Influence of Aerobic Exercise Induced Arousal on Neutral Word List Retrieval in Young Adults

Research article

Previous studies have shown that arousal during the encoding and consolidation phases facilitates memory performance, and that arousing stimuli are better remembered. The current study shifts attention to physical arousal in the retrieval phase. This study was designed to test whether physically induced arousal can enhance memory for neutral words. Participants (N = 48) were randomized over a control and an aerobic condition. On the first day they memorized a list of 30 words, on the second day they either watched a documentary or executed an aerobic cycling exercise before performing a memory recall and recognition test for the words memorized at day one. Prior to the main analyses a manipulation check on subjective and physiological arousal was conducted and a successful condition manipulation was confirmed. However, the analyses showed no significant difference in memory performance between groups. Implications and limitations are discussed.

Keywords: arousal, memory retrieval, aerobic exercise

Dorien Blezer; MA (Neuropsychology) student at Maastricht University, Maastricht, The Netherlands d.blezer@student.maastrichtuniversity.nl
Shauna Cortenraad; BA student at Maastricht University, Maastricht, The Netherlands
Jannin Duijn; MA (Work and Organizational Psychology) student at Maastricht University, Maastricht, The Netherlands
Sofia Kalaai; BA student at Maastricht University, Maastricht, The Netherlands
Alexandra Pres; BA alumni at Maastricht University, Maastricht, The Netherlands
Anuschka Theden; MA (Health and Social Psychology) student at Maastricht University, Maastricht, The Netherlands
Lieveke Vonk; BA student at Maastricht University, Maastricht, The Netherlands

INTRODUCTION

Nowadays, society increasingly expects more from students in regard to cognitive performance at school and university. Prescription of pharmacological stimulants is not an abnormal feature of life anymore. According to a survey of McCabe, Knight, Teter, and Wechsler (2005), 4.1% of students in US universities had used prescription stimulants such as Ritalin, Dexedrine and Adderall in the year prior to the survey. Within the field of psychological research, it has come to light that in addition to pharmacological stimulants, regular physical activity may also have beneficial influences on cognitive performance. This could be a preferential alternative to prescription stimulants for students to achieve better cognitive performance.

Previous work on non-pharmaceutical cognitive enhancement has shown that there is a positive relationship between exercise and cognitive performance in school aged children and in older adults with and without cognitive impairments (Hillman, Erickson, & Kramer 2008; Pano, 2013). Positive effects as result of aerobic exercise in children were found in perceptual skills, IQ, verbal tests, and mathematical ability. Also, exercise had a positive effect on other cognitive functions, for example faster reaction times in healthy older adults as well as in adults with neurodegenerative disorders such as Alzheimer's disease (Pano, 2013).

So far, research has predominantly focused on improving memory in older adults, and most studies have examined manipulations during the encoding and consolidation phases of the memory process. Roig, Nordbrandt, Geertsen, and Nielsen (2013) reviewed evidence for the use of both acute and long-term cardiovascular exercise to improve the encoding of memory. They found that acute aerobic exercise had a positive effect while long-term cardiovascular exercise had no effect on long-term memory. Taking the reviewed studies together, neither acute nor long-term cardiovascular exercise showed improvements in short-term memory, whereas long-term aerobic exercise had small effects on short-term memory. Weinberg, Hasni, Shinohara, and Duarte (2014) investigated the effect of resistance exercise on memory encoding. Resistance

exercise refers to activities such as weightlifting. It improves muscle tone and coordination. They found that a single bout of resistance exercise enhanced episodic memory for emotional pictures compared to neutral ones. More specifically, acute resistance exercise during the encoding and consolidation phases improved long-term memory performance. No difference between negative and positive stimuli was found. They indicated that the enhanced memory in the resistance exercise condition was mediated by resistance exercise induced arousal and possibly by exercise induced acute stress.

