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Sweat So You Don't Forget: Exercise Breaks During a University Lecture Increase On-Task Attention and Learning

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We examined the impact of taking exercise breaks, non-exercise breaks, or no breaks on learning among first year Introductory Psychology students. Three 5-minute breaks were equally distributed throughout a 50-minute computer-based video lecture. The exercise breaks group performed a series of callisthenic exercises; the non-exercise breaks group played a computer game; the no breaks group watched the lecture without breaks. Mind-wandering questions measured attention during the lecture. Exercise breaks promoted attention throughout the lecture compared to no breaks and non-exercise breaks, and resulted in superior learning when assessed on immediate and delayed tests. The exercise breaks group also endorsed higher ratings for narrator clarity and perceived understanding than the other two groups. This is the first study to show that exercise breaks promote attention during lecture and improve learning in university students.

General Audience Summary

We tested the use of exercise breaks as a tool to focus student attention and promote learning. In children, exercise breaks reduce off-task physical behaviors like fidgeting and shifting, while also improving academic performance. However, it is unclear whether the benefits of exercise breaks extend to older students who may manifest off-task behaviors in less overt ways, such as through mind wandering away from the primary task. Incorporating exercise breaks into a university lecture improved on-task attention and memory for lecture material compared to non-exercise breaks or no breaks. Learners who received exercise breaks found the lecturer and lecture material easier to understand than did learners who received no breaks. Engaging minds through classroom learning and practice is a direct route to promoting academic performance, and physical exercise breaks may augment these processes.

Keywords: Physical activity, Mind wandering, Memory, Academic performance, Cognition

We remember what we attend to but our attention has a limited capacity (Engle, 2002). The appropriate allocation of attention during an effortful task, such as listening to a lecture, is critical for durable learning to occur (Shiffrin & Schneider, 1977). However, as time on task increases, minds naturally wander from a selected activity; not surprisingly, the tendency to focus on a lecture declines as the lecture proceeds (Bunce, Flens, & Neiles, 2010). The net effect of reduced on-task attention during a lecture is reduced memory performance, which can impair academic performance (Wammes, Seli, Cheyne, Boucher, & Smilek, 2016). As lectures remain the primary point of content delivery in most university courses, determining strategies

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to sustain attention throughout a lecture period may promote better learning. Exercise breaks incorporated into teaching periods may be one such promising intervention.

In elementary school classrooms, exercise breaks reduce off-task physical behaviors like fidgeting and shifting (Janssen et al., 2014; Ma, Mare, & Gurd, 2014) while improving math fluency (Howie, Schatz, & Pate, 2015; Vazou & Skrade, 2016) and language skills (Martin & Murtagh, 2015; Mullender-Wijnsma et al., 2016). These off-task behaviors are presumed to be a physical manifestation of waning attention and a reduction in such behaviors following exercise represents the refocusing of attention on classroom instruction (Carriere, Seli, & Smilek, 2013). Although these studies position exercise breaks as a promising intervention to promote learning, research making causal connections has been limited. First, there is currently no evidence that directly associates a reduction in off-task behaviors following exercise breaks to improved learning of instructional content; thus, the link between refocused attention and improved learning has not been fully investigated. Second, previous studies have evaluated learning gains from exercise breaks using experiment-based tests such mathematics speed tests, spelling tests, and reading tests (Ma et al., 2014; Mullender-Wijnsma et al., 2016). Although these measures provide insight into the ability of exercise breaks to foster general academic skills and knowledge, they do not directly evaluate how exercise breaks promote learning of authentic instructional material. Third, research on exercise breaks has been limited to school-age children; it is unclear whether the benefits of exercise breaks extend to older students who may manifest off-task behaviors in less overt ways, such as through mind wandering (i.e., the shifting of attention away from the primary task and toward internal cognitions; Smallwood, Fishman, & Schooler, 2007; Wammes, Seli, et al., 2016).

