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Impact of Exercise and Mindfulness Activities on Cognitive Performance

Kayla M. Setzer
Psychology
University of North Carolina Asheville
One University Heights
Asheville, North Carolina 28804 USA

Faculty Advisor: Dr. Melissa J. Himelein

Abstract

Can short-term interventions improve the cognitive performance of college students? Prior research has demonstrated that activities such as exercise and mindfulness are beneficial for managing stress, with some studies indicating positive impacts on cognitive functions as well. However, most studies have examined effects of consistent aerobic exercise or sustained meditation practice rather than shorter exposure to such activities. This research compares the impact of different 30-minute activities on cognitive tasks of memory, attention, and reading comprehension, all areas relevant to effective studying. The study was conducted with first-year college students enrolled in a first-year seminar. Following a 20-minute pretest measuring performance on the cognitive tasks, approximately 130 participants were randomly assigned to one of four intervention groups: exercise (brisk walking), mindfulness (guided meditation), origami (constructing 3-4 models), or a control. The control group was instructed to engage in social media browsing or texting since these are typical behaviors that occur during students' study or class breaks. The interventions were followed by a 20-minute posttest, made up of different versions of the same cognitive tests. Pretest and posttest performance will be compared for each individual; intervention group performance will also be compared. It is anticipated that the exercise, mindfulness, and origami groups will all result in increased scores on cognitive tasks after completing the interventions. The findings have implications for helping first-year students develop productive study routines and taking breaks that assist in maintaining focus and attention.

Keywords: Cognitive Performance, Exercise, Mindfulness

1. Introduction

Modern college students report more stress than college students of any previous generation[1]. Stress comes from a wide variety of social, emotional, economic, and academic problems, ranging from rigorous coursework, to involvement in university organizations, to outside commitments to jobs and family. High levels of stress not only cause physical issues, but also emotional and psychological issues. These issues can, in turn, affect academic performance by interfering with students' ability to take in and retain information, to study effectively, and to think deeply. Consequently, students who can capably manage stress will likely perform better in the classroom.

The present study seeks to investigate the effectiveness of different stress management interventions, focusing in particular on their impact on cognitive abilities. Although most previous research on stress interventions has focused on their psychological benefits, some studies have also begun to examine how they affect cognitive performance. Two coping strategies that have inspired such investigations include exercise and mindfulness activities.

Several studies have evaluated the impact of aerobic exercise on different types of cognitive abilities. For example, Aberg et al.[2] examined the effects of cardiovascular fitness on long-term assessments of cognitive ability such as global intelligence test scores. In a sample of 18-year old males, they found an association between higher cardiovascular fitness levels and higher intelligence test scores. They also examined another group of males, ages 15

to 18. The researchers assessed the males at age 15 and then again at age 18 to see if any fitness increases during this time affected test scores. They found that participants whose fitness levels improved also tended to obtain higher scores on intelligence tests. These promising results suggest a relationship between fitness level and cognitive ability. Though this sample included only males, both fitness and intelligence were assessed over long periods of time.

In a literature review examining the relationship between long-term aerobic exercise and cognitive performance, researchers found that aerobic activity was associated with cognitive performance gains[3]. The researchers examined a wide range of cognitive performance factors (memory, verbal tests, and academic readiness) in school age children 4 to 18 years old. They found that aerobic exercise correlated with increased cognitive performance in all areas for these ages. The researchers also reported that aerobic exercise during childhood benefits cognitive performance later in life.

More relevant to the present study are examinations of the impact of a short-term exercise session (e.g., one single experience of exercise) on cognitive abilities. Tine[4] investigated the effects of a short burst of aerobic exercise on two assessments of cognitive ability: reading comprehension and visual attention. Low- and high-income adolescents were asked to participate in 12 minutes of jogging; their pre and posttest reading comprehension and attention scores were then compared. Tine found that there was a significant increase in scores on both cognitive measures following the exercise, with low-income group members' scores improving much more than high-income group members' scores. The participation in exercise appeared to eliminate the gap in pretest scores previously observed between the two income groups. Although this study had somewhat different objectives than the present research, it does suggest that even small doses of exercise can benefit performance on cognitive tasks in a group of young adults.

In another study of the effect of short-term exercise on cognitive ability, Coles and Tomporoski[5] examined the impact of 40 minutes of aerobic exercise on college students' attention and memory. Free-recall memory was tested by presenting participants with a list of 40 nouns on a screen, followed by a 100-second consolidation period. After this period, participants recalled as many words as possible. Next, participants completed other cognitive tasks, and then were again asked to recall the previously displayed words, an assessment of delayed recall. The researchers found that although the total number of words recalled in after the delay was not different between the exercise and control groups, the number of words remembered from the certain sections of the list, the first and last parts of the list, was significantly greater in the exercise group. This led the researchers to the conclusion that exercise can play a role in the consolidation and encoding of working memory, thereby influencing the processing of long-term memory.

