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Brief Report

Agentic extraversion moderates the effect of physical exercise on executive shifting performance

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ABSTRACT

The present study investigated the impact of physical exercise on the executive shifting function in 24 participants low and 24 participants high in agentic extraversion and tested whether agentic extraversion moderated the exercise effect. Participants accomplished a shifting task and a control task that employed the same materials and response procedure as the shifting task but required less central-executive processing. Physical exercise was varied within subjects. The order of conditions was counterbalanced. After resting, the high agentic extraversion group showed higher cognitive flexibility than the low agentic extraversion group, whereas only the low agentic extraversion group improved after exercise. The results showed that agentic extraversion moderated the exercise effect on shifting performance. Implications concerning the hypothetical dopaminergic mediation were discussed.

1. Introduction

Physical exercise has been assumed to induce physiological changes not only beneficial for a variety of health outcomes, but also for cognitive functioning (Powell, Paluch, & Blair, 2011). In a recent meta-analysis, Chang, Labban, Gapin, and Etnier (2012) revealed that even acute physical exercise has positive effects on performance in several cognitive tasks conducted after exercise. Acute exercise typically consists of a single session of activity in contrast to chronic exercise involving long-term training programs. Chang et al. (2012) observed that the effect sizes varied across the reviewed studies, which was attributed to the neglect of individual difference variables. In the present study, we investigated the moderating role of agentic extraversion (AE), a personality trait related to a particular physiological predisposition and to performance in cognitive tasks.

On the part of cognitive functions, the executive functions of working memory seem to particularly benefit from physical exercise (e.g., Tomporowski et al., 2005). Miyake et al. (2000) theoretically and empirically distinguished the following three executive functions: inhibition of prepotent responses, shifting between mental sets, and updating of working memory contents. Using this taxonomy, Barenberg, Berse, and Dutke (2011) found in their review that acute exercise seemed to improve inhibition but not shifting. We assume that the null results regarding the shifting function were due to the neglect of assessing moderating individual difference variables in the exercise–cognition relation (Chang et al., 2012).

The theoretical relationships of the constructs acute exercise, shifting, and AE are based on overlapping regulations in the mesocorticolimbic dopamine system. Executive functions underlie two phenotypic processes based on dopamine and reinforcement learning mechanisms: *Cognitive stability*, which is influenced by dopamine D1 receptors in the prefrontal cortex and demanded by the inhibition function, and *cognitive flexibility*, which relies on dopamine D2 receptors in the striatum and constitutes updating and shifting. As the optimal functioning of both processes depends on specific dopamine levels following an inverted U-shape function, medium dopamine levels lead to optimal performance and either higher or lower levels result in functioning decrements (Cools & D'Esposito, 2011). The agency facet of extraversion is believed to reflect individual differences in the functioning of the mesocorticolimbic dopamine system (Depue & Collins, 1999; Chavanon, Wacker, & Stemmler, 2013). Extraversion was positively correlated with dopamine receptor density in the striatum in a recent neuroimaging study (Baik, Yoon, Kim, & Kim, 2012). Consistently, Wacker, Chavanon, and Stemmler (2006) observed in their dopamine challenge study, that, on placebo, individuals high in AE showed higher performances in cognitive flexibility than those low in AE. Administration of a dopaminergic agent reversed this pattern. Given that acute intense physical exercise elevated

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dopamine levels in humans (e.g., Winter et al., 2007) and the striatum of rats (Hattori, Naoi, & Nishino, 1994), the mesocorticolimbic dopamine system could be a mediator of the acute physical exercise effect on executive functions. Surprisingly, only one study implemented a marker of individual differences in baseline dopamine metabolism in this field of research. But the authors referred to chronic exercise (Stroth et al., 2011) so that their results do not apply to the effects of acute exercise.

In the present study, we implemented a quasi-experimental design measuring the performance of extreme groups of AE in a shifting and a control task after resting and after acute exercise to test if AE moderated the physical exercise effect on cognitive flexibility. We expected the high AE group to show higher cognitive flexibility than the low AE group under resting conditions, because prior studies suggested that individuals high in AE possess a nearly optimal dopamine metabolism with regard to cognitive flexibility. After physical exercise, the low AE group should improve so that the superiority of the high AE group decreases, because the suboptimal dopamine metabolism of individuals low in AE should benefit from a dopamine release stimulated by physical exercise.

2. Materials and method

2.1. Participants

Participants were 48 students (30 female, 17 male; age: $M = 23, 25$ years, $SD = 3, 48$) from the University of Muenster, screened as high ($N = 24$) and low ($N = 24$) in AE according to the procedure described below.

