Exercise, Learning and Emotional Health: Interdisciplinary Approaches to Translational Action

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EXERCISE, LEARNING AND EMOTIONAL HEALTH: INTERDISCIPLINARY APPROACHES TO TRANSLATIONAL ACTION.

By

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A dissertation submitted in partial fulfillment of the requirements for the

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Exercise, Learning and Emotional Health: Interdisciplinary Approaches to Translational Action.

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ABSTRACT

Exercise positively effects physical, psychological and neurological wellbeing. Though the population at large is becoming increasingly aware of the multi-faceted benefits of exercise, the majority of people fail to meet daily exercise recommendations. Largely, demands of everyday life such as work, school and family take priority over fitness. The issue therefore becomes a matter of time. In a world of media multi-tasking and immediate gratification, the challenge to health professionals becomes incorporation and manipulation of these consistencies to improve exercise uptake and adherence. Focus must shift from the idea of making additional time for exercise, to adding exercise to time already allocated for other priorities. Exercising while reviewing notes or listening to a conference call increases feasibility through decrease in time demand. This dual task notion can be taken a step further. Research suggests that not only can one perform equally well on certain tasks while exercising but they can also, in fact, increase effectiveness of certain tasks while engaged in simultaneous exercise. From here, positive affect toward exercise increases, as does enjoyment and self-efficacy. These being prime mediators of exercise adherence, adherence improves and overall health does concurrently. The overarching purpose of this dissertation was to examine physiological, neurological and psychological benefits of exercise bouts aimed at increasing cognitive function and replacing otherwise sedentary behavior. Three successive yet individual study designs were implemented in addressing this purpose.

The purpose of the first study in this series was to examine physiological and psychological stress in students following a previously established university-driven exercise intervention. The intervention occurs each semester just prior to final exams with intent to add healthy habits to a traditionally sedentary and stressful study week. The intervention was studied
over two semesters, with second semester research completed as an independent study of this dissertation. Because first authorship remains consistent and methodology and results pertain directly to the progression of this dissertation, an appendix has been added summarizing protocol and results. Across semesters, stress hormones, perceived academic stress and psychological affect toward the intervention were measured. Results showed significantly lower perceived academic stress and a trend toward significantly lower physiological stress prior to final exams for students engaged in the intervention as well as significant positive affect toward the intervention itself. It was therefore concluded that a university driven exercise intervention positively effects academic stress, self-efficacy and psychological wellbeing prior to final exams.

Challenges in recruitment across semesters due to an unwillingness of students to compromise study time for exercise lead to the creation of the second study in this series. Existing research indicates increases in memory with exercise; therefore the purpose of the second study was to examine the effectiveness of studying during treadmill exercise in college students compared to sedentary study. Participants sat, walked or jogged while engaged visual vocabulary encoding. Immediate and delayed learning performance was measured, as was psychological affect of enjoyment, retention and utilization. Results showed that walking while studying to be more beneficial to vocabulary definition memorization than jogging while studying, or sedentary study when a student is familiar with studying in general. Results also showed significant positive affect for enjoyment and retention in both walking and jogging groups compared to the sedentary study. The conclusion for this study is that walking while studying improves memory consolidation and treadmill exercise while studying results improves study enjoyment and perceived retention.
While creating a habit toward health behavior in the college years is of utmost importance in sustainment throughout the adult life, the benefits of treadmill exercise and memory consolidation could prove beneficial across the age span. Working adults with little time yet an increasing awareness of their health as they age may be most interested in utilization of such. Differences in comfort and overall cognitive demand to walk while reading may vary among age groups and could affect learning performance. Therefore the purpose of the final study in this dissertation was to compare immediate and delayed retention following an acute bout of dual task treadmill walking and visual vocabulary encoding across adult age groups. This is the first study to compare an exercise-learning intervention across the adult life span and inches toward translation by moving data collection out of the lab and into a community fitness center with recruitment from the membership base. Results indicate that immediate and delayed learning performance was significantly greater in younger adults as was perceived retention. Interestingly, a high level of enjoyment and likelihood of utilize exercise learning remained similar across age groups. The conclusion of this study is that despite differences in effectiveness of simultaneous exercise and learning, people across the adult life find enjoyment in doing so and seek to utilize such behavior.
ACKNOWLEDGEMENTS

Thank you to my co-advisors Dr. James Navalta and Dr. Jack Young, two men who are as different as they are distinguished. Dr. Navalta, thank you for your ever-encouraging perspective, for focusing my energy and for finding humor in the organized chaos. Thank you for living the example of “family first.” Dr. Young (ahem – Jack), thank you for continually bringing me back to the science in the name of clarity and practicality. Thank you for reminding me to have a little fun along the way. Thank you both for your faith in completion irrespective of pregnancy, parenthood and relocation. Thank you for believing.

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Thank you to Dr. Dick Tandy for seeing my strength as an educator and providing a platform in which to preach my passion. Thank you for your continued reassurance and light heartedness. Thank you to Dr. Janet Dufek for ensuring adherence to university protocol and quality of work.

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Lastly, thank you to my dog Addison for being my companion during the many pre-daybreak writing sessions and zero-dark-thirty runs when the words wouldn’t flow.
DEDICATION

Dedicated to Avery and Aralynn; to provide you a better life in all aspects within my power, to teach you to run, dance, laugh and love with reckless abandon in the name of healthy longevity and happiness.
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CHAPTER 1

Introduction

An acute bout of exercise has been shown to have positive effects on the body, the brain and psychological wellbeing. Literature on these topics to date is largely compartmentalized. When taking into account the idea that research is conducted with intent to be disseminated and translated to the target population, this isolated approach potentially limits and slows progression (Robertson & Williams, 2009). To truly assess the effect and transferability of an acute exercise intervention, concurrent interdisciplinary measures should be collected. In a busy and attention-scarce world, people want to utilize time with maximal efficiency. Though detriments have been shown in the culture of media multi-tasking (Aagaard, 2015; Ophir, Nass, Wagner, & Posner 2009), the population majority in its current state appears to be nonetheless likely to engage in a singular focus such as exercise without media. Exercise alone is scarce in America. Newest research by the Center for Disease Control estimates that nearly 80% of adult Americans do not get the recommended amounts of exercise each week (Clarke, Norris & Schiller, 2017). More specifically, nearly half of adults are not meeting aerobic activity guidelines. The determinant of inactivity is gravely apparent in an analysis by Lee et al., (2012) which conservatively concluded that inactivity causes 9% of premature mortality, or more than 53 million of the 57 million deaths that occurred worldwide in 2008.

The aim of scientists is to promote progression. As such, scientists in health professions must adapt to lifestyle status quo by continually seeking bidirectional translational methodology, wherein observations from participants may advise both patient-oriented and fundamental investigation (Robertson & Williams, 2009). Findings must then
move toward practical implementation; failure to do so is known as the second translational block (Robertson & Williams, 2009). Participant-oriented translational studies in exercise implementation and adherence is the junction from physiological research to practical implementation, or better known in clinical fields as “bench to bedside”. The drawbacks of screen time and mobilized media technology are ever being disseminated (Aagaard, 2015; Ophir, Nass, Wagner, & Posner 2009) yet these devices have become a fundamental necessity of school, work and social connections, blurring constructs of timing and location of work and play. Health scientists must therefore seek progression in health through bidirectional translation and interdisciplinary pooling of collective expertise to find a means in which to solicit exercise as an attainable and attractive option as a break from or in unison with technology choices and the ever-busy everyday life. This research examines physiological, neurological and psychological aspects of acute exercise interventions with intent of greatest positive effect for participants.