Mindfulness, defined here as "paying attention in a particular way on purpose, in the present moment, and non-judgmentally"[6] (p.3) is a focus of increasing research in both health psychology and neuroscience. While long-term engagement in mindfulness activities has many demonstrated psychological benefits[7], the impact of mindfulness on cognitive abilities has been examined less frequently.

Researchers Bruin, Zwan, and Bogels[8] compared the interventions of both mindfulness meditation and physical exercise on attention control and executive functioning. The mindfulness intervention consisted of daily self-meditation either through breathing, body, thought or sound meditation, or breathing space. Following training from a mindfulness expert, a schedule of meditation exercises to complete each week was given to participants. The exercise intervention consisted of any activity selected by participants that would increase heart rate and breathing pace; many chose running or cycling. The interventions lasted for a period of five weeks, starting at 10 minutes per day and gradually increasing in time each week until participants reached levels of 20 minutes per day. The researchers found that both interventions helped to improve these areas of cognitive performance, suggesting that both could potentially be helpful interventions for highly stressed college students. Although participants in Bruin et al.'s[9] study ranged in age from 18 to 40, the mean age was 24, which is only slightly older than a typical college student population.

Morrison, Goolsarran, Rogers, and Jha[10] examined the relationship between mindfulness training and sustained attention and working memory. Their sample of college age students completed seven hours of training in mindfulness across a seven-week time span. Training consisted of a weekly 20-minute lecture along with participation in two weekly 20-minute supervised practice sessions; during practice sessions, students listened to audio files on attention focusing and were led through either mindful sitting practice or body scan practice. The participants completed two assessments, one before and one after completion of the intervention, to test the effects of mindfulness training on sustained attention and working memory. The researchers found that mindfulness helped students to increase attention but did not have an effect on memory. However, because attention is a major component of cognitive tasks necessary for success in college, an intervention that successfully increases attention might be especially important for college students.

In one additional study, the effects of mindfulness training on reading comprehension and working memory capacity in undergraduate college students[11] was examined. This study intervention consisted of a two-week training program that taught participants the basics of mindfulness and how to practice it effectively. The curriculum was divided into 45-minute sessions four times a week for two weeks. Participants were instructed in focus-attention meditation and

proper physical posture while meditating; in addition, they completed ten minutes of daily mindfulness activity on their own for the two-week period. Pre and posttest assessments consisted of a reading comprehension task similar to the reading portion of the GRE, and a working memory test of participants' ability to memorize short sequences of letters (3-7) in a specific order. The researchers found that after participation in the two-week mindfulness training and practice, participants improved on both reading comprehension and working memory assessments.

Although each of these studies provides encouraging findings regarding the impact of mindfulness on cognitive tasks, all involved an assessment of impact following a lengthy mindfulness training experience. Can a single experience of mindfulness activity produce such an effect? This question was examined in a study by Watier and Dubios[12] where the impact of a single-session of mindfulness training on executive function and memory in college students was examined. The mindfulness task consisted of listening to an audio recording of mindfulness meditation in which the basics of mindfulness were explained. The researchers found that the mindfulness task was effective in facilitating attention to a task and also helped control emotional interference while completing tasks.

The present study sought to compare the effectiveness of three intervention methods on cognitive ability: aerobic exercise, mindfulness meditation, and participation in origami. While previous research has demonstrated the potential for exercise and mindfulness to improve cognitive task performance, no prior research on the impact of origami participation on physical, psychological, or cognitive variables could be located. However, the practice of origami has much in common with the practice of mindfulness. For example, the specific attention and focus that are required to complete an origami fold are similar to the attention and focus that is stressed in the practice of mediation and many other mindfulness activities. Consequently, it was expected that origami practice might produce similar effects on individuals' ability to be attentive and alert.

While most prior research has focused on exercise and meditation involvement over a period of weeks or months, the present work tested their impact in a brief, one-session format. College students, with busy schedules and high levels of stress, may not be able or willing to adopt practices that require long-term commitment. However, if a one-time exposure of exercise or mindfulness activity can be shown to positively affect cognitive performance, students may be positively disposed to incorporate such an intervention into their daily routine.

