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ORIGINAL RESEARCH

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The experimental effects of acute walking on cognitive creativity performance

Robert Patterson, Emily Frith, Paul D. Loprinzi

Exercise Psychology Laboratory, Physical Activity Epidemiology Laboratory, Department of Health, Exercise Science and Recreation Management, The University of Mississippi, University, MS, USA

ABSTRACT

To examine the experimental effects of acute moderate-intensity walking exercise on cognitive creativity, 20 young adults (M_{age} = 21.3 years) completed a within-subject experimental protocol involving three trials on a single laboratory visit. Trials 1 and 2 were control trials involving creativity task performance. Following Trial 2, participants completed a 15-minute acute bout of treadmill walking exercise. After this, participants completed a Trial 3 creativity assessment. For all trials, both convergent (remote associates task) and divergent (alternative uses task) creativities were assessed. There was no statistically significant experimental effect of acute exercise on convergent creativity performance ($F = 0.48$; $P = 0.62$; $\eta^2 = 0.05$). Results were similar for divergent creativity. Our findings do not provide evidence that acute walking enhances cognitive creativity.

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Cognition; exercise; innovation; novelty; physical activity

Introduction

Cognition, the ultimate function of the brain [1], plays a critical role in nearly all aspects of daily life [2]. Encouragingly, emerging work demonstrates that modifiable factors, such as exercise, can enhance various cognitive parameters, such as memory [3–9]. Exercise psychologists have also become increasingly interested in examining whether exercise can enhance other cognitive parameters, namely cognitive creativity. Compared to research examining the effects of exercise on memory, this emerging line of research examining the effects of exercise on creativity has been considerably less investigated [10–23].

There is no universal definition of creativity, but a common two-criterion definition includes a creative idea as being one that is novel or original and useful, adaptive, or functional [24]. A third criterion of "surprising" or "nonobvious" has also been considered [25,26]. Unquestionably, creativity plays an important role in shaping personal and societal development and advancement [27,28]. Thus, identifying ways to enhance creativity is worthy of investigation.

As noted, emerging work suggests that exercise may help to enhance creativity [10–23]. The mechanism(s) to explain this potential relationship is not clear. Mind wandering is a candidate mechanism that may influence creativity [29], which appears to also associate with exercise [30]. More convincingly, exercise may influence creativity via mechanisms that subserve learning and memory function [31], both of which are key parameters related to creativity [32,33]. As discussed by Hallihan and Shu [31], long-term potentiation (LTP) may be a key contributor to influence creativity. Research also demonstrates that exercise may enhance LTP [8], which is hypothesized to be a key mechanism through which exercise may influence memory function [8], and speculated here to also possibly influence creativity. LTP refers to the functional connection of neurons, and cognitive psychology indicates that connectionist and associative theories are important processes involved in creativity [31]. Regarding the connectionist approach, this model allows for neural networks to change in their strength of connection. This may enhance the adaptability of the response to a stimulus, which may be crucial to creativity as a static model (vs. a changing, dynamic process) does not accurately portray human creativity [31]. Similarly,

Contact Paul D. Loprinzi pdloprin@olemiss.edu Exercise Psychology Laboratory, Physical Activity Epidemiology Laboratory, Department of Health, Exercise Science and Recreation Management, The University of Mississippi, University, MS, USA.

and related to the associative model, creativity may be influenced based on the series of associative neural network nodes that represent an individual's knowledge [31]. Activation of one neural network may spread the activation of another neural network, which in turn, may help facilitate solving a creative solution.

Fixation, or enhanced attention on a particular stimulus, may prevent the spread or activation of neural network nodes that may be required for creativity. In addition to their theoretical review of how LTP may influence creativity, Hallihan and Shu [31] conducted an experimental study evaluating the effects of acute exercise on fixation, and in turn, on creativity. Participants (engineering and non-engineering students) were asked to design a watering system for a household plant. Participants were provided with an example solution (to induce fixation) and then given 10 minutes to generate solutions for the task. Following this, they were given a defixation task (either exercise or no exercise [memory task]), followed by another 10-minutes of idea generation. Results demonstrated that, among the engineering students, those who engaged in the exercise fixation task generated more solutions to the creativity task. However, this exercise-associated effect on creativity was not observed among non-engineering students.

The line of research examining the effects of exercise and cognitive creativity is still underdeveloped but is evolving. Collectively, the current research suggests that exercise prior to a creativity task may help to facilitate creativity [10–23]. This aligns with other work on exercise and memory [3–9]. Additionally, emerging work suggests that exercising during a defixation period may also help to facilitate creativity [31]. The research question of this study was, "Is an acute bout of walking associated with improved creativity performance?" The present experiment (written as a *brief report*) aims to continue to develop this emerging line of inquiry by evaluating the effects of acute walking and creativity task performance among a young adult population. Such an investigation is warranted given the mixed findings on this underdeveloped topic. We hypothesize that an acute bout of walking will improve creativity performance.