Over the years, different theories, which describe a relationship between arousal and cognitive performance, have been developed. Hull's Drive Theory (1943), for example, states that the higher a person's arousal is, the better their cognitive performance will be. In addition, Yerkes and Dodson (1908) described an inverted-U relation between cognitive performance and arousal. They inferred that cognitive test performance increases to an optimum as physiological arousal increases, and drops with higher levels of physiological arousal. This implies that physiological arousal is only beneficial to cognitive performance when it does not exceed the optimum of the curve. Despite the differences between the two theories, both agree on the existence of a possible positive relationship between cognitive performance and arousal.

Rather than examining the effects of arousal during the encoding and consolidation phases, the present study aims to identify the effects of acute aerobic exercise induced arousal during the retrieval phase. Also complementary to most memory enhancement studies, younger adults are of interest in the present study, for two reasons: first, there is a paucity of arousal induced cognitive enhancement studies in younger adults. Second, students are young adults, and investigation into non-pharmaceutical cognitive enhancement methods is highly relevant in a society which puts ever-increasing demands on them.

In the current study, participants were randomly assigned to an experimental or control condition. On the first day both groups performed a Word Learning Task (WLT; Murdock & Bennet, 1960) and were asked to memorize the presented word list. Due to endogenous

noradrenergic activation triggered by arousing words lists, emotionally arousing words are remembered better (Segal & Cahill, 2009). In order to avoid this confounding effect of potentially enhanced memory encoding for arousing stimulus words the present study only used neutral words. On the second day participants in the experimental group completed an aerobic exercise to induce physical arousal, while participants in the control group watched a documentary. Then, all participants performed a delayed free recall and recognition task. The study focused on the effects of arousal on retrieval. Based on previously discussed theories and studies describing a possible positive relation between physical arousal and cognitive performance, the hypothesis was that the aerobic group would recall and recognize more words than the control group.

METHOD

Participants

Forty-eight healthy students (17 male, 31 female) aged 19 to 30 (M = 21.46,

SD = 2.04) from Maastricht University voluntarily participated in the study. Participants were recruited via flyers and advertisements on social media. They were randomly assigned to a control (24 in total; 7 male and 17 female) or aerobic (24 in total; 10 male and 14 female) condition. Every potential participant completed a pre-screening form to ensure that they were healthy and that they did not have any complaints whilst performing sport. Individuals who fulfilled one or more of the following criteria were excluded from the study: treatment with any medication that could potentially cause harm whilst engaging in sportive activities, heart- or vascular disease, physical complaints during sports, overweight or underweight evaluated by Body Mass Index (BMI) criteria (BMI = mass(kg)/(height(m)2, underweight < 18, overweight > 25) and engagement in sportive activities more than twelve hours per week. This latter criterion

was included because endurance trained individuals have a reduced sympathetic activity during submaximal exercise that influences the physiological arousal measures of heart rate and blood pressure (Gregoire, Tuck, Yamamoto, & Hughson, 1996). Female participants were excluded in case they were pregnant to prevent any potential harm to the unborn child. This research was part of a school assignment, therefore only second year bachelor psychology students were allowed to participate. All participants signed an informed consent and received course credits as compensation. The study was reviewed and approved by the ethical committee of Maastricht University.

Materials

Word Learning Task

The WLT consisted of 30 neutral nouns and verbs that were semantically and phonologically unrelated. Examples of these words are "vase" and "fill". Each word was presented in the middle of the screen for 2000 ms followed by a 1000 ms blank screen inter-stimulus interval. Participants were instructed to remember these words by heart as well as possible. After the first presentation of the list of words, participants were instructed to immediately recall out loud the words they remembered. Then, the word list was consecutively presented two more times. The last (and third) presentation was again followed by a request to recall out loud as many remembered words as possible. On the second day participants performed a delayed free recall and the number of correctly recalled words was recorded. After that, they completed a computerized recognition task in which the same 30 words from the previous WLT appeared randomly mixed with 30 new neutral words. Participants were instructed to press the 'X' button on a keyboard when the item was an old word and the 'N' button when the item was new. They were informed that the focus hereby was on accuracy, not on reaction time. Correctly recognized old items,

correctly recognized new items, false alarms and misses were electronically recorded and used for analysis.