Psychological affect toward exercise and as a result of, heavily influences likelihood of exercise adherence, with recent literature noting that empowerment and benefit must be perceived for continued engagement (Farrance, C., Tsofliou, F., & Clark, C., 2016). In 2015, Rhodes and Kate also found that positive psychological affect during and after exercise influenced affective judgments about subsequent exercise adherence. Most recently, Bernstein (2017) showed exercise as a significant predictor on wellbeing and positive affect. Bernstein’s main finding was the facilitation of exercise on emotional recovery and improved emotional flexibility. This coincides with a great body of literature indicating the positive effect of exercise on stress reduction. Accordingly, one study in this dissertation examines stress reduction while all three examine psychological affect.
There is no shortage of literature exhibiting the physiological benefits of exercise from suppression of cardiovascular disease factors to reduction in the risk of multiple forms of cancer. Exercise elicits an internal stress response, which is perceived by the body as eustress or “good stress.” This response largely mirrors the psychological distress or “bad stress” response. Though findings are continually developing, literature to date implies that the difference between beneficial and detrimental stress, according to a review by Heijnen, Hommel, Kibele and Colzato, is the association of exercise-induced stress with increased inactivation of cortisol into cortisone, increased level of anandamide (AEA), brain derived neurotropic factor (BDNF) and serotonin (2016). Additionally, exercise-induced stress at moderate levels has been shown to improve cognition, where psychological stress works in opposition (Colzato et al., 2013). One study within this dissertation examines stress hormone responses to exercise. Throughout the dissertation, physiological aspects of exercise such as heart rate and intensity are also observed but not dictated as Parfitt, Rose and Markland (2000) suggest that allowing individuals to select their own exercise intensity increases physiological and psychological benefit.

Mechanistic neurological benefits of exercise translate to improved memory (Lecki et al., 2014, Szuhany et al. 2015). Improvements in memory with exercise are largely attributed to increase in the aforementioned BDNF and serotonin. Increases in hippocampal BDNF has numerous effects, including: improved synaptic plasticity, neurogenesis, longevity of neurons, long-term potentiation, and hippocampal volume (Lecki et al., 2014). Within the brain, the hippocampus is largely responsible for memory and learning. Memories are encoded through modification of synaptic strength (plasticity) therefore increases in BDNF result in improved memory consolidation (Collingridge & Bliss, 1993). Additionally,
aforementioned increases in serotonin supports memory functions in the hippocampus as well (Haider et al., 2006). The translational neurological benefits of acute exercise examined in this dissertation include short and long-term memory by means of immediate and delayed retention tests. Though not directly measured, academic achievement is assumed to be a byproduct of reduction in academic stress and increase in academic self-efficacy.

The overarching purpose of this dissertation was to examine translational physiological, neurological and psychological benefits of exercise bouts aimed at increasing cognitive function and replacing otherwise sedentary behavior. It is the hope of this research team that examining a triad of interdisciplinary benefits to acute exercise will inspire people into action, increase adherence and support translation to everyday utilization. Within this framework, the following areas were investigated:

1. The three-benefit trifecta of an established exercise intervention aimed at reducing stress in college students near end-of-semester examinations.

2. The three-benefit trifecta of an acute dual-task exercise and learning protocol when implemented in a laboratory setting, measured at varying exercise intensities and compared to sedentary study.

3. The three-benefit trifecta of an acute dual-task walking and learning protocol when implemented in a fitness center setting and measured across the adult age span.
References


CHAPTER 2

Examining the Impact of a University-driven Exercise Programming Event on End-of-semester Stress in Students

Chapter Significance

An established end-of-semester exercise intervention aimed at reducing stress in students provided ideal opportunity to study the aforementioned three-benefit triad. This study focused on exercise as a relief from multi-tasking demands. Physiological and psychological stress was measured as was emotional affect and academic self-efficacy. Cognitive measures were not directly measured though empirical research implies that all aforementioned measurements moderate academic performance and were therefore measured just preceding final examinations.

This study served as the ground roots of this interdisciplinary pilot research. No greater time of stress exists in the university population than surrounding final exams. Much to the credit of Sharon Jalene and the UNLV Community, they created Fitness4Finals, an on-campus physical and mental wellness event provided free to students the week preceding final exams. The singular purpose of F4F is student stress reduction through healthy interactions; a break from traditional sedentary study habits in exchange for 30-60 minutes of exercise, meditation or the like.

Scientific study was warranted to discern statistical evidence of effect while presenting an opportunity to compare physiological and psychological measures of stress.
The downfall of this research lies in the fact that students were indeed highly stressed. Difficulties in recruitment lead to a lack of power within this study, and though results are promising, they may not be reflective of the F4F participant population. Students were simply unwilling to make an additional commitment during a period when time demands are great. UNLV as a predominantly commuter campus may have also swayed decisions to participate in the study as well as in F4F activities. Nonetheless, the methodology and qualitative results of this study gave life and inspiration to further investigations (see Appendix I). Coauthored by Dr. John C. Young and Dr. James W. Navalta.
Abstract

International Journal of Exercise Science V(i): X-Y, 2016. Stress levels in university students peak during the final exam period. An inverse association exists between Physical Activity (PA) and poor mental health. UNLV has created Fitness4Finals (F4F), an event novel in its approach to academic stress reduction by incorporating both physical activity and mental relaxation. To our knowledge, a university-driven programming event aimed at reducing physiological and psychological stress among students approaching final exams had never been studied. Therefore, the aims of this research were to 1) examine the influence of F4F on physiological stress and perceived psychological stress (PPS) and 2) to examine the relationship between physiological stress and PPS. Fifteen full-time university students were recruited to participate in their choice of one of two groups: F4F or control (NonF4F). Pre-F4F and post-F4F measures of physiological stress, measured by salivary cortisol, and perceived psychological stress, measured by survey were collected. The F4F event was held the week prior to final examinations. Participants in the F4F group engaged in one F4F activity per day for the duration of the 3-day event. Results of the repeated measures MANOVA indicated nonsignificant interaction (p = .864) between F4F participation, physiological stress and PPS. PPS and cortisol were not correlated at the onset of the study (r = -0.18, p = 0.48) or at the last sampling period (r = 0.097, p = 0.73). Preemptive elevated levels of PA in the F4F group may have influenced results. Qualitative data indicates a unanimous perceived reduction in stress from F4F participation.

KEY WORDS: Exercise intervention, mental health, exercise physiology, psychophysiology, final exams
**Introduction**

The 2015 National College Health Assessment reported stress and anxiety as the two prominent factors affecting individual academic performance, at rates of 30% and 22% respectively (1). Concurrently, 54% of students failed to meet daily exercise recommendations (29). Furthermore, 32% of students experience even greater levels of stress in peri-exam periods (the times surrounding final exams) as indicated through psychological and physiological markers (23,33). Therefore, attention to both mental health and physical activity (PA) are of utmost importance surrounding final exam periods.

Health behaviors acquired during early adulthood can remain for the adult life (2,7,17,18,19), magnifying the need for intervention during the college years. Cardiovascular disease (CVD) is the primary cause of preventable death in the United States with low cardiorespiratory fitness as the main predictor, and mental stress reported as a main causal factor (6,34). Furthermore, high occurrence of state anxiety throughout the college years can result in chronic mental illness, the stigma of which has many negative impacts throughout an individual’s lifetime (28).

Although mental health and physical activity are distinct areas of health, these areas are correlated. An inverse association exists between PA in college and both poor mental health (adjusted odds ratio (OR): .79, 95% confidence interval (CI)) and perceived stress (OR: .75; 95% CI)(30). Within this population, increases in PA have been linked to increases in mental health inclusive of reduced state and trait anxiety, depression and perceived stress (29). Therefore, the
ideal intervention is one concentrated around final exams that promote both physical activity and stress reduction.

The research presented correlating PA and stress among college students is vastly based on self-reporting, of both perceived stress and time engaged in PA (5,13,20,32). A small number of studies examined participation in physical activity as a college course (3,4). In 2016, a study by de Vries et al. showed that implementation of a 6-week, low intensity exercise intervention reduced study fatigue in university students (10). To our knowledge, just one PA intervention exists with the aim of reducing both psychological and physiological stress specifically during the final exam period, though the effectiveness of this intervention has not yet been studied.

In fall 2014, the University of Nevada, Las Vegas (UNLV) created a novel pilot program, “Fitness4Finals” (F4F), as a 3 day, on-campus PA intervention to reduce final exam stress levels (12). The program has since been held the week preceding final exams during fall and spring semesters and consists of light, moderate and vigorous PA options along with meditation, healthy snacks, and informational booths promoting a variety of health behaviors.

It is possible that participation in one F4F event may help reduce acute psychological and physiological stress. Repeated participation in F4F events throughout one's college career may create a lifelong health behavior of seeking PA at times of high stress. Semi-annually, 28,000 students on the UNLV campus alone experience significantly elevated levels of stress simultaneously. The possible effectiveness of a program such as F4F in helping students to reduce and cope with this stress could prove beneficial on a multitude of levels, with possible positive affects on academic performance (26), mental health, social health and physical health (6,10,26).
The effectiveness of end-of-semester programming (such as F4F) in reducing stress levels has not been tested. Therefore, the primary aim of this research was to examine the influence of a university-driven exercise-programming event on physiological stress and perceived psychological stress. A secondary aim was to examine the relationship between students’ physiological stress and PPS. Findings of this research have the potential to provide a scientific foundation for instituting this type of event on U.S. college campuses to increase PA and reduce final exam stress. In addition, it is possible that repeated participation in exercise event programming throughout one’s college career might result in an acquired health behavior to seek PA and healthy stress reduction techniques during times of high mental stress.

