International Journal of Psychophysiology 92 (2014) 16–25

Contents lists available at ScienceDirect

International Journal of Psychophysiology

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

Generalized lapse of responding in trait impulsivity indicated by ERPs: The role of energetic factors in inhibitory control

Andrea Kóbor [a,b,c,*], Ádám Takács [c], Ferenc Honbolygó [a,c], Valéria Csépe [a,c]

[a] Institute of Cognitive Neuroscience and Psychology, Research Centre for Natural Sciences, Hungarian Academy of Sciences, Magyar tudósok körútja 2, H-1117 Budapest, Hungary
[b] Doctoral School of Psychology, Eötvös Loránd University, Izabella utca 46, H-1064 Budapest, Hungary
[c] Institute of Psychology, Eötvös Loránd University, Izabella utca 46, H-1064 Budapest, Hungary

ARTICLE INFO

Article history:
Received 10 August 2013
Received in revised form 18 January 2014
Accepted 24 January 2014
Available online 31 January 2014

Keywords:
Cognitive Energetic Model
ERP
Eriksen flanker task
Impulsivity
Inhibitory control
Lateralized Readiness Potential

ABSTRACT

Impaired inhibitory control is one of the still debated underlying mechanisms of trait impulsivity. The Cognitive Energetic Model accounts for the role of energetic factors mediating task performance. The aim of the present study was to compare inhibitory control functions of adults with high and low impulsivity by using a modified Eriksen flanker task. Adults were classified as impulsive ($n = 15$) and control ($n = 15$) participants based on the Barratt Impulsiveness Scale. Flanker trials had three levels of required effort manipulated by visual degradation. We analyzed RT, accuracy, and ERPs time-locked to the flanker stimuli. Reaction time of impulsive participants was generally slower than that of controls', but accuracy was similar across groups. N2c showed that monitoring of response conflict was modulated by task requirements independent of impulsivity. The P3 latency was delayed in the impulsive group indicating slower stimulus evaluation. The P3 amplitude was reduced in the control group for moderately degraded incongruent trials suggesting that the attentional resources were employed less. The Lateralized Readiness Potential (LRP) peaked later in the impulsive group irrespective of experimental effects. The amplitude of the positive-going LRP recorded in the incongruent condition was comparable across groups, but the latency was delayed partly supporting a stronger susceptibility to stimulus interference of impulsive participants. Their delayed incongruent negative-going LRP reflected a weaker response inhibition and a slower correct response organization. In conclusion, impaired inhibitory functions in impulsivity could not be unequivocally demonstrated, but we found a generalized lapse of motor activation.

1. Introduction

Trait impulsivity indicates a preference for immediate rewards, risky activities, and novel experiences (Mitchell, 1999). It is characterized by rapid and unplanned reactions to stimuli before thorough processing of information (Arce and Santisteban, 2006). In the DSM (DSM-IV-TR; American Psychiatric Association, 2000), impulsivity is the second most frequent symptom (Boy et al., 2011). There is a growing interest in understanding impulsivity among healthy populations as this trait can be interpreted along a dimension, but the underlying mechanisms across the full range have not been clarified yet (Dimoska and Johnstone, 2007; Kam et al., 2012; Stanford et al., 2009). The present study aimed to elucidate the neuro-cognitive background of trait impulsivity by means of ERP components, focusing on inhibitory control and energetic factors.

Impulsivity is a multi-faceted personality trait (Aichert et al., 2012; Pietrzak et al., 2008) that has been linked to executive functions (EF) (Bari and Robbins, 2013; Franken and Muris, 2006). Inhibitory control, a component of EF, is the ability to successfully respond to task-relevant items while inhibiting inappropriate automatic responses or suppressing interference due to task-irrelevant stimuli (Brydges et al., 2012). There are at least two distinguishable types of inhibitory processes: interference suppression or stimulus interference control, and response inhibition (Bryce et al., 2011; Bunge et al., 2002). The ability to suppress task-irrelevant interfering information is crucial in experimental paradigms such as the Eriksen flanker task (Eriksen and Eriksen, 1974), in which the centrally presented target is flanked by distractors. The flanking characters in relation to the target can be neutral (indicating no response assignment), congruent (indicating the same response tendency as the target), and incongruent (providing response information that conflicts with the response tendency of the target). Increased RT and errors are usually demonstrated for incongruent compared to neutral flankers (interference effect), while congruent flankers reduce RT and errors (facilitation effect) (Kopp et al., 1996). This task has been extensively used to examine interference control (e.g., Brydges et al., 2012; Johnstone and Galletta, 2013; Johnstone et al., 2010; Kopp et al., 1996).

