Spring 5-9-2020

The Effects of High-Intensity Acute Exercise on Implicit Memory and Face-Name Explicit Memory

Morgan Gilbert

University of Mississippi

THE EFFECTS OF HIGH-INTENSITY ACUTE EXERCISE ON IMPLICIT MEMORY AND FACE-NAME EXPLICIT MEMORY

by
Morgan Hunter Gilbert

A thesis submitted to the faculty of The University of Mississippi in partial fulfillment of the requirements of the Sally McDonnell Barksdale Honors College

Oxford
May 2020

Approved by

____
Advisor: Dr. Paul Loprinzi

____
Reader: Dr. KoFan Lee

____
Reader: Dr. Matthew Reysen

Dedicated to the memory of my Papa, Bobby Gene Gilbert Sr. Your strong will and love is what has made me into the hardworking student I am today. You taught me to dream, and I will forever hold your memory in my heart. I love you.

ACKNOWLEDGEMENTS

Dr. Loprinzi,

I want to thank you for all of your time and efforts that you dedicated towards myself and this thesis. Thank you for giving me the opportunity to work in your laboratory for the past two years. You pushed me to tackle this thesis, and your guidance will be one of the most memorable parts of my college career at the University of Mississippi.

My parents,

Thank you for all of the love and support you have given me. Thank you for allowing me to reach for the stars and achieve my dreams. Without your support of my education, I would not be able to call this University home. Your love is what gave me the push I needed to succeed. I love you both so much.

Dr. Reysen and Dr. Lee,

Thank you for all of your help in the editing and defense process. Your time and dedication allowed for this thesis to become a reality.

Sally McDonnell Barksdale Honors College,

Thank you for your guidance and opportunities. Your funding to the Exercise and Memory Laboratory allowed for this thesis to come to fruition. Thank you for providing a place of comfort and motivation, and I am forever thankful for this opportunity to write this thesis.

The University of Mississippi School of Applied Sciences,

Thank you to all of my professors and advisors who have dedicated themselves to my education. Your leadership gave me the knowledge and confidence for this thesis, and for all of my future academia. Thank you for your time and support.

ABSTRACT

MORGAN HUNTER GILBERT: The Effects of High-Intensity Acute Exercise on Implicit Memory and Face-Name Explicit Memory
(Under the direction of Dr. Paul Loprinzi)

Objective: The majority of previous research evaluate the effects of acute exercise on memory function have focused on explicit memory tasks involving word-list paradigms. For more real-world application, the present experiment evaluates whether high-intensity acute exercise can improve implicit memory function as well as increase one's ability to remember names associated with faces (face-name paradigm). **Methods**: A two-arm, parallel-group, randomized controlled intervention was employed. Participants (N=91; M_{age} = 20 yrs) were randomized into one of two groups, including an experimental group and a control group. The experimental group exercised for 20 minutes on a treadmill at a high-intensity (75% of heart rate reserve), while the control group engaged in a seated, time-matched task. Explicit memory was assessed via a face-name paradigm in which participants encoded and subsequently recalled names that were paired with faces. Implicit memory was evaluated with computerized program involving spatial-temporal integration. **Results**: The acute exercise group recalled more face-name pairs than the control group (11.16 words vs. 9.79 words), but this did not reach statistical significance (p = .25). There were also no group differences for implicit memory (p = .57). **Conclusion**: We did not observe convincing evidence that high-intensity acute exercise influences face-name explicit memory or implicit memory function.

However, future work on this under-investigated topic is needed.

Keywords: Cognition; cognitive function; physical activity

TABLE OF CONTENTS

Background

Have you ever wondered how you remember simple tasks such as how to ride a bicycle or how you can remember the face of someone you just met? These are both systems of the brain's long term memory function, implicit and explicit memory function respectively. Both implicit and explicit memory function deal with the body's conscious and unconscious ability to obtain and recall information. While both of these memory types are two separate ways the brain processes long term memory, the overall mechanisms behind them are all too similar.