Methods

Participants

This study was quasi-experimental in nature. Participants were allowed the choice to participate or refrain from participation in the Fitness4Finals event, making this a 2-group nonrandomized trial. Participants were also allowed to maintain any regular PA activity.

The study inclusion criterion was as follows: university students enrolled full-time and in “good health” as defined by the ACSM American Heart Association Questionnaire. Students with contraindications to exercise were excluded from participation in the F4F group but were allowed to participate in the nonF4F group.

Participants were recruited from undergraduate and graduate courses. Number of goal participants was unknown, as a study of this nature has never been performed. Therefore, researchers did not set a minimum of maximum number of participants. A total of 17 students
volunteered for the study, with 15 completing the study in its entirety: 7 students in the control and 8 students in the F4F participation group. Institutional Biomedical IRB approval was granted prior to recruitment and data collection, and all participants provided written informed consent.

Table 1: Participant demographics by group.

<table>
<thead>
<tr>
<th></th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>174±4</td>
<td>81±12</td>
<td>27.7±6</td>
</tr>
<tr>
<td>F4F</td>
<td>171±11</td>
<td>74±15</td>
<td>28.9±7</td>
</tr>
</tbody>
</table>

Protocol

Data was collected surrounding the F4F event during the Fall 2015 semester. Participants volunteered on a basis of intent to participate in Fitness4Finals (F4F/experimental group) or to refrain from participation in Fitness4Finals (nonF4F/control group). Demographic data (Table 1), average weekly engagement in PA and average weekly engagement in sedentary study were self-reported by students prior to the F4F event.

F4F is held during the UNLV study week, which is the period of time just preceding final exam week. It was a 3-day on-campus event. Daily events included light, moderate and vigorous exercise options, meditation classes, healthy snacks and informational booths on differing health topics. Exercise offerings varied in intensity, modality and duration. Light intensity exercises included yoga (50 minutes in duration, see figure 1), Pilates (50 minutes), and Thai-chi (50 minutes). Moderate intensity offerings included fitness walking (50 minutes), stair climb (10-30 minutes) and participation in the Flash mob (4 minutes). High intensity offerings included boot camp (50 minutes, see figure 2), cardio kickboxing (50 minutes) and obstacle course (1.5 – 5 minutes). Certified practitioners implemented all classes. Students representing differing clubs
and departments, such as Nutrition Sciences, Student Government and Kinesiology, ran the informational booths, provided healthy snacks, and advocated healthy lifestyle behaviors.

Students in the F4F group were instructed to participate in a minimum of one F4F activity per day for the duration of the 3-day F4F event. Students in the control group were asked to continue with their normal schedule and to adhere to their decision to refrain from participation in F4F activities.

*Figure 1.* Example yoga class held during Fitness4Finals available to students.

*Figure 2.* Example boot camp held during Fitness4Finals available to students.
Measurement

Measures of physiological stress and PPS were taken Pre-F4F (baseline) and post-F4F. The F4F event occurred Tuesday, Wednesday and Thursday, the week preceding final exams. Pre-F4F collection occurred on Monday, prior to F4F and post-F4F collection occurred on Friday, following the conclusion of F4F.

PPS is an aggregate score obtained from Cohen’s Perceived Stress scale survey (1983). This is the most widely used psychological instrument for measuring the perception of stress; with ten items designed to identify how unpredictable, uncontrollable, and overloaded participants find their lives. Example questions include: “In the last month, how often have you felt that you could not cope with all the things you had to do?” and “In the last month, how often have you felt that you were on top of things?” Participants chose their answers from a Likert scale ranging from 0 (Never) to 4 (Very often). Scores were obtained by reversing responses to the four positively stated items and the summing across all scale items. Higher total scale scores indicated higher PPS.

Physiological stress was measured via cortisol levels in whole saliva, collected through the passive drool method. Cortisol was assessed using a commercially available kit as instructed by the manufacturers (Salimetrics, Carlsbad, CA). As cortisol levels rise and fall in a natural circadian rhythm, participants were required to provide saliva samples within the same two-hour time frame on both pre and post collection days. Levels of cortisol rise independently of circadian rhythm in response to stress. Levels were compared to known “normal” cortisol ranges, dependent on age and gender.
Perceived reduction in stress as a result of participation in Fitness4Finals was also assessed qualitatively. Participants in the F4F group provided a written answer to the question, “do you feel that participation in Fitness4Finals events helped to reduce your end-of-semester stress?” Participants could respond “yes,” “no,” or “indifferent,” with the option to elaborate open-endedly.

Statistical Analysis

Participation in F4F served as the dichotomous independent variable, and PPS and physiological stress served as repeated continuous dependent variables, measured at pre and post time points. Due to the relatable nature of the dependent variables, they were examined simultaneously. This analysis includes both between and within subject measurements. As such, data were analyzed using a doubly repeated measures multivariate analysis of variance (MANOVA). Similarly, PPS and physiological stress data were analyzed for correlation using a mixed-measures ANOVA.

Statistical analyses were completed using SPSS, version 24 with significance at the p<0.05 level. Qualitative data was collected from F4F participants by means of survey during the final data collection.

Results

Upon entrance to the study, participants in the F4F group reported higher mean weekly engagement in PA and lower mean weekly engagement in sedentary study (Table 2).
Table 2: Weekly engagement in PA and sedentary study per group.

<table>
<thead>
<tr>
<th></th>
<th>PA</th>
<th>Sedentary Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>7.33±5.2</td>
<td>13.0±9.4</td>
</tr>
<tr>
<td>F4F</td>
<td>9.86±6.42</td>
<td>7.68±6.0</td>
</tr>
</tbody>
</table>

Statistical results indicated a nonsignificant group x time interaction $F = .147, p = .864$. Additionally, $\eta^2 = .024$ indicated the interaction effect between PPS and physiological stress was not substantial.

PPS and cortisol were not correlated at the onset of the study ($r = -0.18, p = 0.48$) or at the last sampling period ($r = 0.097, p = 0.73$) (Table 3). Mean scores revealed lower PPS from the F4F group across time points.

Table 3: Mean stress measurements by group at pre and post time points.

<table>
<thead>
<tr>
<th></th>
<th>Pre F4F</th>
<th>PostF4F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salivary Cortisol (PS)</td>
<td>0.306±.17</td>
<td>0.264±.16</td>
</tr>
<tr>
<td>Perceived Stress Scale (PPS)</td>
<td>16.71±6.2</td>
<td>15.29±4.7</td>
</tr>
<tr>
<td>F4F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salivary Cortisol (PS)</td>
<td>0.373±.19</td>
<td>0.286±.16</td>
</tr>
<tr>
<td>Perceived Stress Scale (PPS)</td>
<td>12.38±4.6</td>
<td>11.63±3.7</td>
</tr>
</tbody>
</table>

(PS) = physiological stress; (PPS) = perceived psychological stress

Eight out of the eight F4F participants answered “Yes” to the qualitative question “Do you feel that participation in Fitness4Finals events helped to reduce your end-of-semester stress?” Furthermore, seven of the eight F4F participants chose to elaborate on their response (Table 4). Comments present a common theme of mental relaxation as a result of participation in F4F.
Table 4. Qualitative responses: “Do you feel that participation in Fitness4Finals events helped to reduce your end-of-semester stress?”