Methods

Study design

This study was approved by the authors' institutional review board and all participants provided written consent prior to participation. The present experiment was a within-subject study design. Participants completed a single laboratory visit that involved three creativity assessment trials with an acute bout of exercise between the second and third trials (O O T O; O = creativity observation, T = treatment [exercise]).

After baseline surveys were completed (described below), they completed the first creativity assessments, which involved an alternative uses task (AUT) assessment followed by a remote associates task (RAT) assessment (described below). Following this first "control" creativity assessment, they rested quietly for 15 minutes and then completed the second "control" creativity assessment (a different AUT and RAT assessment). After this, they completed a 15-minute bout of acute walking on a treadmill (described below). Participants then rested (sat) for 5 minutes following the acute bout of exercise and then completed the last creativity assessment (a different AUT and RAT assessment).

With this (O O T O) design, we hypothesized that there would be no changes in creativity with the first two control assessments, but a significant increase would occur after the exercise treatment (i.e., the third assessment). A non-change between the first two assessments would suggest that there is no learning effect, and thus, if a change occurs for the third assessment, this would be driven by an exercise-induced effect. Also, we employed a single laboratory visit as opposed to a multi-day experiment, as this single visit helps to minimize any potential between-day differences in various parameters (e.g., mood) that could confound the findings. Additionally, this within-subject design helps to minimize the individual differences in creativity that could be confounded by a between-group experimental design.

Participants

In brief, 20 participants (college students) were recruited via a non-probability sampling approach (classroom announcements and word-of-mouth). Participants were recruited from the authors' institution. This sample size is consistent with our other related experimental work on exercise and cognition [3–7]. Participants were ineligible for this study if they were outside the 18–35-year age range, self-reported being a current smoker, had a concussion in the past 30 days, were pregnant, currently taking medication to regulate mood, or took marijuana or other illicit substances in the past 2 days. Furthermore, if they exercised 5 hours prior to the visit or consumed caffeine 3 hours prior, the visit was rescheduled.

Measures

Exercise

Researchers instructed participants to walk on a treadmill (Woodway treadmill) for 15 minutes and select an appropriate pace by saying "*Please select a pace similar to one you would choose if you were late to class. Thus, it will not be a leisurely walk. Nor will it be a run.*" The self-selected pace was maintained during the exercise bout (i.e., the speed did not vary).

Creativity assessments

For each of the three trials, participants completed an AUT to assess divergent creativity. Following this task, and for each trial, participants completed an RAT to assess convergent creativity. The RAT [34,35] has demonstrated suggestive evidence of psychometric validity. Similarly, the AUT has been shown not to correlate with RAT, providing a suggestive evidence of discriminate validity [35]. Both the AUT and RAT tasks were 3 minutes in duration for each of the trials.

Alternative uses task (AUT)

For the AUT, participants were instructed to list (via writing down on paper) as many possible uses for a household item (e.g., towel). In the three trials, participants completed this task for a different household item. The household items for the three respective trials were paper clip, towel, and brick. For the AUT, outcomes included *fluency*, flexibility, and *elaboration*.

Fluency refers to the total number of responses generated. Participants were instructed to write down responses where the item (e.g., towel) is not originally intended to be used for. As an example, if they reported "to dry off with," they were not given a fluency score for the household item, "towel." Similarly, if they reported a repeat response (e.g., "dry hair off," "dry legs off," etc.), they were not given a fluency score.

Flexibility refers to the number of different categories used (e.g., two categories generated from the following: towel used to plug a leak and towel used to prop a door open). *Elaboration* refers to the amount of detail provided (e.g., 0 points for, "towel used to prop the door open," with 1 elaboration point for, "towel used to prop the door open to prevent the wind from slamming it shut."). Another commonly assessed AUT outcome is originality, which refers to how original the response was (e.g., comparing the response to all other responses in the sample). For this experiment, we did not calculate, and thus, did not report an originality score for several reasons. First, our employed sample was relatively small ($N = 20$). Thus, an "original" response in a small sample may inflate its potential originality. Second, originality scores tend to highly correlate (e.g., $r = 0.80$ to $r = 0.90$) with fluency scores (reported herein) [36,37]. Third, even after fluency is partialled out of the originality assessment, the reliability is very low [38–40].