Converging lines of evidence further support a role for exercise in promoting general cognitive function and academic learning. An acute bout of exercise prior to completing a task promotes executive functioning and working memory (Chang, Labban, Gapin, & Etnier, 2012), along with immediate and long-term memory for basic motor skills (Roig, Skriver, Lundbye-Jensen, Kiens, & Nielsen, 2012), word lists (Coles & Tomporowski, 2008), and picture–location associations (van Dongen, Kersten, Wagner, Morris, & Fernández, 2016). With respect to academic learning, students of all ages who have a higher level of physical fitness also have higher academic achievement both in the classroom and on standardized tests (Carlson et al., 2008; Grissom, 2005; Singh, Uijtdewilligen, Twisk, Van Mechelen, & Chinapaw, 2012). Although controlled studies that test memory for complex educational material are lacking, an acute bout of exercise does have direct effects on the brain by increasing arousal via the release of stress hormones known to improve attention and memory (McEwen, 2007). Exercise-induced increases in epinephrine may improve on-task attention during the lecture, while activation of the hypothalamic-pituitary-adrenal (HPA) axis leading to increases in cortisol may improve memory for the lecture material (Brisswalter, Collardeau, & René, 2002). This cascade of arousal responses to physical exercise is expected to be absent in non-exercise breaks (such as playing a computer game) which would thus be less effective at supporting attention and memory for the lecture material.

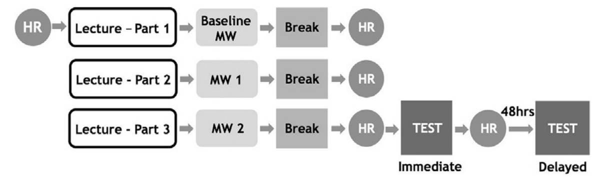

Figure 1. Experimental design. The lecture was divided into three parts. Participants watched each part of the lecture, followed by a mind-wandering question (MW), a break (unless part of the no breaks group) and a measure of heart rate (HR). This process was repeated until the lecture was complete, followed by an immediate learning test. After 48 h participants returned and completed a delayed learning test.

The present study examined the attention and learning impact of three 5-minute breaks distributed throughout a 50-minute computer-based video lecture taken from a post-secondary Introductory Psychology course. The *exercise breaks* group performed a series of callisthenic exercises; the *non-exercise breaks* group played a simple visual matching computer game (Bejeweled), which acted as a sham break to control for the level of arousal. The *no breaks* group watched the lecture continuously without breaks. Figure 1 provides a schematic of the experimental design. The lecture was divided into three parts. For each part, participants watched the lecture and answered a mind-wandering question to gauge on-task attention. Then they completed the experimental break (unless part of the no breaks group) and provided a heart rate measure as an index of physiological arousal. We hypothesized that exercise breaks during learning of university-level educational content would heighten physiological arousal to promote on-task attention and improve learning compared to non-exercise breaks and no breaks.

Method

Participants

The a priori recommended sample size was 75 participants based on .90 power estimate for a small-to-medium effect size (Subramaniapillai, Tremblay, Grassmann, Remington, & Faulkner, 2016); two additional participants were recruited (for a total of 77) due to missing cells. Thus, 77 undergraduate students at McMaster University enrolled in an Introductory Psychology course (78% females; age $M \pm SD = 18.7 \pm 1.4$ years; 18–22yrs old) were recruited from an online recruitment portal and were pre-screened for prior exposure to lecture content. Only participants without prior exposure to the lecture content could enlist in the study. The study was conducted at McMaster University. All participants provided informed consent (study approved by McMaster Research Ethics Board, # 2014 131) and were compensated with course credit for their participation.

Materials

Lecture. Participants watched a condensed 50-min computer-based lecture about form perception, corresponding to about one week's worth of content and taken directly from the Introductory Psychology course. The course curriculum includes both in-class and online components and thus the lecture used in this study represents how the course material is authentically delivered. Participants were accustomed to viewing such online lectures; however, they had not previously viewed this particular lecture, which was scheduled to appear later in the course.

Exercise and non-exercise breaks. The exercise breaks consisted of five 50-s experimenter-led callisthenic exercises (jumping jacks, heeltaps, high knees, split jumps, and hamstring kickers) separated by a 10-s rest. Since the experimenter had to lead the exercise sessions, this precluded the study from being blinded. This was done to ensure consistency in data collection across conditions.