Arousal manipulation check

The Self-Assessment-Manikin (SAM; Lang, 1980) on arousal was used to test the subjective experience of arousal in participants. The SAM was presented on paper and consists of 5 drawings of manikins, which are depicted in a progressively more aroused manner, as illustrated in Figure 1. Participants were asked to choose which of the nine slots (one underneath and one between each manikin) best reflected their subjective feeling of arousal at that moment. Physical arousal was assessed by measuring heart rate and systolic and diastolic blood pressure using an ambulatory blood pressure unit.

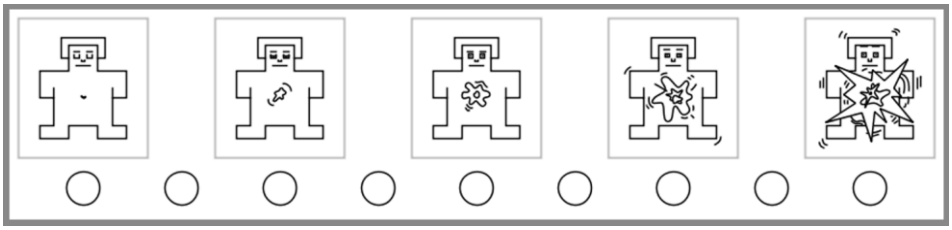

Figure 1. *Self-Assessment-Manikin on subjective arousal. Adapted from Lang (1980).*

Experimental manipulation

In the aerobic condition participants were instructed to cycle for 15 min on a home trainer at moderate intensity to induce physical arousal. To avoid fatigue, the difficulty level was set at three or four out of a range of twelve levels. Towels and water for the participants were provided. Participants assigned to the control condition were instructed to watch a non-arousing documentary about bicycle touring through the Kimberley for 15 min.

Filler task questionnaires

Physical Activity Rating

The Physical Activity Rating (PA-R; Jackson, Blair, Mahar, Wier, Ross, & Stuteville, 1990), which assesses how much sport the individual performed per week for the previous six months, was used. The questionnaire consists of a seven-point scale in which every ascending number of the scale is accompanied by a description of a higher level of physical activity. Participants were required to choose the number that best reflected their personal situation in respect to their overall level of physical activity. A sample item is 'Does not participate regularly in programmed recreation, sport, or physical activity'.

Sport Emotion Questionnaire

Participants completed the Sport Emotion Questionnaire (SEQ; Jones, Lane, Bray, Uphill, & Catlin, 2012), which evaluates different feelings participants experience at that precise moment. It contains 22 items that described different feelings which participants rated on a five-point scale, from 'not at all' to 'extremely'. Example items are 'nervous', 'enthusiastic' and 'happy'.

Barrett Impulsiveness Scale

The Barrett Impulsiveness Scale (BIS; Patton, Stanford, & Barratt, 1995), a questionnaire that measures inhibition, was used. Participants read a statement, such as 'I am self-controlled', and choose how often they act or think that way from 1 ('rarely/never') to 4 ('almost always/ always').

Procedure

Participants who did not fulfil any of the exclusion criteria received an information email with some further study requirements. They were instructed not to consume any drinks containing caffeine (for example coffee and energy drinks) within two hours before participation. Furthermore, participants were required to not drink alcoholic beverages and to not take recreational drugs within eight hours before participation. Also, smoking was not permitted within one hour before the experiment. Individuals were asked to eat a light meal before taking part in the study but they should not have eaten anything within one hour before the start of the experiment. All requirements had to be fulfilled prior to both sessions and were verbally checked by the experimenter before testing. Additionally, all participants were recommended to wear loosely fitted clothes, so they would not know in which condition they were but were able to exercise if needed. Moreover, caffeine, alcohol and recreational drugs are believed to have the potential to influence performance (Heishman, Arasteh, & Stitzer, 1996; Burke, 2008).