Rightfully so, it is important that we analyze both implicit and explicit memory separately to better understand the overlaps that occur in their mechanisms. To reiterate, implicit memory focuses on the unconscious recall. That is the mind involuntarily uses previous experiences in order to consolidate memories to be recalled later. Within implicit memory there are two primary types: procedural and priming. Procedural memory is like the earlier example of a bike ride, it is the unconscious recalling of a basic procedure. In this example, it relates to how you no longer have to think carefully through each step of riding a bike such as how to balance and then how to petal. Instead, one can simply push off for their bike ride without having to give the process much thought. The other half to implicit memory is called priming. Priming is most commonly used in the research background as it is the process of using stimuli such as words or pictures to induce the unconscious recall of other words or pictures later on.

This is incredibly popular in the research community because of its simplicity to replicate and reproduce.

Contrarily, explicit memory revolves around the ability of conscious recall.[22] That is the mind voluntarily uses previous experiences to later recall that same information. Within explicit memory there are also two different types: semantic and episodic. Semantic memory is basic facts such as 2+2=4. These types of memory do not take a lot of thought, but rather “roll of the tongue” for most. On the other hand, episodic memory is one’s ability to recall personal events such as people’s names and their own birthday.[23] To emphasize, these are personal experiences, and this type of memory deals directly with how people use those previous encounters to recall information later on. Relating to the episodic memory branch of explicit memory, this study focused on the example of face name recall. That is participants were given certain faces with paired names to memorize however they seemed fit. For some, this could have been relating a name back to a relative they know of the same name, or even certain characteristics that stood out for that face in particular. This is what is called ecological memory, and is a great real life example of the explicit memory function.

Diving deeper into ecological memory, it can be described as the capability of the past states or experiences of a community to influence the present or future ecological responses of the community (Hai, et al. 2011). This plays a major role in ecosystems in particular as it can relate to how members of a community interact with one another. For best example, it is how one can interact with a stranger and remember that encounter in order to co-consolidate the name and other features of that particular person. This is also the type of memory that is vital to processes such as natural selection. Certain traits can be seen as more desirable, and it is the mind's ability to consolidate those likeable features that leads humans to be more decisive towards the familiar. It is also important to note that face name recall in particular consists of two primary portions; recognizing the face and recalling the name. There is no clear definition that one dominates over the other, but rather is person-specific.

Before diving into the complexity of the brain implications of both implicit and explicit memory, it is vital to first recall the overall memory consolidation process. This three-step process consists of the encoding, consolidation, and retrieval stages. Beginning with encoding, this is simply the person's ability to be exposed to the stimulus and convert this stimulus into a neurological message to be consolidated in the brain. This stimulus is usually identified using the five senses: taste, touch, sight, smell, and hearing, and later converted into a visual, acoustic or semantic stimulus.

Secondly, the now converted stimulus must become consolidated via pre- and post-synaptic neuron stimulus. To simply put it, the activation of glucocorticoid receptors allow calcium protein kinases to phosphorylate the activation of the CREB cycle. This activation of the CREB cycle thus allows a sustained synthesis of brainderived neurotrophic factors. Thus, glucocorticoid receptor activation recruits pre- and post- synaptic mechanisms to mediate memory consolidation (Alberini, et al. 2015). This process is overall vital to the stabilizing of the memory in the brain as a new long term memory for later recall.

The final stage of the memory process is that of retrieval. In the long-term memory specific process of recalling, it is usually accomplished by the use of a pre-exposed stimulus. For example, when one tries to search for a lost item, they usually attempt to retrieve the memory of where they last placed it by tracing their steps. This is in hopes that a pre-exposed stimulus, such as a particular room, might aid in the recalling of the last known position of that item. In short, the retrieval process deals with the recalling of the neural pathway between the pre- and post- synaptic neurons in order to best reiterate the key parts that link the memory to the stimulus.

As previously mentioned, the overlapping of the brain regions of both implicit and explicit memory are all too similar. Though each exhibits independent significance, *it is the overlap* that is of research interest. The first portion of similarity comes from the encoding and consolidation phases. When encoding a long-term memory, both the implicit and explicit memory utilizes the use of the hippocampus in the temporal region of the brain. As stated earlier, the overall process that occurs within the hippocampus deals with the consolidation process. In implicit memory, the brain uses automatic sensorimotor actions to consolidate stimulated actions, so later when recalling these actions, it becomes an automatic response. Since the hippocampus is mainly responsible for autobiographical memories, both methods rely on the exposure to personal stimuli to concrete the consolidation for later recall, so it makes sense that both explicit and implicit rely heavily on this region of the brain. The main difference lies in the fact that implicit once again relies on the use of automatic sensorimotor actions for that involuntary, automatic response while explicit relies on the voluntary control of memory encoding and consolidation.