The non-exercise breaks consisted of playing the computer game, Bejeweled, on the same computer as the video lecture for an equal time period as the exercise breaks. In pilot testing ($N = 15$), Bejeweled was rated as the most enjoyable among four computer game options (Bejeweled = 39%, Pacman = 25%, Tetris = 19%, Pong = 17%). Other non-exercise breaks, such as web browsing, viewing social media, or listening to music were disqualified because of the potentially arousing effects of the emotional content (Scherer & Coutinho, 2013) and variance in enjoyment across participants. Sitting silently was also disqualified as a non-exercise break because of the potential for rumination on the lecture material or life events (Schwarzer, 1996).

Arousal. A pilot protocol was conducted to assess the accuracy of carotid artery monitoring by pairing it with a heart rate (HR) monitor and comparing the two values. There was no significant difference between the values provided by the two methods, $t(5) = 0.16$, $p = .88$. Given that HR monitors require an under-the-clothes chest band and a properly synced wrist monitor, the carotid artery method was chosen to minimize participant burden and optimize data collection efficiency.

Attention. We used a validated mind-wandering question for classroom research (Wammes, Boucher, Seli, Cheyne, & Smilek, 2016). The question read, "Which of the following responses best characterizes your mental state just before this screen appeared?" The answer options were (1) on task, (2) intentionally mind wandering, or (3) unintentionally mind wandering. There were a total of three mind-wandering questions: baseline (after the first part of the lecture), Time 1 (after the second part), and Time 2 (after the final part). Prior work by Szpunar, Khan, and Schacter (2013) relied on a single mind-wandering question at the end of the experimental session. In the present study, the three mind-wandering questions were distributed equally throughout the lecture to more accurately capture mind wandering without relying on retrospective judgment. To minimize interference during learning, mind-wandering questions occurred prior to each break (except for controls, who did not receive a break but were administered the mind-wandering question at a similar time point during the lecture).

Learning. Learning was evaluated using a 30-question multiple-choice test that was answered immediately following the lecture. Participants returned 48 h later to complete a delayed test with different questions, matched for content and difficulty.

Perceptions. Immediately after viewing the lecture, participants provided subjective ratings of the lecture with respect to their perceptions of difficulty, engagement, interest, understanding of the content, and narrator clarity using a 7-item Likert scale (see Appendix 1 for description of subjective measures). Two questions were used to assess each construct, and the average rating was used in the analysis. Prior research examining exercise breaks during classroom instruction reported that children perceived the classroom time as being more enjoyable, and teachers perceived greater participation and engagement from their students following the exercise breaks (Camahalan & Ipock, 2015; Mulrine, Prater, & Jenkins, 2008). The novelty of the present study is that we evaluated both perceptions and performance indicators to provide a more comprehensive assessment of learning (Moullin, 2004). Exercise breaks were expected to produce a better learning experience as evidenced by higher perception ratings.

Physical activity level. Participants completed the Physical Activity and Sedentary Behaviour Questionnaire (Tremblay et al., 2007) to verify no group differences in physical activity prior to the study. Physical activity was derived from participants' response to the following question: "How many minutes per week do you engage in moderate-to-vigorous physical activity?"

Procedure

Participants were randomly assigned to *exercise breaks* ($N = 26$), *non-exercise breaks* ($N = 23$), or *no breaks* ($N = 28$). We randomized using the free online randomizer tool (randomization.com), which applies the method of randomly permuted blocks. Figure 1 provides a schematic of the experimental design. During each experimental session, approximately four participants, who were assigned to the same experimental group, watched the computer-based form perception lecture using individual laptops with attached headsets. For exercise or non-exercise breaks groups, three 5-minute breaks were distributed approximately every 17 min. This time interval structure is similar to work done by Ma et al. (2014), where 4-min exercise breaks were introduced after 20 min of classroom instruction. Participants in the no breaks group watched the lecture continuously without a break. A mind wandering question was presented before each break or at a similar time point in the lecture for the no breaks group.

