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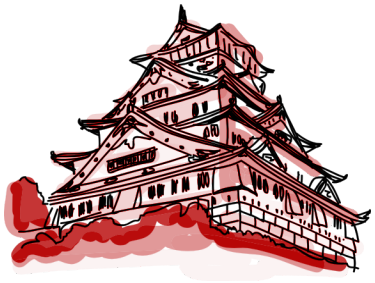

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Hacking the (nervous) system: Using physical activity to enhance reading speed and comprehension in a foreign language

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Abstract

This study investigated the effectiveness of using physical activity as a means of improving reading speed and comprehension in a second language. The treatment group (n = 6) engaged in acute exercise for about 9 minutes twice weekly for 10 weeks. At the same time, a control group (n = 6) spent 9 minutes twice weekly engaged in a placebo activity of keeping an English journal for 10 weeks. After each 9-minute session both the control and experimental group read a timed reading passage and answered ten questions based on what they had read. A test of reading comprehension was used to pre-test and post-test the subjects. No significant score difference was found between the two groups' post-test scores on the reading comprehension test or reading speed after the 10-week intervention, however a significant difference was found between the two groups' reading comprehension scores on the reading passages. The data suggest that acute physical activity has the capacity to improve reading comprehension in a foreign language, but the limit of this potential is uncertain. The discussion considers this ambiguity and examines how some of the issues associated with this small study might be remedied.

Introduction

The ability to read quickly and confidently has been linked to better grades in school (Whitten et al, 2016), future job success (Ritchie & Bates, 2013), and greater overall happiness and wellbeing (Billington et al, 2013). It has also been shown to keep memory and thinking power intact and to help the mind stay young and sharp (Wilson et al., 2013). And yet, reading fluency is a skill that, regrettably, many people lack. Developing it can be a challenge, but with a little practice and a plan, even struggling readers can improve over time.

To be considered fluent, one must be able to read with appropriate speed, accuracy, and expression (Hasbrouck, 2020). Good readers can read (short or) long passages while sustaining their attention, holding relevant information in their memory regardless of whether they are reading for pleasure or academically (Shanahan, 2021). Fortunately, there are a number of methods to assist those experiencing difficulty reading, including: repeated reading, monitored oral reading, reader's theater, and modeling. Another way to improve reading competency is to practice reading faster. This technique was first pioneered by Evelyn Wood in the late 1950s with her Reading Dynamics training program and then applied in foreign language classrooms by Edward Fry shortly thereafter. More recently, Paul Nation and his colleagues at Victoria University of Wellington have raised the bar on what is possible with a speed reading course by creating a series of texts that control for lexis and grammar as a means of fluency development.

For students learning to read in a foreign language (L2), the importance of reading fluency cannot be overstated. The ability to read quickly while maintaining adequate comprehension is a foundational learning skill for most college-level courses and proficiency in reading is beneficial for anyone required to read large amounts of material (Grabe, 2014). This is especially true in settings where higher scores on language proficiency tests (i.e., TOEFL and TOEIC) can lead to scholarships, opportunities to study abroad, and ultimately, to higher paying jobs (ETS, 2022). In addition to extrinsic goals associated with improvement, reading is one of the fastest and most efficient ways for an individual to "take in" information. English, for example, is usually spoken at about 150 words per minute, while an average person can read at about 250 words per minute or faster (Fry, 1963).

Literature review

Developing fluency through speed reading interventions

Interest in the effect timed reading instruction has on fluency continues to grow steadily (Cohen, 2011; Griffith and Rasinski, 2004; Hudson et al, 2005; Skinner et al, 2009). With just a few minutes practice two or three times a week a speed reading course can bring about a dramatic change in readers' speed (Rayner et al., 2016) and accuracy (Tran, 2012; Tran and Nation, 2014). For example, in the first of two studies investigating the impact a speed reading course had on ESL learners' reading fluency, Macalister (2008) had 29 participants studying in a pre-university English proficiency class in New Zealand read seventeen 400-word texts taken from a twenty-unit timed reading series. After comparing the average speed of his students' first three passages with their average speed on the last three readings he found that 25 of the 29 students had increased their speed by between five and 143 words per minute (WPM). At the end of the course Macalister retested his students to determine whether they had maintained their gains in speed by having them read the final three passages of his study's source material. He reported that 14 of the 29 students showed additional improvement from the end of the speed reading course to the delayed posttest at the conclusion of the term.

