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Research Article

Exercising Before Learning Enhances Long-Term Memory for Foreign Language Vocabulary and Improves Mood

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ABSTRACT

It is well documented that exercise plays a critical role in maintaining physical health. More recently, a growing body of research has begun to focus on the mental benefits of exercise ranging from reducing depression to enhancing various cognitive abilities like memory and attention. These abilities are paramount for learning to occur, and thus, exercise has the potential to facilitate and enhance the learning experience. To further this line of research, a within-subject study was conducted that analyzed the effect a short bout of exercise before learning a set of English phrasal verbs (PVs) had on both short- and long-term memory retention. In addition, a Japanese version of the Positive and Negative Affect Schedule (PANAS) questionnaire was used to measure the effect exercise had on mood. Using a pre- post and delayed posttest design, participants (N = 37) took part in two different learning conditions, a sedentary condition (sitting and reading) and exercise condition (treadmill walking) before learning a set of PVs. Using a paired samples t-test, results show that exercise does not improve short-term memory of PVs, but has a small-to-medium positive effect on long-term memory of PVs. Moreover, exercise had a strong positive effect on mood. In sum, this study supports the view that exercise enhances the encoding of new information into long-term memory and improves the wellbeing of the individual.

Keywords: physical exercise, memory, cognition, learning, phrasal verbs

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INTRODUCTION

Exercise plays a critical role in the physical health of the individual, warding off such diseases as type-2 diabetes (Sanz et al., 2010), stroke (Kernan et al., 2014), colon cancer (Devin et al., 2019), and postponing mental decline associated with ageing (Yaffe et al., 2009), and thus has numerous survival advantages (see Chakravarty et al., 2008). However, the impact exercise has on learning is less understood. The design of classrooms with many desks aligned in rows typically supports a sedentary learning style where learners usually remain seated for the extent of the class period. Moreover, the learning of a foreign language (hereinafter, L2) prioritizes sedentary behavior with the learners focused on a task at hand, which could be a reading, speaking, or conversation task, and the body plays at best a marginal role in the learning endeavor. It should be noted that this is not always the case. Total physical response (TPR) (Asher, 1966) developed in the 1970s focused on coupling language with action whereby the learner performed the action using movement (e.g., "wipe the table"). More recently, language teachers have also used embodied learning (Birdsell, 2021) to increase opportunities to pair language with action as well as drama-based learning approaches (Kalogirou et al., 2019). Nonetheless, learning and specifically language learning is still widely perceived as a cognitive process, involving thought, memory, and creativity, and physical movement is often perceived as a distractor, rather than a facilitator of them. Yet, over the past couple decades, a growing body of research has begun to focus on the mental benefits of exercise, and this includes both reducing depression (Kvam et al., 2016) and enhancing various cognitive abilities such as creativity (Aga et al., 2021), attention (Liu et al., 2020), and memory (Coles & Tomporowski, 2008; Labban & Etnier, 2011; Schmidt-Kassow et al., 2014).

This study expands this line of research by examining the effect physical exercise has on the learning of vocabulary in an L2 as well as its impact on the positive and negative affect of study participants.

The outline of this paper is as follows. In the first section, I review research on physical exercise and how it has been studied within an experimental setting. Then, I discuss a growing body of research that highlights the link between physical exercise and various cognitive functions like memory, creativity, and language. Finally, I provide an outline of the present study. In the subsequent sections, I describe the methods and the results, and finally discuss the findings along with limitations and practical applications.

LITERATURE REVIEW

Physical Exercise

Physical activity involves any form of movement made by the skeletal muscles that uses energy while physical exercise (PE) is a subcategory of physical activity that is planned and structured with the goal of improving or maintaining physical fitness (World Health Organization, 2010). As a construct to be used in research, PE may vary on a number of factors such as duration, frequency, intensity, and type of activity. For example, some studies have used treadmills (Hillman et al., 2009; Schmidt-Kassow et al., 2014) and others cycling machines (Aga et al., 2021), as the type of PE activity. The intensity of PE in research is usually measured by a certain percentage of the estimated maximum heart rate (HR). This is commonly measured using the following equation, HR_{max} = [208 – 0.7 x age] in healthy adults (Tanaka et al., 2001), so for 20-year-old university students this is 194 beats per minute (BPM). If the goal is to reach 60% estimated HR_{max}, as indicated in the Hillman et al. (2009) study, this would result in roughly 116 BPM. However, the intensity level of PE varies widely between each study, and some have also used high intensity or anaerobic exercise like sprinting as the intervention (lactate levels greater than 10 mmol/l) (Winter et al., 2007). As for frequency, this also varies between studies based on whether it uses a single acute bout of PE, usually with a duration of 15–20 min or some form of chronic PE intervention that continues over a certain amount of time. In short, using PE as a variable in research may differ on a number of factors as noted above.

Physical Exercise and Cognitive Function

Narrative (Loprinzi et al., 2017; Tomporowski, 2003) and large meta-analytic reviews (Chang et al., 2012; Loprinzi et al., 2019; Roig et al., 2013) have confirmed the positive effect PE has on a variety of cognitive functions. For example, Roig et al. (2013) reviewed 29 studies that investigated the effect of acute cardiovascular interventions on memory and found that it had a moderate effect on short-term memory (standard mean difference [*SMD*] = 0.11), and moderate to large effect on long-term memory (*SMD* = 0.52). Moreover, Ludyga et al. (2016) reported in a meta-analysis that a single bout of moderate aerobic exercise improves working memory in pre-adolescent children and older adults. The memory tests used in these studies vary considerably such as an associative vocabulary learning task (Winter et al., 2007), a verbal memory task (Salas et al., 2011), and a face-name matching task (Griffin et al., 2011).

