies implicating frontally-centered inhibitory control mechanisms in intentional memory suppression in DF (Nowicka et al., 2011; Wylie et al., 2008), as well as other cognitive inhibition paradigms (Anderson et al., 2004; Levy and Anderson, 2008; Depue et al., 2007). Interestingly, Yang et al. found that the N2 associated with the forget cue was further enhanced following negative pictures, suggesting that forgetting negative material requires greater inhibitory effort. Accordingly, they observed an equivalent behavioral DF effect for both neutral and negative pictures, indicating this inhibitory mechanism was effective at overcoming automatic emotional memory enhancement. Thus, the anterior N2 component can be considered an electrophysiological correlate of cue-induced memory inhibition.

1.2. ERP correlates of emotional memory enhancement

Emotional stimuli are preferentially encoded and retained in memory (Anderson et al., 2006; Kensinger and Corkin, 2003). Several lines of research suggest that the late positive potential (LPP) may be a reliable neurophysiological marker of enhanced emotional memory encoding (Dolcos and Cabeza, 2002; Früholz et al., 2011; Palomba et al., 1997). The LPP is a sustained, slow-wave ERP component that is more prominent in response to emotionally evocative versus neutral stimuli. The LPP typically emerges 300–400 ms after stimulus onset (Fischler and Bradley, 2006; Hajcak et al., 2010; Moran et al., 2013), is most pronounced around 400–600 ms (Schupp et al., 2006), and can be sustained for up to a second post-stimulus (Hajcak & Olvet, 2008). Functionally, the LPP is thought to reflect an increase in attention to, and processing of, intrinsically motivating stimuli (Hajcak et al., 2010). This enhanced processing may occur outside conscious awareness, as LPP modulation has been observed with very short stimulus presentation times (e.g., 120 ms; Schupp et al., 2006). These data have contributed to the *enhanced perception hypothesis* of the LPP, which posits that the LPP is an electrophysiological manifestation of facilitated perceptual processing of the stimulus that elicited the LPP (Brown et al., 2012). Such facilitation may, in turn, lead to stronger memory encoding of affective stimuli. For example, Palomba et al. (1997) detected a more sustained, positive-going waveform spanning the 300–900 ms window for emotionally arousing stimuli that were subsequently associated with better recall relative to neutral and low arousing stimuli. Similarly, Dolcos and Cabeza (2002) reported an enhanced positivity for arousing versus neutral pictures over centroparietal sites in the 400–600 ms window, which corresponded to improved recognition performance. In their review of emotion-related ERP effects, Olofsson et al. (2008) stated

[1] Emotionally significant stimuli are often conferred an automatic memory advantage termed the emotional enhancement of memory (e.g., Anderson et al., 2006; Kensinger and Corkin, 2003, 2004; Sommer et al., 2008).