In a follow up study, Macalister (2010) looked at whether gains in reading speed made as a result of training in timed reading had the potential to transfer to other,

"authentic" texts. Students in his study (n = 36) were divided into two groups: 24 participants received daily reading fluency instruction and 12 did not. Macalister used the same training material as his 2008 study, however he added an additional three outside readings taken from an essay written by author George Orwell. When he analyzed the results, he found that students who had received training in speed reading (16 of 24 students) were able to transfer those gains to other, unfamiliar and unpracticed texts more easily than those who had not received the reading instruction. Like his previous study, Macalister discovered that his students' improved reading rates remained after having participated in speed reading practice. Regretfully however, Macalister did not report whether his students' accuracy had improved alongside their gains in speed in either of his two studies mentioned here, which makes extrapolation somewhat difficult.

A similar study conducted by Chung and Nation (2006) looked at the influence a speed reading course had on 49 university students studying English in Korea. Participants in their study read 23 texts over a period of nine weeks, with 19 of the texts read under the teacher's supervision and five read at home as homework. Nearly all of the students progressed during the study and several made remarkable gains ranging from 73 to 97 WPM. Overall, the results showed a 52% increase in speed based on the differences between the average of the students' first three readings and their last three readings. Regretfully this study did not have a control group, nor was comprehension assessed, although studies that have come since have demonstrated that training in speed can improve both reading rate and accuracy.

A paper by Chang (2012) did just that. Her study compared the effect of timed reading and repeated oral reading on 35 adult students of English studying in Taipei. Over the course of 13 weeks, participants in the timed reading group read 52 short passages while those in the repeated reading group read 26 passages. Her results showed a 49% gain (50 WPM) made by the speed readers, whereas the repeated oral readers gained only 27% (23 WPM). Comprehension scores for the speed readers improved by 10% whereas the oral repeated readers showed no gains. She, too, reported that readers' speed gains remained after she administered a follow-up test six weeks later. Based on the results of her study, Chang concluded that activities which boost reading rate may be worthwhile to include when planning or delivering L2 reading instruction.

A year later Chang and Millett (2013) compared the impact of timed reading and timed repeated reading on 26 Taiwanese university students' speed, comprehension, and transferability to previously unpracticed texts. All of the students in their study engaged in speed reading training for 13 weeks. The experimental group read each passage five times and answered comprehension questions after the first and fifth reading, while the control group read each passage once and answered questions immediately following the reading. Both groups made gains in reading rate and comprehension, however the timed repeated reading group outperformed their peers who had not practiced. At the end of the study, the authors reported that those who had done timed repeated reading had improved their reading rate by 47 WPM whereas the speed reading group who had not reread the passages improved by only seven WPM. According to the authors, the students' accuracy over the course of the intervention also increased; the timed repeated readers improved their comprehension scores by 19 percent, whereas the students who had not reread texts improved by only five percent.

Finally, Tran, and Nation (2014) investigated the effect a timed reading intervention would have on students studying English in Vietnam. Their goal was to measure changes in their students reading speed, comprehension, and memory span. In their study, 116 college freshmen were divided into groups. Half of the students did a speed reading course while the other half did not. The group receiving the treatment showed gains of over 50 WPM and read at 70% accuracy as measured by comprehension questions administered after each reading. This finding is consistent with other studies demonstrating that it is possible to increase reading speed without decreasing comprehension. Tran and Nation speculate that their students' overall language skill

may have improved as a result of having participated in the study and note that a relationship between increases in both reading speed and memory span exists, however they conceded that reading speed is not necessarily a good predictor of memory span.

Developing reading comprehension through physical activity

Procedures like speed reading, oral reading, and repeated reading have likely helped thousands, if not millions, develop fluency (Grabe, 2010; National Reading Panel 2000; Samuels, 1979; Scammacca et al., 2015; Wanzek et al., 2010), but it may be possible to hack them in such a way that they offer more learning in less time. An emerging body of multidisciplinary literature suggests that physical activity stimulates the brain making it more malleable and receptive to new information, which can better facilitate learning (Hillman et al., 2008; Ratey and Hagerman, 2008). In other words, by increasing our heart rate we can increase our capacity to retain knowledge and the speed at which we process what we learn (Best 2010; Hansen, 2016). It stands to reason that the effects of physical activity could influence the reading process tremendously.