Het, Ramlow, and Wolf (2005) found that administered cortisol leads to diminished memory performance. Since it is known that natural cortisol levels fluctuate during the day and peak in the morning (Adam, Hawkley, Kudielka, & Cacioppo, 2006; Pruessner et al., 1997), all experimental appointments were scheduled between 1 and 6 p.m. to minimize differential effects of morning cortisol peaks. The study consisted of two lab sessions, which took part 24 hours apart. Figure 2 shows an overview of the procedure for the study.

Day 1

Participants read an information letter describing the objectives of the study and were asked to sign the informed consent form. Then, they filled out the PA-R and SEQ. Neither questionnaire was used for further analysis; both were commissioned to create time in the experiment to settle the participant down in the laboratory conditions and to slow their heart rate. This took about

5 min. Next, the subjective state of arousal of each participant was assessed using the SAM. After the SAM, heart rate and blood pressure (systolic and diastolic) were measured using an ambulatory blood pressure unit. After that, participants performed the computerized WLT and their immediate free recall scores were recorded. Finally, participants filled out the BIS. It was used to mislead participants in regard to our actual hypothesis and was not further analyzed. The day 1 session lasted about 20 min.

Day 2

At the start of day 2, participants again were asked to fill out the SEQ and the SAM. The SEQ was administered to settle participants down and was not used for further analysis. Next, heart rate and systolic and diastolic blood pressure were measured. Thereafter, the experimental treatment took place. Participants assigned to the aerobic condition cycled for 15 min and participants in the control condition watched the documentary for 15 min. Immediately after this, blood pressure and heart rate were measured in both conditions for the second time of the day, and the SAM was filled in again. Next, participants were asked to perform a delayed free recall. They recalled out loud as many words as they could remember of the WLT from the previous day. The researcher recorded all of the remembered words on a sheet of paper. This task was followed by a computerized recognition task. At the end of the day 2 session participants were debriefed, granted their course credits and thanked for participation. The second session lasted for about 35 min.

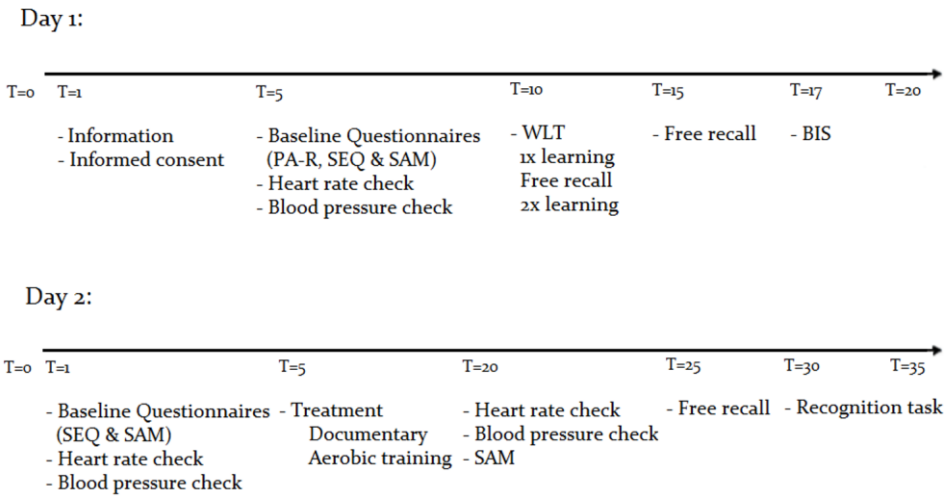

Figure 2. *Procedure overview with a timeline of the two testing days. t, time in minutes; PA-R, Physical Activity Rating; SEQ, Sport Emotion Questionnaire; SAM, Self-Assessment-Manikin; WLT, Word Learning Task; BIS, Barrett Impulsiveness Scale.*

Statistical Analyses

A randomization check was conducted to test whether arousal measures (i.e., SAM, systolic and diastolic blood pressure and heart rate) indeed did not differ between conditions before experimental treatment. The arousal measurements were collected on three different points in time: Once on the first day and twice on the second day, right before and right after the experimental treatment. The data of the first day were averaged with the first measurement of the same variables on the second day. These averages served as pre-test baselines for all arousal variables and two-tailed independent samples t-tests were conducted to check successful randomization. The two free recall tasks of the first day also were averaged and a two-tailed independent samples t-test were conducted to rule out baseline differences between conditions.