2.2. Materials and variables

We measured AE with the German questionnaire Marburger Agentische Extraversion (MAE, Wacker, 2005). It consists of 30 items, with 10 items each measuring the three constructs happiness, dominance, and achievement. The instrument is reliable (Cronbach's $\alpha = .87$ for the total score) and has acceptable factorial and discriminant validity for impulsivity and sociability (Wacker, 2005).

Demographic and health-related information was recorded to assess the participants' aptitude for the experimental procedure. Predefined exclusion criteria were recent intake of drugs or medication affecting neurotransmitter systems and inability to perform physical exercise due to diseases.

We conducted a refined Conconi Test (Conconi et al., 1996) on bicycle ergometers to determine individual anaerobic thresholds that indicate physical capacities. Given that the subjective exercise demands and the corresponding physiological cascade depend on individual capacities, pedaling resistances at the anaerobic thresholds were used for a manipulation check for intense exercise.

Physical exercise was manipulated in a resting and in an intense exercise condition. In the resting condition, participants sat down in a comfortable chair for 10 min and listened to soft music. Heart rate was measured before and after resting. The intense exercise condition consisted of two bouts of ergometer cycling with gradually increasing physical demands respectively. Participants were instructed to cycle at a constant pace of 70 rpm (rpm) with an acceptable corridor of 60–80 rpm. They cycled at 25 watts pedaling resistance for a 2 min warm-up. Then, pedaling resistance was raised by 25 watts every 10 s until participants indicated exhaustion or pedaling speed dropped below 60 rpm. A 3 min recovery phase at 20 watts followed before the second bout began. The protocol ended with a 4 min recovery phase at 20 watts. Heart rate was recorded continuously.

We applied a shifting task (Baadte & Dutke, 2013) to measure cognitive flexibility. Additionally, we employed a self-constructed control task. The stimuli varied on two dimensions, color (blue or yellow) and shape (circle or triangle), and appeared clockwise in the four quadrants of the monitor. Participants were asked to make judgments about these stimuli within 5 s by pressing two labeled keys. In the control task, participants judged the shape of the stimuli in the first block (circle vs. triangle) and color in a separate second block (blue vs. yellow). Each block consisted of 16 practice trials and 32 experimental trials. In the following shifting task participants judged the shape of the stimuli when the stimuli appeared in the top two quadrants of the monitor and the color when stimuli appeared in the bottom two quadrants. The shifting task consisted of one block with 16 practice trials and three blocks of 32 experimental trials each. Compared to the control task, a predictable task shift in every second trial was required. For example, judging a stimulus in the top right quadrant is a no-shift trial, because the same criterion as in the previous trial was used (shape). In contrast, judging a stimulus in the bottom right quadrant is a shift trial, because a different criterion than in the previous trial was required (color). This criterion shift demands central executive resources and typically results in latency costs. We expected latencies in *control trials* (control task) to be shortest, because set shifting is not required. Latencies in *shift trials* are expected to be longest because set shifting is required. Latencies in *no-shift trials* (shifting task) should be longer than in control trials, because long-term costs of the set shift persist. However, they should be shorter than latencies in shift trials, because in the current trial no set shifting is required and transient costs do not emerge. Based on these latencies, two measures of executive performance were calculated: the difference in mean latency between shift trials and no-shift trials (*shift costs*), and the difference between the mean latency in shift trials and control trials (*shift control costs*). We expected the shift control costs to be higher and the more sensitive measure than shift costs.

2.3. Design and procedure

First, a sample of 152 students from the University of Muenster was recruited for an MAE screening. To form extreme groups, 24 participants high in AE with overall MAE scores above 14 (upper third of the sample) and 24 participants low in AE from the lower third of the sample scoring below 6 were selected. The sample size was a priori approximated to detect a medium effect size according to calculations, G$*$Power 3.1.5, $\alpha = .05$ and $\beta = .95$, targeting a within–between interaction omnibus model test.

The quasi-experimental procedure comprised three sessions which were conducted at the same time and day of the week in three consecutive weeks. Participants were told not to consume caffeine or nicotine 1 h before the sessions started and to abstain from sports and alcohol 24 h before the sessions. In the first session, participants gave written informed consent, completed the health screening, practiced on the cognitive tasks, and performed the Conconi Test. In sessions two and three, the intervention preceded control and shifting task. Physical exercise was manipulated within subjects so that in both AE groups half of the participants rested in the second session and exercised in the third session and vice versa. Order of conditions (resting–exercise, exercise–resting) was counterbalanced. The design was implemented as a single participant procedure. Participants received 20 Euro for their participation.

3. Results and discussion

3.1. Preliminary analysis

One participant was excluded due to antidepressant medication. Forty-seven participants remained in the analysis and