A landmark study by Hillman et al. (2008) observed that exercise had a positive effect on cognition and executive function among young children. Participants in their study (n = 20; age = 9.5 years) completed two separate inhibition tasks: once after 20 minutes of seated rest and again after 20 minutes of treadmill walking at moderate intensity. The tasks were completed on separate days and counterbalanced across participants with the goal of assessing whether exercise induced changes in the children's attention span and academic achievement. In addition to the flanker tasks, the authors also tested scholastic achievement using the Wide Range Achievement Test to examine reading comprehension, spelling, and mathematics. The results indicated greater response accuracy and a larger degree of cognitive control following exercise relative to seated rest. Interestingly, when the individual academic tests were examined separately, improvements were observed on the reading comprehension assessment following exercise, however no differences were observed for spelling and mathematics. The authors concluded that acute exercise had a beneficial effect on the participants' cognitive control as well as their reading comprehension skills, leading them to assert that single, acute bouts of moderate-intensity aerobic exercise are related to faster cognitive processing speed and cognitive control of attention in children.

Numerous other authors have reported similar findings to Hillman and his colleagues. A 2014 study by Tine also found that short bouts of physical activity can enhance visual attention and improve reading comprehension in adolescents. In her study, which featured low- and high-income college students (n = 85), participants first took the d2 Test of Attention and then either jogged in place for 12 minutes or sat and watched a 12-minute film clip. After watching the video, all students retook the visual attention test and completed a comprehension task taken from the reading section of a Barron's GRE Test Preparation book. Based on her results, Tine asserted that acute sessions of aerobic activity had improved the selective visual attention and reading comprehension of her experimental group. Furthermore, she found that the window of increased concentration lasted about 45 minutes after the exercise ceased, roughly the same duration as a typical high school or college class. This finding led her to theorize that encouraging students to engage in even a short bout of physical activity prior to the start of class could provide a brain boost lasting nearly the span of class. It is worth noting that although Tine's study found a statistically significant difference between the mean scores of low-income participants, she did not find the same difference among students from the high-income range.

Flanigan (2021) conducted a similar study to determine whether physical activity could improve the reading comprehension and motivation of struggling elementary school children and got similar results. Participants in his informal study (n = 18) underwent six weeks of baseline testing to gather data on their reading comprehension. This was followed by a four-week intervention combining activities like basketball, kickball, tag, and relay races together with reading texts and comprehension questions

derived from the school's reading curriculum. During the study, participants had to first answer a reading comprehension question correctly for the chance to complete a task or compete in an activity. If a student missed the question they were not given a chance to compete and play was forfeited to the other team. At the end of the week students were given 10 reading comprehension questions based on the week's reading: six multiple choice, one short answer, one true/false, and two essay questions. By the end of the study, Flanigan found a significant difference in the performance of his students prior to and after the intervention, leading him to speculate that the incorporation of physical activity had improved their reading comprehension scores and increased their motivation to read.

Despite the many successes teachers and researchers have had utilizing exercise in classrooms, not all studies have reported meaningful improvements in academic achievement. For example, Earney, Berg, and Wallert (2015) looked at the impact activity breaks had on student performance in mathematics and reading in a first-grade classroom when students engaged in physical activity before the start of instruction. Data were collected from 38 students using teacher feedback, student self-assessment, a teacher log, and weekly mathematics and reading tests. Activity breaks were four minutes in length and included yoga, dance, and a variety of cardiovascular exercises. The findings, however, were inconclusive and not considered significant as participants' reading scores only increased slightly and their scores in mathematics remained the same over the course of the intervention. Although teachers and students enjoyed the activity breaks in the classroom, no statistically significant improvement in academic achievement was found.

