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Brief aerobic exercise immediately enhances visual attentional control and perceptual speed. Testing the mediating role of feelings of energy

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ABSTRACT

While the effects of acute exercise on mood and cognitive functions have been separately documented over the last decade, recent findings have pointed to a possible connection between affective responses to exercise and cognitive performance. The main objective of this study was to test whether the effects of acute exercise on cognition were mediated by changes in feelings of energy. One-hundred-and-one undergraduate students were randomized into one of two experimental conditions: 15 min of jogging at "moderate" intensity, or 15 min of relaxation/concentration (control condition). Perceptual speed, visual attentional control, working memory, and cognitive flexibility were assessed pre- and post-intervention in both groups via the Trail Making Test. Self-rated feelings of energy were also recorded pre- and post-intervention. Only completion time for the TMT-A significantly improved from pre- to post-intervention in participants who exercised compared with participants who practiced relaxation/concentration. No Group × Time interaction was found with regard to the other TMT variables. Finally, changes in feelings of energy were found to fully mediate the relationship between exercise and perceptual speed/visual attentional control. Taken together, our data suggest that a brief bout of moderate intensity exercise can improve the efficiency of certain cognitive processes through increases in feelings of energy, but further research is required to evaluate the duration of benefits and to determine whether these apply to other populations.

1. Introduction

Since 1990, dozens of studies have concluded that acute exercise bouts can improve cognitive performance on a variety of tasks following exercise (for review see Basso & Suzuki, 2017; Chang, Labban, Gaplin, & Etnier, 2012; Lambourne & Tomporowski, 2010; McMorris & Hale, 2012). Overall, the magnitudes of these positive effects are generally small (meta-analytic effect size of 0.10 to 0.20), but larger effects have been reported for types of tasks that involve executive control processes (e.g., attentional control, cognitive flexibility), whereas the average effects for memory and reaction time tasks have been found to be close to zero (Chang et al., 2012). The tasks typically used to assess the effects of acute exercise on cognition include scores for accuracy of performance and speed of processing. The meta-analysis by McMorris and Hale (2012) revealed that only processing speed is improved post-exercise. Although exercise intensity has frequently been considered to influence the size of exercise effects, Chang et al. (2012) found that intensities ranging from "light" (50%–63% of maximal heart rate, MHR) to "very hard" (> 93% MHR) improve cognitive functioning following exercise when cognitive tests are administered after a delay longer than 1 min. Similarly, although a number of studies have indicated that the facilitating effect of exercise dissipates almost immediately (e.g., Audiffren, Tomporowski, & Zagrodnik, 2008), one of the main findings from the meta-analysis by Chang et al. (2012) is that benefits of acute exercise on cognitive performance are still evident 15 min after exercise cessation.

Additionally, acute exercise has also been shown to improve affect and mood states for at least 30 min after exercise before returning to baseline (for review, see Ekkekakis, Parfitt, & Petruzzello, 2011; Ekkekakis, Hargreaves, & Parfitt, 2013; Reed & Ones, 2006). A matter of crucial importance is exercise intensity, as there is ample evidence that only acute exercise at intensities below the respiratory

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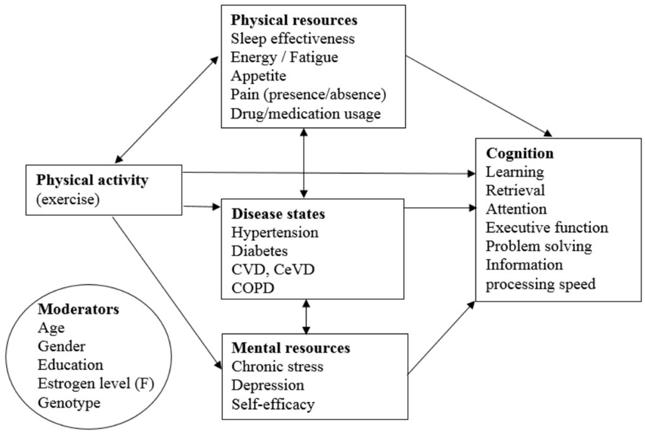

Fig. 1. Putative model of the role of mediators in acute or chronic effects of exercise on cognition (Spirduso et al., 2008). F = female; CVD = cardiovascular disease; CeVD = cerebrovascular disease; COPD = chronic obstructive pulmonary disease.

compensation point (RCP) can increase self-reported positive affect (Ekkekakis et al., 2011). Exercise duration, in addition to intensity, has long been considered to significantly influence exercise-induced mood changes. However, the meta-analysis by Reed and Ones (2006) revealed no differential effect of exercise duration on post-exercise affect for bouts from 7 to 60 min, with only exercise durations longer than 75 min resulting in detrimental effects.