There are a number of physiological factors that may play a role in the enhancing effect of physical exercise on cognitive functions. First, cardiovascular fitness is associated with modifications in hippocampal volume, even into late adulthood (Erickson et al., 2011), and improves hippocampal function (Griffin et al., 2011). The hippocampus is a subcortical structure of the brain located in the medial temporal lobe, and is important for learning as it is involved in the encoding and consolidation of memories. In a recent meta-analysis, Firth et al. (2018) looked at different types of exercise (e.g., stationary cycling, walking, etc.) and found that aerobic exercise was associated with significant positive effects on hippocampal volume in comparison to control conditions. Moreover, greater hippocampal volume has been shown to enhance academic performance of children (Esteben-Cornejo et al., 2021). Secondly, a bout of exercise increases the volume and velocity of cerebral blood flow to the brain, which improves cognitive performance in such domains as creativity (Chavez-Eakle et al., 2007). Thirdly, exercise has the potential for creating optimal situations for neuronal plasticity by increasing neurotrophic factors like brain derived neurotrophic factors (BDNF), and thus plays an important role in memory formation (Etnier et al., 2016; Loprinzi & Frith, 2019). Increasing BDNF through exercise can slow the natural process of hippocampal atrophy, resulting in improved memory (Erickson et al., 2012). The hippocampal anatomy declines with age, increasingly as we get older (Fjell et al., 2009; Fraser et al., 2015) and reductions in hippocampal size has a detrimental effect on verbal and non-verbal episodic memory performance (Gorbach et al., 2017). Finally, a growing body of research has begun to focus on how neuroplasticity induced by aerobic fitness is not limited to the hippocampus, but improves the functional connectivity of larger distributed networks related to executive function (frontoparietal network), attention and learning (dorsal/ventral attention networks), and memory (default mode network) (Knaepen et al., 2010; Talukdar et al., 2018). This further indicates the malleability of the brain and shows how PE plays a crucial role in optimizing cognitive function.

Foreign Vocabulary Learning as a Cognitive Task. Learning vocabulary in an L2 is a demanding cognitive task that requires both attention and memory skills. In English, phrasal verbs (PVs) consist of a verb and a particle, such as "break out" and "work out." They are highly frequent in the English language, distinctly polysemous, and may range widely in their degree of idiomaticity (Gardner & Davies, 2007; Thim, 2012). Their high frequency in the English language makes them important vocabulary for learners. For example, the *Cambridge Phrasal Verbs Dictionary* provides the user a list of 6000 phrasal verbs in the English language while others estimate that there is one PV in every 150 words of English (Gardner & Davies, 2007). However, the high frequency of them in the language along with their polysemous and idiomatic nature make them notoriously difficult for foreign language learners and many learners simply avoid them altogether (Liao & Fukuya, 2004; Siyanova & Schmitt, 2007).

In order to tackle this issue, researchers (e.g., Birdsell, 2021; Condon, 2008) have extensively studied PVs in the L2 context, mainly by way of analyzing the effectiveness of different teaching approaches. For example, Birdsell (2021) had three groups of participants learn a set of PVs under three different learning conditions: (1) PVs with mother tongue (L1) translation, (2) PVs with corresponding images that conveyed their meanings, and (3) PVs with videos of students enacting the meaning of them. Participants across all three groups statistically improved their scores on a posttest, but findings also suggest that watching people enact the meaning of them was more effective than learning them through L1 translations. Such a study shows the importance of the body for learning vocabulary and reflects a growing field of research in education that examines the role movement has on learning (see Macrine & Fugate, 2022). However, this line of research usually examines movement that is congruent with meaning (e.g., enactment and gestures). In contrast, research that looks specifically at the effect of exercise before learning a set of PVs, as far as the author knows, has not been previously done. Therefore, PVs have the potential to be good material as a cognitive task to measure vocabulary retention in a study that examines the impact exercise has on memory.

Physical Exercise and Positive Affect

With regard to positive affect and PE, this has been well known since the time of Hippocrates. He is often credited with saying, "if you are in a bad mood, go for a walk." Recent research demonstrates that a simple two-week running intervention can reduce depression-related symptoms (Fink et al., 2021). There is an abundance of literature reviews confirming the psychological benefits of physical exercise on quality of life and mood (e.g., Mandolesi et al., 2018; Penedo & Dahn, 2005). Runners have been well aware of this phenomenon for some time, calling it "runner's high" – a euphoric state of elation and happiness. For a while, this was attributed to the increase secretion of β-endorphins during exercise and thus appropriately called the endorphin hypothesis (Moore, 1982; Thorén et al., 1990) and made a long-lasting impression within mainstream culture. However, due to a number of issues with this view (e.g., blood-brain barrier; endorphins are produced in the blood and cannot pass through into the brain), researchers began to look for other explanations, and one current theory proposes that the positive mood from exercising comes from endocannabinoids (Dietrich & McDaniel, 2004). Endocannabinoids are endogenous lipid messengers that produce psychological rewards, such as reducing anxiety and higher feelings of overall wellbeing as well as improving memory (Piomelli, 2003). Others also point out that physical exercise increases levels of serotonin (Korb et al., 2010; Young, 2007), an important neurotransmitter for regulating mood. Why exercise enhances mood is still not fully understood. However, as indicated in a recent meta-analytic review (Buecker et al., 2021), physical activity is widely accepted as enhancing positive affect and is important for overall wellbeing. Over the past decade, wellbeing has also become an important factor in education, particularly from the approach of positive psychology. Proponents of this approach (e.g., Seligman et al., 2009) suggest when learners experience positive wellbeing, their motivation and overall success in school improves.