Research conducted by Tiberi et al. (2020) also concluded that not all physical activity produces the same growth-inducing results for the mind. Their study looked at the effect cooperative learning skills taught during gym class had on fifth and sixth-grade elementary school students' reading comprehension scores. Specifically, the study sought to determine whether highly structured PE classes can positively affect mental skills and the acquisition of knowledge in students via interdisciplinary gym lessons. Over the course of two weeks, students in their study (n = 33) took part in four high structure, high thinking classes and four low-structured, low-thinking classes during PE class. The high-structured, high-thinking sessions involved participants trying to solve adventure education problems using cooperative learning techniques they had learned, while the low thinking, low structure sessions required students to engage in recreational physical activities, like jumping rope and hula hoop. After each type of 45-minute gym class, the students were given a passage to read and tested on their comprehension using questions based on the text. All of the students participated in both types of classes. Data generated by the study showed that on days when students engaged in high-thinking and high-structured activities their reading comprehension scores were better. The researchers also observed that students' attention and focus were also better on days when they engaged in high-thinking activities as opposed to the days when they only did low-structure activities.

Developing second language through physical activity

There is mounting evidence that suggests regular physical activity improves cognitive function and promotes brain plasticity, which may result in deeper awareness and a greater capacity to learn. Vigorous exercise is thought to cause the brain to produce and release brain-derived neurotrophic factors (BDNF) which act like "Miracle-Gro" fertilizer promoting brain growth and learning (Ratey and Hagerman, 2008). With the application of technological advances such as blood sampling, heart monitoring, and brain scanning machines researchers are now able to track and document what happens in the nervous system in real time.

A now highly cited paper by Winter et al. (2007) clearly demonstrated the positive effect physical activity had on memory and language acquisition. Seeking to learn more about the immediate effect of exercise on cognition, Winter and his colleagues tested 27

healthy male subjects in three areas: high impact anaerobic sprints, low impact aerobic running, and a period of rest. Immediately before and after each of the five treatment sessions occurred, participants' blood samples were analyzed for BDNF and then 15 minutes after the session took place participants sat an associative learning task with pairings of object pictures and novel pseudowords. The results indicated that vocabulary learning was faster after intense physical exercise when compared to the control and aerobic conditions. Interestingly, after just two sprints of less than 3 minutes each the researchers found that subjects learned 20% faster compared to moderate exercise or being sedentary. In addition to learning faster, the individuals in the anaerobic condition demonstrated a significant increase in serum BDNF levels. The sprinters' sustained levels of BDNF also correlated positively with learning success. The authors' main takeaway was that intense exercise directly improves learning and in situations where an immediate boost of learning is necessary, quick bouts of physical activity may be beneficial. Other studies have demonstrated a positive association between acute exercise-induced BDNF levels and short-term memory.

A study by Shmidt-Kassow et al. (2010) investigated whether simultaneous exercise influenced the verbal learning performance of a physically active group (cycling) as compared to a physically passive group. The subjects (n = 12; 8 women), all native German speakers roughly 25 years old, were divided equally into two groups and asked to learn 80 French vocabulary words over a period of three weeks. Training sessions were conducted three times per week for 30 minutes each and participants were tested after every third learning session to assess their learning progress. During that time the active group cycled at a medium exertion level in synchrony to the vocabulary presentation. Blood samples were drawn from each participant during the second session to measure their BDNF levels before, immediately after and then again post intervention. Two-tailed t-tests were conducted after every vocabulary test and planned comparisons revealed that the cycling group did significantly better than the passive group. Throughout the study brain imaging responses to memorized materials and behavioral data were gathered and measured leading the authors to argue that simultaneous physical activity had had a positive influence on learning.

Finally, a recent study by Liu et al. (2017) examined the relationship between physical activity and second language learning over a two-month period. Liu and her colleagues recruited 40 college-age Chinese men and women trying to learn English and divided them into two groups. The control group studied vocabulary while seated in a rote-learning type of position and the experimental group rode exercise bikes at a gentle pace (60% of their aerobic capacity) prior to and then during the first part of their instruction sessions. Both groups studied vocabulary the same way: by watching large monitors with words and images projected onto the screens. Each group was shown 40 words per session with the word sequence repeated several times during the session. Afterward, the students rested briefly before taking a vocabulary quiz. After the quiz they responded to sentences containing the vocabulary they had studied to determine whether the word was being used appropriately. The researchers found that the cyclists outperformed the sedentary group every time. They also discovered that the group simultaneously studying while exercising had a deeper understanding of the vocabulary words at the sentence level and also maintained their improved performance one month post-intervention. This discovery prompted the authors to assert that physical activity and movement had improved their participants' language learning ability and brought about an improvement that extended further than simply aiding in recall; according to them, it deepened the understanding of the vocabulary the subjects learned.