<table>
<thead>
<tr>
<th>Participant</th>
<th>Response</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Yes</td>
<td>The ability to check out of my day with a group of people with a common goal.</td>
</tr>
<tr>
<td>6</td>
<td>Yes</td>
<td>I used to be an athlete, so I was used to high intensity, high stress exercise. The Pilates and yoga classes did help me feel that high and reduce my stress.</td>
</tr>
<tr>
<td>7</td>
<td>Yes</td>
<td>The meditation event was very helpful in reducing stress and gave ways to continue to cope with and de-stress in the future. Working out also helped because it felt like I was still sticking to a routine.</td>
</tr>
<tr>
<td>8</td>
<td>Yes</td>
<td>I was able to clear my mind and it helped me focus more when I did have to sit down and study.</td>
</tr>
<tr>
<td>9</td>
<td>Yes</td>
<td>I was very excited for the flash mob, a good break from seriousness of studying. I felt mentally relaxed after yoga and meditation.</td>
</tr>
<tr>
<td>13</td>
<td>Yes</td>
<td>It gave me an active outlet and break from schoolwork.</td>
</tr>
<tr>
<td>16</td>
<td>Yes</td>
<td>(Did not provide comment)</td>
</tr>
<tr>
<td>17</td>
<td>Yes</td>
<td>I felt compelled to relax my mind.</td>
</tr>
</tbody>
</table>

Discussion

The primary aim of this investigation was to determine if college students participating in an end-of-semester university-driven exercise-programming event would report lower psychological and physiological stress leading into final exams. According to our analysis, no correlation exists between participation in F4F and physiological and psychological stress reduction. These findings are inconsistent with past research, which show strong correlations between physical activity and stress reduction (3,4,5,10,13,20,22,32,33).

Results showed a lack of correlation between physiological stress and PPS. This finding aligns with past research, which has found the association between perceived and physiological stress to be weak and divergent (9,14,15,21,27). Oldenhinkel et al. found changes in cortisol levels with perceived arousal and unpleasantness ($F(3,586)=76.0$, $p<.001$). Conversely, Cohen et
al. found no association between cortisol and changes in anxiety in response to stressors (-.21), (9). Additionally, sixty percent of quality field studies assessed by Hjortskov et al. showed no association between self-reported mental stress and salivary cortisol response, thirteen percent reported negative association and 27 percent reported positive association (14).

Future research with adjustments in stress measuring tools is warranted to clarify the qualitative and quantitative results. A perceived stress measurement tool with specific measurement focus on academic stress may provide more accurate assessment of end of semester stress. A more acute measure of physiological stress may be seen through salivary alpha-amylase or salivary pH, as opposed to salivary cortisol (8,25,28). Lastly, the addition of a baseline stress reading prior to end-of-semester collection could add validity and strength to findings. As this was a pilot investigation, further research with increased subject numbers is warranted.

Discrepancies between our findings and past research could infer that F4F does not impact stress levels in student participants. However, qualitative data provides an alternate view as 100% of F4F participants self-reported feeling a reduction in their perceived level of stress following participation in the event, with communal emphasis on mental relaxation. This leads us to believe that the physiological measures of stress taken in this study do not adequately reflect the overall sensation experienced by participants. Mean data per group may indicate that students, who inherently choose to engage in greater amounts of PA, also choose to participate in F4F. This elevation in PA may explain the lower levels of PPS and slightly higher cortisol levels. Decreases in PPS for the F4F group may not be seen as their baseline scores are preemptively depressed. Steady engagement in PA (prior to and during F4F) may prevent a decline in cortisol levels, as this is a byproduct of exercise. Additionally, an emerging theory relating to fatigue
proposes a two-compartment taxonomy comprised of physiological fatigue and perceived fatigue (11). While more investigation is necessary, it is possible that an analogous relationship exists with regard to stress. It is possible that while the physiological measures of stress in the present study were not significantly different, the perceived stress reduction reported by the Fitness-4-Finals participants is influential.

Acknowledgements: Thank you to Sharon Jalene, creator of Fitness4Finals for allowing us to study and report on this event and to Dr. Navalta and Dr. Young for their expertise.
References


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CHAPTER 3

Exer-study: a translational approach to walking while studying for improved memory consolidation.

Chapter Significance

The three-benefit triad was directly measured in this study when exercise was utilized in conjunction with media learning. Physiological influences of heart rate and corresponding exercise intensity were measured. Translational neurological benefits were measured by means of vocabulary memorization. Lastly, emotional affect of enjoyment and usefulness were measured.

Difficulties in recruitment during our initial Fitness4Finals study reiterated the idea that exercise habits remain secondary to demands of work, school and family. How could we then convince students that exercise was worth their while? The concept of exercise study sessions arose holistically as it was a discussion on personal past utilization that gave light to the idea that it may be an integral piece of the puzzle. Would students be more willing to spend time exercising if it did not detract from study time? Furthermore, could simultaneous exercise and studying actually improve memorization compared to sedentary study? Perhaps most importantly, would students enjoy and utilize such a study modality?

A look into the literature showed minimal research on dual-task exercise and learning. The extant research did reveal increases in learning following an acute bout of exercise and auditory encoding on a stationary bike. With the goal of translation in our research, we wanted to know if students could walk and learn, such as walking to class prior to an exam or reviewing...
notes on a treadmill the evening prior. Research from the preceding decade concluded that treadmill walking while studying was detrimental to learning due to increased cognitive demand (overstimulation). The perpetuation of portable devices and habits of the media multi-tasking generation over ten years however, has made walking and reading an everyday endeavor. As such, new research was warranted. The findings herein could be complimented by further exploration into effect differences in dual-task exercise-studying by age, sex, and learning type. Co-authored by Dr. John C. Young and Dr. James W. Navalta.
Abstract

The effectiveness of treadmill exercise while studying has shown divergent results. The purpose of this study was to examine the effectiveness of studying during treadmill exercise in college students compared to sedentary study. Translational methodology was applied. Participants were systematically assigned to one of three study modality groups: jogging (self-selected pace, n=10), walking (self-selected pace, n=10), or sedentary (n=10), in which they studied vocabulary words with correct definitions for ten-minutes. Vocabulary tests were given prior to, 5-minutes post and 24-hours post study session. Multivariate effects of mode of study was significant ($F_{(4, 48)} = 3.6, p = .012, \eta^2 = .23$), when average engagement in study was controlled for. Jogging and sedentary groups showed significant decreases in scores from 5-minutes to 24-hours, while the walking group remained relatively unchanged. Walking group scored significantly higher in enjoyment and perceived retention compared to sedentary ($r = 1.056, P = .05$ and $r = .833, P = .04$, respectively). Walking at a self-selected pace while studying is more effective for both immediate learning performance and retention of learned information than jogging or sitting sedentarily while studying. Walking while studying may be the optimal mode of study for memory consolidation in college-aged students.
Introduction

Over the past decade, a surge in literature has emerged examining the relationship between exercise and cognition. Systematic approaches have differed but results remain consistent; exercise benefits cognitive performance (Chang, Labban, Gapin, & Etnier, 2012; Tomporowski, 2003). Prior research has shown an increase in academic achievement as a result of exercise (Taras, 2005; Castelli, Hillman, Buck & Erwin, 2007; Lucht, 2013; Setaro, 2016), which may be mediated by the positive effect of physical activity on memory consolidation.

Within the brain, the hippocampus is largely responsible for memory and learning. Physical activity increases hippocampal brain derived neurotropic factor (BDNF) expression, resulting in improved synaptic plasticity, neurogenesis, longevity of neurons, long-term potentiation, and overall hippocampal volume (Vaynman et al. 2004, Lecki et al., 2014). Memories are encoded through modification of synaptic strength (plasticity) therefore increases in BDNF result in improved memory consolidation (Collingridge & Bliss, 1993). Additionally, increases in serotonin supports memory function in the hippocampus (Haider et al., 2006). This neurophysiological research is synchronous with applied research examining exercise and memory consolidation.

Proactive and simultaneous implementation of exercise in conjunction with a cognitive task has shown to improve memory function. Coles & Tomporowski, 2008; Salis, 2013; Hötting, Schickert, Kaiser, Röder & Schmidt-Kassow, 2016; and Zach & Shalom (2016) found increases in delayed recall of information following proactive moderate intensity exercise. Labban & Etnier (2011) and Zach & Shalom (2016) found proactive exercise to have an
immediate positive effect. The effect of simultaneous exercise and learning on memory has been studied to a lesser extent. In 2010, Schmidt-Kassow, Kulka, Gunter, Rothermich & Kotz were the first to show that simultaneous physical activity during vocabulary learning facilitates memorization of new items. Participants engaged in auditory learning while cycling for 30 minutes, repeating this once per week for 3 weeks. Schmidt-Kassow et al. (2013) then compared the effects of cycling during auditory learning versus cycling prior to auditory learning on long-term memory performance. Results indicated significantly better performance for the simultaneous group comparatively.