2. Method

2.1 Participants

Participants consisted of 121 students (33 male, 86 female, 2 otherwise-identified) enrolled in first-year seminar courses at a small public liberal arts college in the southeastern United States. The mean age of the participants was 18.60 years (SD=4.74). Participants self-reported their race and ethnicity, and the majority of the sample identified as White, non-Latino (82.5%). Students represented a broad range of intended majors.

2.2 Measures

The pretest consisted of a description of the research and informed consent, a demographic section, and two cognitive measures: a reading comprehension test and a short-term memory task. In addition, participants were asked to include student identification numbers so that their pretests and posttests could be matched. The posttest contained the cognitive measures as well as a brief survey assessing attitudes toward the interventions.

2.2.1 reading comprehension

The reading comprehension test was adapted from Tine[13], who examined the impact of exercise on cognitive abilities, including reading comprehension. The specific reading passages and subsequent items selected for inclusion were taken from Mortini[14], whose E-Reading Worksheets website produces texts and questions for multiple reading levels, and is designed for educational facilities to assess reading comprehension levels. Based on the assumption that participants in the present study would have reading levels at the maximum level available on the website, Grade 12, all materials were rated as suitable for grades 8 to 12 or for grades 9 to 13.

The reading comprehension test consisted of a 1-page nonfiction reading passage followed by 10 multiple choice questions. Participants were given eight minutes to complete both the reading and the comprehension test items. The pretest and posttest were identical in format, with the passages of equivalent length and difficulty.

2.2.2 short-term memory task

The memory portion of the assessment consisted of an adapted version of the Rey Auditory Verbal Learning Test[15] (RAVLT). A verbal list of fifteen unrelated nouns was read to participants twice at the beginning of the assessment. The list was read at a rate of one word every two seconds. After they completed the reading comprehension test, participants were given two minutes to recall all the words they could remember from the list and write them on their test booklets. Participants' total number of words accurately remembered on this task was considered their short-term memory *recall.* Next, students were given a list of 20 words, including five distractor items, and asked to check which ones had been on the original list; they were also given two minutes for this task. The total number of words remembered accurately on this task was participants' short-term memory *recognition.*

2.2.3 attitudes toward interventions scale

To evaluate participants' attitudes toward the different interventions, four questions were devised assessing participants' enjoyment of the interventions, their perceptions of the interventions' effectiveness (perceived impact on focus and attention, and perceived impact on tension/anxiety), and their likelihood of using interventions in future studying. There was also a section for additional comments about the intervention experience. Question items were rated on a 5-point Likert scale from one (completely disagree) to five (completely agree).

2.3 procedure

The study took place in a large conference room facility, with all students participating at the same time. Following an explanation of the study provided by the researchers, the primary investigator read the word lists for the memory task and timed each section of the test. Seven volunteers assisted the researcher by circulating around the room and ensuring that participants were following directions.

Following the pretest, each participant was randomly assigned to one of four intervention groups. The interventions were Origami (n=28), Mindfulness (n=30), Exercise (n=32), and a no-intervention control group (n=32). Each group participated in their assigned intervention for 30 minutes. Members of all groups were asked to refrain from talking during the interventions.

2.3.1 origami

The origami group participants walked together to a smaller room in another building on campus, where they were led through multiple origami folds. The instructor explained some of the basic folds of origami and common terms used in the craft. He then led students through three beginner folds (the crane, frog, and lotus flower) by demonstrating them and by giving verbal instruction. Students asked the instructor questions about the different folds and steps during the exercise. After the allotted time for the intervention was completed, students were led back to the large testing room.

2.3.2 mindfulness

The mindfulness group participants also walked together to a smaller room in another building on campus, where they were met by a faculty member with extensive training in contemplative practices, including mindfulness. He began with a brief description of mindfulness and its potential benefits, and then led students through a short visualization exercise. He then led students in discussion of their impressions of the experience, which he followed with another short guided meditation exercise. Students again briefly shared their perspectives before returning to the large testing room.

2.3.3 exercise

The exercise group participated in a brisk walk around campus, which was led by the primary researcher. This walk was conducted at a moderate pace with the intention of elevating heart rate. Students' varying fitness levels were

considered by having the primary researcher at the front of the group and a student helper at the rear of the group. Students were instructed to pick a walking rate that would result in moderate exercise for them. The walk around campus was a large loop course that went through the outskirts of campus in the effort to minimize distraction. After students completed the course of walking, they were led back to the large testing room.

2.3.4 No-intervention control

The control group was co-led by two first-year seminar instructors, who informed students that they could use their phones or other electronic devices to engage in texting or social media use. The only limitations given were that they must remain seated and could not talk to other group members.