Finally, the other main difference between the use of brain regions of both the implicit and explicit memory deals with the retrieval stage. This act of voluntary versus involuntary retrieval is what sets these memory processes apart. With explicit memory, this is once again going to rely heavily on the temporal, hippocampus area of the brain as it must remember the pre- and post- synaptic pathway used to consolidate the retrieved memory. On the contrary, implicit memory uses an automatic response, and it is even shown that implicit retrieval produces a decrease in the hemodynamic response, termed “repetition suppression” (Schacter and Buckner, 1998).

While taking in mind the overall mechanism of both implicit and explicit memory function, it is important to understand the best ways to present these processes in a research setting. This involves three main regions of the brain: the occipital lobe, the left angular gyrus, and the left inferior frontal cortex. First with the occipital lobe, this will be dealing primarily with visual stimuli. This can be presentation styles such as asking a participant to recall differing scenery or visual cues such as differing facial features for face name recall. Lastly, both the left angular gyrus and left inferior frontal cortex aid in the presentation style of words. While the left angular gyrus primarily deals with the relation to words such as one's emotion towards a word, the left inferior frontal cortex deals more with the sounds accompanied by words. This can include not only the participant's ability to relate a sound to its corresponding word, but also the hearing of words being read aloud.

Overall, the two main types of long term memory, implicit and explicit memory, *vary primarily in their recalling phases*. With the dual effect of the usage of the hippocampus, it is significant in research to analyze the dual effects if both implicit and explicit memory are co-stimulated. This provides a gateway for the use of real life experiments, such as face name recall and environment stimuli, to show the influence both of these types of long term memory could have on the overall role of humans in the ecological system.

Introduction

Over the last decade, an accumulating body of research provides suggestive evidence that acute exercise may enhance episodic memory function,[1-6] the retrospective recall of contextually based information, typically considered within a spatial-temporal domain. However, as we emphasized recently,[7] this acute exercise-memory relationship is complex, likely moderated by multiple exercise dimensions (e.g., intensity, modality, etc.) and memory subsystems (e.g., implicit, working, procedural memory). As we detailed recently,[8-10] mechanisms through which acute exercise influences episodic memory is likely driven through induction of long-term potentiation.

The majority of research that has evaluated the effects of acute exercise on episodic memory has relied on simplistic, laboratory-based memory tasks, often involving encoding a list of words or a short paragraph. Few studies, however, have examined the effects of acute exercise on real-world episodic memory tasks, such as the face-name memory task. This task, similar to paired-associative learning tasks, involves remembering names with faces. Clearly, such an evaluation is a real-world, ecological assessment of memory. The dynamics of social interaction often involves meeting new individuals and being informed of their names. Anecdotally, most of us have likely experienced situations where, despite just being told someone's name, fail to subsequently remember their name, even within minutes. This emerging field of research, face-name association, has identified fascinating insights to explain these challenges associated with face-name encoding and retrieval.

Various brain structures have been implicated in face-name associations, including bilateral hippocampi, fusiform gyrus, occipital cortex, and dorsolateral and inferior prefrontal cortex.[11,12] These brain regions, as well as complex cognitions, such as executive function, influence face-name associations.[13] Such brain regions and cognitions have been shown to be influenced by acute, aerobic exercise.[14] Based on this, we recently examined whether acute, moderate-intensity exercise could enhance face-name memory performance.[15] In this between-subject, randomized controlled experimental design, those who exercised prior to the face-name memory task recalled more face-name pairs during the immediate (6.60 vs. 6.20) and delayed assessments (6.25 vs. 5.75); however, these differences were not statistically significant. Relatedly, we also demonstrated similar results (i.e., non-statistically significant higher memory from acute exercise) in a different experimental study that examined the effects of acute, moderate-intensity exercise on source memory function.[16] The present experiment extends these previous studies in three main ways. First, the sample size (n=20 per group; N=40) in these previous studies were relatively small, and thus, were possibly underpowered to detect statistically significant differences. Thus, the present study employs *a larger sample size* to address this limitation. Second, emerging work suggests that *high-intensity acute exercise* (vs. lower intensity) is more beneficial in enhancing episodic memory.[17] As a result, the present experiment employs a higher-intensity acute exercise protocol. Thirdly, as we discussed in our previous experiment,[15] our null findings for the face-name memory study may have been a result of an insufficient amount of time spent encoding the face-name pairs, as demonstrated by the relatively low face-name memory scores (potential floor effect). As a result, herein, we have participants complete two memory encoding cycles.