Immediately following each break and at the very beginning and end of the initial experimental session, participants measured their heart rate (HR) by applying their middle and index fingers to their carotid artery for 15 s (note that participants were trained to use this method prior to the experiment). We multiplied the recorded value by four to determine the number of beats per minute. The control group provided HR measures at similar time points as the exercise and non-exercise breaks groups, and this was done immediately after responding to each mind-wandering question.

Learning was assessed by a comprehension test that was administered immediately after the lecture. The test questions were drawn from the Introductory Psychology course test bank.

The lecture perceptions questionnaire was administered immediately after the learning assessment, following which the last HR measure was collected. Delayed learning was assessed 48 h later. The completion time for the control condition was approximately seventy minutes (50 min lecture; 20 min for the learning test and questionnaires). The completion time for the exercise and non-exercise breaks conditions was approximately ninety minutes (50 min lecture; 15 min [3× 5 min] of breaks; 3–5 min of total transition time between breaks and lecture; 20 min for the learning test and questionnaires).

Statistical Analyses

Software package SPSS Version 23 was used for analyses. Arousal and learning were assessed by separate mixed-model ANOVAs with a between-subject factor of Group (exercise breaks, non-exercise breaks, no breaks) and a within-subject factor of Time. To measure off-task attention, unintentional and intentional mind wandering were collapsed for the analyses. Analyses focused on attention *on-task* (coded as 0) versus *off-task* (both unintentional and intentional mind wandering, coded as 1). The initial mind-wandering question, done prior to the experimental manipulation, was added as a covariate in a binary logistic regression model as a baseline measure of attention, with simple linear contrasts comparing groups. Both immediate and delayed learning tests had high internal consistency reliability scores (Immediate $\omega_h = .96$; Delayed $\omega_h = .96$). We also conducted a 3×2 repeated-measures ANCOVA to determine whether the benefit of exercise breaks emerged at different stages in the lecture (with a between-subject factor of Group and a within-subject factor of Lecture Time; the outcome measure was performance on the immediate test questions that evaluated the material that was presented after each exercise break). We controlled for any baseline differences in learning across groups by adding performance from the first part of the lecture as a covariate.

To directly test our hypothesis that heightened physiological arousal from exercise would promote on-task attention and improve learning, we conducted Spearman's correlations to test the strength of the association of arousal following the exercise breaks with the measures of attention and learning. Subjective perception ratings were assessed with separate one-way ANOVAs with a between-subject factor of Group.

Results

Manipulation Check

Spearman correlation confirmed that the pairs of perception questions were significantly correlated, all $p < .004$; all rs > .36; all $r^2 > .13$, and the average score between perception questions was computed. There were no group differences in physical activity among the groups, $F(2, 73) = 0.82$, $p = .44$, confirming that individuals of similar levels of physical activity were assigned to each group. All analyses met assumptions of normality.

Table 1
Arousal During Lecture

	Exercise breaks *M* (*SD*)	Non-exercise breaks *M* (*SD*)	No breaks *M* (*SD*)
HR Pre	84 (34)	77 (18)	85 (12)
HR Break 1	136 (39)***	75 (16)	83 (12)
HR Break 2	145 (42)***	73 (16)	80 (10)
HR Break 3	145 (41)***	73 (12)	79 (11)
HR Post	93 (34)*	76 (13)	78 (10)

Note. Heart rate (HR) in beats per minute (bpm) was higher following each exercise break compared to the other groups, and these group differences remained until the end of the experimental session (HR post; main effects of group and a group × time interaction: all $p < .001$). Parentheses denote standard deviation. Independent samples *t* test revealed significant differences between the exercise breaks group compared to the other groups, which were not significantly different from each other at any time point.
*$p < .05$; ***$p < .001$.