After study completion of all participants, two researchers reviewed all AUT responses and scored *fluency*, *flexibility*, and *elaboration*. When disagreements occurred on scoring, the two researchers re-scored and re-discussed the responses until agreement was reached. Notably, for one of the scorers involved in this experiment, our laboratory's previous work [41] has demonstrated adequate inter-rater reliability (ICC > 0.80).

Remote associates task (RAT)

For this task, participants were presented with three unrelated words and were charged with identifying a common associate word. As an example, the word "ball" is the common associate for "basket," "eight," and "snow." For each of the three trials, participants completed 10 different items. Thus, the outcome for this RAT task, for each trial, was the number of correctly identified associate words (range = 0–10). See Appendix A for the triad items that were used for the three trials. For the three trials, the difficulty level was matched, based on the normative data [42].

Surveys

Participants self-reported their moderate-to-vigorous physical activity (MVPA) using the two-item physical activity vitals sign survey (expressed as MVPA minutes/week) [43]. To assess psychological status, participants completed the patient health questionnaire (PHQ-9). For this survey, participants rated nine items (e.g., feeling down, depressed, or hopeless) on a Likert scale (0, not at all; to 3, nearly every day). The outcome of this assessment was the summed score across the nine items (range = 0–27). Finally, as a measure of intelligence quotient (IQ), participants completed a 25-question IQ test, in the form of a 3 × 3 matrix, modeled

Appendix A

RAT List—Trial 1	RAT Answer
Aid/Rubber/Wagon	Band
Dream/Break/Light	Day
Flower/Friend/Scout	Girl
Cat/Number/Phone	Call
House/Thumb/Pepper	Green
Blank/List/Mate	Check
Rain/Test/Stomach	Acid
Note/Chain/Master	Key
RAT List—Trial 2	**RAT Answer**
Sense/Courtesy/Place	Common
Boot/Summer/Ground	Camp
Mouse/Bear/Sand	Trap
Down/Question/Check	Mark
Iron/Shovel/Engine	Steam
Dress/Dial/Flower	Sun
Off/Military/First	Base
Nose/Stone/Bear	Brown
RAT List—Trial 3	**RAT Answer**
Peach/Arm/Tar	Pit
Type/Ghost/Screen	Writer
Basket/Eight/Snow	Ball
Horse/Human/Drag	Race
Wheel/Hand/Shopping	Cart
Mill/Tooth/Dust	Saw
Shock/Shave/Taste	After
Roll/Bean/Fish	Jelly

after Raven's Progressive Matrices. Scores were converted to an IQ metric. These surveys were completed to evaluate the participant's behavioral (MVPA), psychological (depression), and cognitive (IQ) attributes, all of which may influence cognitive creativity, and potentially, exercise-related creativity.

Statistical analysis

All analyses were computed in SPSS (v. 24). The independent variable was the experimental condition (i.e., exercise or no exercise). For each creativity outcome (i.e., dependent variable), a one-way repeated measures ANOVA was employed. When the F value from the repeated measures ANOVA was statistically significant, Bonferroni-corrected t-tests were employed to evaluate differences across the three trials. Mauchly's test of sphericity was evaluated for each model; no models violated this test of sphericity (all P's > 0.10). Effect size estimates [partial eta-squared (η^2_p)] were computed and reported. Statistical significant was established as an alpha of 0.05.

Results

Table 1 displays the characteristics of the experimental sample. Participants, on average, were 21 years old, with the sample equally distributed across sex (50% female). The majority of the sample was non-Hispanic white (60%), with 20% being non-Hispanic black. There was heterogeneity with regard to the sample's habitual physical activity behavior, but on average, participants were physically active (mean MVPA, 290 minutes/week). The sample had a relatively low depression (3.6) and IQ (95.7) scores.

Table 1. Characteristics of the sample (N = 20).

Variable	Point estimate	SD
Age, mean years	21.35	1.3
Gender, % Female	50.0	
Race, % non-Hispanic white	60.0	
Waist circumference, mean cm	80.75	18.1
MVPA, mean minutes/week	290.2	241.5
PHQ-9, mean	3.6	2.5
IQ, mean	95.7	14.2

cm = centimeters, IQ = intelligence quotient, MVPA = moderate-to-vigorous physical activity, PHQ = patient health questionnaire.

The main experimental findings are displayed in Table 2. For Trial 3, participants averaged 3.6 mph during the walking trial. There was no statistically significant experimental effect of acute exercise on RAT performance (F = 0.48; P = 0.62; η^2_p = 0.05). Results were similar for AUT-related flexibility (F = 0.83; P = 0.45; η^2_p = 0.08) and elaboration (F = 1.31; P = 0.29; η^2_p = 0.12). However, there was a significant main effect for time for AUT fluency (F = 9.4; P = 0.002; η^2_p = 0.51). This effect, however, was driven by an increase in fluency from trials 1 to 2 (i.e., from the first control assessment to the second control assessment). Paired t-test analyses indicated that fluency significantly increased from Trials 1 to 2 (t = 3.7; P = 0.001), whereas there was no change from Trials 2 to 3 (t = 0.41; P = 0.68). Although not shown in tabular format, we computed the bivariate correlation between self-reported MVPA and each of the creativity outcomes. Self-reported MVPA was not statistically significantly associated with any of the creativity outcomes for any trial (all P's > 0.05). We also did not observe any interaction effects for gender or mood status (all P's > 0.05).