---

* Corresponding author at: Institute of Cognitive Neuroscience and Psychology, Research Centre for Natural Sciences, Hungarian Academy of Sciences, Magyar tudósok körútja 2, H-1117 Budapest, Hungary. Tel.: +36 13826821.

E-mail addresses: kobor.andrea@ttk.mta.hu (A. Kóbor), takacs.adam@ppk.elte.hu (Á. Takács), honbolygo.ferenc@ttk.mta.hu (F. Honbolygó), csepe.valeria@ttk.mta.hu (V. Csépe).

http://dx.doi.org/10.1016/j.ijpsycho.2014.01.008

Of the several existing measures of trait impulsivity (Bari and Robbins, 2013), one of the most widely used instruments is the Barratt Impulsiveness Scale (BIS; Patton et al., 1995; Stanford et al., 2009). Although impulsive traits measured by questionnaires do not often correlate with behavioral measures of impulsivity due to various reasons (Bari and Robbins, 2013), some evidence suggests that weaker response inhibition can be explained by increased trait impulsivity, at least in a small portion (Aichert et al., 2012). It is not clear, however, in what extent impaired sub-processes of inhibitory control underlie trait impulsivity in non-clinical populations (Dimoska and Johnstone, 2007). Moreover, different experimental modulations could affect ongoing performance in inhibitory tasks yielding mixed results.

Inhibitory control in trait impulsivity could be interpreted in the framework proposed by the Cognitive Energetic Model (CEM; Sanders, 1983). According to this model, energetic factors such as arousal, activation, and effort mediate task performance. The CEM per se is a hierarchical and integrative model of energetic and structural mechanisms, and it assumes that adaptive information processing depends on three levels of functioning. These levels incorporate computational processing stages such as encoding, decision making, and motor organization (response); energetic mechanisms or state factors such as arousal, effort, and activation; and a management level or the EF. In particular, arousal refers to slow, input-related tonic changes in the energetic state while activation is a task-related phasic physiologic readiness to respond (Barry et al., 2005; Johnstone et al., 2010). Arousal and activation pools provide energetic supply to the specific computational processing stages. In a task with varying cognitive load, the effort pool could provide a compensatory mechanism to mobilize and regulate the other two energetic resources in order to adjust behavior and to achieve an optimum level of performance (Johnstone and Galletta, 2013; Sanders, 1983; Sergeant, 2000; Smulders and Meijer, 2008). However, performance improves only at a moderate level of task difficulty. While a higher required effort may induce over-arousal or over-activation, a low effort level may induce under-arousal or under-activation, both leading to suboptimal behavioral performance (Yerkes and Dodson, 1908). Eysenck (1993) proposed that individuals with high impulsivity have lower arousal than those with low impulsivity. Therefore a task which increases arousal could improve the performance of high impulsives and deteriorate that of low impulsives. One possibility of varying task difficulty is to degrade the intensity or quality of visual signals that influences the encoding stage of information processing (Johnstone et al., 2010; Sanders, 1983). This manipulation is specifically sensitive to low arousal, and therefore mobilizes effort pool.

Besides behavioral measures, event-related brain potentials (ERPs) provide insight into the temporal resolution of inhibitory control, as well as into that of the neural stages of information processing incorporated in CEM. The anterior/central N2 and the central/centro-parietal P3 components are of relevance in the flanker task as they show general sensitivity to resisting the interference caused by distractors (Johnstone et al., 2009). The N2 component is found to peak between 200 and 450 ms after stimulus onset, and it is functionally linked to cognitive control. A frequent finding of ERP studies using the flanker task is that the N2 can be divided into two distinct subcomponents (Gehring et al., 1992; Kopp et al., 1996) reflecting control-related and mismatch-related functions (Folstein and Van Petten, 2008). However, some previous flanker studies failed to find two N2s (e.g., Johnstone et al., 2009, Johnstone and Galetta, 2013), and the classification scheme of the apparent subcomponents (N2a, N2b, N2c) is not always consequent (Folstein and Van Petten, 2008). The N2b is considered to indicate the attentional detection of deviations from the prevailing visual context (Kopp et al., 1996). As reported by Johnstone et al. (2010), the N2b amplitude in a flanker task appeared to be sensitive to stimulus degradation and therefore to the increasing difficulty of visual discriminability. The N2c is thought to reflect the inhibition or suppression of the automatically, but erroneously primed responses (Gehring et al., 1992; Kopp et al., 1996), or more generally, the process of response conflict monitoring (Folstein and Van Petten, 2008; Kopp and Wessel, 2010; Yeung et al., 2004).