Conclusions regarding optimal modality of exercise during learning have varied. Lambourne and Tomporowski (2010) found simultaneous cycling improved cognitive performance, while simultaneous treadmill exercise was detrimental. This was in agreement with earlier studies, which suggested that walking on a treadmill required increased cognitive resources and may decrease confidence, especially in participants who were unfamiliar with the apparatus. In 2014 however, Schmidt-Kassow, Zink, Mock, Thiel, Vogt, Abel et al. controlled for this issue and found very light treadmill walking during auditory learning resulted in increased vocabulary retrieval compared to sedentary auditory learning.

To our knowledge, immediate and delayed memory consolidation following treadmill walking while studying, treadmill jogging while studying, and sedentary study has not been compared. Additionally, translational methodology of simultaneous treadmill exercise and studying has yet to be tested. Therefore, the purpose of this study was to examine the learning effectiveness of a 10-minute bout of simultaneous walking or jogging and studying in college students when compared to sedentary study. Increased hippocampal activity during walking and
jogging may elicit increased immediate and delayed retention of information when compared to sedentary study. The cognitive demand required to study while exercising however, may negate positive effect. We therefore, hypothesized that jogging would provide greater benefit than sedentary study and that walking would have the greatest effect. Procedural methodology was translational in nature, mimicking study situations that present-day college students may utilize. Such situations may include reviewing notes while walking to an exam or studying from a laptop or tablet while utilizing cardiovascular equipment within a university wellness center. Evidence suggests a correlation between exercise and memory consolidation. The goal of this study was to establish optimal exercise conditions to facilitate memory on a widely encountered learning task (vocabulary definitions). Such specification will provide clear evidence for students to increase engagement in and educators to promote exercise while studying. The resulting increase in physical activity level could lead to increases in physical health, mental health and academic performance (Bunce, Flens & Neiles, 2010; Petruzzello, 1991).

Methods

Participants

Participants were recruited on a volunteer basis from a university in the southwest region of the United States. Inclusion criteria required participants to be registered as a full or part-time university student, in good health as defined by the ACSM American Heart Association Questionnaire (Cardinal, 1999), and willing and able to jog on a treadmill at a self-selected pace for 10 minutes. This study was reviewed and approved by the university institutional review board. All participants signed a university-approved informed consent prior to data collection.
A total of 30 students (female, N = 20; male, N= 10) volunteered and completed the study in its entirety. Participant demographic information can be seen in Table 1.

**Protocol**

Participants completed a profile questionnaire inclusive of demographic information, average number of hours spent in sedentary study per week and average number of hours engaged in exercise per week. Since the extent to which a student regularly studies and/or exercises has the potential to influence primary results of this study, self-reported average number of weekly hours engaged in academic study and average weekly hours engaged in exercise were run as covariates. Students were given a list of vocabulary words and asked to provide any known definitions. This vocabulary test, administered at 3 time points, included 30 randomly selected words from the vocabulary portion of the Scholastic Aptitude Test (Salis et al 2013). Tests were pen and paper, as traditionally used in the classroom setting. Baseline vocabulary knowledge was measured just prior to study session, immediate retention was measured via posttest administered at 5-minutes post study session, and delayed retention was measured via posttest at 24-hours post study session.

Participants were systematically assigned to either the sedentary study group (n=10), or one of two exercise study (exer-study) groups: treadmill walking at a self-selected pace (n=10) and treadmill jogging at a self-selected pace (n=10).

Vocabulary words with definitions were provided via laptop computer (MacBook Air, Apple, Cupertino, CA) for each study modality group as to replicate common present-day study methods. Screen format was identical to that of the pen and paper test. For the exer-study
groups, the laptop was placed at chest level ahead of the participant and fixed to the treadmill (Landice, L7, Randolph, NJ) to ensure stability. Exer-study group participants were given 3 minutes to acquaint themselves with the treadmill; finding their preferred pace and font size. The students were instructed to remain at this pace for the duration of the 10-minute study session. Those assigned to the sedentary group studied the SAT vocabulary words and definitions for ten-minutes while sitting quietly. All tests were completed in the same laboratory. To estimate exercise intensity, participant heart rate (HR) was recorded during all exer-study sessions.

Following the ten-minute study session, participants were provided water and a five-minute “brain break” in which they were asked to play Tetris or Solitaire to deter from continued inner repetition of words and definitions (Salas, 2011). Participants again completed the SAT Vocabulary test immediately following the five-minute break and returned to the lab twenty-four hours later to repeat the test for a third and final time before finishing with a three-question exit survey.

**Measurement**

Heart rate was reported via pulse-oximeter (Shenzhen Creative Industry CO; Shenzhen, China), recorded every two-minutes during exercise. Average HR was calculated from minutes 6, 8, and 10, allowing participants 6 minutes to reach steady state.

Enjoyment of study modality, perceived retention of information and likelihood of implementation for future study behavior were measured via Likert scale questionnaire. Participants indicated the degree to which they agreed or disagreed with the following
statements: “I enjoyed studying in this manner,” “I feel that I have retained information studying in this manner,” and “I will use this method of studying in the future.” Participants circled the number (1-5), where the numbers corresponded to the following: 1 = Strongly Disagree, 2 = Disagree, 3 = Indifferent, 4 = Agree, 5 = Strongly Agree.

Vocabulary tests were given raw scores, determined by the number of correct definitions provided out of 30 possible. To control for subjectivity in scoring, tests were separated from group and participant identifiers, and scored by two individuals: one member of the research team and one equally educated outside party. The given scores for each test were then averaged to provide a raw score. To account for prior vocabulary knowledge, adjusted scores were calculated for the 5-minute and 24-hour posttests by subtracting the number of correct definitions on the pretest from each raw posttest score.

**Statistical Analysis**

Our primary aim was to determine if study modality made a difference in students’ vocabulary learning. Exercise modality served as the categorical independent variable, and vocabulary test scores at 5-minutes, 24-hours and change score from 5-minute to 24-hours served as the continuous dependent variables. Statistical analysis was performed with Statistical Package for the Social Sciences (SPSS) 24.0 software (Armonk, New York). Data were first analyzed using a one-way multiple analysis of variance (MANOVA), with all assumptions met. Average number of hours engaged in sedentary study, and in exercise per week, were run as covariates to control for possible influence on outcome. These analyses include both between and within subject measurements. As such, data were analyzed using repeated measures
multivariate analysis of covariance (MANCOVA), with all assumptions (homogeneity of regression coefficients and variance-covariance matrices, Levene’s Test of Homogeneity of Error Variances, etc) met for both analyses. Change scores per group were analyzed using pairwise comparisons per group. A one-way ANOVA was used to determine the effect of study modality on enjoyment of study mode, perceived retention of information and likelihood to use study mode. Significance levels for pairwise comparisons, ANOVA and MANOVA analyses were set at 0.05 level. Bonferroni adjustment was implemented in MANCOVA analyses, utilizing an alpha level of 0.025 to control for Type I error.

Results

Preliminary data screening identified one outlier warranting removal. Final analyses were based on 29 total participants (n = 10 jogging; n = 9 walking, n = 10 sedentary).

The walking group exercised at an average intensity of 47% (±0.05%) estimated heart rate maximum, with a range of 39%-54%. The jogging group exercised at an average intensity of 72% (±0.07%) of the estimate maximal heart rate, ranging from 60%-82%.

Data were first analyzed using a one-way multiple analysis of variance (MANOVA) with mode of study as the independent variable and 5-minute and 24-hour posttest scores as dependent variables. All assumptions were met in this analysis. Differences in study modality were not significant ((F (4, 50) = 1.9, p = .12, η² = .13).

The data were twice submitted to a one-way multivariate analysis of covariance (MANCOVA) with study modality as the independent variable (jogging, walking, sedentary). Average weekly minutes engaged in study was run as covariate, followed by average weekly
minutes engaged in exercise. All assumptions were met per analysis. Study modality had a statically significant influence on the adjusted mean of the linear combination of posttests and change score when average time engaged in study was controlled for (Wilks’ Lambda = .687, $F_{(4, 48)} = 3.6, p = .012, \eta^2 = .23$). Study modality exerted a statistically significant difference on the adjusted mean of 5-minute posttest ($F = 3.448, p = .048$), 24-hour posttest ($F = 4.327, p = .024$), and 5-minute to 24-hour change score ($F = 4.165, p = .027$), demonstrating a high practical significance. Specifically, vocabulary retention scores in the walking group trended toward significance at 5 minutes following the exer-study session compared to the jogging group ($p = .051$). Joggers retained significantly fewer correct definitions 24-hours post exer-study session than the walkers ($p = .022$). Interestingly, change scores from 5-minute to 24-hour posttests differed significantly between the walking and sedentary group ($p = .025$). Upon returning for the 24-hour posttest, the sedentary group forgot an average of nearly three definitions while the walker’s retained all learned definitions (Table 2).

