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Physical activity as an enhancer of vocabulary learning: a brief narrative overview

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1 Introduction

Current research on the impact of physical activity on the human body indicates that exercising not only promotes physical health (e.g. prevention of metabolic and cardiovascular disease), but that it also has an impact on mental health and cognitive processes. In fact, it has been noted that bouts of exercise can enhance executive function performance (Álvarez-Bueno, Pesce, Cavero-Redondo, Sánchez-López, Martínez-Hortelano & Martínez-Vizcaíno 2017, Chang, Labban, Gapin & Etnier 2012), and that the combination of regular and acute physical activity (PA) could serve both as a protection and as an enhancer of EF and memory (Roig, Thomas, Mang, Snow, Ostadan, Boyd & Lundbye-Jensen 2016) throughout the lifespan.

One small but rapidly developing field of research focuses on the impact of acute PA on memory processes. The available reviews and meta-analyses have concluded that, in addition to the already established effects on short term memory, acute physical activity may have a medium-to-large effect on long-term memory (Roig, Nordbrandt, Geertsen & Nielsen 2013). The potential applications of this finding are numerous, as LTM has been identified as a key component of successful learning. If the enhancing effect of PA could be fine-tuned to target specific learning instances, it could provide a non-invasive, classroom-friendly means to boost learner performance at all levels of education.

In the field of second language acquisition, we would be particularly interested in knowing whether exercise can be utilised as an enhancer for second or additional language learning. In the following sections I will review available information regarding the impact of exercise on declarative memory formation and consolidation and discuss how these findings can be translated to vocabulary learning.

2 Learn faster

A seminal study on the effects of acute PA on memory concluded that those participants who exercised at an intense pace were able to acquire novel vocabulary items at a faster rate than those who exercised moderately or those who did not exercise (Winter, Breitenstein, Mooren, Voelker, Fobker, Lechtermann & Knecht 2007). In this study, the authors assessed the vocabulary learning outcomes of 30 male, L1 German speakers in three conditions: relaxed (control), moderate (40 minute low impact running) and intense exercise (2 sprints of 3 minutes at increasing speed).

The participants took part in each exercise condition with a minimum interval of a week in-between exposures. The vocabulary-learning paradigm, consisting of an associative-learning task in which the participants heard a pseudoword followed by a picture of an object, began 15 minutes after the start of the exercise (or rest) intervention. This task contained both correct pseudoword-object pairings as well as incorrect ones, the former appearing 10 times as often as the latter during exposure. The subjects were asked to state whether they believed the pairings presented were correct or incorrect by pressing a button. Their reaction times and the accuracy were recorded. The first post-test was performed immediately after the first learning session; two subsequent tests were completed with a week and ¿ 8 months' delay. On all three tests, the participants completed a translation task in which the subjects were presented with pairs of German words and pseudowords and had to state whether the pairings were correct. They also performed a free recall task on the one-week test. An analysis of the learning speed, as derived from the participants' correct and incorrect responses during exposure, showed that learning speed increased by 20% when it took place following intense exercise. Although there was no significant difference in the memory performance of the groups in the immediate and delayed tests, further analyses revealed that subjects in the intense condition outperformed those in the moderate condition in the 1-week test.

3 Remember more

Not only can exercising help people learn new vocabulary fast, but mounting evidence suggests that it can also increase the amount of vocabulary items they learn.

In a series of studies using the concurrent-exercise paradigm, Schmidt-Kassow and colleagues found that participants who cycled while learning novel words were able to recall a larger number of items than those who were at rest for the same amount of time. In the first study (Schmidt-Kassow, Kulka, Gunter, Rothermich & Kotz 2010), participants were exposed to 80 pairs of words, one in their L1 (German) and one in a foreign language (French), during nine learning sessions distributed over a period of three weeks. The exposure to the word-pairs occurred while they were either cycling or at rest (while sitting on the bicycle), three times per week. After three instances of learning, at the end of the first week, the participants had a testing session in which they were asked to translate the newly acquired French words into German. This test was repeated twice more, at the end of the sixth and ninth learning session. The testing phase was conducted at rest while sitting down at a table for all participants. The experimenters examined how many items the participants were able to translate, and discovered that those in the exercise condition consistently outperformed those in the rest condition. In addition to this behavioural measure, information about Event Related Potentials (ERPs) before and after the three-week vocabulary training was also recorded. The objective was to observe whether mismatched pairs of words (e.g. *fleur *[flower]*-Hund *[dog]*) would elicit larger N400 effects in exercising participants, thus signalling that they were

able to integrate the new words into their lexical system, a hypothesis they we able to confirm.

Despite having found evidence for an enhanced performance of the exercise group both at the behavioural and electrophysiological level, Schmidt-Kassow and colleagues still had no information regarding the underlying mechanisms that would promote enhanced memory performance following or during exercise. To study this, they conducted a second experiment (Schmidt-Kassow, Deusser, Thiel, Otterbein, Montag, Reuter & Kaiser 2013) in which they also observed the possible mediation of brain-derived neurotrophic factor (BDNF) on the exercise-induced cognitive outcomes. The subjects (105 monolingual German females) participated in two learning sessions followed by two delayed vocabulary retention tests, administered 48-hours after encoding. During the second learning session, blood samples were obtained after vocabulary testing, after the exercise or rest intervention, and after vocabulary learning. The exercise intervention had two conditions: exercise-during-encoding and exercise-prior to encoding. The results showed that the participants in the exercise-during-encoding condition performed better in the vocabulary tests when compared with the rest condition. Contrary to the findings of previous experiments (e.g. Winter et al. 2007, the results of the endocrinological part of the study showed no effects of BDNF in the participants' performance.