In addition to evaluating whether acute exercise can enhance explicit-based face-name memory performance, another novel aspect of this experiment is to evaluate the effects of acute high-intensity exercise on implicit memory function. Implicit memory differs from explicit memory in that, for the former, encoding occurs at the subconscious level. As we have detailed elsewhere,[18] and unlike explicit memory function, *very limited research has examined the effects of exercise on implicit memory function*. A relationship between acute exercise on implicit memory is plausible given that explicit and implicit memory may be interrelated and share similar neural mechanisms.[19,20]

To address these above gaps in the literature, and to continue to develop this emerging area of research, the purpose of this study was twofold: 1) evaluate the effects of acute, high-intensity exercise on face-name explicit memory function, and 2) evaluate the effects of acute, high-intensity exercise on implicit memory function. We hypothesized that acute, high-intensity exercise would be associated with greater explicit and implicit memory function when compared to a controlled, seated task.

Methods

Study Design

A two-arm, parallel-group, randomized controlled intervention was employed. Participants were randomized into one of two groups, including an experimental group and a control group. The experimental group exercised for 20 minutes on a treadmill, while the control group engaged in a seated, time-matched task. An overview of the study procedures for each group are as follows:

Exercise and Control Groups

- 20-min of experimental manipulation
  - (either treadmill exercise at high-intensity for exercise group or video for control group)
- Rest for 5-minutes (thus, control group watches video for 25-min)
- Encode Face-Name Pairs – 2 cycles of encoding.
- Arithmetic problems for 30-sec
- Immediate recall of Face-Name Pairs
- Complete WWW (what-where-when) task
- Rest (video) until 20-min has elapsed since the encoding of face-name pairs
- Delayed recall of Face-Name Pairs
- Complete implicit memory task (i.e., specific questions from WWW task)

Participants

The total sample size included 91 participants. This is based on an a-priori power analysis from our previous experiment,[15] demonstrating that 90 participants would be needed to achieve a statistical power of 0.80 (1-β error probability), with inputs of 0.05 (α error probability), 2 groups, 2 time-point assessments (immediate and delay), and an estimated η^2_p of 0.02. Recruitment occured via a convenience-based, non-probability sampling approach (classroom announcement and word-of-mouth). Participants included undergraduate and graduate students between the ages of 18 and 27 yrs. Additionally, and consistent with other related studies,[21] participants were excluded if they:

- Self-reported as a daily smoker [22,23]
- Self-reported being pregnant [24]
- Exercised within 5 hours of testing [25]
- Consumed caffeine within 3 hours of testing [26]
- Had a concussion or head trauma within the past 30 days [27]
- Took marijuana or other illegal drugs within the past 30 days [28]
- Were considered a daily alcohol user (>30/month for women; >60/month for men)[29]

Exercise Protocol

The exercise bout involved exercising (jogging) on a treadmill for 20 minutes. Participants exercised at approximately 75% of their heart rate reserve (HRR). This corresponds with vigorous-intensity exercise.[30] As the participants jogged, the treadmill speed and/or incline were manipulated to keep the participant's heart rate within 10 beats per minute of the targeted heart rate. This modality and duration of acute exercise was chosen based on previous work demonstrating a memory enhancing effect.[31]

The HRR equation used to evaluate exercise intensity is: HRR = [(HRmax - HRrest) * % intensity] + HRrest. To calculate HRrest, at the beginning of the visit, participants will sit quietly for 5 minutes, and HR will be recorded from a chest-worn Polar HR monitor. To estimate HRmax, we will calculate the participants estimated HRmax from the formula, 220-age.[32]

Control Protocol

During all resting periods (for both the exercise and control groups), participants self-selected a video to watch, including either an episode of The Office or Big Bang Theory. They were instructed to be engaged in the video, as after viewing the video, they were asked to write down several different events/scenes that occurred during the video. The purpose of this was prevent potential rehearsal of the memory task. Notably, this video control period has been shown to not enhance memory, and thus, is a suitable control condition.[33]

Face-Name Memory Assessment

Participants completed a computer-based face-name memory task, which took approximately 10-minutes to complete. This task involves two main phases, including a study phase and a test phase. For the study phase, participants were exposed to 24 face-name pairs (of varying facial symmetry),[34] each separated by 6-seconds. Participants were instructed to try and memorize the name (only first name was provided) with the face, as subsequently they were asked to try and recall the name associated with each face. Participants completed two cycles of this study phase.