Arousal

Exercise breaks significantly increased arousal compared to non-exercise breaks and no breaks (Table 1). The HR for the exercise breaks increased to approximately 70% of the age-predicted HR max, indicating a moderate-to-vigorous level of intensity for the exercise group. The HR of the exercise-breaks group following each break was higher than the HR of the other two groups. These group differences remained until the end of the experimental session (i.e., after the learning test and questionnaires; see Table 1). Higher HR following each break in the exercise breaks group was supported by main effects of Group, $F(2, 72) = 28.60$ $p < .001$, $\eta_p^2 = .44$, and Time, $F(4, 288) = 65.73$, $p < .001$, $\eta_p^2 = .48$, as well as a Group × Time interaction, $F(8, 288) = 87.84$, $p < .001$, $\eta_p^2 = .71$. Post hoc independent-samples *t* tests confirmed that the exercise breaks group had higher HRs compared to the other two groups following the first exercise break until the end of experimental session (see Table 1). In contrast, the non-exercise breaks group and no breaks group were not significantly different form each other at any time point, all $p > .05$.

Attention

Table 2 and Figure 2A depict the attention results. As the lecture progressed, exercise breaks promoted greater on-task attention than non-exercise breaks or no breaks (Figure 2A). When time points were analyzed by separate binary logistic regressions, there were no group differences following the first mind-wandering question (Time 1; $p > .05$). Group differences were observed at the second mind-wandering question (Time 2), with the exercise breaks group engaging in more on-task attention than the non-exercise breaks group, OR = 6.59, 95% CI = 1.77, 24.50, $p < .01$, and the no breaks group, OR = 3.98, 95% CI = 1.22, 12.96, $p < .05$.

Learning

Table 3 and Figure 2B depict the learning results. Exercise breaks resulted in better test performance on both immediate and delayed assessments than non-exercise breaks or no breaks

Table 2
Descriptive Statistics for Mind Wandering Questions Across Groups

	Exercise breaks			Non-exercise breaks			Control		
	Baseline $N = 25$	T1 $N = 25$	T2 $N = 25$	Baseline $N = 22$	T1 $N = 22$	T2 $N = 22$	Baseline $N = 28$	T1 $N = 28$	T2 $N = 27$
On task	19	18	18	12	16	7	19	16	11
Off task	6	7	7	10	6	15	9	12	16
Unintentional	6	6	5	7	6	10	9	11	13
Intentional	0	1	2	3	0	5	0	1	3

Note. Collapsed mind wandering is represented by number of participants endorsing on-task versus off-task attention at each mind-wandering question: Baseline (covariate), Time 1 (T1), and Time 2 (T2). Pre-collapsed mind wandering is represented by number of people endorsing each mind-wandering options.

