Physiology & Behavior 158 (2016) 128–136

Contents lists available at ScienceDirect

Physiology & Behavior

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

Brain mechanisms that underlie the effects of motivational audiovisual stimuli on psychophysiological responses during exercise☆

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HIGHLIGHTS

- We investigated the mechanisms that underlie environmental motivational stimuli.
- A highly fatiguing handgrip-squeezing task was employed.
- Motivational stimuli enhanced task performance and situational motivation.
- The stimuli modulated brain activity in the frontal and central brain areas.
- Effects of fatigue on efferent control were ameliorated by the motivational stimuli.

ARTICLE INFO

Article history:
Received 7 January 2016
Received in revised form 1 March 2016
Accepted 2 March 2016
Available online 3 March 2016

Keywords:
Motivation
Exercise
Sensory aids
Muscle fatigue
Brain waves

ABSTRACT

Motivational audiovisual stimuli such as music and video have been widely used in the realm of exercise and sport as a means by which to increase situational motivation and enhance performance. The present study addressed the mechanisms that underlie the effects of motivational stimuli on psychophysiological responses and exercise performance. Twenty-two participants completed fatiguing isometric handgrip-squeezing tasks under two experimental conditions (motivational audiovisual condition and neutral audiovisual condition) and a control condition. Electrical activity in the brain and working muscles was analyzed by use of electroencephalography and electromyography, respectively. Participants were asked to squeeze the dynamometer maximally for 30 s. A single-item motivation scale was administered after each squeeze. Results indicated that task performance and situational motivational were superior under the influence of motivational stimuli when compared to the other two conditions (~20% and ~25%, respectively). The motivational stimulus downregulated the predominance of low-frequency waves (theta) in the right frontal regions of the cortex (F8), and upregulated high-frequency waves (beta) in the central areas (C3 and C4). It is suggested that motivational sensory cues serve to readjust electrical activity in the brain; a mechanism by which the detrimental effects of fatigue on the efferent control of working muscles is ameliorated.

1. Introduction

Sensory stimulation such as music listening and video watching has been commonly used as a means by which to increase situational motivation during exercise [26,33]. Auditory and visual stimuli also serve to reallocate an individual's attentional focus to external influences and thus make exercise feel more enjoyable, even at relatively high intensities [31]. Despite the fact that motivational stimuli have been used extensively in the realms of exercise and sports [34,35,47], the mechanisms that underlie the effects of music and video during physically demanding tasks are hitherto under-researched.

A possible explanation underlying the beneficial effects of sensory stimuli during exercise involves the integration of multiple physiological systems (e.g., central and peripheral; see [49]). In such instances, the attentional and emotional effects of sensory stimuli can permeate throughout the body, modulating the pulmonary, cardiac, hormonal, and muscular systems (e.g., [15,63,70]). Although sensory stimuli influence cerebral and psychophysiological responses, engaging in exercise increases an individual's rating of perceived exertion, with corollary narrowing of attentional focus toward fatigue-related sensations; such internal cues have a detrimental effect on situational motivation (e.g., [25,33]). It is logical, therefore, that cerebral and psychophysiological measures be taken in tandem during exercise in order to explore the

☆ This research was supported, in part, by grants from the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior.
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http://dx.doi.org/10.1016/j.physbeh.2016.03.001
0031-9384/

mechanisms that underlie interventions that entail external sensory stimulation.

1.1. Exercise intensity and psychological responses

Simple patterns of movement such as walking are relatively easy for the human brain to direct. During low-intensity exercise, individuals are readily able to allocate attention to task-irrelevant cues such as auditory and visual stimuli. The reallocation of attentional focus toward environmental (*outward*) distractions tends to evoke positive affective responses [4,11,26]. However, as the exercise intensity increases, an individual's attentional focus is forced toward task-relevant cues such as the higher respiration rate and acidosis in the muscles (internal association/*inward monitoring*; [57,59]). Thus, exercise performed at a high-intensity (i.e., beyond ventilatory threshold) normally elicits a decrease in affective valence owing to the effects of fatigue on the affective regions of the brain (see [38]).

High-intensity exercise increases the emission of corollary discharges (parallel messages) to the brain regions associated with exertion [5,17]. Fatigue-related symptoms cause a detrimental effect on situational motivation, voluntary control of movements, and neural activation of the working muscles [45]. Interestingly, Jones et al. [31]) identified that sensory stimuli can make exercise more pleasurable even at high-intensities, meaning that audiovisual stimuli may partially overcome the negative sensations elicited by increasing exercise intensity.