More recently, Liu, Sulpizio, Kornpetpanee & Job (2017) used a the same dual-task design to observe whether non-novice language learners (i.e. people who already had a little knowledge of the language taught in the experiment) could benefit from concurrent physical activity while learning new vocabulary items. In addition to assessing recognition for the newly-learnt words, the researchers used a grammaticality judgement task to test the participants' ability to distinguish canonical vs. non-canonical uses of newly-learnt vocabulary in sentences. As in previous experiments, learning while exercising provided a boost to participants' performance on both the item recognition task and the grammaticality judgement. What is more, this advantage was sustained when tested four weeks later. These studies have shown that concurrent PA can act as a booster of vocabulary learning, by enhancing learners ability to recall newly learnt items after the learning phase, and by promoting integration of these novel items into the lexicon. But it may not be necessary to exercise during learning to obtain these advantages. The results of one of our recent studies (Pastorino Campos & Williams 2017) indicate that when even if the exercise intervention takes place before, not during, encoding, the participants seem to be benefitting from an exercise-induced boost to their memory performance. In this experiment, we tested 44 Spanish monolingual children to observe whether having exercised prior to learning could have an effect on their ability to recall novel word-forms and meanings, immediately after exposure and with a short (24 hours) and long (one week) delay. Like in Winter et al.'s experiment, in this case all children participated in the two experimental conditions, with exercise (30 minutes of moderate physical activity) or without exercise (30 minutes of a passive activity, like colouring). Interestingly, we found that exercise alone could not account for the differences in performance we observed when children exercised or not. Rather, the effect of exercise was moderated by three factors: time (immediate vs. delayed),

gender, and type of linguistic content assessed (memory of word-forms vs. form-meaning connections). Acute PA seemed to only affect memory for word-forms, while not affecting memory for word-meaning connections. In addition to this, we observed that while children did not differ in their immediate performance after exercise or rest, there were significant differences in the number of items recalled on the first delayed test, performed 24 hours after exposure. Surprisingly, this effect was only present in males; females' memory seemed to be relatively unaffected by prior exercise.

4 Forget less?

We have evidence indicating that a bout of PA can increase speed of learning and number of items encoded, but what happens after learning? Can physical activity help us not forget the vocabulary we have learnt?

Research into the effects of PA on memory is only beginning. Theoretical models explaining the effects of PA on cognition indicate that, given the metabolic changes brought about by exercise, we should be able to observe memory effects. Indeed, exercise has been shown to induce increases in neurogenesis and in the release of BDNF and other molecules (e.g. insulin like growth factor), processes that have been linked to gains in memory formation and consolidation.

The reviews available on the subject have begun to confirm these hypothetical effects. Roig and colleagues (Roig et al. 2016, 2013) have noticed that the effects of acute PA on memory may not be seen immediately, and suggest the inclusion of delayed measures of recall so as not to overlook effects that may not appear straightaway. This suggestion, together with the analysis of the data from the review, indicates that physical activity may not only affect encoding, but also the consolidation of new memories.

The reviews mentioned above focus on general memory mechanisms. As noted by these authors, to date there is little information about how acute PA may affect the consolidation of newly-acquired information, and even less direct evidence of how it may impact the consolidation of linguistic information. Without further studies looking at this specifically, and to consolidation of vocabulary in particular, it is hard to make definite conclusions. Nonetheless, we can observe that in the majority of the studies reviewed above some or all of the enhancing effects of acute PA are observed in delayed tests, usually performed one day or more after learning. This could indicate that exercising may exert a protective effect against forgetting after initial encoding, acting during consolidation. What is more, it may signal that physical activity may interact with other, more established, mechanisms for the consolidation of linguistic stimuli, such as sleep (Brown, Weighall, Henderson & Gaskell 2012, Dumay & Gaskell 2007, Henderson, Weighall, Brown & Gaskell 2012, Tamminen, Payne, Stickgold, Wamsley & Gaskell 2010).

5 Conclusion & future directions

Increasing evidence indicates that acute PA can act as an enhancer of memory for vocabulary learning. We have reviewed studies showing beneficial effects of exercising on the speed of vocabulary learning (Winter et al. 2007) and on the number of items learnt (Liu et al. 2017, Pastorino Campos & Williams 2017, Schmidt-Kassow et al. 2013, 2010). In addition, we have observed that the benefits tend to appear with a delay, thus suggesting that PA could help the consolidation of the recently learnt vocabulary items, thus protecting these new memory traces against forgetting. This observation is supported by the findings of reviews and meta-analyses on the effects of PA on memory (Roig et al. 2016, 2013), but further research, that addresses the effects of PA on the consolidation of linguistic information, is required in order to make more definite conclusions.

The finding that exercise can help boost vocabulary learning has direct applications to both language learners and teachers. However, despite these encouraging first results, much more research is needed before we are able to design PA interventions that can directly influence the way we learn languages. For example, little is known regarding the impact that individual differences between learners may mediate or modulate the effects of PA on memory for language learning. Gaining more knowledge with regards to the specific characteristics of a memory-enhancing exercise intervention could lead to the design and implementation of language learning strategies that could harness its beneficial effects.

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