Nonetheless, there are still a number of unknowns regarding other variables that may influence the positive effect that exercise has on wellbeing. For example, does the setting and method impact this positive affect? In other words, does walking on a treadmill inside still contribute to improving mood? This is important to consider based on two points. Firstly, being in nature also has a positive impact on mood (McMahan & Estes, 2015) and exercise commonly occurs outside, so being in nature could have a confounding effect. Secondly, the treadmill historically was invented as a rehabilitation device for prisoners to suffer and sweat (Shayt, 1989) and thus again brings to question whether the method of exercise (e.g., freely walking on a path and treadmill walking) has an impact on mood and one's wellbeing. In short, exercise has a positive effect on mood, but still a number of questions remain on this topic.

Finally, measuring affect or one's emotional state usually relies on self-report questionnaires. One of the most widely used scales is the 20-item Positive and Negative Affect Schedule (PANAS) (Watson et al., 1988). Ten items measure positive affect (e.g., interested, excited) and the other 10 measure negative affect (e.g., distressed, irritable), and the questionnaire uses a 5-point Likert scale (ranging from 1 – *very slightly or not at all* to 5 – *extremely*) to measure affect within a certain context. In addition, a Japanese version has been developed and tested and shown to be reliable (Kawahito et al., 2011).

The Present Study

Formal teaching methodologies that use movement as a way to enhance L2 learning have been around at least since the 1970s, such as TPR (see Asher, 1966). Recently, work in the neurosciences has empirically supported such an approach for teaching (García et al., 2019). In addition, research from the L2 classroom has also confirmed the benefit of movement as a way to facilitate the learning of vocabulary either through gesture (Macedonia, 2014; Morett, 2014) or simply watching others enact the meaning of the words (Birdsell, 2021). These studies look at when the language is paired with congruent action. However, few studies (e.g., Schmidt-Kassow et al., 2014) have examined the relationship between a single, acute bout of physical exercise and learning vocabulary in an L2 and this study aims to fill this gap. Therefore, the research questions (RQs) investigated in this study are:

- RQ1: Does a short bout of physical exercise by Japanese university students before learning a set of English phrasal verbs enhance the learning of them?
- RQ2: Does physical exercise improve their mood?

METHOD

Research Design

A number of factors influence the design of a study that investigates the effect exercise has on a cognitive task, such as the age of the participants, type of intervention (a single bout of exercise or long-term exercise), the intensity and type of exercise (high to low intensity; treadmill, cycling and other cardiovascular forms of exercise or strength training exercise), the timing of the exercise intervention (before, during, or after the cognitive task), and deciding what cognitive ability (memory, creativity, or language) and how to measure this ability. In this study, it was decided to have participants perform a single bout of moderate exercise lasting 20 min before the learning session. The 20 min time slot has been used in previous studies (Hillman et al., 2009), and exercising before memory encoding has been suggested to be the optimal time (Labban & Etnier, 2011). The target cognitive ability used as the measurement during this learning session was a set of phrasal verbs in English, an L2 for the participants. Phrasal verbs are notoriously difficult for L2 learners due to them being highly polysemous and metaphorical and thus deemed as appropriate material to use in order to measure L2 vocabulary learning.

Participants

A total of 39 Japanese university students (M_{age} = 19.78; range: 18–26; female = 19) participated in this study. They came from all faculties and schools of the university (Humanities and Social Sciences, Education, Science and Technology, Agriculture and Life Science, Health Science, and Medicine). They were recruited through flyers and posters. The study was conducted at two different time periods; one at the end of the second term (February) of the 2021–2022 academic year and the second during the first term (June) of the 2022–2023 academic year. Participants received renumeration as decided by the university for their participation (1,000 yen/hr). The experiment was approved by the Faculty of Education Ethics Review Board at Hirosaki University. All subjects were informed about the aims of the study and gave their written consent and could withdraw from the study without any penalty (in total, two withdrew after the first meeting due to scheduling conflicts, so a total of 37 completed all four sessions). All participants were native Japanese speakers and had at least 6 years of formal English education. Their present English level and their physical fitness level were not criteria for inclusion in this study. Their English level was not assessed at the start of the research. Their level of fitness and health was assessed by using an adapted Japanese version of the International Physical Activity Questionnaire (Craig et al., 2003), a self-reported activity measurement. On average, the participants reported engaging in 3.16 days (range: 0–7) of moderate or vigorous exercise for on average 39 min (range: 0–180 min). Figure 1 shows the wide range of physical activity of the participants in this study ranging from those who are highly active to those who are non-active throughout a given week.

