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Valence and arousal of emotional stimuli impact cognitive-motor performance in an oddball task

Yingzhi Lu[a,1], Kyle J. Jaquess[a,b,1], Bradley D. Hatfield[b,c], Chenglin Zhou[a,*], Hong Li[d]

[a] School of Kinesiology, Shanghai University of Sport, China
[b] Department of Kinesiology, University of Maryland, College Park, United States
[c] Neuroscience and Cognitive Science Program, University of Maryland, College Park, United States
[d] Research Centre for Brain Function and Psychological Science, Shenzhen University, China

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ABSTRACT

It is widely recognized that emotions impact an individual's ability to perform in a given task. However, little is known about how emotion impacts the various aspects of cognitive -motor performance. We recorded event-related potentials (ERPs) and chronometric responses from twenty-six participants while they performed a cognitive-motor oddball task in regard to four categories of emotional stimuli (high-arousing positive-valence, low-arousing positive-valence, high-arousing negative-valence, and low-arousing negative-valence) as "deviant" stimuli. Six chronometric responses (reaction time, press time, return time, choice time, movement time, and total time) and three ERP components (P2, N2 and late positive potential) were measured. Results indicated that reaction time was significantly affected by the presentation of emotional stimuli. Also observed was a negative relationship between N2 amplitude and elements of performance featuring reaction time in the low-arousing positive-valence condition. This study provides further evidence that emotional stimuli influence cognitive-motor performance in a specific manner.

1. Introduction

It is widely recognized that emotions impact an individual's ability to perform in a given task. For example, in sport, emotion plays a notable role in athletic performance (Janelle, 2002; Robazza, Pellizzari, Bertollo, & Hanin, 2008; Triplett, 1898). Despite an extensive collection of literature, how emotion impacts the various aspects of cognitive-motor performance, remains an ongoing question in the study of sport and human performance. For example, will seeing an injury occur to a fellow player impact how an athlete proceeds with future performances? Or how will seeing an opponent make an error affect the neurocognitive processes behind decision making and motor responses? The answers to these questions remain unclear. This may be due to the fact that our understanding of the brain, the source of the vast majority of behavior, is still in its early stages. The present research will contribute to the existing literature by further investigating the effects of emotion, generated by emotionally-charged stimuli, on the performance of a cognitive-motor task, as well as how those emotional stimuli are processed in the brain. In this experiment, we use a fundamental approach to facilitate greater understanding of the relationship between emotional processing and cognitive-motor performance using measures of response time to target stimuli in an oddball task.

Many studies have investigated the effects of emotion-eliciting stimuli on various features of cognitive performance. For example, memory of both positive and negative emotional stimuli tends to be better than that of neutral stimuli (Hamann, Ely, Grafton, & Kilts, 1999), and this effect appears to be modulated by mental stress, retarding this effect for positive stimuli (Luethi, Meier, & Sandi, 2008). Furthermore, attention appears to be captured by emotional stimuli, but this effect, too, can be modulated by such factors as attentional reserve (i.e., attentional resources unused by the task at hand) (Pessoa, Kastner, & Ungerleider, 2002) or state anxiety (Bishop, Duncan, Brett, & Lawrence, 2004). Additionally, the perception of emotional stimuli can further affect cognitive performance, as shown by the positivity offset, referring to a tendency for the positive motivational system (as opposed to the negative

* Corresponding author at: 188 Henreng Road, Yangpu District, School of Kinesiology, Shanghai University of Sport, China.
E-mail address: chenglin_600@126.com (C. Zhou).
[1] These two authors contributed equally to this work.

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motivational system) to favorably respond at low levels of arousal, and the negativity bias, referring to a tendency for the negative motivational system to favorably respond at high levels of arousal (Cacioppo & Berntson, 1999; Ito & Cacioppo, 2005).

While knowledge of how emotional stimuli impact cognition is enlightening, it ignores an important aspect of human life: movement. More often than not, an event is responded to in a cognitive-*motor* fashion rather than a purely cognitive one. Some studies that have attempted to examine how emotional stimuli impact cognitive-motor performance have taken measures of response time with mixed results. Some studies have verified that response time is slowed by certain emotional stimuli (Verbruggen & De Houwer, 2007; Vuilleumier, Armony, Driver, & Dolan, 2001) while quickened by others (Hare et al., 2008). However, research by Polich and colleagues (Olofsson & Polich, 2007; Rozenkrants & Polich, 2008), using emotional images in an oddball task, failed to observe any differences in response time between emotional and neutral stimuli. One experiment by Robinson, Storbeck, Meier, and Kirkeby (2004) came close to more completely addressing this issue using a series of experiments to show a pervasive interaction between emotional valence and arousal on response time using various cognitive-motor tasks, such that response times were faster under conditions of high-arousal, negative-valence and under conditions of low-arousal, positive-valence. However, in their series of experiments, Robinson et al. employed tasks and/or instructions not optimized to investigate the impact that emotional stimuli have on cognitive-motor task performance. More importantly, however, all of the studies above did not adequately distinguish between and account for the fundamental aspects of response time, which can be divided into reaction time (the time from stimulus presentation to the initiation of the response movement) and movement time (the time of the response movement).