When average time engaged in weekly exercise was controlled for, study modality did not have a statistically significant influence on the adjusted mean of the linear combination of posttests (Wilks’ Lambda = .741, $F_{(4, 48)} = 1.942, p = .119, \eta^2 = .13$).

Results indicate average number of minutes engaged in study per week moderates the effectiveness of exer-study. Specifically, students who engaged in walking while studying retained significantly more vocabulary definitions at 24-hours than those who studied sedentarily when average study hours were held constant. Average number of minutes engaged in exercise per week did not moderate the effects of exer-study.
Significant differences between groups were found in enjoyment of study modality ($F_{2, 26} = 3.163, P = .03$) as well as perceived retention of information ($F_{2, 26} = 4.2, P = .026$). Post-hoc comparisons revealed significantly higher scores for the walking group compared to the sedentary group for enjoyment of study ($r = 1.056, P = .05$) and perceived retention of information ($r = .833, P = .04$). Higher perceived retention scores for jogging vs. sedentary also trended toward significance ($r = .700, P = .09$) (Figure 1).

**Discussion**

The aim of the present study was to examine the learning effectiveness of a ten-minute bout of simultaneous walking or jogging and studying when compared to sedentary studying on the cognitive task of vocabulary definition encoding. In balancing the positive influence of BDNF expression in the brain during exercise and increased cognitive demand of exercising while studying, we hypothesized that jogging would provide greater benefit than sedentary study and walking would have the greatest effect. This hypothesis was partially correct. Though non-adjusted mean scores were highest for the walking group when covariates were not controlled for, 5-minute, 24-hour and change scores of learned vocabulary definitions did not significantly differ between study modality groups.

When the extent to which participants typically engaged in sedentary study was held constant, study modality did significantly affect the number of vocabulary definitions retained at 5-minutes and 24-hours post, as well as the change score between these posttests. These findings provide evidence that the amount a student engages in (traditional sedentary) study may influence the extent to which they will benefit from exer-study. It is possible that students who
study often are cognitively prepared for the focused required during exer-study and therefore experience less cognitive stress and/or stimulation than students who study less. Students who are less accustomed to focused studying may find the study task alone cognitively challenging. The addition of simultaneous exercise may result in overstimulation, causing detriment to learning. Amount of time engaged in weekly exercise did not moderate the benefits of walking while studying. This result is positive in that walking while studying may benefit sedentary and active college students alike whom are accustomed to weekly studying.

The greatest benefit of walking while studying is shown in delayed retention. Walkers remembered significantly more definitions than joggers at 24-hours. Perhaps of more interest is the significant difference in change scores between the walking group and the sedentary group from 5-minutes to 24-hours. Changes scores from 5-minute post-test to 24-hour post-test were 80% worse in the sedentary group compared to the walking group. The jogging group’s 5-minute to 24-hour change score fell in between, at 50% the retention score of the walking group. This warrants further investigations. Neurophysiological explanations for increased memory consolidation at a walking pace include: increases in cortisol, renewal of BDNF signaling pathway, prefrontal and occipital cortex activation and deactivation of the anterior cingulate cortices and left frontal hemisphere (Hötting et al., 2016; Li, Men, Chang, Fan, Ji, & Wei, 2014; Schmidt-Kassow et al., 2014; Chih-Wei Wu, 2007). These explanations have been shown for longer exercise bouts and may be transferrable to the parameters of the current study.

Living in the technological age of constant screen viewing may also prove mechanistic in influencing the benefits of exer-study, possibly explaining the discrepancy between the conclusions of Lambourne and Tomporowski (2010) and this study. Students have essentially
become accustomed to walking and viewing a screen and therefore may perceive exer-study to be similar to their normal behavior. Contextual interference (CI) theory, which stems from but is not consolidated to motor-control research, states that engagement in divergent tasks (such as walking and studying) creates CI, wherein the continuous need to refocus on the cognitive task through physical distraction results in increased long-term memory consolidation (Shea & Morgan 1979). Because students have become accustomed to walking and viewing a screen, they may no longer perceive reading while walking as cognitively challenging.

Lack of likelihood to implement walking as a study modality, regardless of elevated enjoyment and perceived retention also warrants further study. It is possible that providing students autonomy to choose exer-study modality may increase the likelihood of utilization, while also investigating 10-minute memory consolidation in other modalities. Future research into the application of the aforementioned explanations on simultaneous treadmill exercise and learning is warranted.

Overall, our results showed that walking while studying is more beneficial to vocabulary definition memorization than jogging while studying or sedentary study when a student is familiar with studying in general. Results also showed that retention scores were significantly worse when studying while sedentary or jogging when compared to walking. Finally, results showed that participants enjoyed both forms of exer-study (walking and jogging) significantly more than sedentary study, and perceived significantly greater retention of information as well. The results of this study suggest students who study while walking to class or whom incorporate walking into their study routine may experience increased effectiveness in consolidation of
information. Increased academic achievement and improved physical health may be secondary benefits.

Acknowledgements: Thank you to Dr. Navalta and Dr. Young for their mentorship and expertise.

Table 1. Participant demographics by group.

<table>
<thead>
<tr>
<th></th>
<th>Jogging</th>
<th>Walking</th>
<th>Sedentary</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>66.3±3.7</td>
<td>65.9±3.4</td>
<td>66.9±5.2</td>
<td>0.88</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>67.7±15.9</td>
<td>63.1±12.9</td>
<td>72.08±22.34</td>
<td>0.55</td>
</tr>
<tr>
<td>Age</td>
<td>26.6±6.7</td>
<td>28.6±11.4</td>
<td>28.7±8.8</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Groups did not significantly differ from one another in height, weight, or age (p<0.05).

Table 2. Means and Adjusted Means for 5-minute post test, 24-hour posttest and change score.

<table>
<thead>
<tr>
<th>Group</th>
<th>5-minute Post Test</th>
<th>24-hour Post Test</th>
<th>Change Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>Adjusted Mean</td>
</tr>
<tr>
<td>Jogging</td>
<td>13.1</td>
<td>7.1</td>
<td>12.1</td>
</tr>
<tr>
<td>Walking</td>
<td>17.3</td>
<td>4.6</td>
<td>19.0</td>
</tr>
<tr>
<td>Sedentary</td>
<td>16.8</td>
<td>5.3</td>
<td>16.3</td>
</tr>
</tbody>
</table>

*Significant difference at $p < 0.05$.

Figure 1. Perceived enjoyment, retention and utilization. This figure illustrates differences in perceived enjoyment, retention and utilization per exercise modality group following 10-minute study session. * Indicates significance at the $p \leq 0.05$. 
References


CHAPTER 4

Age moderates learning performance but not enjoyment during dual task treadmill walking and digital vocabulary memorization.

Chapter Significance

Thus far, this dissertation has focused on the three-benefit triad during exercise in young adults alone. While F4F results concluded positive affect and reduced stress from participation in acute exercise, translational neurological benefits were purely speculative. Our exer-study research found promising translational neurological benefit in the form of increased retention following an acute bout of exercise while studying, yet this result was dependent on traditional study habits. Our final study looked to investigate the three-benefit triad during acute exercise across the adult age span. This study also moved toward breaking through the second translational block through practical implementation by conducting research in a community setting outside of the university population. Physiological measures of heart rate and corresponding exercise intensity were taken as well as participant fitness level. Psychological affects of enjoyment, usefulness and likelihood to utilize were again measured and translational neurological benefits of immediate and delayed retention were compared across age groups.