Following the interventions, all participants returned to the large room where the pretest was given. As soon as all students were reassembled, the posttest was administered. A debriefing session followed the posttest in which all four interventions were described to participants, the rationale for the study was provided, and students were able to ask questions and discuss their thoughts in small groups.

3. Results

The three cognitive measures (reading comprehension, short-term memory [STM] recall, and short-term memory [STM] recognition) at both Time 1 (pre-intervention) and Time 2 (post-intervention) were calculated. Table 1 shows the means and standard deviations on each of the measures.

Table 1. Pretest and posttest means and standard deviations of cognitive measures. STM = short-term memory; 1 = measures at Time 1 (pre-intervention); 2 = measures at Time 2 (post-intervention).

	Reading 1	Reading 2	STM Recall 1	STM Recall 2	STM Recognition 1	STM Recognition 2
Theoretical Range	0 - 10	0 - 10	0 - 15	0 - 15	0 - 15	0 - 15
Origami Mean (SD) n=28	7.75 (2.12)	7.11 (1.75)	8.71 (3.42)	6.79 (3.35)	12.54 (3.51)	12.43 (2.76)
Mindfulness Mean (SD) n=30	8.20 (2.41)	7.90 (1.88)	9.90 (3.13)	7.77 (3.82)	13.76 (1.90)	13.40 (2.43)
Exercise Mean (SD) n=32	8.25 (2.08)	6.71 (2.48)	8.31 (2.22)	6.41 (3.77)	12.56 (2.50)	11.84 (3.23)
Control Mean (SD) n=30	7.97 (2.34)	7.30 (2.04)	8.84 (3.52)	7.48 (3.34)	12.55 (2.83)	12.65 (3.10)
Overall Mean (SD) n=121	7.97 (2.34)	7.30 (2.04)	8.93 (3.12)	7.11 (3.58)	12.84 (2.84)	12.57 (2.93)

Overall Time 1 and Time 2 means for each of the cognitive measures were compared using paired samples t-tests. The results showed that were significant declines from Time 1 to Time 2 on two of the measures: reading comprehension ($t[120]=3.37$, $p<.001$) and STM Recall ($t[120]=5.70$, $p<.001$).

Next, Time 2 means for each of the cognitive measures were compared across the interventions groups. A series of ANCOVAs was conducted to examine whether Time 2 differed across any of the interventions after being controlled for Time 1. As indicated in Table 2, no significant differences across any of the intervention groups were detected.

Table 2: ANCOVA tests comparing cognitive measures at Time 2 across intervention groups.

Time 2 Measure	Sum of Squares	F	Sig
Reading 2	14.04	1.52	.213
STM Recall 2	12.32	.39	.758
STM Recognition 2	12.48	.82	.485

During the final part of the experiment, the participants completed the four-item attitude questionnaire evaluating their perceptions of the interventions in which they participated. A one-way ANOVA comparing participants' ratings on each question revealed significant differences on three items. Table 3 shows the mean and standard deviation for each question, by group.

Table 3: Attitude question means and standard deviations for each intervention group. Each item was rated on a 5-point scale (1 = completely disagree, 5 = completely agree). *p < .05; **p < .001.

Intervention group	Impact on focus and attention	Impact on tension and anxiety	Enjoyment	Use of intervention in future
Origami (n=28)	2.18 (1.16)	2.18 (1.28)	3.82 (1.22)	2.75 (1.29)
Mindfulness (n=30)	2.73 (1.17)	1.73 (1.14)	3.63 (1.16)	3.30 (1.21)
Exercise (n=32)	2.03 (1.03)	2.72 (1.33)	2.63 (1.07)	1.97 (.97)
Control (n=30)	2.33 (1.12)	2.20 (1.06)	3.17 (1.29)	2.73 (1.34)
Overall	2.32 (1.14)	2.22 (1.25)*	3.29 (1.26)**	2.68 (1.28)**

Post-hoc analyses were conducted to determine which groups differed from each other. On the question regarding perceived impact of the intervention on tension and anxiety, scores for participants in the mindfulness and exercise groups were significantly different. On the question regarding enjoyment of the intervention, exercise differed significantly from both origami and mindfulness, and on the question regarding prospective use of the intervention in the future, mindfulness and exercise significantly differed. These findings and direction of the differences are evident in Table 3.

4. Discussion

This study compared the effectiveness of three interventions hypothesized to improve cognitive performance in students: mindfulness, origami, and exercise. Contrary to expectation, we found that none had a positive impact on posttest measures of reading comprehension or memory. Students in the interventions did not significantly differ from

students in a no-intervention texting control group on the posttest measures. In fact, overall there was a statistically significant decrease on two of three measures from the pretest to the posttest.