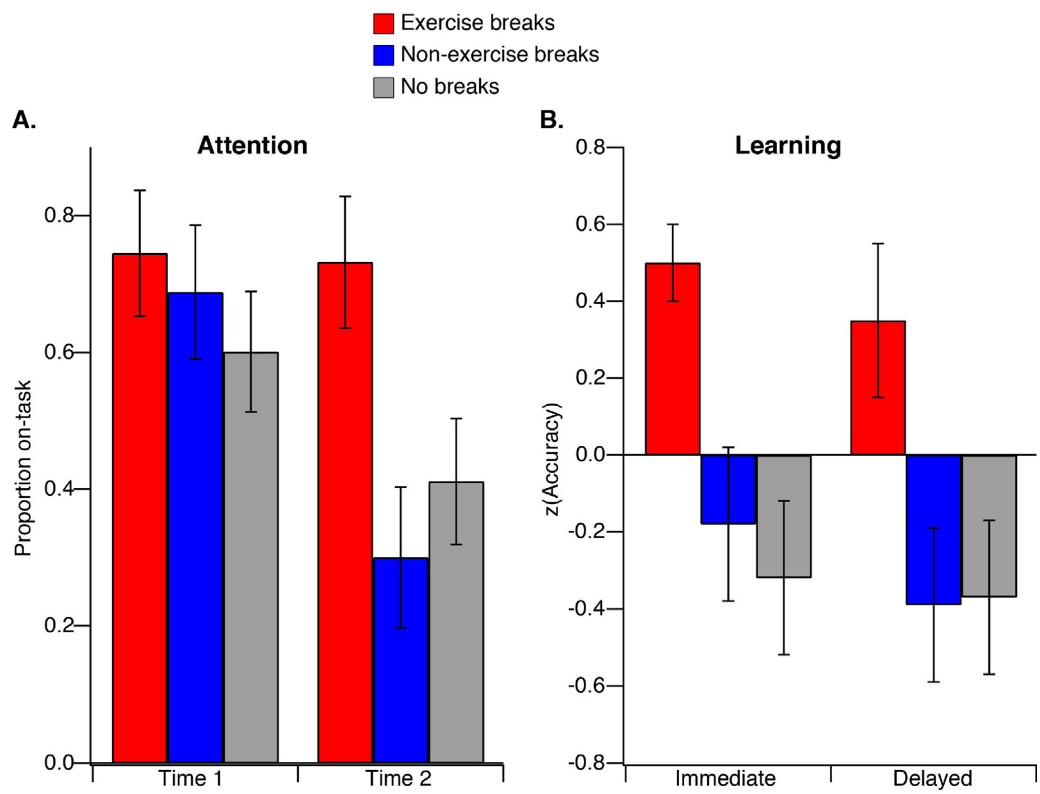

Figure 2. Attention during lecture and learning of the lecture material. (A) As the lecture progressed, exercise breaks prevented a reduction in on-task attention compared to non-exercise breaks or no breaks. Proportion of participants reporting on-task attention controlling for baseline attention was used to illustrate attention differences across groups, although statistical analyses were conducted on dichotomous mind-wandering values (0 = on-task, 1 = off-task). Error bars represent ± SE. (B) Exercise breaks resulted in better test performance on both immediate and delayed assessments than non-exercise breaks or no breaks. For illustrative purposes, immediate and delayed test performances were normalized into a *z* score using the mean (46.1%) and standard deviation (10.5%) for the immediate test. This was done to normalize performance to the average so that it would improve generalizability and also to anchor the delayed performance to the immediate test. Error bars represent ± 1 SE.

(Figure 2B). This was supported by a main effect of Group, $F(2, 73) = 9.34$, $p < .001$, $\eta_p^2 = .20$. Post hoc independent-samples *t* tests confirmed that group differences were driven by higher test scores for exercise breaks compared to non-exercise breaks, *Cohen's* $d = 1.1$; $t(47) = 4.07$, $p < .001$, and no breaks, *Cohen's* $d = 1.2$; $t(51) = 3.90$, $p < .001$, with a large magnitude of effect. Test scores for the non-exercise breaks and no breaks groups were not significantly different from each other, $t(48) = 0.25$, $p = .81$.

An ANCOVA was conducted to determining whether differences in learning on the immediate test emerged at different points of the lecture across groups (controlling for baseline differences in learning from Lecture Part 1). There was a main effect of Group, $F(2, 73) = 4.82$, $p = .011$, $\eta_p^2 = .12$, as previously revealed by the omnibus ANOVA reported above. Importantly, there was no effect of Time, $F(1, 73) = 0.93$, $p = .34$, $\eta_p^2 = .13$, or interaction between Group and Time, $F(2, 73) = 0.98$, $p = .38$, $\eta_p^2 = .26$.

Spearman's correlations (Table 4) revealed that heightened physiological arousal from exercise was associated with learning as assessed by both immediate and delayed tests but was only associated with on-task attention near the end of the lecture as

Table 3
Descriptive Statistics for Untransformed Learning Outcomes

	Exercise breaks	Non-exercise breaks	Control
Immediate learning	.51 (.05)	.44 (.10)	.43 (.13)
Lecture Part 1	.51 (.13)	.49 (.16)	.42 (.16)
Lecture Part 2	.55 (.19)	.42 (.17)	.49 (.19)
Lecture Part 3	.49 (.12)	.40 (.13)	.39 (.16)
Delayed learning	.50 (.10)	.42 (.12)	.42 (.10)

Note. Table 3 provides a breakdown of learning outcomes by lecture part for immediate learning. Delayed learning was not assessed by lecture part because of the time delay between lecture exposure and testing, which would have confounded meaningful interpretations of the association between on-task attention and lecture learning. Learning is represented by proportion correct on the learning assessment. Parentheses denote standard deviation.