During the test phase, participants re-viewed the images (with the name not present) one at a time, for 10-seconds per image; i.e., they had 10-seconds to write down the name of the face. For both the short-term and delayed assessments, the max score is 24.

WWW Task (Used for Implicit Memory Assessment)

The WWW is a computerized task assessing 'what-where-when' episodic memory, taking approximately 10-minutes to complete. Details of this task have been discussed elsewhere.[35,36] In brief, this task involves 'hiding' items (e.g., food items, such as an apple, donut, etc.) in various scenes, then later indicating what items were hidden, where and on what occasion. This requires the integration of item, location and temporal memory into a single coherent representation (What-Where-When memory, WWW). Reliability for this task has been previously demonstrated (ICCs > 0.7).[36] The outcome variables assessed included an absolute WWW score (in which the location of the correct object for the correct time is identified exactly), and the proportion of correct responses for the separate what, where and when sub-tasks. This study used the 'hard" difficulty version of the task (version F).

In addition to evaluating episodic memory performance from this WWW task, we used this task to also evaluate implicit memory, modeled after other work.[37] The specific questions that were created from this WWW task to evaluate implicit memory included:

- What was the scenery for the first scene?
- How many trees were in the first scene?
- Was there a mountain in the first scene?
- How many houses were in the first scene?
- Was the sun visible in the first scene?
- What was the scenery for the second scene?
- How many cups were on the table in the second scene?
- How many chairs were in the second scene?
- What color was the soda can (which was located in the refrigerator, glass door)?

- How many windows were in the second scene?
- What was located in the cabinet in the second scene?
- What color was the floor in the second scene?

For this implicit memory task, a total of 12 points (1 point per question) were possible, with a higher score indicative of a greater implicit memory performance. One-point was awarded for each correct response. This implicit memory assessment occurred immediately after the delayed assessment of the face-name task.

Statistical Analysis

All statistical analyses were computed in JASP (v. 0.9.1). A two-factor mixed measures ANOVA was employed for the face-name memory outcome. Main effects for time (immediate and delay assessments) and group, as well as group by time interaction effects, were evaluated. For the WWW and implicit memory outcomes, an independent t-test was used to evaluate group differences. Statistical significance was set at an alpha of 0.05. Eta-square (η^2) was calculated as an estimate of effect size.

Results

Table 1 displays the demographic and behavioral characteristics of the sample.

Table 1. Participant characteristics

	Exercise (N=43)	Control (N=48)	P-Value
Age, mean years	20.11 (1.36)	20.10 (1.56)	.96
Gender, % Female	86.05	83.33	.72
Race-Ethnicity, # White	81.39	81.25	.09
MVPA, mean min/week	120.34 (99.4)	161.35 (123.0)	.09

MVPA, Moderate to vigorous physical activity (measured via the Physical Activity Vitals Sign Questionnaire).

Table 2 displays the heart rate responses across the experimental groups.

Table 2. Heart rate responses

	Rest	5-min	10-min	15-min	20-min	Post (rest)
Exercise	81.3 (12.8)	154.6 (14.3)	162.0 (7.0)	166.0 (4.9)	166.6 (5.5)	95.5 (12.5)
Control	82.2 (13.6)	-	-	-	-	80.3 (14.6)

Figure 1 displays the explicit memory results for the face-name memory task. The mean (SD) number of correct face-name pairs between the exercise and control groups, respectively, for immediate memory were 11.16 (4.4) and 9.79 (4.3). The respective results for delayed memory were 10.65 (5.1) and 9.87 (4.0). There was no main effect for group, $F(1, 89) = 1.34$, $p = .25$, $\eta_2 = .01$, main effect for time period, $F(1, 89) = 1.21$, $p = .27$, $\eta_2 = .001$, or group by time period interaction, $F(1, 89) = 2.34$, $p = .12$, $\eta_2 = .001$.