Several factors may have played a role in the lack of primary findings in this study. For example, the time spent participating in interventions may have been too short to influence the cognitive measures. Most of the prior research guiding this study assessed the impact of interventions conducted over several days or weeks; one session of an intervention may simply not be enough time for an impact to take place.

While Tine's[16] study did find benefits of short-term exercise on reading comprehension, Tine operationalized aerobic exercise as jogging, rather than the walking definition employed here. The use of jogging likely caused an increase in participants' heartrates that was higher than the increase experienced by participants in the present study. Perhaps vigorous activity is a necessary component of exercise in order for an impact on cognitive performance to take place.

Some methodological issues of note may also have lessened the likelihood of detecting significant findings in this study. Due to last-minute room changes outside of the experimenter's control, participants in the origami and mindfulness groups spent approximately 15 minutes walking back to the original testing room following their interventions. This unanticipated delay before the posttest could be initiated may have been enough time for cognitive benefits to dissipate. Clearly, the ideal situation would have been to test students immediately upon finishing their respective interventions.

The testing environment itself might also have affected performance. To ensure consistency in the cognitive testing, the assessment was conducted in one large room on a Friday afternoon. Students may not have been motivated to put forth their best effort on the tests, particularly on the posttest when fatigue may also have played a role. The large room made it difficult to monitor student responses and directly encourage their effort. The finding that overall cognitive performance declined from pretest to posttest suggests that such factors played a role.

Finally, the sensitivity of the cognitive measures could have affected the results. Considering performance on the reading comprehension pretest, 70% of the sample received scores of 8 or higher out of a maximum score of 10, including 31% receiving a perfect score. As a result of their initial high scores, participants were less likely to make significant gains on their posttest.

However, study participants did differ across groups in their attitudes toward the intervention experiences. There were significant differences between groups on three out of four survey questions. First, students in the mindfulness group perceived their tension and anxiety to have decreased more following the intervention than did students in the exercise group. Second, students in both the mindfulness and origami groups enjoyed the intervention more than did students in the exercise group. Third, students in the mindfulness group were more likely than students in the exercise group to report that they would be likely to try the intervention during a study break in the future.

Students' apparent lack of enthusiasm for the exercise intervention was surprising. The day on which the intervention took place was a sunny, warm, autumn day, and the walk took place through an attractive, wooded area of the campus. However, one factor that could have created more negative attitudes towards exercise was the lack of talking allowed during the intervention. Perhaps students view exercise and walking as a more social than physical activity, and when this aspect of the activity was not allowed, they may have been frustrated. Although participants in all of the intervention groups were asked to refrain from talking, it is possible that participants perceive mindfulness or origami as quiet activities and therefore accepted the talking limitation more easily.

Across multiple studies, mindfulness has been observed as being valuable for psychological well-being and explicit and implicit emotional regulation[19]. These benefits of emotional regulation could explain participants' positive attitudes, particularly their perceptions of lowered anxiety and higher enjoyment. Previous researchers have explored the perceived benefits of mindfulness and found that they include heightened attention, improved stress management, and a better ability to remain calm[20]. Of course, if participants were also aware of these benefits, their perceptions may have been biased in favor of mindfulness.

One other difference between the mindfulness and origami participants and the exercise participants that might have affected perceptions has to do with the group facilitators. Both the mindfulness and origami interventions were conducted by popular and charismatic full professors on campus, whereas the exercise intervention was led by students. It is possible that ratings were influenced as a result.

Although the use of one-time interventions of mindfulness, origami, and exercise did not show any changes in cognitive ability, participants did enjoy participating in mindfulness and origami, significantly more than exercise, and somewhat (though not statistically significantly) more than texting or social media, the control group activity. This information suggests that such interventions have practical value in their appeal to students, which could be helpful in the design of both future experiments and potential study skills training.

Given the methodological challenges of the present study, future research on effectiveness of short-term interventions is nonetheless worth continued focus. Investigators should test the interventions with more sensitive measures, in better controlled surroundings, with, ideally, incentives to motivate students' effort and persistence.

Of course, it is also possible that one-time interventions are simply not enough to create the changes needed for improved cognitive performance. Perhaps "quick fixes" do not work and instead sustained effort and hard work are necessary for mastery of the various interventions. Future research might consider assessing just one intervention but considering different "levels," for example, one session versus a few sessions versus multiple sessions.

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