Discussion

Compared to other lines of research examining the effects of exercise on memory or other cognitions [7,8], considerably less research has examined the effects of acute exercise on creativity. This was the motivation for this brief report, which evaluated the effects of acute walking exercise on creativity.

Table 2. Creativity performances across the three trials ($N = 20$).

Variable	Trial 1 (control)	Trial 2 (control)	Trial 3 (post-exercise)	Test-Statistic
RAT, mean	2.25 (1.7)	2.65 (1.6)	2.50 (1.9)	$F = 0.48$; $P = 0.62$; $\eta^2_p = 0.05$
AUT, mean				
Fluency	5.55 (1.9)	6.95 (2.6)	7.20 (2.7)	$F = 9.4$; $P = 0.002$; $\eta^2_p = 0.51$
Flexibility	4.45 (1.4)	4.90 (1.7)	4.75 (1.5)	$F = 0.83$; $P = 0.45$; $\eta^2_p = 0.08$
Elaboration	0.95 (1.0)	0.60 (0.8)	1.00 (1.1)	$F = 1.31$; $P = 0.29$; $\eta^2_p = 0.12$
Resting Heart Rate, mean bpm	68.25 (14.0)	69.1 (14.8)	71.8 (11.3)	
End of Exercise Heart Rate, mean bpm	–	–	113.2 (18.1)	
Exercise Speed, mean mph	–	–	3.65 (0.3)	

A 1 (group) × 3 (trials) repeated measures ANOVA was computed for each (i.e., 4) of the 4 creativity outcomes.
AUT = alternative uses task, bpm = beats per minute, mph = miles per hour, RAT = remote associates task.

Unlike previous work [10–23], we did not observe any beneficial effect of acute walking exercise on creativity task performance. This is an important observation as it brings light to the possibility that acute exercise may not robustly enhance cognitive creativity performance. This may help spawn the development of additional research to see if, for example, exercise intensity or exercise modality may have a differential effect on cognitive creativity.

As stated, majority of the work on this topic has provided some suggestive evidence that exercise can acutely improve creativity [10–23]. However, not all work demonstrates such a beneficial effect. For example, Colzato et al. [10] demonstrated that, for "inactive" individuals (defined as exercising less than one time per week across a 2-year time frame), acute high-intensity exercise impaired convergent creativity. Additionally, other creativity parameters were not influenced by moderate- or high-intensity exercise [10]. Flexibility performance on the AUT was statistically significantly augmented in the rest condition, when compared to intense exercise, but not moderate-intensity exercise. This effect persisted within active and inactive participants.

Further, it is not possible to make a direct comparison between our findings and the other work on this topic due to considerable methodological differences. For example, some studies employed a dancing protocol [14,19], provided insufficient detail on the study methodology [17], and intermixed a variety of different exercise modalities and intensities into the protocol [15]. Thus, from a methodological standpoint, considerable work standardizing protocols and methodology on this topic is needed. Relatedly, this line of inquiry could be improved by greater transparency on the specific details of the measurements employed. For example, studies rarely indicate which household items are employed for the serial AUT assessments. For repeat assessments, it is unclear if participants are naturally more creative for certain household items. Similarly, studies rarely provide the triad of items used for the RAT assessments. Thus, and as an example, it is unclear if studies are employing pre- and post-RAT assessments of similar difficulty level. In addition to these methodological concerns, future work should consider evaluating the temporal effects of acute exercise on creativity. Similar to the work of Hallihan and Shu [31], it would be useful to investigate if acute exercise can influence mechanisms (e.g., fixation) associated with creativity.

Limitations of this study include the relatively small sample size and only evaluating the effects of acute exercise on select parameters of creativity. Strengths of this study include the experimental approach and the study's novelty. Future work on this topic should continue to evaluate if exercise can influence cognitive creativity. Such work should also consider different aspects of exercise, such as acute versus chronic exercise, and different exercise intensities, durations, and modalities.

In conclusion, our findings did not provide evidence that acute walking at a moderate intensity was associated with cognitive creativity. This field is still in its infancy, and thus, needs additional research. Focusing on methodological improvement and potential mechanisms is warranted.

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