There is some evidence for this view in the context of responding to emotional stimuli, especially for reaction time. Baumeister, Bratslavsky, Finkenauer, and Vohs (2001) reported in an extensive review that negatively valenced emotional stimuli engage more mental resources than positively valenced emotional stimuli, leading to longer reaction times. Regarding arousal, the stop-signal paradigm used by Verbruggen and De Houwer (2007) designed to isolate reaction time showed that reaction time is slowed by highly arousing emotional stimuli relative to less arousing stimuli, potentially due to these highly arousing emotional stimuli drawing attention away from the task at hand (De Houwer & Tibboel, 2010), regardless of stimulus valence (Vogt, De Houwer, Koster, Van Damme, & Crombez, 2008). These individual findings suggest a relationship between valence and arousal regarding cognitive-motor performance, such that low-arousal, positive-valence emotional stimuli may reduce reaction time while high-arousal, negative-valence stimuli may increase reaction time. That said, some studies have shown that high-arousal, negative-valence stimuli are related to reduced reaction time (Hofmann, Kuchinke, Tamm, Võ, & Jacobs, 2009; Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006; Öhman, Flykt, & Esteves, 2001). As such, an interaction between arousal and valence may reveal that both low-arousal, positive-valence stimuli and high-arousal, negative valence stimuli will yield reduced reaction times.

Research in how emotional stimuli impact movement time, specifically, is sparse. One study by Coombes, Janelle, and Duley (2005) assessed changes in movement time during a tracing task due to viewing emotional images, finding that negatively valenced emotions shortened movement time relative to positively valenced emotions. However, this effect disappeared when task performance was linked to the presentation duration of emotional stimuli. These results may serve to inform an instance in which an immediate response must be made to the appearance of an emotionally-charged stimulus.

Finally, in a study assessing both reaction time and movement time measures during the performance of a simple cognitive-motor task, Van Gemmert and Van Galen (1997) observed that, while reaction time was slowed under high-arousal, negative-valence conditions, movement time was unaffected. This finding indicates that movement time, specifically, may be unaffected by the valence and arousal of emotional stimuli, while reaction time, specifically, is indeed impacted.

The studies highlighted above indicate that negative emotional stimuli produce poorer cognitive-motor performance than positive emotional stimuli, and that highly arousing stimuli tend to produce poorer cognitive-motor performance than less arousing stimuli during many types of tasks in which the goal is to minimize response-time. From these propositions, it is possible to extrapolate a potential interaction between valence and arousal, supported by the studies discussed here, such that less arousing positively valenced emotional states lead to better overall cognitive-motor performance than highly arousing, negatively valenced emotional states. However, the degree to which the elements of performance (i.e., reaction time and movement time) are affected by these emotional states requires further investigation. The present study will further explore this issue using the International Affective Picture System (IAPS; Lang, Bradley, and Cuthbert (1999)) as emotional stimuli in an oddball task while assessing chronometric responses (Henderson, Rose, & Henderson, 1992) in an effort to analyze elemental aspects of human performance.

To investigate the supposed interaction between emotional stimuli and cognitive-motor performance, there must first be confidence that the individual is indeed responding to different emotional stimuli (i.e., positive/negative valence, high/low arousal) in a typical way. Given the obtrusive nature of subjective assessment of emotion, psychophysiological measures of emotional processes were used in the present study as manipulation checks, specifically those measures derived from the event-related potential (ERP).

Although many ERP components may be reflective of emotional processes, the P2, N2 and the late positive potential (LPP) have been most extensively investigated in the literature. The P2 component, a positive-going wave peaking within 200 ms, is thought to represent the processing of the elemental aspects of a stimulus such as color, brightness, and size (Thorpe, Fize, & Marlot, 1996) and is also sensitive to the processing of emotional stimuli (Carretié, Ruiz-Padial, López-Martín, & Albert, 2011; Olofsson & Polich, 2007). Findings from Carretié and colleagues indicate that the P2 may be primarily affected by stimulus arousal rather than stimulus valence, such that high levels of arousal elicits a larger, more positive P2 than low levels (Carretié, Hinojosa, Martín-Loeches, Mercado, & Tapia, 2004; Carretié, Martín-Loeches, Hinojosa, & Mercado, 2001). However, other research shows that the P2 is also affected by stimulus valence such that negative stimuli elicit larger amplitudes than positive stimuli (Olofsson & Polich, 2007; Yuan et al., 2007). Like the P2, the N2 component, appearing around 260 ms, has also been shown to respond differentially to emotional stimuli. Specifically, N2 amplitudes have been found to be larger for highly arousing stimuli than less arousing stimuli (Keil et al., 2001; Rozenkrants & Polich, 2008). Other research has shown that the N2 is also sensitive to valence, such that negatively valenced stimuli displayed higher N2 amplitudes than positively valenced stimuli (Carretié et al., 2004; Schupp, Flaisch, Stockburger, & Junghöfer, 2006). In addition, the LPP component reflects, among other things (Cano, Class, & Polich, 2009; Moser, Hajcak, Bukay, & Simons, 2006), sustained attention to, and perceptual processing of, emotional stimuli (Solomon, DeCicco, & Dennis, 2012). Several studies have observed larger LPP amplitudes for negatively valenced images, which may be related to enhanced elaborative processing of negatively valenced images compared to positively valenced or neutral pictures (Cano et al., 2009). Con-