The promising results of dual-task walking while studying in university students inspired the question of translation across age groups. Comparing age groups would also give insight into the theory that normalized use of portable media in younger generations eases cognitive demands of walking while learning. To date, differences in learning performance following an acute bout
of dual task exercise and visual encoding has not been compared across adult age groups. Our study was the first to do so and is in fact, one of the very few acute exercise intervention studies to compare results across age groups. Additionally, examining differences in effect on immediate and delayed retention would serve to add continuity to extant research while also providing a broader translational foundation for adults of all ages. Furthermore, examining qualitative data in differing perceptions of enjoyment, retention and likelihood of utilization across age groups gives insight into overall usefulness of this intervention and is of utmost importance to translation. Co-authored by Dr. John C. Young and Dr. James W. Navalta.
Abstract

Minimal research exists on immediate and delayed learning performance following an acute bout of dual task exercise and learning. Existing literature has focused solely on 1) young adults 2) long-term retention and 3) auditory encoding. In an effort to build continuity the purpose of this study was to examine adult age as a moderator of immediate and delayed learning performance following an acute bout of dual task treadmill walking and visual vocabulary encoding. Methods: Participants were categorized by age: 15-25, 26-35, 36-45, and 46-55 (n=8 per group 15-45, n=9 for 46-55 group, total N = 33). Participants completed a 40-word vocabulary test at 3 time points: baseline, 5-minutes post intervention and 24-hours post. Following the baseline test, participants studied the words with correct definitions for ten-minutes while walking on a treadmill at a self-selected pace. Retention test were then completed at aforementioned time points. Perceived enjoyment, retention and likelihood of utilization were also measured. Results: Significant differences in 5-minute and 24-hour retention scores were found between age groups (F3, 29 = 5.7, p = .003 and F3, 29 = 6.3, p = .002 respectively). Delayed (24-hour) retention scores were significantly worse than immediate (5-minute) retention scores across age groups (t = 5.684, p < .00). Perceived retention significantly differed between age groups (F3, 29 = 4.1, p = .016). Conclusion: Adult age moderates immediate and delayed learning performance following an acute bout of dual task exercise and learning yet enjoyment and likelihood of utilization remain consistently high across age groups.
Introduction

Literature has largely shown an increase in cognitive function as a result of a single (acute) bout of exercise (Chang, Labban, Gapin, & Etnier, 2012; Lambourne and Tomporowski, 2010). Fluctuation in size of positive effect as well as in divergent conclusions are a result of vast variability in protocols. Inconsistencies in time, intensity and modality of exercise, choice of instrumentation, timing of measurement, and discrepancies in sample size and sample age make generalization difficult (Rathorne and Lom, 2017). In an effort to build continuity, this research examined differential effects of an acute bout of dual task exercise and encoding across time points and age groups. To our knowledge, learning performance following a dual-task exercise study session has not been compared at multiple time points or among varying age groups.

Exercise, whether acute or prolonged, has been shown to improve memory function and facilitate learning through a number of mechanistic properties (Dinoff, Herrmann, Swardfager, Liu, Sherman, et al., 2016; Szuhany, Bugatti, & Otto, 2014). Working memory appears to be predominantly influenced by increases in serotonin and brain derived neurotropic factor (BDNF) within the hippocampus (Collingridge & Bliss, 1993; Haider et al., 2006; Lecki, Oberlin, Voss, Prakash & Szabo-Reed 2014; Vaynman, Ying, & Gomez-Pinilla, 2004). BDNF expression improves synaptic plasticity, neurogenesis, neuron longevity, long-term potentiation, and overall hippocampal volume (Vaynman et al. 2004, Lecki et al., 2014). Increases in serotonin support memory function in the hippocampus through increased neural excitability (Haider et al., 2006).
This neurophysiological research is synchronous with applied research examining exercise and memory consolidation.

Learning performance following an acute bout of simultaneous exercise and vocabulary encoding has been shown effective in recent research (Schmidt-Kassow, Kulka, Gunter, Rothermich & Kotz, 2010; Schmidt-Kassow, et al., 2013; Schmidt-Kassow, et al., 2014). In 2010, Schmidt-Kassow, et al. were the first to show that dual task exercise (i.e. bicycling) during auditory vocabulary encoding facilitates memorization. Vocabulary retention twenty-four hours post dual task study session was significantly better for the spinning group compared to the sedentary study group. Performance measures reflected mechanistic measures as the spinning group also showed larger N400, or event-related potential within an EEG. Schmidt-Kassow et al. (2013) then compared the effects of dual-task cycling and auditory learning to cycling prior to auditory learning and sedentary learning, on long-term memory performance. Results indicated significantly better performance for the dual-task group comparatively. Levels of serum BDNF were measured pre and post interventions however mechanistic findings failed to reflect performance findings as no significant difference was found between groups. In a follow-up study, light intensity treadmill walking during vocabulary encoding was compared to sedentary study with results again indicating significantly better learning for the dual task exercise group compared to the sedentary group (Schmidt-Kassow, et al., 2014). Serum BDNF levels and cortisol did not significantly differ between groups.

The aforementioned literature provides foundational insights into dual task exercise and learning but are not without limitations. Age of participants in these studies is restricted to 18-30 years. It is unknown if differences in retention exist following a short bout of dual task exercise
learning across age groups. Schmidt et al. (2014) concluded that level of comfort on a treadmill significantly influenced learning performance in young adults, an effect that may be exacerbated as participants increase in age. Long-term memory was solely tested in these studies as learning performance was measured at 24-hours following each intervention. In animal models, the positive mechanistic effects of exercise have been shown to dissipate as quickly as 5-minutes following an acute bout (Szuhany et al., 2014) and may follow suit in humans. Additionally, Tomporowski noted that benefits in memory performance were negligible if tested within the first 10 minutes of exercise (2010) however this research is based on test administration during the first 10-minutes of exercise learning. No research currently exists examining the retention benefits following a 10-minute dual-task exercise learning session. These findings drive the need to additionally test working memory through the administration of an immediate retention test. Finally, auditory vocabulary encoding has been solely utilized to this point. The rise in portable electronics and behaviors of the media-multitasking generation (Aagaard, 2015) make it logical to also compare the effect of visual encoding across age groups while engaged in treadmill walking.

The overarching goal of this line of research is translation and utilization. It is therefore imperative to assess participant affect (emotion) toward exercise learning sessions. Exercise adherence literature shows that empowerment and benefit must be perceived for continued engagement (Farrance, C., Tsolflou, F., & Clark, C., 2016). Interestingly, this approach is rarely combined in cognitive research and to our knowledge has not yet been tested during dual-task exercise learning studies. As such, levels of enjoyment, perceived retention and likelihood of utilization will be examined.
With these open questions in mind, the purpose of this research was to compare immediate and delayed retention following an acute 10-minute bout of dual task treadmill walking and visual vocabulary encoding across adult age groups. Participants were grouped by age in years as follows: 15-25, 26-35, 36-45, and 46-55. We ascribed the following hypotheses:

1) Age group and learning performance would be negatively correlated with significant differences in immediate and delayed retention between age groups.

2) Participants across age groups would perform significantly better on the immediate retention test compared to delayed retention.

3) Learning performance would be positively correlated to enjoyment, perceived retention and likelihood of utilization.

Methods

Participants

After gaining approval by the university institutional review board with facility authorization, individuals aged between 15 and 55 years were recruited from a community center in the southeast region of the United States. Inclusion criteria required participants to be in good health as defined by the ACSM American Heart Association Questionnaire (Cardinal, 1999), willing and able to complete a 3-minute step-test (stepping onto and off of a 12-inch step at a steady pace for 3 minutes) and willing and able to walk on a treadmill at a self-selected pace for 10 minutes while reading. Participants read and signed a university-approved informed consent prior to data collection. Parental consent and youth assent forms were approved for potential participants under the age of 18 though went unused as all volunteers were of adult age. A total
of 33 participants (N = 24 females; N = 9 males) volunteered for and completed the study in its entirety. Number of participants per age group was as follows: 15-25 = 8, 26-35 = 8, 36-45 = 8, and 46-55 = 9. This sample size provides power analysis indicated 92% power for detecting a moderately large sized effect when employing the traditional .05 criterion of statistical significance. Participant demographic information can be seen in Table 1.

Protocol

Participants first completed a profile questionnaire inclusive of age, height, weight, and minutes of average weekly exercise, then asked to rate their level of enjoyment of 1) learning, 2) vocabulary and definitions, and 3) exercise. A 3-minute step test was then completed to determine level of estimated cardiorespiratory fitness. Following the step test, participants completed a SAT vocabulary pre-test. This pen and paper test, which would be administered three times in total throughout the duration of the study (baseline, 5-minutes post and 24-hours post exercise learning session), included 40 randomly selected words from the vocabulary portion of the Scholastic Aptitude Test (Salis, 2013). Participants were to match each word to the correct definition, listed in random order on the same page. These words are appropriate for participants of all age groups. Tests were not timed as to prevent undue stress and possible detriment to performance.