Virtually no study to date has examined whether there is an association between affective responses to acute exercise and the effects of acute exercise on cognitive function. However, recent findings and conceptual models outline a plausible, though still unconfirmed, framework in which positive affective responses to exercise may promote gains in cognitive performance. For example, Spirduso, Poon, and Chodzko-Zajko (2008) have developed a theoretical model accounting for the impact of both chronic and acute exercise on cognition (see Fig. 1). Among other suggested pathways, exercise is thought to improve feelings of energy, which in turn may optimize conditions for cognitive functioning. Feelings of vigor and energy represent a specific affect/mood state in the high-arousal positive (HAP) affective quadrant from the circumplex model (Yik, Russell, & Barrett, 1999). It consistently has been noted that short-duration acute exercise (15–40 min) performed at a “light” (50%–63% MHR) to “moderate” (64%–76% MHR) intensity enhances feelings of energy (for review, see Loy, O'Connor, & Dishman, 2013).

Given all the evidence presented above, the aim of the present study was to assess the effects of a short-duration exercise bout (15 min) performed at “moderate” intensity on visual attentional control, perceptual speed, working memory, and cognitive flexibility in a large sample of young adults. A second aim was to determine whether changes in feelings of energy mediated the effects of exercise on these cognitive abilities.

2. Material and methods

2.1. Ethics statement

This research was conducted in accordance with the Declaration of Helsinki and its subsequent amendments. All participants gave their formal, written consent, and were fully debriefed after the experiment. Participation was voluntary and participants could quit the experiment at any time without negative consequences. All data were analyzed and stored anonymously.

2.2. Participants

Participants were 101 undergraduate students (mean age 20.76 years, SD = 1.22; 72 men and 29 women) from the University of Reims Champagne-Ardenne, Northeastern France. The experimentation occurred as part of a 2-h practical class (eight classes were needed to reach this sample size). All selected classes participated in this research at the beginning of the second semester (January and February 2017) and were scheduled at the same time of the day (between 2 pm and 4 pm). For various administrative and practical reasons, a cluster randomization design was employed so that all participants from a given class received one of two interventions: aerobic exercise (i.e., “experimental” group) or exercises of concentration and relaxation (i.e., “control” group). Group-randomization was preferred over randomization at the individual level as it was not feasible to perform more than one intervention for participants in the same classroom (sessions were handled by only one experimenter in each class). The random assignment to interventions for the initial class was performed by flipping a coin in the air (heads = exercise, tails = concentration/relaxation), and then interventions were alternated for the following classes. Participants were asked to refrain from physical activity 24 h before testing, and to refrain from energy drinks, caffeine and tobacco as these are stimulants that may impact feelings of energy.

2.3. Measures

2.3.1. The profile of mood sates (POMS)

The Vigor-Activity (VA) subscale of the Profile of Mood States (POMS; McNair, Lorr, & Droppleman, 1992) was used to assess participants' level of perceived energy. The VA subscale has seven items: “lively”; “active”; “energetic”; “vigorous”; “alert”; “full of pep”; and “cheerful”. Participants were instructed to rate their mood “right now”, “at this moment”. Responses were recorded on a 5-point continuum from 0 (*much unlike this*) to 4 (*much like this*); total scores range from 0 to 28. The POMS has been validated in French language by Cayrou et al. (2000) and both translated subscales exhibit high internal consistency (0.82 < Cronbach's alphas < 0.92).

2.3.2. The Trail Making Test (TMT)

Participants' speed of processing was evaluated using the Trail Making Test Part A (TMT-A; Reitan & Wolfson, 1985). This test is administered in the form of a A4-size sheet of paper with circled numbers (from 1 to 25) randomly distributed across the page. Participants were instructed to connect numbers in sequential order (i.e., 1, 2, 3, etc.) as fast as possible (without compromising accuracy). Completion time (in seconds) was recorded to the nearest 0.1 s using a digital stopwatch. The TMT-A assesses visual attentional control and perceptual speed (Sanchez-Cubillo et al., 2009).

The Trail Making Test Part B (TMT-B) was also completed. In Part B, both letters (A to L) and numbers (1 to 13) are presented on the paper sheet, and respondents have to draw connecting lines in ascending order while alternating between the numbers and the letters (1, A, 2, B, 3, C, etc.). The TMT-B is a multifaceted test but completion time for this task primarily assesses working memory (Sanchez-Cubillo et al., 2009).

The TMT B-A score (which was calculated as the difference between the TMT-B and the TMT-A completion times) is thought to provide a relatively pure indicator of cognitive flexibility (Sanchez-Cubillo et al., 2009), which is a fundamental component of executive control and refers to one's ability to efficiently switch between tasks (Cañas, Antoli, Fajardo, & Salmeron, 2005).

2.4. Procedure

As mentioned above, intervention and data collection were implemented during eight different practical classes. Each class (~10 to 14 students) was randomly assigned to either the aerobic exercise