Table 4
Spearman's Correlations Following Exercise Breaks With Measures of Attention and Learning

	Attention			Learning	
	Baseline	T1	T2	Immediate	Delayed
Arousal					
HR1	.09	−.03	.22	.28*	.39**
HR2	.03	−.003	.27*	.33**	.39**
HR3	−.05	−.04	.32**	.30**	.44**

Note. Time 1 (T1), Time 2 (T2).
$^*p < .05$; $^{**}p < .01$.

Table 5
Subjective Perception Ratings

	Exercise breaks	Non-exercise breaks	No breaks
Interest	5.2 (1.1)	4.8 (1.3)	4.4 (1.2)
Engagement	4.6 (1.0)	4.1 (1.2)	4.1 (1.2)
Narrator clarity	5.7 (1.0)	5.1 (1.1)	4.8 (1.2)
Difficulty	4.4 (1.1)	4.7 (1.3)	4.2 (1.2)
Understanding	4.6 (0.9)	4.0 (1.0)	3.8 (1.3)

Note: Mean perceived interest, engagement, narrator clarity, difficulty and understanding ratings across conditions using Likert scale 1–7. Higher values indicate greater endorsement. Parentheses denote standard deviation.

revealed by a significant correlation with mind-wandering question at Time 2. There were no significant correlations between attention and learning, all $p > .3$.

Subjective Perception

Main effect of group was found for narrator clarity, $F(2, 64) = 4.01$, $p = .02$, $\eta_p^2 = .11$, and perceived understanding, $F(2, 64) = 3.49$, $p = .037$, $\eta_p^2 = .10$ (Table 5). Post hoc independent-samples t tests revealed that the exercise breaks group perceived the narrator to be clearer than the no breaks group, $t(46) = 2.77$, $p = .008$, and their own understanding to be better than both non-exercise breaks group, $t(37) = 2.19$, $p = .035$, and the no breaks group, $t(46) = 2.49$, $p = .017$. There were no group differences with respect to perceived difficulty, interest, or engagement.

Discussion

The present study demonstrates the benefits of exercise breaks on attention and learning using authentic course materials with university students. Incorporating exercise breaks improved on-task attention and memory for lecture material compared to non-exercise breaks or no breaks. Furthermore, subjective perception ratings suggest that learners who received exercise breaks found the lecturer and lecture material easier to understand than learners who received no breaks.

This is the first study to demonstrate that the benefits of exercise breaks on learning extend to older students. Although consistent with prior findings with elementary school children (Janssen et al., 2014), an important difference is that children's off-task behavior is typically more overt through actions such as fidgeting (Ma et al., 2014; Mullender-Wijnsma et al., 2016) compared to that of a trained adult learner who is more accustomed to proper classroom etiquette. The mind-wandering questions used here provided a window into the covert off-task behavior of university students (Wammes, Boucher, et al., 2016). Despite age differences in the manifestation of off-task attention, the results suggest that exercise breaks improved attention and memory for these older learners as well.

On-task attention declined as the lecture progressed, but only for the *non-exercise* and *no breaks* groups. The *exercise breaks* buffered against declines in attention resulting in superior engagement during the latter part of the lecture compared to the other two groups. Although this suggests that exercise breaks may not necessarily result in a direct boost for on-task attention, the exercise breaks did seem to be beneficial for learning by mitigating otherwise natural reductions in attention as lecture length increased. This finding has important implications for the integration of exercise breaks into classroom, workplace, and training contexts suggesting that the greatest benefit of exercise breaks is for long-duration learning or work sessions during which attention becomes increasingly depleted (Wammes, Boucher, et al., 2016).

This study underscores how connections between brain and body physiology affects complex cognitive function. Spearman's correlations showed that physiological arousal was associated with both on-task attention at the end of the lecture and learning as assessed by both immediate and delayed tests. This finding lends support for the HPA activation hypothesis, with exercise-induced arousal facilitating the release of stress hormones known to improve attention and memory (McEwen, 2007). While engaging minds through classroom learning, study, and practice is a direct route to promoting academic performance, physical exercise may augment these processes. Collectively engaging both the body and the mind during classroom learning may have a direct positive impact on attentional fortitude and educational outcomes.