Next, for the purpose of conducting a manipulation check, difference scores were obtained by means of subtracting the baseline averages from the data of the third measurement, again on all arousal measures. One-tailed independent samples t-tests (since the aerobic condition was meant to increase physical arousal) were conducted on all difference scores.

The first dependent variable, the delayed free recall on day 2, was analyzed using a one-way ANCOVA. Despite successful randomization the average score on the two free recall tasks of the first day was used as a covariate to enhance the test's statistical power. A power calculation was conducted.

The second dependent variable concerned the recognition task. Data were obtained by means of scoring the number of correctly recognized old items, correctly recognized new items, false alarms and misses. In this way, the recognition measure qualifies as a Signal Detection Theory measure and hence requires a sensitivity index (d') calculation as proposed by Stanislaw and Todorov (2009). This encompasses that the scores on correctly recognized old items and false alarms were first transformed to Z-scores. Then, the Z-scores from false alarms were subtracted from correct old, and from these different scores an independent samples t-test was conducted. In sum, the formula that was used to calculate the sensitivity index was d' = Z(correct old) – Z(false alarm).

RESULTS

Randomization and manipulation check

Randomization checks showed no differences in arousal measures between conditions at baseline measurements, SAM: $t(46) = -1.51$, $p = .14$, systolic blood pressure: $t(46) = -.42$, $p = .68$, diastolic blood pressure: $t(46) = -.16$, $p = .87$, heart rate: $t(46) = .02$, $p = .98$. The two free recall tasks of the first day also confirmed successful randomization, $t(46) = -.29$, $p = .77$.

The manipulation check showed that there was a significant increase in SAM-scores, $t(46) = -7.96$, $p < .001$, systolic blood pressure, $t(46) = -7.45$, $p < .001$, and heart rate, $t(46) = -7.52$, $p < .001$, indicating an increase in SAM, systolic blood pressure and heart rate after the exercise. Diastolic blood pressure did not show a significant difference across conditions, $t(46) = -.44$, $p = .66$. Figure 3 illustrates the manipulation check variable findings.

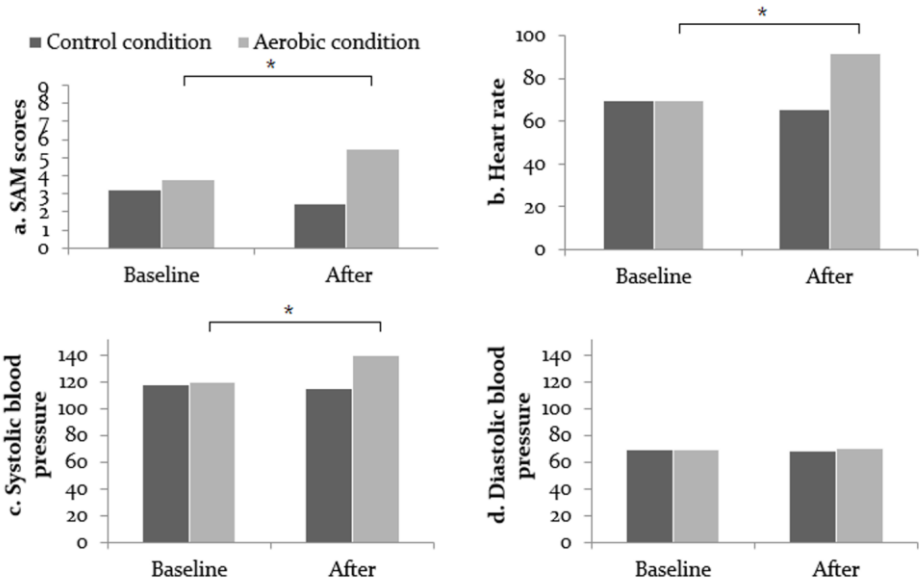

Figure 3. *Manipulation check measurements on SAM scores (a), heart rate (b), systolic blood pressure (c), and diastolic blood pressure (d). After the experimental treatment all arousal variables except diastolic blood pressure were significantly higher in the aerobic condition. SAM, Self-Assessment-Manikin. * p < .05.*

