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Conscientiousness is associated with improvement in visuospatial working memory and mood following acute physical exercise: A randomized controlled trial

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ABSTRACT

Background: In recent years, there has been heightened interest in the short-term effects of physical exercise on cognition and mood state. However, personality traits that may account for individual differences have not been studied.

Aim: To investigate whether conscientiousness is associated with improvement in visuospatial working memory (VS-WM) and mood following acute physical exercise.

Method: 69 healthy young adults (M = 25.9, SD = 3.17) were randomly assigned to one of two groups: acute physical exercise; resting control. All completed the Big-5, Profile of Mood States (POMS), and a computerized standardized cognitive battery in Hebrew. The acute physical exercise was a 15-minute moderate-intensity (60% of predicted maximal heart rate) cycle ergometer test. After a 5-minute rest participants completed the POMS again and an alternate form of the computerized battery.

Results: Multiple regression yielded a significant interaction between conscientiousness and group on VS-WM ($p = 0.037$) and on positive mood ($p = 0.02$). Simple slope analysis revealed strong positive correlations in the acute physical exercise group between conscientiousness and VS-WM ($p < 0.001$), and between conscientiousness and positive mood ($p < 0.001$), respectively. No correlations were found in the control group. The main effect of group was significant for positive mood ($p < 0.001$) but not for VS-WM ($p = 0.14$).

Conclusions: Individuals who are relatively more conscientious demonstrate better cognitive function and more positive mood following acute physical exercise.

1. Introduction

Recent studies have shown that prolonged physical activity facilitates neuroplasticity in the brain leading to improved cognitive performance (Bamidis et al., 2014; Hötting & Röder, 2013), particularly visuospatial working memory (VS-WM) (Albeck, Sano, Prewitt, & Dalton, 2006; Guo et al., 2016; Stroth, Hille, Spitzer, & Reinhardt, 2009). Similarly, physical activity has been shown to facilitate positive mood state (Lambourne & Tomporowski, 2010; Stroth et al., 2009; Yeung, 1996). However, fewer studies have investigated the effects of acute physical exercise on cognition and mood state. Moreover, while some individuals are positively affected by the exercise and present large gains in cognitive performance, others feel overtaxed and may even report a decline in cognitive function (Lambourne & Tomporowski, 2010). Hence, when evaluating cognition and mood enhancement following acute physical exercise, it is necessary to account for individual differences as well.

One of the basic substrates of higher cognitive function is working memory (WM) (Farber, Beteleva, & Ignat'eva, 2004). Indeed the construct of WM, which involves active maintenance of task-relevant information (Jaeggi, Buschkuehl, Shah, & Jonides, 2014), can be said to underlie nearly all complex cognitive functions (Miyake & Shah, 1999) and is critical for the acquisition of knowledge and skills (Phye & Pickering, 2006).

Recent studies have shown an improvement in WM following prolonged physical activity training (Albeck et al., 2006; Guo et al., 2016;

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Stroth et al., 2009), which may be attributed to facilitation of neuroplasticity in such WM-related brain structures as the right prefrontal lobe (Bamidis et al., 2014; Hötting & Röder, 2013). The positive effects of routine engagement in physical activity (Hötting & Röder, 2013) have led to increased interest in the short-term effects of such exercises on cognitive function (Byun et al., 2014). There is evidence that even single bouts of physical activity (after warm-up) improve VS-WM in rats (Aguiar et al., 2011). In humans, such acute exercise has been shown to lead to improved mood among young adults (Lambourne & Tomporowski, 2010) and reduction of transiently depressive symptoms (Yeung, 1996). According to the inverted-U hypothesis (Yerkes & Dodson, 1908), acute moderate-intensity exercise provides the optimal level of arousal and hence has the most beneficial effect on cognitive performance (Kamijo et al., 2004) relative to low- and high-intensity. Moreover, mood state has been shown to improve with moderate-intensity (40–60% VO2max) exercise (Farrell, Gustafson, Morgan, & Pert, 1987) at durations of at least 10–15 min, but not > 45 min (Ekkekakis, Hall, VanLanduyt, & Petruzzello, 2000; Woo, Kim, Kim, Petruzzello, & Hatfield, 2009).