Purpose of Study

The review of literature for this study suggests that reading fluency can be improved through dedicated practice and that physical activity promotes brain plasticity which

correlates highly with increased capacity for learning. Despite the success teachers and researchers have had applying physical activity toward academic goals in L1 settings, it has received limited attention in L2 classrooms and no studies previously have examined the effect short bouts of exercise have on reading speed and comprehension in a foreign language. The goal of this study was to determine whether a brief stair-climbing protocol could elicit an improvement in the reading speed and comprehension of second-year university students studying English as a foreign language (EFL) in Japan.

Research Questions

This paper describes an experiment in which acute physical activity was used to improve reading fluency in lower-intermediate level EFL university students. Specifically, the purpose was to establish whether physical activity had any effect on learners' reading speed and comprehension. Therefore, the following two research questions were posed:

1. Is there a significant difference between the reading comprehension ability of lower-intermediate EFL learners who exercise acutely and those who do not as measured by the TOEFL iBT Test (ETS, 2013)?

2. Does physical activity significantly improve lower -intermediate level EFL students' reading speed and comprehension ability as measured by participation in a speed reading course (Millet, 2017)?

   (Null hypothesis) Stair climbing (6 flights 3x) will have no effect on the reading speed and comprehension in Japanese university students studying English.

   (Alternate hypothesis) Stair climbing (6 flights 3x) will improve the reading speed and comprehension of Japanese university students studying English.

Methods

Participants

The data from this study came from two small classes of second-year students studying at a private Japanese university in the department of Business Administration. The mean TOEFL PBT score used to stream the students was 499 (*SD = 29.13)*. All participants, nine women and three men, were at least 19 years old. There were no restrictions/regulations on age or gender made or measured for as variables. Prior to participation, no students reported physical or mental challenges that could inhibit them from taking part in the study and all students gave written informed consent. Students were informed that data collected as a result of involvement in the study would not affect their grades in the class.

A non-probability sample method was used which allowed the two classes to stay together: one formed the experimental group (n = 6), who undertook the twice weekly exercise treatment, and the other formed the control group (n = 9), who performed what was considered a placebo activity of journal writing in place of exercise. However, the data from three participants of the control group were eliminated as they failed to complete all the readings and sit the post-test.

Materials and Procedures

Each 90-minute-long class convened twice every week for 16 weeks, however the research outlined here lasted for 11 weeks. The main objective for the classes was to develop language proficiency and skill in English using business-related topics as the source material. The author taught both classes and followed the same planned sequence of instruction in each class. A week before the experiment began both classes watched a 15-minute video on how exercise benefits brain health. Following the video clip the two groups sat the reading section of the TOEFL iBT (Educational Testing Service, 2013) as a baseline measure. This test measures the language aptitude of students studying English at the lower to intermediate levels and is well known and respected all over the world. The reading section of the test has 50 four-choice items and requires roughly 60 minutes to conduct.

Starting from the following class, all students read two texts per week beginning from the fourth week of the semester. The materials for the study were taken from 4,000 BNC Speed Readings for ESL Learners (Millet, 2013), which consists of twenty 400 word passages, each with ten comprehension questions. The readings are on general topics and are written within the British National Corpus 4,000 most frequently used words of English. Students were instructed to read as quickly as possible aiming for the fastest time they could while maintaining roughly 70% comprehension, meaning that seven out of ten comprehension questions should be answered correctly.

Prior to completing the reading activity, the treatment group engaged in a brief exercise regimen. Starting from the classroom on the sixth floor, students walked downstairs to the first floor and back three times. The researcher accompanied the students during every session. Each flight of stairs had 22 stairs.. The total distance walked was approximately .75 kilometers and took approximately 9 minutes to complete. The metabolic equivalent of the task (MET) has an intensity level of roughly 4.7 METs (Ainsworth et al., 2000). Running, by comparison, equates to about 8 METs and jumping rope to over 6. Following the stair climbing routine the students were given a light refreshment, then began the day's reading task. Class then proceeded as normal upon completion of the activity.