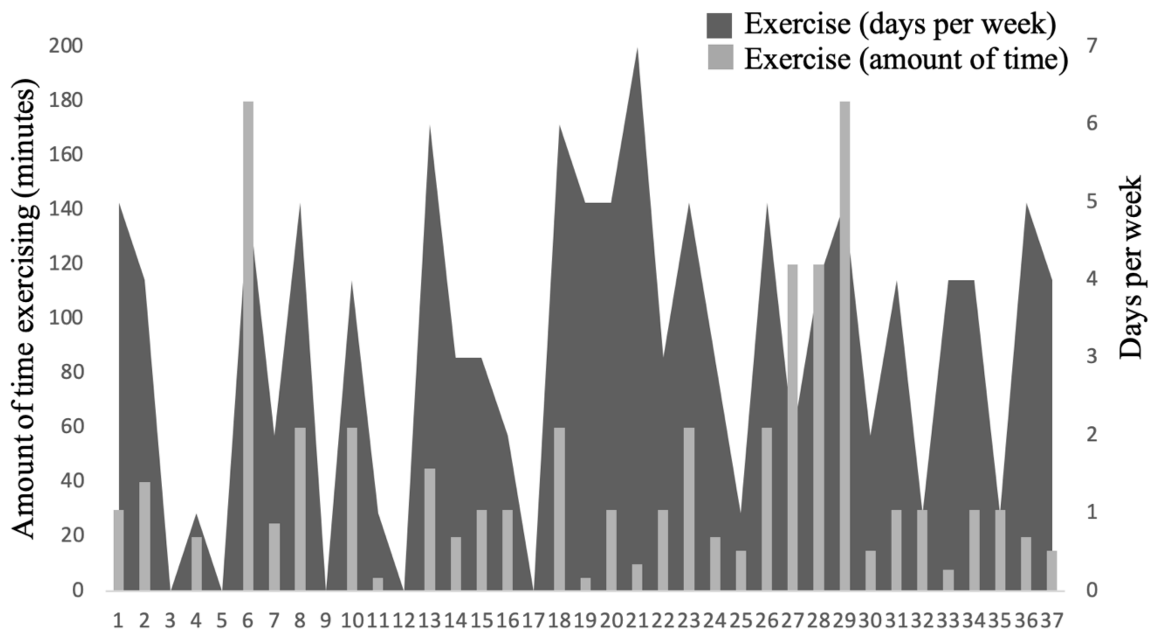
Materials

An English PV test was developed for this study to use as the dependent variable. In total, this test consisted of 40 items that were then further divided into two 20-item sets used as the material for the teaching interventions for the two conditions. Each set consisted of seven verb stems (e.g., hand, break) that made up the 20 PV items (e.g., hand out, break down) (see Appendix for the full list). The test did not use multiple choice, to avoid the possibility of guessing, and instead used a style based on previous studies with PVs (see Birdsell, 2021; Garnier & Schmitt, 2016) where participants are presented with a sentence (the context) and then the first letters for the PV and a definition of it in parenthesis at the end of the sentence. The participant then had to type in the correct answer. They were also informed not to guess, but to leave it blank if they did not know the answer. Below is an example item from the PV test with the answer "hand out."

- *A number of years ago, she decided she would h___ o___ free books to all the children in her home county in Tennessee. (give, distribute)*

In addition to measuring performance on an L2 vocabulary test, a questionnaire to assess participants' current mood using the Japanese version (Kawahito et al., 2011) of the 20-item PANAS (Watson et al., 1988) was used in this study. Adequate reliability and validity of the original and Japanese versions of PANAS have been confirmed with good internal reliability for positive items (Cronbach's α = 0.86) and negative items (Cronbach's α = 0.89) (Kawahito et al., 2011). Moreover, Kawahito et al. (2011) produced the same two factors (positive and negative affect) as the original, where the positive items correlated with measures for happiness and satisfaction while the negative items correlated with depression. This questionnaire was used to measure the emotional state of the participants at two different times – one after sitting and reading and one after walking on the treadmill.

