Neuroscience 307 (2015) 138–150

MULTIPLE STAGES OF INFORMATION PROCESSING ARE MODULATED DURING ACUTE BOUTS OF EXERCISE

T. BULLOCK,* H. CECOTTI AND B. GIESBRECHT

Department of Psychological and Brain Sciences, University of California, Santa Barbara, CA, USA

Institute for Collaborative Biotechnologies, University of California, Santa Barbara, CA, USA

Abstract—Acute bouts of aerobic physical exercise can modulate subsequent cognitive task performance and oscillatory brain activity measured with electroencephalography (EEG). Here, we investigated the sequencing of these modulations of perceptual and cognitive processes using scalp recorded EEG acquired during exercise. Twelve participants viewed pseudo-random sequences of frequent non-target stimuli (cars), infrequent distractors (obliquely oriented faces) and infrequent targets that required a simple detection response (obliquely oriented faces, where the angle was different than the infrequent distractors). The sequences were presented while seated on a stationary bike under three conditions during which scalp recorded EEG was also acquired: rest, low-intensity exercise, and high-intensity exercise. Behavioral target detection was faster during high-intensity exercise compared to both rest and low-intensity exercise. An event-related potential (ERP) analysis of the EEG data revealed that the mean amplitude of the visual P1 component evoked by frequent non-targets measured at parietal–occipital electrodes was larger during low-intensity exercise compared to rest. The P1 component evoked by infrequent targets also peaked earlier during low-intensity exercise compared to rest and high-intensity exercise. The P3a ERP component evoked by infrequent distractors measured at parietal electrodes peaked significantly earlier during both low- and high-intensity exercise when compared to rest. The modulation of the visual P1 and the later P3a components is consistent with the conclusion that exercise modulates multiple stages of neural information processing, ranging from early stage sensory processing (P1) to post-perceptual target categorization (P3a).
© 2015 IBRO. Published by Elsevier Ltd. All rights reserved.

Key words: attention, physical activity, aerobic exercise, cognition, EEG, ERP.

*Correspondence to: T. Bullock, UCSB Attention Lab, Department of Psychological and Brain Sciences, University of California, Santa Barbara, CA 93106, USA.

E-mail addresses: twbullock@googlemail.com (T. Bullock), hub20xx@hotmail.com (H. Cecotti), barry.giesbrecht@psych.ucsb.edu (B. Giesbrecht).

Abbreviations: ANOVA, analysis of variance; BPM, beats per minute; EEG, electroencephalography; ERP, event-related potential; FDR, false discovery rate; NTVA, neural theory of visual attention; RPE, Rating of Perceived Exertion; RTs, reaction times; VO_2max, maximal oxygen consumption.

http://dx.doi.org/10.1016/j.neuroscience.2015.08.046
0306-4522/© 2015 IBRO. Published by Elsevier Ltd. All rights reserved.

INTRODUCTION

Prolonged physical exercise can have important sustained and transient benefits across the human lifespan. Higher levels of aerobic fitness can enhance cognitive performance in children (Drollette et al., 2014; Hillman et al., 2014) and adults (Themanson and Hillman, 2006; Bullock and Giesbrecht, 2014), and consistent aerobic activity may help alleviate age-related cognitive decline (Colcombe et al., 2004, 2006; Hayes et al., 2013). Brief, acute bouts of exercise also have transient and generally positive effects on behavioral performance across numerous cognitive domains (for reviews see Lambourne and Tomporowski, 2010; Chang et al., 2012). Scalp recorded electroencephalography (EEG) measurements acquired after an acute bout of exercise have not only revealed subtle changes in patterns of brain activity post-exercise, but also that these changes correlate with human performance (e.g. Hillman et al., 2003; Drollette et al., 2014; Tsai et al., 2014).

While there are clear effects of exercise on brain activity measured subsequent to the bout of physical activity, it is also important to elucidate the nature of the changes that occur in the brain during exercise because these changes may be linked to cognitive performance in a way that is different than when the measurements are made after exercise. A handful of studies have acquired EEG data during an acute bout of exercise (Yagi et al., 1999; Grego et al., 2004; Pontifex and Hillman, 2007), and this approach has the potential to offer unique insight into how patterns of neural activity associated with human performance are influenced during exercise. Indeed, global patterns of neural activity in the alpha, beta and theta frequency bands can be modulated during a bout of exercise (e.g. Kubitz and Mott, 1996; Nybo and Nielsen, 2001; Bailey et al., 2008; Fumoto et al., 2010). These findings provide valuable insight into exercise-induced changes in global oscillatory activity; however, the analytical techniques used in these studies involve computing a Fourier transform over timespans of several minutes, thus precluding one from being able to observe the temporal dynamics of information processing.