The use of auditory stimuli during exercise has attracted considerable interest over the last two decades [36,68], and a psychologically-grounded conceptual framework has also been proposed as a means to further understanding of the antecedents, moderators, and consequences of music use during exercise [32]. Thus, researchers and exercise professionals can take a more targeted and scientifically-grounded approach when using auditory stimuli in the exercise context. Nonetheless, it is evident that the most potent effects manifest from a combination of auditory and visual stimuli (e.g., [43]). Unfortunately, the use of videos during exercise has only seldom been the subject of scientific investigation [3,26,31].

1.2. Brain activity during exercise

The human brain has rarely been analyzed during exercise and this is due to the fact that technology that facilitates such analysis has only been developed in recent years [54]. Movement patterns and muscular contractions cause artefacts that often compromise the quality of electrical signals. However, artefacts can be identified and excluded by use of computational procedures (see [61,66]). Through analyzing brain activity during exercise, researchers are able to identify the brain regions associated with a certain movement pattern (e.g., cycling; [29]), as well as the influence of music on electrical responses (e.g., [60]).

The scientific community has encountered considerable difficulties in explaining the means by which motivational audiovisual stimuli ameliorate the effects of fatigue and enhance exercise performance [31,47]. There is compelling evidence that mental fatigue upregulates low-frequency waves in the frontal and central regions of the cortex [16]. This mechanism is intended to slow down bodily activities, downregulate physiological arousal, and engender long-term recovery. The increase of low-frequency waves in the body can also be identified in the muscles when a given exercise is performed to the point of volitional exhaustion [67]. Therefore, it is plausible that, motivational stimuli partially downregulate low-frequency waves (4–13 Hz; [16]) in the central motor command and frontal cortex with consequent effects on the spectral components of the working muscles.

1.3. Aim of the present study

The present piece of research aims to elucidate the mechanisms that underlie the effects of audiovisual stimuli on psychophysiological responses during exercise. A fatiguing test was employed that entailed use of a handgrip dynamometer. Auditory and visual stimuli were used as a means to increase situational motivation and prevent fatigue-related symptoms from entering focal awareness [26,57]. The brain and muscle electrical activities were recorded by use of EEG and electromyography (EMG), respectively.

1.4. Research Hypotheses.

1.4.1. Situational motivation

The use of a motivational audiovisual clip was expected to increase exercise engagement [68], perceived activation, and situational motivation [33]. Neutral stimulation was also used as a means by which to isolate any effects that were not associated with the combined influence of visual and auditory sensory cues. The neutral stimulus was expected to cause minor effects on attentional focus but not alleviate the effects of fatigue-related symptoms, because of the high levels of perceived exertion associated with the proposed task. In this case, only sensory strategies considered to be highly stimulative were hypothesized to influence high-intensity exercises [27].

1.4.2. Muscular activity

Motivational audiovisual clips were expected to reallocate an individual's attentional focus to external sensory cues. Therefore, fatigue-related signals were not expected to act upon voluntary control and neural activation [18]. Accordingly, stimulative sensory cues were expected to increase power output, maintain the firing rate of electrical signals to the working muscles, and decrease the recruitment of motor units over time. Neutral stimulation (irrelevant stimulus), on the other hand, was expected to decrease neural output and firing rate, and increase motor unit recruitment over time in order to compensate for the increasing symptoms of peripheral fatigue [14].

1.4.3. Brain activity

The use of a motivational audiovisual stimulus was hypothesized to increase the predominance of high-frequency waves (14–30 Hz) in the premotor and motor areas of the brain as a means by which to compensate the detrimental effects of interoceptive sensory cues and corollary discharges on the efferent control of working muscles [48]. We also hypothesized that a motivational audiovisual stimulus would ameliorate the effects of fatigue-related symptoms by downregulating low-frequency waves (4.0–13.9 Hz; theta and alpha frequencies) in the frontal and central regions of the cortex [16].

2. Method

2.1. Selection of environmental stimuli

During the first stage of the present study, 10 participants (5 women and 5 men; $M_{age} = 20.7$ years, $SD = 0.8$ years; $M_{height} = 171.6$ cm, $SD = 8.5$ cm; and $M_{mass} = 68.9$ kg, $SD = 12.5$ kg) were invited to assess the affective qualities of the visual and auditory stimuli by use of the Self-Assessment Manikin (SAM; [10]). Similar approaches have been taken to assess the affective qualities of auditory and visual stimuli in past research (e.g., [26,40]). Participants who were engaged in this preparatory phase were not also involved in the experimental phase, but shared a similar demographic profile to experimental participants. The presentation order of the two pieces of video footage was counterbalanced.

The motivational video clip used in the present study (see https://www.youtube.com/watch?v=9d1QYV0er5o) portrayed a well-known arm-wrestling bout drawn from the movie *Over The Top* [22]. This