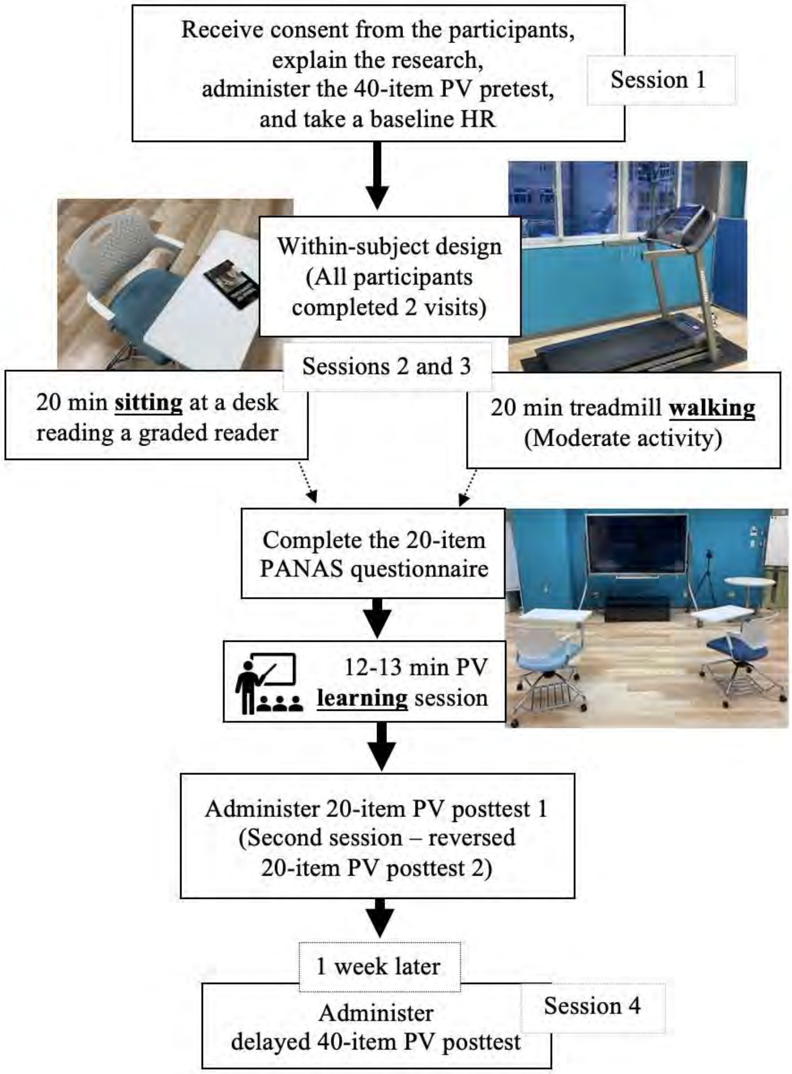
Figure 1. *Weekly Amount of Physical Exercise by the Participants (N = 37) in This Study*



Procedure

The participants came to the lab four separate times. In the first session, they participated in one pre-experimental evaluation session where they signed the consent form, which explained the purpose of the study. They took the 40-item PV pretest to measure their current knowledge of the phrasal verbs used in this study, and finally scheduled the next two sessions. During the next two sessions, they came to the lab in pairs, at a time they had chosen to either first walk on a treadmill, or to sit and read a book. So, half did the treadmill walking before the learning intervention for Session 2, and the other half did the sitting/reading before it. Then, for Session 3, these roles were reversed. For the treadmill condition, participants walked for 20 min at a moderate speed (on a Horizon treadmill TR3.0 at 50–60% of their estimated HR_{max}), walking for a total distance of 1.7 to 2.1 km depending on the fitness of the individual. For the sitting/reading condition, the participant sat in an adjoining room at a desk and read a graded reader in English (Lewis Carol's *Through the Looking Glass*) also for 20 min. Immediately afterwards, the paired participants sat together in the same room and completed the Japanese version of the PANAS. Next, they watched a 12–13 min PowerPoint video recording of the researcher presenting Set 1 (20 items) of the PVs on a Big Pad (Sharp PN-L702B, 70-inch LCD Panel, 1538.9 x 865.6 mm, 1920 x 1080 pixels). Then, they took a PV test to measure short-term memory (STM). During the next session, the roles were reversed and they learned Set 2 (20 items) of the PVs. Finally, after one week, for the fourth session, all the participants took a delayed posttest consisting of the complete 40-item PVs to measure long-term memory (LTM) retention of the PVs (see Figure 2 for the schematic representation of the study design).

Figure 2. *Schematic Illustration of the Study Design*



Note: PV (phrasal verbs), HR (heart rate).

Statistical Analysis

The statistical analysis was conducted with SPSS (Statistical Package for Social Sciences) (Version 27.0) (IBM, 2020). As a within-subject study, paired samples *t*-tests were conducted to compare the differences between the individual scores after completing the two different conditions. To measure STM, the pretest score was compared with the posttest score (taken immediately after the learning session). To measure LTM, the pretest score was compared with the delayed posttest score (taken a week later). To measure the effect of exercise on mood, using data collected from the PANAS at two different times (after the sitting/reading, herein referred to as the "sedentary" condition and after the treadmill walking, herein referred to as the "exercise" condition), the individual scores for positive affect and negative affect were aggregated into two scores and then were compared using a paired samples *t*-tests.

RESULTS

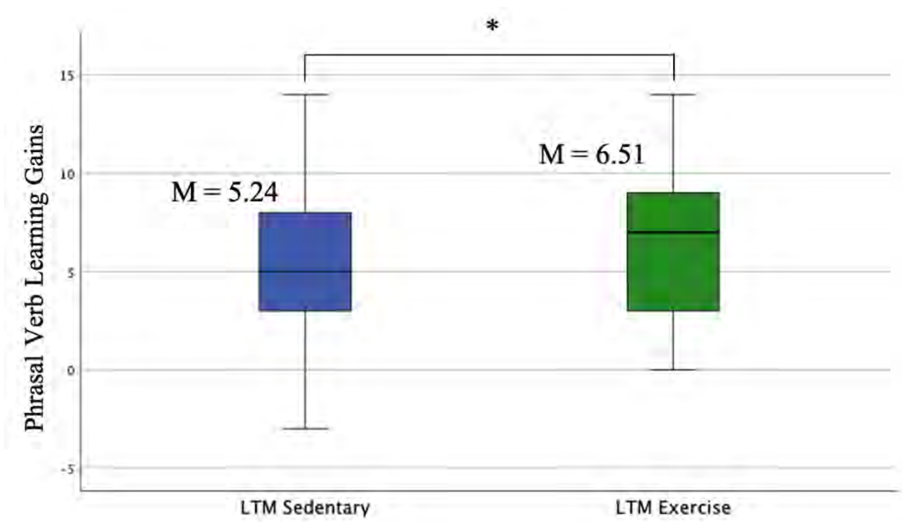
Vocabulary Learning: Short- and Long-Term Memory