Free recall and sensitivity index

An ANCOVA that was used to determine a statistical significant difference between the aerobic (M = 16.47) and control (M = 16.41) conditions on free recall on the second day, controlling for the covariate average recall on the first day, did not show a significant effect, $F(1,45) > .01$, $p = .94$ (see Table 1). The power calculated for the ANCOVA to detect a small to medium effect size of $f = .20$ turned out to be .29, which is very limited.

The independent samples t-test used on the sensitivity index obtained from the recognition data also did not yield a significant difference between aerobic (M = -.241) and control (M = .241) conditions, $t(44) = 1.07$, $p = .29$ (see Table 2).

Condition	Recall 1 - Day 1		Recall 2 - Day 1		Average - Day 1		Recall - Day 2		Covariance corrected recall - Day 2	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Control condition	11.88	5.00	20.79	6.39	16.33	5.37	16.21	6.91	16.47	4.45
Aerobic condition	12.25	4.52	21.25	5.14	16.75	4.57	16.67	7.04	16.41	4.45

Table 1. *Recall data (means and standard deviations)*

Condition	Correct old		False Alarms		Sensitivity index (d')	
	M	*SD*	*M*	*SD*	*M*	*SD*
Control condition	26.83	3.73	2.09	2.45	.241	1.70
Aerobic condition	28.17	2.08	2.00	1.83	-.241	1.34

Table 2. *Recognition data (means and standard deviations)*

DISCUSSION

The aim of this study was to explore the effect of physically induced arousal on retrieval of neutral words. The possibly enhancing influence of physical arousal on cognitive performance can be of particular importance to educators who set environmental conditions to maximize a student's performance. Students could potentially benefit from this research area by knowing how to enhance memory retrieval by doing physical exercise. Previous studies focused on the encoding and consolidation phase and on emotional stimuli. The present study however, was conducted to test the influence of physically induced arousal on retrieval of neutral words.

The hypothesis was that participants in the aerobic exercise group would recall more words on the second day in comparison to participants in the control condition. Also, it was expected that participants in the aerobic condition would perform better on the recognition task. A manipulation check was conducted by obtaining SAM-scores and measuring blood pressure and heart rate before and after manipulation. The manipulation check was effective in increasing all measures except for diastolic blood pressure. An explanation might be that diastolic blood pressure in normotensive subjects shows only minor changes during exercise as opposed to systolic blood pressure, because of adequately reduced peripheral resistance in

healthy adults (Palatini, 1988). Due to the fact that only 48 subjects participated in the current study, the above explanation would be plausible since the sample size might have been too small to detect a very small effect size. Despite no difference being found in diastolic blood pressure, one could conclude that because systolic blood pressure increased in the aerobic condition, diastolic blood pressure is no longer needed to indicate that arousal was induced. However, on both the recall and recognition measures no significant difference in memory performance was found between conditions and the null hypothesis was rejected.

Most studies have investigated the effect of aerobic exercise on cognition during childhood and in elderly. It is pointed out that in these populations various cognitive processes benefit from exercise (Hillman, Erickson, & Kramer, 2008). However, there are few studies that have investigated the influence of aerobic exercise on memory retrieval in young healthy adults. Cognitive performance is at its peak during young adulthood, hence leaving less room for exercise-related improvement of memory in this population (Salthouse & Hasker, 2006). This might be a reason why only few researchers are interested in investigating the effect of exercise on memory in young adults.