Instead of participating in the twice weekly 9-minute stair-climbing procedure, students in the control group remained seated and wrote freely for 9 minutes in an English journal before completing the speed reading task. At the start of the study, each student received a writing journal and was instructed to write freely without revising or erasing. Students were encouraged not to consult dictionaries but were not forbidden from doing so either. The rationale for providing students time to do topical freewriting for 10 weeks was that it would offer them a pedagogically sound course of study (Raimes, 1986), yet would be unlikely to have a more meaningful effect on a student's reading speed or comprehension (Shanahan & Lomax, 1986). Journal keeping has a MET intensity level of about 1.8 (Ainsworth et al., 2000). The researcher looked over the journals every day and occasionally made supportive comments to the participants, but refrained from offering suggestions on word usage, content, or grammar.

Results

To find out whether short bouts of acute exercise could influence L2 learners' reading comprehension, a pre- and post-test was conducted. Table 1a shows the means and standard deviations of the scores on the TOEFL iBT pretest. Based on the results, both groups were comparable; the experimental group scored 5% lower than the control group, however the difference was not considered significant.

Table 1a
Pre-test means and standard deviation for control and experimental groups

	Experimental Group		Control Group			
TOEFL iBT	*M*	*SD*	*M*	*SD*	*t* value	Sig
	12.67	5.35	13.33	5.31	-0.216	$p = .8330$

Table 1b presents the post-test means and standard deviations of the scores by the control group and the experimental group on the reading portion of the TOEFL iBT. Both groups improved over their pre-test scores, however the difference was considered insignificant. Despite the similarity in the groups' scores, it is interesting to note that the experimental group outperformed their control group peers on post-test after having scored lower on the pre-test.

Table 1b
Post-test means and standard deviation for control and experimental groups

	Experimental Group		Control Group			
TOEFL iBT	*M*	*SD*	*M*	*SD*	*t* value	Sig
	16	3.98	15.5	6.81	-0.155	$p = .8797$

In order to determine whether physical activity influenced students' reading rate and comprehension as a result of participating in the exercise regimen both between groups and within groups *t*-tests were conducted. This study measured their times and scores using a modified version of Chung & Nation's (2006) approach to calculation: students' first and last three reading speeds and comprehension scores were averaged and then compared. The goal of this study was to determine whether there was a difference in the speed and comprehension of students who performed acute physical activity before engaging in a speed reading activity versus those who did not. It was hypothesized that students who exercised prior to speed reading would read faster and score higher on comprehension questions than those who did not. To test this hypothesis, independent samples *t*-tests were conducted. Table 2a shows that the two groups had identical mean scores and no significant differences at the beginning of the intervention. However, Table 2b below reveals that the six participants in the experimental group *(M* = 7.22, *SD* = 0.80) demonstrated significantly better accuracy than the 6 of the control group (*M* = 5.89, *SD* = 1.14), $t(10) = 2.32$, $p = .04$ at the end of the intervention. The effect size was large (Cohen's $d = 1.35$). These findings suggest that those who exercise before speed reading may be more likely to score higher on tests of reading comprehension than those who do not.

Table 2a
First three reading units (comprehension scores)

	Experimental Group		Control Group			
1st 3 units (comp scores)	*M*	*SD*	*M*	*SD*	*t* value	Sig
	6.33	0.6992	6.33	1.1352	0	$p = 1$

Table 2b
Last three reading units (comprehension scores)

	Experimental Group		Control Group			
last 3 units (comp scores)	*M*	*SD*	*M*	*SD*	*t* value	Sig
	7.22	0.8073	5.89	1.1148	2.326	$p = .0423$

Table 3a shows the results of the *t*-test conducted to compare the average speeds for the participants' first 3 units of the study. As evident, there was no significant difference in rate, $t(10) = .4466$, $p = .664$, despite the control group ($M = 130$, $SD = 36.63$) achieving faster reading speeds than the experimental group ($M = 138$, $SD = 32.4$). The results suggest that the two groups were similar, but not totally identical.

Table 3a
First three reading units (speed in seconds)

	Experimental Group		Control Group			
1st 3 units (speed/ secs)	*M*	*SD*	*M*	*SD*	*t* value	Sig
	138.89	32.4	130	36.63	.446	$p = .664$

Table 3b presents the mean average times for participants' last three readings of the study as measured by a *t*-test.Participants in the experimental group who engaged in aerobic activity prior to reading ($M = 67.77$, $SD = 15.86$) failed to read significantly faster than the control group who sat passively writing in their journal ($M = 79.44$, $SD = 41.28$) before completing the day's reading activity, $t(10) = -0.646$, $p = .532$. The effect size was medium (Cohen's $d = .373$).