What are the potential effects of exercise on brain responses measured during physical activity? Theories of attention suggest that cognitive performance can decline when there is competition for resources (Kahneman, 1973; Hockey, 1997). One suggestion is that activation of the neural circuits involved in the control of gross muscle movements during physical activity may draw processing resources away from the frontal lobe networks, causing a decline in the performance of more complex cognitive tasks (Dietrich, 2003; Dietrich and Sparling, 2004). This hypothesis predicts effects on relatively late stages of cognitive processing, which is generally consistent with studies that have acquired EEG data during exercise (Yagi et al., 1999; Grego et al., 2004; Pontifex and Hillman, 2007). However, evidence from several recent intra-cranial recordings in mice during treadmill running suggests that behavioral state can have strong modulatory effects on early visual processing (Niell and Stryker, 2010; Ayaz et al., 2013; Saleem et al., 2013; Fu et al., 2014). Thus, acute bouts of physical activity may affect multiple stages of neural information processing.

The event-related potential (ERP) technique is well-suited to isolate the specific stages at which experimental manipulations influence information processing and several studies have used this technique to investigate fluctuations in post-perceptual stages of information processing during exercise. Two studies have focused on the P3 ERP component: a large, robust positive deflection typically centered around the parietal cortex which is considered to reflect brain activity associated with updating of the stimulus environment in memory (Donchin, 1981). P3 amplitude may reflect the amount of resources that are allocated to stimulus processing (e.g. Polich, 1987, 2007; Kok, 2001) and the latency of the P3 is considered to index stimulus classification speed (Kutas et al., 1977; Magliero et al., 1984). For example, Yagi et al. (1999) had participants perform visual and auditory ‘‘oddball" tasks, whereby they either monitored a stream of visual or auditory stimuli and responded to infrequent target stimuli (oddballs) while ignoring frequent stimuli (standards). Participants performed this task at rest, during a bout of cycling (at 65–75% of heart rate max), and during a post-exercise recovery session. When comparing the exercise condition to rest and recovery conditions, not only were reaction times (RTs) reduced and error rates increased, the peak latency and amplitude of the parietal P3 ERP component evoked by targets was also reduced. However, these results are difficult to interpret given that the changes in P3 amplitude and latency may just reflect the speed-accuracy trade-off rather than the effects of acute exercise per se. There is also evidence that extended bouts of exercise can have markedly different effects on the P3. Grego et al. (2004) had participants perform an auditory oddball task during a three-hour bout of cycling at ~66% of maximal oxygen consumption (VO_2max). They found a temporary increase in P3 amplitude between the first and second hour, followed by increased peak latency after 2 h, suggesting possible effects of both physiological arousal and fatigue on processing during an extended bout of exercise. The evidence from these studies suggests a complex effect of exercise on the neural indices of information processing, which may be influenced by several factors, such as task demands and the intensity and duration of the bout of exercise.

While the P3 is thought to measure post-perceptual recognition processes, one study has used the ERP technique to test whether earlier stages of information processing are modulated during an acute bout of exercise. Pontifex and Hillman (2007) had subjects perform a flanker task (Eriksen and Eriksen, 1974) during rest and exercise at 60% of maximum heart rate. Modulations of the parietal N1, fronto-central P2 and global N2 components during exercise were observed, which the authors suggested reflects modulation of earlier processes associated with visual discrimination (Vogel and Luck, 2000), selective attention (Talsma and Kok, 2001) and conflict monitoring (Yeung et al., 2004). Additionally, there were increased errors on incongruent trials during exercise compared to rest and increased P3 amplitude and latency at frontal and lateral sites. When considered together, these results indicate that exercise may modulate patterns of neural activity associated with both early and later stages of cognitive processing.

Present aims

While extant ERP studies have offered valuable insight into how dynamic patterns of brain activity are modulated during acute bouts of aerobic exercise, there are a number of questions that remain unanswered. First, although early visual processing associated with the flanker task can be modulated during a bout of exercise (Pontifex and Hillman, 2007), this task is not ideal for the investigation of the earliest stages of processing in extrastriate visual cortex, because the visually evoked response measured at the scalp is a combination of the response to the target and the flankers, so it is unclear when exercise is having its earliest effects on task-relevant information processing. Second, the mechanism by which arousal influences later stages of information processing is currently unclear. Polich (2007) suggests that arousal may increase resources and this might be an effective mechanism for suppressing the response to task-irrelevant stimuli. However, none of the previous ERP study designs allow for a measure of the unique neural response to rare task-irrelevant stimuli. Third, previous ERP investigations have all involved comparison of neural activity during rest and relatively high-intensity exercise, but there have been no attempts to look at how these effects interact with varying intensities of exercise.

The present study had three main aims. First, to test whether exercise can modulate early sensory processing we presented participants with stimuli known to evoke a robust parieto-occipital P1 component (Kasper et al., 2014). Second, to investigate the influence of exercise-induced arousal on both task-relevant *and* task-irrelevant stimuli, we presented a ‘‘three-stimulus" version of the oddball task. Participants viewed a stimulus sequence consisting of frequently appearing non-targets (standards), rare-non-targets (distractors) and targets (targets), and only responded to targets. Distractors and targets presented in a three-stimulus oddball task are known to evoke two subcomponents of the P3 complex which are commonly referred to as the P3a and P3b,

Download English Version:

https://daneshyari.com/en/article/4337444

Download Persian Version:

https://daneshyari.com/article/4337444

Daneshyari.com