As previously stated, Roig et al. (2013) demonstrated that acute cardiovascular exercise improved memory encoding and consolidation in healthy young adults. Interestingly, different types of aerobic exercise had different effects on different memory components. The absence of statistically significant results in the present study compared to previous studies might be explained by the memory component retrieval that was manipulated here. For example, Weinberg et al. (2014) investigated the effects of resistance exercise performed during memory consolidation by means of a low-intensity one-leg knee extension/flexion task, whereas this study used aerobic exercise to induce arousal during the retrieval phase. Moreover, the fact that the current study had low power, due to the fact that only 48 subjects participated, could also explain why no effect of condition was found on memory retrieval. Finally, Weinberg et al. (2014) used positive, neutral and negative visual images as memory stimuli, thereby inducing an arousal

coupled to stimulus valence during the encoding phase, while the present study used only neutral words. Neutral stimuli were opted for to avoid memory enhancement due to arousal induced by the stimuli, as it has been demonstrated that arousing material is better remembered (Segal & Cahill, 2009).

Some suggestions for improvement for future research can be made. Firstly, the present study made use of a WLT as a memory task. However, it is possible that creating a different study set-up that has more in common with real exam situations might yield different results and be of even more interest. Real exam situations differ from the task used in this study in that retrieval of more complex concepts, not simple neutral words, is required. A memory study set-up that perhaps bears more commonalities to exam conditions is for example the Deese-Roediger-McDermott paradigm (Roediger & McDermott, 1995). It would be interesting to know if these suggested alterations in study design would yield different outcomes in memory performance. Secondly, the present study used an experimental design but other designs might generate valuable data in respect to the investigation of the relation between cognitive performance and physical arousal. For instance, next to an experimental treatment design a quasi-experimental design could be conducted to examine the direct influence of pre-existing differences in arousal levels. Finally, the current study compared the retrieval of words between groups of individuals who performed aerobic exercise and individuals who watched a documentary. It would be interesting to investigate the possible effects of different types of physical exercise, such as exercise emphasising flexibility, muscle tone, relaxation, coordination and calisthenics on memory retrieval (Chang, Pan, Chen, Tsai, & Huang, 2012).

Some limitations of the present study design should be mentioned. To start, the use of university students as participants presents several limitations. Generalization of the results from a student population to the general population is not guaranteed. Further, students are generally scholarly educated and cognitively able. This may lead to ceiling effects with regard to the amount of words retrieved on the recognition task and possibly some obscured treatment

effects. Furthermore, the above mentioned cognitive peak during young adulthood could be a factor of influence on memory retrieval. Secondly, the testing period was limited to only three weeks due to practical restrictions, so only a limited amount of participants was tested. Consequently, the statistical power of the analyses was compromised and likely would have been insufficient to uncover a potential significant effect. Further research can conceivably overcome the above stated limitations and look into other study compositions and designs as suggested earlier, to learn more about the opportunities of physical activity as a cognitive enhancer.

In conclusion, the current study looked into the ability of aerobic exercise to increase memory retrieval and thereby its function as a non-pharmaceutical cognitive enhancer. Although aerobic exercise effectively increased arousal, no significant results were obtained in memory performance following aerobic exercise right before retrieval.

REFERENCES

Burke, L. M. (2008). Caffeine and sports performance. Applied Physiology, Nutrition, and Metabolism, 33(6), 1319-1334. http://dx.doi.org/10.1139/H08-130

Chang, Y., Pan, C., Chen, F., Tsai, C., & Huang, C. (2012). Effect of resistance-exercise training on cognitive function in healthy older adults: A review. *Journal of Aging and Physical Activity, 20*(4), 497-501. http://www.ncbi.nlm.nih.gov/pubmed/22186664

Gregoire, J., Tuck, S., Yamamoto, Y., & Hughson, R. L. (1996). Heart rate variability at rest and exercise: Influence of age, gender and physical training. *Canadian Journal of Applied Physiology, 21*(6), 455-470. http://dx.doi.org/ 10.1139/h96-040

Heishman, S., Arasteh, K., & Stitzer, M. L. (1996). Comparative effects of alcohol and marijuana on mood, memory, and performance. Pharmacology Biochemistry and Behavior, 58(1), 93-101. http://dx.doi.org/10.1016/S0091-3057(96)00456-X

Het, S., Ramlow, G., & Wolf, O. T. (2005). A meta-analytic review of the effects of acute cortisol administration on human memory. *Psychoneuroendocrinology, 30*(8), 771-784. http://dx.doi.org/ 10.1016/j.psyneuen.2005.03.005

Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: Exercise effects on brain and cognition. *Nature Reviews Neuroscience, 9*(1), 58-65. http://dx.doi.org/10.1038/nrn2298

Hull, C. L. (1943). *Principles of behavior*. New York: Appleton- Century-Crofts.