Based on the Shapiro-Wilk test, the variables for measuring learning gains in short and long-term memory for the different conditions (sedentary and exercise) were normally distributed. To obtain these variables, first, the 40-item pretest scores were divided into Session 2 and Session 3 scores based on the 20-items for these learning sessions. Next, the pretest scores were subtracted from two 20-item posttest scores to provide two short-term memory learning gains (sedentary and exercise conditions). A paired samples *t*-test was conducted to analyze the difference between the two conditions, sedentary (M = 9.03, SD = 2.96) and exercise (M = 9.57, SD = 3.45), $t(36) = 0.86$, $p = 0.393$, 95% CI [-0.73, 1.81]. So, for short-term memory, there was no statistical difference in the learning gains between being sedentary and exercising before the learning sessions. The same procedure was done with the delayed posttest scores to analyze the difference between the two conditions, sedentary (M = 5.24, SD = 3.66) and exercise (M = 6.51, SD = 3.63), $t(36) = 2.24$, $p = 0.032$, $d = 0.37$, 95% CI [0.12, 2.42] on long-term memory (see Figure 3). Thus, for long-term memory, exercising before learning showed significantly higher scores compared to being sedentary with a small to medium effect size based on Cohen's *d*. Figure 4 shows the distributed scores among the participants for long-term memory gains. It should be noted that two participants in the sedentary condition actually decreased their scores. In total, 20 participants had higher language gains after excising, 13 participants had higher gains after being sedentary, and four were even between the two conditions (see Figure 4 for the complete set by the participants). So, to answer RQ1, a short bout of exercise by Japanese university students before learning a set of English phrasal verbs enhances the learning of them, but only for long-term memory.

Mood

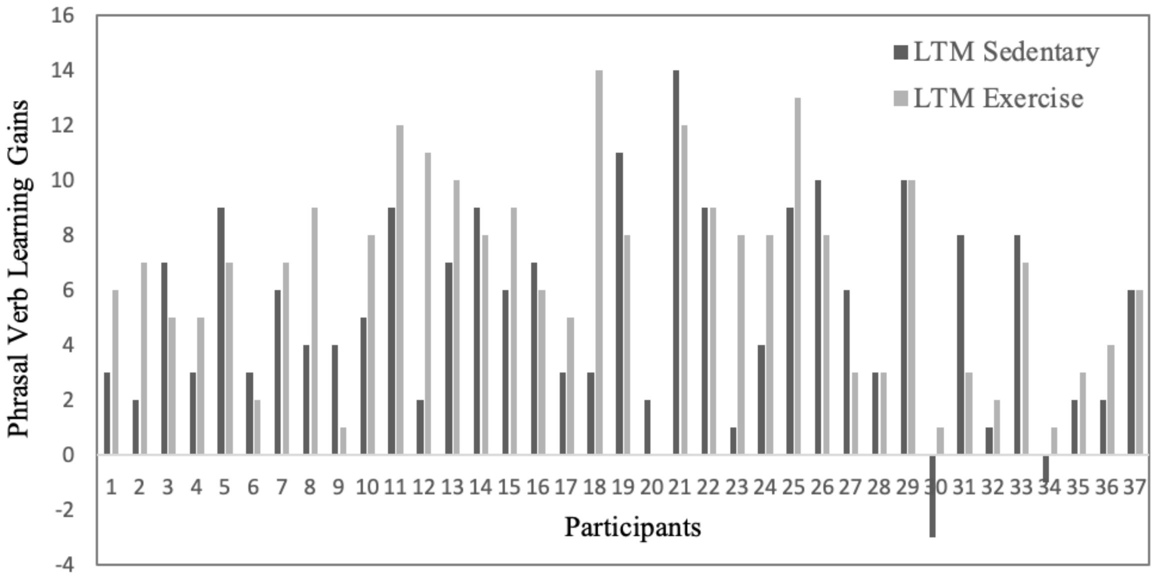
The 20-item PANAS questionnaire has 10 items for positive affect and 10 items for negative affect. These 10 items were aggregated to produce a single score for each emotional state. Two paired-samples *t*-tests were conducted to compare positive and negative affect of the participants for the two conditions. For positive affect, there was a significant difference in scores for the exercise (M = 33.49, SD = 12.16) and sedentary (M = 22.92, SD = 7.44) conditions, $t(36) = 6.51$, $p = 0.00$, $d = 1.01$, 95% CI [7.08, 14.05]. Thus, after exercising, the participants showed significantly higher scores for positive affect compared to after being sedentary with a large effect size based on Cohen's *d*. On the other hand, for negative affect, there was not a significant difference between these two conditions; exercise (M = 13.62, SD = 4.68) and sedentary (M = 14.73, SD = 4.54), $t(36) = -1.22$, $p = 0.23$, 95% CI [-2.95, 0.74]. To answer RQ2, exercise strongly improves the overall mood of the student participants by increasing their positive affect, but it does not have any effect on negative affect.