Table 3b
Last three reading units (speed in seconds)

	Experimental Group		Control Group			
last 3 units (speed/ secs)	*M*	*SD*	*M*	*SD*	*t* value	Sig
	67.77	15.86	79.44	41.28	-.064	$p = .532$

Because participants of second-language speed reading programs typically improve their speeds (Chang, 2012; Chung and Nation, 2006; Millet, 2013), a paired-samples *t*-test was conducted to look at the change that occurred within the control group and the experimental group over the duration of the study. Table 4a presents the means and standard deviations of the control group's first 3 reading speeds versus their final three speeds. Not surprisingly, the control group's final speed increased over their first three units.

Table 4a
Control group: first 3 reading units (speed/secs) vs last readings (speed/secs)

	First 3 units (speed/ secs)		Last 3 units (speed/ secs)			
Control Group	*M*	*SD*	*M*	*SD*	*t* value	Sig
	130	36.63	79.44	41.28	-5.95	$p = .001$

Table 4b presents the results of the dependent samples *t*-test conducted to compare the experimental group's speed over the course of the intervention. As indicated, there was a highly significant difference in rate, $t(5) = -9.56$, $p = .00021$, suggesting that the experimental group had dramatically improved their speed while engaged in the study. Although both the control and experimental group improved, the experimental group improved more based on the results.

Table 4b
Experimental group: first 3 reading units (speed/ secs) vs last readings (speed/ secs)

	First 3 units (speed/ secs)		Last 3 units (speed/ secs)			
Experimental Group	*M*	*SD*	*M*	*SD*	*t* value	Sig
	138	32.15	67.77	15.86	-9.56	$p = .00021$

Discussion

In response to the first question of the study, the mean performance of the two groups' reading comprehension scores on the TOEFL iBT did not reach statistical significance as measured by between-group *t*-tests. It is possible that 10 weeks is insufficient time for such treatment to take effect or to be of consequence in improving overall language acuity when using that type of test. Developing reading skill, particularly in an L2, is a progression that likely occurs over time and may involve a maturation process before any kind of noticeable change manifests itself. Therefore, the full benefits of using physical activity to enhance reading comprehension remain to be seen.

With regard to the second research question, a significant difference was not found between the two groups' reading speeds as measured by an independent samples *t*-test. That said, the difference is worth pointing out that the experimental group reduced their speed by 51%, whereas the control group only managed a 39% decrease. There was, however, a statistically significant difference in comprehension found in the mean performance of those exercising prior to attempting the reading activities versus those who did not. This implies that exercising prior to reading may have helped facilitate the reading process and assisted in comprehension. With regard to the readers' speed, it is worth noting that the control group began the intervention reading slightly faster, although subjects in the experimental group caught up to and eventually surpassed their non-exercising peers. As it is not uncommon for reading rate to improve after participating in a speed reading course, a within groups *t*-test was conducted and the effect size between the two groups measured. The results showed that both groups had improved, however the treatment group had outperformed the control group. It is difficult to speculate why this occurred, but, based on what is known about how the

brain works it seems plausible to suggest that participants' accelerated heart rate and increased blood flow triggered a reaction which may have been at least partially responsible for their improved cognitive function (Hansen, 2016).

Another explanation for the experimental group's improvement may be attributable to the effect physical activity has on mood and emotion. Previous studies have reported that exercise can affect attitude, anxiety, and attention (Lane and Lovejoy, 2001; Ratey and Hagerman, 2008) in positive ways. It is conceivable that the neurochemicals released during physical activity served to alter the mind state of the stair climbing group, which led to a greater willingness to participate. It is also conceivable that students in the control group improved their scores over the course of the study due to calming effects of freewriting. As there was very little in the way of pressure on students in the control group (i.e. no fear of errors in grammar, spelling, etc.) it is plausible that they too felt more at ease and consequently were able to read faster on the test material. Previous studies have shown that simply participating in a speed reading program can help improve reading speed. It is possible that the faster times found in this study were due to having engaged in the procedure itself, however that doesn't do enough to explain the difference in comprehension between the two groups. The discrepancy in reading rate, despite not having achieved statistical significance, suggests that there may be more to unpack here outside of merely taking part in the intervention.