An interesting observation was that non-exercise breaks did not provide additional improvement in attention or memory over having no breaks at all. Although this is in line with our hypothesis that heightening physiological arousal from exercise is a key component in the initiation of refocused attention and learning, it is possible that other non-exercise breaks may be equally beneficial through alternative mechanisms. One possibility is that the computer game played during the non-exercise break may have acted as a second cognitive task as opposed to a cognitive break. Switching between two cognitive tasks can deplete attention and impair performance for both tasks (Rogers & Monsell, 1995; Wylie & Allport, 2000); thus, alternating between the lecture and the cognitive game may not be equivalent to other non-exercise breaks that are not as cognitively demanding, such as mindfulness meditation (Lutz, Slagter, Dunne, & Davidson, 2008; Semple, 2010). There is also some evidence that including low-stakes quizzes during a lecture can reduce mind wandering and boost performance (Szpunar et al., 2013), thus offering an alternative method for promoting attention and learning distinct from exercise breaks.

Another alternative explanation is that the change in context that was specific to the exercise breaks group (i.e., completely moving away from the computer screen) may be a key contributor to helping learners sustain their attention and improve their comprehension rather than physiological changes due to exercise. A non-exercise breaks condition that alters the break context so that attention is removed from the learning environment (i.e., computer screen) but is also non-exercise in nature would evaluate this alternative hypothesis. Identifying non-exercise breaks that could produce similar attentional and learning gains would have a practical benefit for students or learning environments under which physical exercise may be restricted. Furthermore, the study's findings have the potential to inform the structure of massive open online courses (MOOCs) that require students to view extended video lectures on a computer screen. Perhaps breaking up content delivery with prompted short exercise breaks will foster learning in both the classroom and online environments.

While this study provides an important step toward understanding how exercise breaks improve attention and learning in an academic setting, there are limitations which warrant further study. It may not be feasible to perform these exercises in all university lectures, especially classrooms with space restrictions. Future research should evaluate whether exercises that require less physical space can generate similar attention and learning benefits. Also, determining the optimal dose of exercise break (e.g., 1, 2, 3 breaks) and the interaction with lecture duration (e.g., 1-hour class, 3-hour class) will be essential for incorporating exercise break prescriptions into the educational curriculum. Although mind-wandering questions are the principle research tool for capturing state attention, the limitation of this introspective measure must be acknowledged. Furthermore, this sample consisted of more females than males. Although sex may impact the effect of exercise on physical outcomes (Hands, Parker, Larkin, Cantell, & Rose, 2016), there is no evidence to suggest that sex would alter the impact of exercise on these cognitive outcomes in young adults (Hülya Aşçı, 2009).

In conclusion, this is the first study to demonstrate the benefits of exercise breaks on learning extend to older students by inducing a state of physiological arousal promoting on-task attention and memory. Engaging students in physical exercise breaks during classroom instruction may promote their ability to optimally engage their attentional resources and thus become better learners.

Conflict of Interest Statement

The authors declare no conflict of interest.

Author Contributions

All authors contributed equally to the generation of ideas, experimental design, analysis, and reporting. KL led data collection.

Appendix 1.

Subjective Perception Measures

Please rate your agreement with the following statements based on the scale indicated:

1 = absolutely disagree
2 = mostly disagree
3 = somewhat disagree
4 = neutral
5 = somewhat agree
6 = mostly agree
7 = absolutely agree

Perceived Interest

1. I found the material presented in this lecture to be interesting
2. The material captured my interest

Perceived Understanding

1. I found that the presentation style helped me to understand the lecture material
2. I found that I had a meaningful understanding of the material overall

Perceived Narrator Clarity

1. The narrator clearly communicated the material
2. I understood what the narrator was saying with minimal effort

Perceived Difficulty

1. The lecture material has a high level of difficulty
2. The information was difficulty to understand

Perceived Engagement

1. I found the lecture engaging
2. The lecture captured my attention

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