Personality traits have been found to be associated with individual differences in academic achievement among college students, with achievement best explained by level of conscientiousness (Vedel, 2014). Indeed the role of personality traits like openness to experience and neuroticism in predicting cognitive performance remains unclear (Busato, Prins, Elshout, & Hamaker, 2000; O'Connor & Paunonen, 2007), but the role of conscientiousness is well-established. For example, Black (2000) found that only level of conscientiousness added incremental validity to cognitive performance (Black, 2000). As a trait, conscientiousness is deemed to reflect the ability and propensity to be organized, motivated and persistent in attaining delayed goals (Costa & MacCrae, 1992). Previous studies have found that higher levels of conscientiousness are associated with greater occupational and academic success, and with behaviors that promote health and longevity (Ozer & Benet-Martinez, 2006). For example, more conscientious individuals tend to exercise more frequently than less conscientious individuals (Raynor & Levine, 2009) and more conscientious older adults walk faster and show less decline in walking speed over a 3-year period (Tolea et al., 2012). Conscientiousness level is also linked to cognitive training motivation, a crucial factor in improving cognitive function due to a robust positive correlation between motivation and learning outcomes (Colquitt, LePine, & Noe, 2000). Lastly, more conscientious individuals may show greater commitment to task completion due to their competitiveness and motivation to excel and improve their skills (Studer-Luethi, Jaeggi, Buschkuehl, & Perrig, 2012), higher self-efficiency, and stronger desire to learn (Komarraju & Karau, 2005).

In addition, previous studies have shown that more conscientious individuals derive more benefit from different kinds of training. For example, De Vibe et al. (2015) found that conscientious individuals had a significantly greater reduction in stress levels after participating in a seven-week Mindfulness-Based Stress Reduction (MBSR) program consisting of physical and mental exercises to increase mindfulness of experiences in the present moment, didactic teaching on mindfulness, stress, stress management and mindful communication, and a group process to facilitate reflections on practicing mindfulness both at home and during classes(De Vibe et al., 2013). Moreover, Studer-Luethi et al. (2012) investigated whether personality interacts with two types of visual WM interventions – 1- and 2-back training tasks. They found that conscientiousness is correlated with overall cognitive training outcomes, such that higher levels of conscientiousness were associated with better overall performance and greater enjoyment from the training.

However, there is no study to date investigating the effect of acute physical exercise on cognition and mood state that takes individual differences into account.

In the present study, we aimed to examine whether level of conscientiousness is associated with improvement in VS-WM and facilitation of mood state following acute physical exercise as compared to a resting control group. Two primary hypotheses were evaluated such that:

1) Higher level of conscientiousness (as measured by a summary score computed from Likert-style ratings; see Methods) was expected to be associated with greater improvement in VS-WM among participants in the acute physical exercise group as compared with the resting control group.
2) Higher level of conscientiousness (as measured by the summary score) was expected to be associated with greater facilitation of mood state among participants in the acute physical exercise group as compared with the resting control group.

More generally, the present study aims to examine the effect of acute physical exercise on cognitive performance and mood state as a function of individual differences in personality. To our knowledge, ours is the first study designed to examine this relationship. Ultimately, our study aims to help determine which individuals will benefit most from acute physical exercise. Indeed our findings may have practical implications for designing short-term, personalized interventions to enhance cognition and mood state among cognitively intact individuals.

2. Methods

2.1. Participants

G*Power was used to estimate an adequate sample size for a multiple regression with three predictors (group, time, group × time). Total sample size required to detect a medium effect ($f2 = 0.17$) was 66 for power of 0.80 ($p < 0.05$, 2-tailed) [based on Byun et al., 2014; Feldt et al., 2010].

Sixty-nine subjects participated in the study (27 males and 42 females; age, mean ± SD: 25.9 ± 3.17 years). Participants were recruited via ads posted on social networks or on campus and were paid 100NIS or course credit for participation. All participants completed a health screening questionnaire prior to the study to confirm that they were healthy with no history of neurological or psychiatric disorders, color blindness or functional limitations precluding moderate exercise. All had normal or corrected-to-normal vision. Participants were randomly assigned to the exercise ($n = 35$) or resting control ($n = 34$) group (Table 1). After detailed explanation of the study procedure, each participant provided written informed consent prior to participation. This study was approved by the Institutional Ethics Committee.

2.2. Materials

2.2.1. Demographic questionnaire

Personal and demographic information including age, gender and years of education, was collected by self-report at the beginning of the study visit (Table 1).

2.2.2. Psychological measures

The Hebrew version of the Profile of Mood States (POMS-H) (Netz, Zeav, Arnon, & Daniel, 2005), widely used in sports and exercise (Leunes & Burger, 2000; Yeung, 1996), was administered to evaluate changes in mood state. The POMS-H contains 28-items scored on a 5-point Likert-style scale ranging from 0 ("not at all") to 4 ("extremely") and includes five subscales, each computed by summing the contributing items: 1) Tension; 2) Fatigue; 3) Depression; 4) Anger; 5) Vigor. The Vigor subscale consists of 7 items and serves as a measure of positive mood state. For the Vigor subscale, internal consistency (*Cronbach's* α) has been found to range from 0.60 to 0.91 in multiple cohorts, and high concurrent validity has been shown when compared with scales measuring equivalent constructs (Netz et al., 2005). In the