Since reading without comprehending would be futile, the need to accurately remember and process what was read is essential. Previous research has reported that increasing reading speed can cause a loss of reading comprehension (Miyata et al., 2012), but others have found that encouraging people to read slightly faster can produce improved comprehension (Walczyk et al., 2012). Although participants in both groups of this study achieved higher rates of reading speed, it was the experimental group, not the control group, who read with greater accuracy by its end. It is possible that some of the gains were the result of a practice effect that occurred, in which participants grew accustomed to the readings and the format associated with performing the task, but that does not explain why the experimental group improved while the control group regressed.

Alternatively, speculating that physical activity was solely responsible for the gains made by the experimental group or that simply climbing stairs can help an individual read faster or recall more is just as unlikely. Instead, it appears that the combination of exercise and learning to read more efficiently may have worked together interdependently to generate the results reported here. Adding a "hack" like physical activity into a language curriculum could be a way to speed up the learning process by helping students to learn more without actually having to teach them more.

Limitations

This study had several limiting factors which must be acknowledged. The first was that only a small number of women took part in the experimental group. A sample size of six female participants is not large enough to say with any confidence that physical activity influenced learning or helped improve reading comprehension. Under some conditions, a relationship between reading and writing can exist and it is possible that by freewriting the control group improved their reading speed over the duration of the study. Future studies must address this shortcoming by replicating it with a larger sample size that also includes male participants and a different design.. A second limitation was that no data were gathered actually linking exercise to cognition. The positive benefits associated with increased cerebrovascular blood flow and heart rate must be measured and analyzed. A third limitation was variability. There was no way to control for the day-to-day inconsistencies which occurred such as weather (e.g., excessive humidity), participants' mood, energy levels, or sleep patterns. A fourth

limitation was that all of the women were young, healthy, and relatively active adults, thereby making generalizations to a larger population unreliable. A fifth limitation concerned the data itself. The data generated for this study came from students' self-reported progress graphs and inadvertent errors in recording may have occurred. Finally, this study only measured the results of a stair-climbing/ exercise regimen on reading speed and comprehension for 10 weeks, leaving open many different possibilities regarding the long-term effects of such a practice on language learning.

Conclusion

In this study the effect of physical exercise on reading speed and comprehension was investigated over a 10-week period using a control and experimental group. Although both groups' comprehension scores improved over the duration of the experiment, the findings showed only a slight statistical difference between them on the first assessment, the TOEFL iBT reading section. On the second assessment, the speed-reading intervention, no significant difference was found between the two groups' reading speeds, despite the experimental group catching up to and eventually surpassing the experimental group. As noted previously, improvements in speed are common among participants of such programs, so the fact that both groups improved is not surprising. Nevertheless, a significant difference was found between the control group and the treatment group in which the treatment group scored higher on comprehension questions than the control group.

It may thus be concluded that physical activity has some impact on EFL learners' reading fluency; however, the degree to which this can be stated conclusively remains unclear. More thorough research using exercise to promote L2 reading and learning in general must be done before this can be stated assertively or with any confidence.

The results of this study support the work of Liu and her colleagues (2017) and Shmidt-Kassow et al. (2010) in that they found physical activity caused an improvement in their subjects' capacity to learn foreign languages. Although their tasks were focused on vocabulary acquisition, both sets of authors interpreted their results as evidence that exercise could positively influence participants' L2 learning potential.

Previous research has suggested that exercise promotes brain plasticity, which can facilitate deeper, more impactful learning. It follows that applying the cognitive benefits associated with physical activity toward a specific goal like learning to read fluently could have more impact on uptake than simply practicing reading on its own. In many academic settings, particularly at the collegiate level, physical activity is noticeably absent from the curriculum. Some teachers may feel apprehensive about using dedicated class time for anything other than pedagogical pursuit, but as little as 10 minutes of moderate physical activity can make a big difference in the learning process because it has been shown to prime the mind's pump, effectively preparing it to make stronger and more plentiful neural connections.

As noted above, more robust studies must be conducted before any kind of formal declaration can be made regarding the efficacy of pairing exercise with L2 learning and reading interventions. Future studies should be undertaken to examine how best to maximize the benefits associated with physical activity and their application toward second and foreign language learning.

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