Figure 3. *Boxplot of Learning Gains for LTM in Both Conditions*



Note. *$p < 0.05$. LTM (long-term memory).

Figure 4. *Distributed Scores for the Learning Gains for LTM in Both Conditions*



Note. LTM (long-term memory).

DISCUSSION

The current study investigated whether L2 vocabulary learning is affected by acute PE prior to the learning intervention and how PE affects mood. To answer RQ1, the results provide evidence that exercising prior to learning has a beneficial effect on long-term memory, but not for short-term memory. This partially confirms findings from recent meta-analyses that compiled studies across different types of cardiovascular exercise (acute, long-term), exercise interventions (walking, running, cycling), intensity (light, moderate, intense), and memory tasks (visual-auditory, visual-spatial) and found that exercise had a small to moderate effect on memory (Chang et al., 2012; Roig et al., 2013). As noted by Roig et al. (2013) and others (Kramer et al., 1999), the relationship between exercise and cognition is a complex one. Better understanding this relationship is worth further investigating since long-term memory is essential for L2 learning. Having a depth and breadth of vocabulary knowledge in the L2 is obviously crucial for reaching fluency and some estimates suggest that knowledge of the most frequent 5,000 words and overall knowledge of 8,000 to 9,000 words is required to reach the highest levels of fluency and understanding in English as a foreign language (Nation, 2006).

Moreover, the dangers of being sedentary are well known, often resulting in chronic diseases (heart disease, type-2 diabetes) and premature death and has a high economic cost on society (Sallis, 2009). Blair (2009) even suggests that inactivity is one of the most prominent public health problems of the 21st century, and his greatest concern is that "physical activity is undervalued and underappreciated by many individuals in public health and clinical medicine" (p. 1). Physical activity has a similar fate in the field of education where it is often undervalued as a pedagogical means to improving students' cognitive abilities. Nonetheless, this could be changing, as research in the field of embodied cognition (Barsalou, 2008), which emphasizes the grounding of language in the sensorimotor and emotional systems, begins to have an impact on L2 education (see Birdsell, 2020).

Prior research in the field of L2 learning (Birdsell, 2021; Macedonia, 2014) has mainly focused on the coupling of congruent action with the language to enhance the learning of it. This includes using enactment and gestures in the L2 classroom to improve the learning outcomes by enriching the encoding of the words. In other words, Mayer et al. (2015) showed that when one learns vocabulary with movement, as in gestures, this results in better long-term memory retention. Moreover, words that have been learned with gestures also recruit visual and motor cortical areas during the retrieval process, thus strengthening the semantic representation for them (Mayer et al., 2015). The current study expands this line of research and suggests that action alone, as in, physical movement before the learning has the potential to enhance learning outcomes. What this indicates is that the body is more deeply connected to cognition than previously assumed. These two types of learning processes are quite different. For example, when learning with gesture or enactment the added motor information deepens the encoding of the learning event. However, PE before the learning event increases attention (Liu et al., 2020), and these attentional resources are crucial for working memory. A growing body of research in the field of second language acquisition (SLA) has theorized the impact working memory has on L2 speech performance and overall L2 aptitude (Wen & Skehan, 2011). Therefore, movement before learning could be beneficial from an attentional perspective. Empirical studies that have examined the benefits of physical movement for L2 learning are limited and mainly come from research in the laboratory (e.g., Schmidt-Kassow et al., 2014). However, research has looked at other forms of movement, and this includes studies that had participants do some movement-based activities during the language learning class, such as dance (Hanks et al., 2019) and drama (Rothwell, 2011). Results from these studies show that movement improved memory of the L2 vocabulary, learners had a more positive response to the learning event (Hanks et al., 2019), and increased their interest in it (Rothwell, 2011). This leads to the second RQ concerning how PE impacts mood.

To answer RQ2, results from the data collected during the two research conditions show that PE strongly enhances positive mood in the participants. With regard to this point, the current study contributes two important findings to the literature on the relationship between PE and mood. First, as indicated in the Method section (see Figure 1), participants in this study varied greatly in the amount of physical activity they do on a weekly basis and some even reported doing no activity during the week. This suggests that positive affect improves after doing exercise even within a group of non-athletes, including some highly sedentary people. Walking and long-distance running is something that humans evolved to do ever since we became bipedal and thus are a central part of being human (see Branble & Lieberman, 2004). The question whether it evolved as a form of medicine is highly unlikely (see Lieberman, 2015); however, exercise has the potential to promote wellbeing. A second key finding in this study is that this improved positive affect is not based on other factors, like being in nature since all the participants performed this exercise in a controlled indoor environment. In addition, the gait of the participants was restricted to the treadmill machine, and so they did not have the freedom of movement, as when one is walking on a path. Again, it should be noted here that the treadmill was developed to make prisoners "suffer" (Shayt, 1989), but instead this study shows that in fact it boosts positive feelings. So, in short, this study further supports the wealth of evidence (Buecker et al., 2021) that PE improves the mood of the individual.