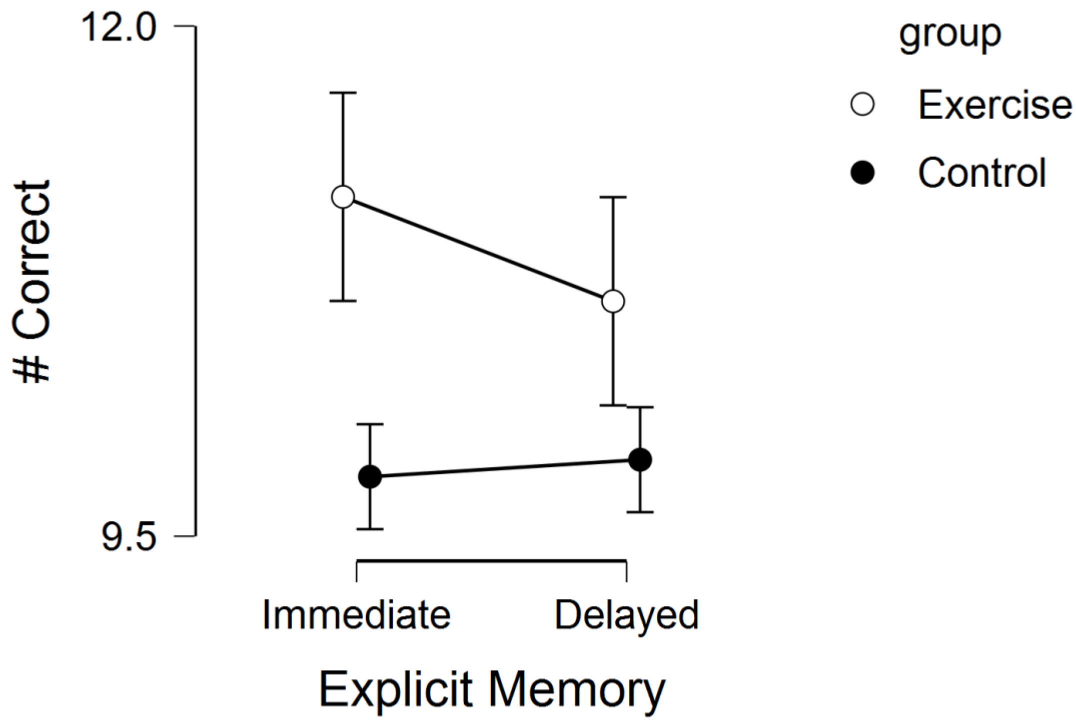

Figure 1. Face-name results (# of correct face-name pairs) between the exercise and control conditions. Error bars represent 95% CI.

Table 3 displays the WWW and implicit memory results across the two groups. There were no statistically significant differences in WWW or implicit memory between the exercise and control groups.

Table 3. WWW and implicit memory results

Variable	**Exercise**	**Control**	**Test Statistic**
WWW, mean %	50.17 (21.2)	53.81 (22.8)	$t(89) = .78$, $p = .43$, d = .16
Implicit memory, mean #	7.30 (1.7)	7.52 (1.9)	$t(89) = .56$, $p = .57$, d = .12

Values in parentheses represent standard deviations

Discussion

The present experiment is an extension of our previous research. We previously evaluated the effects of moderate-intensity acute exercise on face-name memory.[15] In this prior experiment,[15] moderate-intensity acute exercise did not increase face-name memory performance. We anticipated this result was due to our relatively small sample size (N=40), utilization of an insufficient encoding of the face-name pairs (single exposure), and too low (moderate-intensity) of an exercise intensity. As a result, for the present experiment, we increased the sample size (N=91), doubled the encoding duration (two exposure cycles), and employed a high-intensity bout of exercise. Despite these modifications, the present experiment did not provide convincing evidence of a beneficial effect of acute exercise on face-name memory function. However, and although not statistically significant, the acute exercise group recalled more face-name pairs than the control group (11.16 words vs. 9.79 words). Another novel aspect of the present experiment was the evaluation of implicit memory function. As we detailed previously in a systematic review,[18] very few studies among humans have evaluated the effects of acute exercise on implicit memory. Similar to our explicit memory results in the present experiment, we also did not observe any effects of acute exercise on implicit memory.