Jackson, A. S., Blair, S. N., Mahar, M. T., Wier, L. T., Ross, R. M., & Stuteville, J. E. (1990). Prediction of functional aerobic capacity without exercise testing. *Medicine and science in sports and exercise, 22*(6), 863-870. http://dx.doi.org/10.1249/00005768-199012000-00021

Jones, M. V., Lane, A. M., Bray, S. R., Uphill, M., & Catlin, J. (2005). Development and validation of the sport emotion questionnaire. *Journal of Sports and Exercise Psychology*, *27*(4), 407-431. http://dx.doi.org/10.13072/midss.117

Lang, P. J. (1980). Behavioral treatment and bio-behavioral assessment: Computer applications. In J. B. Sidowski, J. H. Johnson, & T. A. Williams (Eds.), *Technology in mental health care delivery systems* (pp. 119-137). Norwood, NJ: Ablex.

McCabe, S. E., Knight, J. R., Teter, C. J., & Wechsler, H. (2005). Non-medical use of prescription stimulants among US college students: Prevalence and correlates from a national survey. *Addiction, 100*(1), 96–106. http://dx.doi.org/10.1111/j.1360-0443.2004.00944.x

Murdock, J.R., & Bennet, B. (1960). The immediate retention of unrelated words. *Journal of Experimental Psychology, 60*(4), 222-234. http://dx.doi.org/10.1037/h0045145

Palatini, P. (1988). Blood pressure behavior during physical activity. *Sports Medicine, 5*(6), 353-374. http://dx.doi.org/0112-1642/88/0006-0353/$11.00/0

Pano, G. (2013). Physical activity benefits for Alzheimer's disease. *Journal of Human Sport and Exercise, 9*(1), 319-325. http://dx.doi.org/ 10.14198/jhse.2014.9.Proc1.15

Patton, J. H., Stanford, M. S., & Barratt, E. S. (1995). Factor structure of the Barratt Impulsiveness Scale. *Journal of Clinical Psychology, 51*(6), 768-774. http://dx.doi.org/10.1002/1097-4679(199511)

Roediger, H. L., & McDermott, K. B. (1995). Creating false memories: Remembering words not presented in lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*(4), 803-814. http://dx.doi.org/10.1037/0278-7393.21.4.803

Roig, M., Nordbrandt, S., Geertsen, S. S., & Nielsen, J. B. (2013). The effects of cardiovascular exercise on human memory: A review with meta-analysis. *Neuroscience and Biobehavioral Reviews, 37*(8), 1645-1666. http://dx.doi.org/10.1016/j.neubiorev.2013.06.012

Salthouse, T. A., & Hasker, P. D. (2006). Organization of cognitive abilities and neuropsychological variables across the lifespan. *Developmental Review, 26*(1), 31-54. http://dx.doi.org/10.1016/j.dr.2005.09.001

Segal, S. K., & Cahill, L. (2009). Endogenous noradrenergic activation and memory for emotional material in men and women. *Psychoneuroendocrinology, 34*(9), 1263-1271. http://dx.doi.org/10.1016/j.psyneuen.2009.04.020

Stanislaw, H., & Todorov, N. (1999). Calculation of signal detection theory measures. *Behavior Research Methods Instruments & Computers, 31*(1), 137-149. http://dx.doi.org/10.3758/BF03207704

Weinberg, L., Hasni, A., Shinohara, M., & Duarte, A. (2014). A single bout of resistance exercise can enhance episodic memory performance. *Acta Psychologica, 153*, 13-19. http://dx.doi.org/10.1016/j.act.psy.2014.06.011

Yerkes, R.M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology, 18*(5), 459-482. http://dx.doi.org/ 10.1002/cne.920180503