From a pedagogical perspective, positive affect facilitates student engagement and acts as a buffer against disaffection (King et al., 2015). This heightened positive affect, as items measured in the PANAS questionnaire, includes being interested, excited, enthusiastic, and attentive, which are all important factors for learning to occur. Such positive emotions broaden awareness through promoting exploratory action, and this broadening effect subsequently builds a repertoire of resources, which include important skills and knowledge that enhance health, survival, and fulfillment (Fredrickson, 1998). Fredrickson (2001) developed this into what is widely known as the broaden and build theory of positive emotions. Interest in the role of positive emotions and language learning has recently grown substantially, mainly anchored within positive psychology. For example, MacIntyre and Gregersen (2012) suggest that positive emotions allow learners to be more aware of the language input and thus absorb the language more effectively. Others (Gregersen, 2013) suggest that positive emotions increase the learners' enjoyment of learning and thus making it more personally meaningful. As a consequence, learners become more resilient when faced with the challenges of learning a foreign language. Positive affect is closely linked to engagement, which refers to the degree a language learner is involved in doing a language learning task (Hiver et al., 2021), and thus, viewed as a key factor to the overall language learning process. Taken together, this study demonstrated that PE before an L2 learning intervention promotes positive affect, which, in turn, has numerous cognitive and emotional advantages to optimize learning.

Limitations and Practical Implications

One limitation of this study is that it did not take into consideration the English level of the participants. In the recruitment material, a certain level of English competence (e.g., score on a standardized test) was not a prerequisite, and therefore students of all levels took part. The material, vocabulary in an L2, favored participants with higher level L2 (English) competencies. Moreover, the learning intervention was completely in the L2 of the participants, and therefore the cognitive load for the lower-level individuals was greater than for the others. High cognitive load has a detrimental effect on the learning task (Sweller et al., 2011). However, since this study used a within-subject design, this likely had a minimal effect on the results. Future research could divide the participants into L2 proficiency levels, and for each level then use different learning intervention materials that are more suitable for the participants' L2 abilities. A second limitation of the study is the small sample size of the participants, and therefore caution is warranted in interpreting the results, and further research is needed to confirm these findings.

There are a number of practical implications of this study. First, with regard to school settings, active breaks involving PE, like a brisk walk performed before executive attention-demanding tasks, such as learning an L2 may facilitate the learning and improve the mental wellbeing of students. This would suggest the need to redesign campuses to make PE more available (e.g., walking tracks, gyms), acceptable as an activity done during the school day (e.g., short PE slots in the schedule), and the necessity to educate students, teachers, and staff to the importance of PE for learning and mental health. However, PE continues to be neglected in schools for a number of possible reasons. First, it is often seen as something restricted for certain types of individuals, "athletes," and not inclusive to everyone. Secondly, schools from secondary to the tertiary levels have a growing sense of pressure to publicly show the success of their students on high stakes tests, often resulting in the reduction of PE activities since there is the perpetual belief that it is something completely uncorrelated with academic performance. However, as indicated throughout this paper, overwhelming evidence has accumulated over the past decade that contradicts this assumption. Moreover, as this study shows PE can enhance learning, and equally important the wellbeing of the students, and many others (e.g., Syväoja et al., 2018) have also shown that greater sedentary behaviors can, in fact, negatively affect academic performance. Yet, it should be noted that caution is warranted since there is still considerable amount of debate and inconsistencies in the evidence (see Donnelly et al., 2016), and further research exploring the relationship between PE and academic performance is needed.

CONCLUSION

This study contributes to a growing body of research that demonstrates the beneficial effects of PE on long-term memory, particularly in this study, for vocabulary learning in an L2. Moreover, it provides strong evidence that PE improves one's mood and overall wellbeing. The idea that movement enhances higher-order cognitive processes, like thought is far from new. Indeed, Aristotle was nicknamed the "Walker" (*peripatētikós*), because he took over a former gymnasium as a place to lecture (Gros, 2014, p. 130). This implies that walking improved his ability to think. However, education like other modes of modern life (e.g., the workplace) has shifted to a sedentary approach to learning, thinking, and working. As indicated throughout this paper, accumulating evidence across a wide range of fields suggests a need to return to the view that physical exercise has a wide range of benefits for learning and thinking. Therefore, it is important to consider ways to more deeply integrate PE into both the academic and office environments and mindsets of the students, teachers, employees, and employers. This will likely have favorable results for both physical and mental health of the individuals. It can also enhance learning.

Author's Contributions

The author alone contributed to all stages of research planning, designing, data collecting, analyzing, interpreting the results, and writing the manuscript reported in this study.

Ethics Approval

This study was approved by the Faculty of Education Ethics Review Board at Hirosaki University.

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APPENDIX

Phrasal Verbs Sets 1 and 2 Used in the Study

Phrasal Verbs: Set 1	hold	hold on hold back hold up
	stand	stand up to stand out
	break	break up break down (not working) break down (destroy something like a wall or door) break out
	put	put up with put off put on
	take	take off (improve) take off (remove an item of clothing) take up
	turn	turn around turn down turn up
	wear	wear off wear down
Phrasal Verbs: Set 2	back	back down back out of (move in backward manner) back out of (withdraw from a commitment) back up
	get	get by get over get up get down
	hand	hand out hand down
	look	look back on look down on look up
	show	show up show off
	fall	fall behind fall for fall apart fall through
	work	work out