Our null findings may be a result of several factors. Despite the acute exercise group accurately recalling more face-name pairs, this difference was not statistically significant. As such, it is possible that our sample size was still too small to observe a statistically significant difference. In addition to considering this, future work should also consider re-evaluating this paradigm, but consider utilizing a within-subject design, which are more statistically powerful.

Strengths of this study include the experimental design, study novelty, and practical implications. Potential limitations to consider include the homogenous sample of young adults, estimation of maximum heart rate used to prescribe exercise intensity, and not including an objective evaluation of the participant’s cardiorespiratory fitness. Regarding the latter, in theory, cardiorespiratory fitness could moderate the effects of high-intensity acute exercise on memory, as individuals may respond (physiologically and psychologically) differently to high-intensity exercise based on their fitness level. However, we did compute a sensitivity analysis that controlled for self-reported moderate-to-vigorous physical activity, a proxy for fitness, and this did not alter our main findings.

In conclusion, the present experiment does not provide convincing evidence that high-intensity acute exercise enhances face-name explicit memory or implicit memory. Future experimental work on this novel topic is needed.

Acknowledgments – We have no conflicts of interest and no funding was used to prepare this manuscript.

References

1. Bisaz, R., Travaglia, A., & Alberini, C. M. (2014). The neurobiological bases of memory formation: from physiological conditions to psychopathology. *Psychopathology*, *47*(6), 347–356. https://doi.org/10.1159/000363702

2. Buckner, R. L., Koutstaal, W., Schacter, D. L., Rosen, B. R., 2000. Functional MRI evidence for a role of frontal and inferior temporal cortex in amodal components of priming. *Brain 123* (3), 620-640

3. Haynes IV JT, Frith E, Sng E, et al. Experimental Effects of Acute Exercise on Episodic Memory Function: Considerations for the Timing of Exercise. *Psychol Rep.* 2018:33294118786688.

4. Loprinzi PD. Association between habitual physical activity on episodic memory strategy use and memory controllability. *Health Promot Perspect.* 2018.

5. Loprinzi PD, Blough J, Crawford L, et al. The temporal effects of acute exercise on episodic memory function: Systematic review with meta-analysis. *Brain Sciences.* 2019;9(4):87.

6. Ponce P, Loprinzi PD. A bi-directional model of exercise and episodic memory function. *Med Hypotheses.* 2018;117:3-6.

7. Siddiqui A, Loprinzi PD. Experimental Investigation of the Time Course Effects of Acute Exercise on False Episodic Memory. *J Clin Med.* 2018;7(7).

8. Loprinzi PD, Frith E, Edwards MK, et al. The Effects of Exercise on Memory Function Among Young to Middle-Aged Adults: Systematic Review and Recommendations for Future Research. *Am J Health Promot.* 2018;32(3):691-704.

9. Loprinzi PD. An integrated model of acute exercise on memory function. *Medical Hypotheses*. 2019;126:51-59.

10. Loprinzi PD, Edwards MK, Frith E. Potential avenues for exercise to activate episodic memory-related pathways: a narrative review. *Eur J Neurosci.* 2017;46(5):2067-2077.

11. Loprinzi PD, Ponce P, Frith E. Hypothesized mechanisms through which acute exercise influences episodic memory. *Physiol Int.* 2018;105:1-13.

12. Loprinzi PD. The effects of exercise on long-term potentiation: A candidate mechanism of the exercise-memory relationship. *OBM Neurobiology*. 2019;3(2):13.

13. Sperling RA, Bates JF, Cocchiarella AJ, et al. Encoding novel face-name associations: a functional MRI study. *Hum Brain Mapp.* 2001;14(3):129-139.

14. Sperling R, Chua E, Cocchiarella A, et al. Putting names to faces: successful encoding of associative memories activates the anterior hippocampal formation. *Neuroimage.* 2003;20(2):1400-1410.

15. Mitchell MB, Shirk SD, McLaren DG, et al. Recognition of faces and names: multimodal physiological correlates of memory and executive function. *Brain Imaging Behav.* 2016;10(2):408-423.

16. Hsieh SS, Huang CJ, Wu CT, et al. Acute Exercise Facilitates the N450 Inhibition Marker and P3 Attention Marker during Stroop Test in Young and Older Adults. *J Clin Med.* 2018;7(11).

17. Farris A, Loprinzi PD. Experimental effects of the effects of acute exercise on real-world ecological memory. *Journal of Science in Sport and Exercise.* 2019.