Similarly to the N2, the P3 occurring at 250–700 ms after stimulus onset is also related to inhibitory control processes (Johnstone et al., 2009, 2010; Kopp and Wessel, 2010). The peak latency of P3 is considered as a measure of stimulus evaluation time (Polich, 2007). Several studies using the flanker task reported amplitude increase and latency delay of the fronto-central or central P3 elicited by incongruent trials as compared to congruent ones (Folstein and Van Petten, 2008; Ridderinkhof and van der Molen, 1995). More specifically, a larger P3 amplitude is assumed to reflect the employment of increased attentional resources (Kok, 2001). However, as it was shown, P3 would also indicate the amount of resources available for stimulus processing, therefore an amplitude reduction and latency increase suggested that resources were needed elsewhere (Beauducel et al., 2006). At the same time, as Johnson (1986) proposed, a decreased P3 amplitude might also signify decision uncertainty, and this could imply the occurrence of smaller P3 amplitude in case of effortful processing (Fritzsche et al., 2011). Accordingly, if the presented stimulus was harder to discriminate, P3 amplitude could change in both directions, while P3 latency would be delayed.

A third ERP component related to the flanker task is the Lateralized Readiness Potential (LRP), which is a correlate of the motor preparation process before the overt response is given (e.g., Heil et al., 2000; Kopp et al., 1996). The LRP is an index of selective motor activation (e.g., Coles, 1989; Eimer, 1998), therefore useful for studying motor processes in real time. This component summarizes the electrical potential differences of electrodes placed over the motor cortex contra- and ipsilateral to the response hand in a single measure (Coles, 1989; Ridderinkhof and van der Molen, 1995; Szűcs et al., 2009). This waveform could indicate covert incorrect response preparation (erroneous response priming) even if the overt behavioral response is correct (i.e., correct keypress); this characteristic is crucial in case of conflicting stimuli (e.g., in the incongruent condition of a flanker task, see also Coles, 1989; Kopp et al., 1996). By calculating the LRP, an incorrect response preparation followed by a correct response preparation can be detected in an incongruent condition (Bryce et al., 2011). According to the arguments of Bryce et al. (2011, p. 682) amplitude and latency of the initial response preparations can be considered to be indices of interference suppression, i.e., how the conflict is experienced at first, and how irrelevant information is filtered out. Additionally, the transition from incorrect to correct activation in the incongruent condition could reflect the later response inhibition process.

Deficient inhibitory control in trait impulsivity has not been consistently supported on the basis of previous N2 and P3 findings. However, a reduced P3 amplitude in impulsive participants was a general result of former studies using various tasks (Chen et al., 2007; De Pascalis et al., 2004; Russo et al., 2008). This was interpreted either as an outcome of ineffective allocation of the available attentional resources, or as a consequence of attenuated physiological arousal. At the same time, the latency of P3 has been shown to be unaffected in impulsive participants (Russo et al., 2008). The BIS subscale scores differentially predicted N2 and P3 measures in a modified continuous performance task, however, the total score was neither related to any of these ERP indices (Kam et al., 2012). In contrast, Russo et al. (2008) demonstrated that lower P3 amplitudes in a two-choice visual oddball task predicted higher BIS total score. Only one study has investigated the effect of impulsiveness on response preparation in stop-signal paradigm (Dimoska and Johnstone, 2007). Results showed enhanced response activation (larger LRP amplitudes on failed stop trials), and enhanced response inhibition (larger N1/P3 complex on successful stop trials) in the high compared to the low impulsive group, although no group differences emerged at the behavioral level. Furthermore, only a small number of studies have tested directly the ERP correlates of certain aspects of the CEM by using different inhibitory control paradigms (Benikos and Johnstone, 2009; Benikos et al., 2013; Johnstone and Galletta, 2013; Johnstone et al.,