18. Rigdon B, Loprinzi PD. Experimental effects of acute exercise on source memory recognition. *Journal of Behavioral Health.* 2019;8(2):59-65.

19. Loprinzi PD. Intensity-specific effects of acute exercise on human memory function: Considerations for the timing of exercise and the type of memory. *Health Promot Perspect.* 2018;8(4):255-262.

20. Loprinzi PD, Edwards MK. Exercise and Implicit Memory: A Brief Systematic Review. *Psychol Rep.* 2018;121(6):1072-1085.

21. Barco A, Bailey CH, Kandel ER. Common molecular mechanisms in explicit and implicit memory. *J Neurochem.* 2006;97(6):1520-1533.

22. Dew ITZ, Cabeza R. The porous boundaries between explicit and implicit memory: behavioral and neural evidence. *Ann N Y Acad Sci.* 2011;1224:174-190.

23. Yanes D, Loprinzi PD. Experimental Effects of Acute Exercise on Iconic Memory, Short-Term Episodic, and Long-Term Episodic Memory. *J Clin Med.* 2018;7(6).

24. Jubelt LE, Barr RS, Goff DC, et al. Effects of transdermal nicotine on episodic memory in non-smokers with and without schizophrenia. *Psychopharmacology (Berl).* 2008;199(1):89-98.

25. Klaming R, Annese J, Veltman DJ, et al. Episodic memory function is affected by lifestyle factors: a 14-year follow-up study in an elderly population. *Neuropsychol Dev Cogn B Aging Neuropsychol Cogn.* 2016:1-15.

26. Henry JD, Rendell PG. A review of the impact of pregnancy on memory function. *J Clin Exp Neuropsychol.* 2007;29(8):793-803.

27. Labban JD, Etnier JL. Effects of acute exercise on long-term memory. *Res Q Exerc Sport.* 2011;82(4):712-721.

28. Sherman SM, Buckley TP, Baena E, et al. Caffeine Enhances Memory Performance in Young Adults during Their Non-optimal Time of Day. *Front Psychol.* 2016;7:1764.

29. Wammes JD, Good TJ, Fernandes MA. Autobiographical and episodic memory deficits in mild traumatic brain injury. *Brain Cogn.* 2017;111:112-126.

30. Hindocha C, Freeman TP, Xia JX, et al. Acute memory and psychotomimetic effects of cannabis and tobacco both 'joint' and individually: a placebo-controlled trial. *Psychol Med.* 2017:1-12.

31. Le Berre AP, Fama R, Sullivan EV. Executive Functions, Memory, and Social Cognitive Deficits and Recovery in Chronic Alcoholism: A Critical Review to Inform Future Research. *Alcohol Clin Exp Res.* 2017.

32. Garber CE, Blissmer B, Deschenes MR, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med Sci Sports Exerc.* 2011;43(7):1334-1359.

33. Frith E, Sng E, Loprinzi PD. Randomized controlled trial evaluating the temporal effects of high-intensity exercise on learning, short-term and long-term memory, and prospective memory. *Eur J Neurosci.* 2017;46(10):2557-2564.

34. Clinic M. Exercise intensity: How to measure it. 2018, June 12; https://www.mayoclinic.org/healthy-lifestyle/fitness/in-depth/exercise-intensity/art-20046887.

35. Blough J, Loprinzi PD. Experimental manipulation of psychological control scenarios: Implications for exercise and memory research. *Psych.* 2019;1(1):279-289.

36. Rhodes G, Sumich A, Byatt G. Are average facial configurations attractive only because of their symmetry? *Psychological Science.* 1999;10:52-58.

37. Cheke LG. What-where-when memory and encoding strategies in healthy aging. *Learn Mem.* 2016;23(3):121-126.
38. Cheke LG, Simons JS, Clayton NS. Higher body mass index is associated with episodic memory deficits in young adults. *Q J Exp Psychol (Hove).* 2016;69(11):2305-2316.
39. Cheke LG, Clayton NS. Do different tests of episodic memory produce consistent results in human adults? *Learn Mem.* 2013;20(9):491-498.
40. Zhong-Yu, S., & Hai, R. (2011). Ecological memory and its potential applications in ecology: A review. *Yingyong Shengtai Xuebao*, *22*(3).