The 10-minute exercise learning session was completed on a Cybex Intelligent Suspension treadmill (Cybex International, Inc., Medway, MA). Vocabulary words with definitions were provided via laptop computer (MacBook Air, Apple, Cupertino, CA). Screen format was identical to that of the pen and paper test. Following pre-test completion,
participants were given the necessary time to acquaint themselves with the treadmill and computer screen before settling on a self-selected walking pace and font size. Participants were allowed to vary walking speed for comfort as long as ability to read was not compromised. Heart rate was recorded every 2 minutes.

Water and 5 minutes of rest and were provided upon completion of the 10-minute exercise learning session. Seated at a desk, participants worked on a difficult digital jigsaw puzzle during this time in an effort to prevent internal repetition of words and definitions. At 5-minutes post exercise study session, participants repeated the SAT vocabulary test to assess immediate retention. Returning ~24-hours later, participants completed the final vocabulary test and finished participation by completing a three-question exit survey rating perceived enjoyment, perceived retention of information and likelihood of utilization.

Measurement

Ratings of enjoyment of learning and exercise were recorded to assess baseline differences among age groups, preconceived notions may influence performance and/or ratings of enjoyment, retention and utilization post exercise study session. Measured via Likert scale questionnaire, participants indicated the degree to which they agreed or disagreed with the following statements: “I enjoy learning,” “I enjoy learning vocabulary words and definitions,” and “I enjoy exercise.” Participants circled the number (1-5), where the numbers corresponded to the following: 1 = Strongly Disagree, 2 = Disagree, 3 = Indifferent, 4 = Agree, 5 = Strongly Agree. Similarly, enjoyment of study modality, perceived retention of information and likelihood of utilization were measured using the same Likert scale. Participants indicated the
degree to which they agreed or disagreed with the following statements: “I enjoyed learning in this manner,” “I feel that I have retained information learning in this manner,” and “I will use this method of learning in the future.”

To ensure safety and determine exercise intensity, heart rate was recorded every two minutes. Displayed via pulse-oximeter (Shenzhen Creative Industry CO; Shenzhen, China) and placed on the non-dominant index finger of the participant, the pulse-oximeter allowed researchers to record heart rate without interrupting the participant’s focus. Heart rate readings were then averaged and exercise intensity was determined by average percent of estimated heart rate max (220-age).

Vocabulary tests were given raw scores, determined by the number of correct definitions provided out of 40 possible. To control for subjectivity in scoring, tests were separated from age group and participant identifiers prior to scoring. The baseline test was used to control for prior vocabulary knowledge. Immediate (5-minute) and delayed (24-hour) retention scores were calculated by subtracting the number of correct definitions on the pretest from each raw posttest score.

Statistical Analysis

Statistical analysis was performed with Statistical Package for the Social Sciences (SPSS) 24.0 software (Armonk, New York). Our primary aim was to determine if age mediates immediate and delayed learning performance following an acute bout of dual task exercise learning. Age group served as the categorical independent variable and vocabulary test scores at 5-minutes and 24-hours served as the continuous dependent variables with first being analyzed a
one-way analysis of variance, followed by Tukey’s HSD post-hoc test to confirm differences. Bivariate correlations were run between age and 5-minute posttest, as well as age and 24-hour posttest. A one-way ANOVA was also used to determine the effect of age group on enjoyment of learning mode, perceived retention of information and likelihood to use learning mode, again utilizing Tukey’s HSD test to confirm differences between groups. A pairwise t-test was used to determine within-subjects 5-min to 24-hour performance across age groups.

Secondary analyses included one-way ANOVAs to determine baseline vocabulary scores, as well as enjoyment of learning and exercise, differences in walking speed between groups and exercise intensity. A bivariate correlation analysis was run between exercise intensity and learning performance. Significance levels for pairwise comparisons, ANOVAs and bivariate correlation analyses were analyzed at 0.05 level.

Results

Baseline: No significant differences were found between groups for baseline enjoyment of learning, enjoyment of learning vocabulary or enjoyment of exercise, with participants reporting strong enjoyment of both (M = 4.7 and M = 4.73 respectively). Additionally, no significant differences in pre-test scores were found between groups (F3, 29 = 1.9, p = .147).

Hypothesis #1: Significant differences in 5-minute posttest scores were found between age groups (F3, 29 = 5.7, p = .003) (Figure 1). The 15-25 group performed significantly better than 46-55, recalling an average of 8 definitions more (p = .048) (Figure 1a). The 26-35 group performed significantly better than 36-45 (p = .049) and 46-55 group (p = .004) recalling an average of 8 and 11 definitions more than their elder counterparts respectively (Figure 1b).
Significant differences between age groups were also found in 24-hour posttest scores ($F_{3, 29} = 6.3, p = .002$) (Figure 1). The 15-25 group performed significantly better than the 46-55 group ($p = .026$), recalling 9 more definitions on average (Figure 1c). The 26-35 group performed significantly better than the 36-45 group ($p = .036$) and the 46-55 group ($p = .004$), recalling an average of 9 and 12 more definitions respectively (Figure 1d). Finally, a significant negative correlation was found between age and both immediate and delayed learning performance ($r = -.51, p = .002$ and $r = .525, p = .002$ respectively), as seen in Figures 2 and 3.

Hypothesis #2: Across age groups, participants performed significantly worse on the delayed (24-hour) retention test compared to the immediate (5-minute) retention test ($t = 5.684, p < .00$), forgetting an average of 2.4 definitions collectively. Change scores from 5-minute to 24-hour posttest did not significantly differ between age groups ($F_{3, 29} = .519, p = .672$). Means and standard deviations by age group concerning this hypothesis can be found in Table 2.

Hypothesis #3: Following the exercise learning session, age groups unanimously agreed to enjoyment of exercise learning and likelihood of utilization, therefore differences were insignificant (Table 3). Perceived retention did however significantly differ between age groups ($F_{3, 29} = 4.1, p = .016$) (Table 3), with post-hoc differences shown between the 26-35 group, and the 46-55 group ($p = .018$) (Table 3a). Differences between the 15-25 group and 46-55 group trended toward significance ($p = .063$) (Table 3**). Accordingly, the data show a moderately strong correlation between perceived retention and vocabulary scores at both 5-min ($r = .56, p = .001$) and 24-hours ($r = .60, p < .01$), however, enjoyment and likelihood of utilization were not correlated with learning performance scores. Finally, each qualitative perception was strongly correlated to one another: enjoyment and utilization ($r = .856$), enjoyment and perceived
retention (r = .760) and retention and utilization (r = .821) with unanimous significance levels of 
p < .01. No correlation was found between cardiovascular fitness level and affects of enjoyment, retention or utilization.

Secondary Analyses: Significant differences were found in walking speed between the 26-35 and 46-55 groups (F_{3, 29} = 4.9, p = .007) (Figure 4). 26-35 year olds walked at an average speed of 2.89mph, while 46-55 year olds walked an average of .75mph slower at 2.13mph. Difference in exercise intensity as determined by calculating percentage of estimated heart rate max was significant (F_{3, 29} = 3.1, p = .041) (Figure 5), post-hoc tests indicate a significant difference between the 26-35 group which averaged an intensity of 47% HR max and the 46-55 group, averaging 56% HR max (p = .036). Negative correlations between exercise intensity and vocabulary performance was not found to be significant at 5-min (r = -.28, p = .114) but was so at 24-hour posttests (r = -.31, p = .076). Linear trend lines in Figure 6 illustrate this. No correlation was found between retention scores and cardiovascular fitness level.

Discussion

The purpose of this research was to compare immediate and delayed retention following an acute 10-minute bout of dual task treadmill walking and visual vocabulary encoding across age groups. The design intended to examine (i) the correlation between age group and learning performance and significant differences in immediate and delayed retention between age groups (ii) performance across age groups on immediate verses delayed retention and (iii) perceptions of enjoyment, retention and utilization of dual task exercise learning across age groups.
As hypothesized, we found that collectively, 15-35 year olds performed significantly better than their 36-55 year old counterparts on both immediate and delayed retention. Age and performance are not perfectly correlated as suspected as the 26-35 year old group performed consistently better than the 15-25 year olds albeit not significantly. Nonetheless correlational values indicate that learning performance following dual task exercise learning dissipates as age increases. Age related memory changes may play a mechanistic role in this result as brain cells essential to encoding and retrieval process decrease in number with age. Level of stimulation may also explain differences in performance among age groups. Lambourne & Tomporowski, and Schmidt-Kassow, 2014 discuss exercise as a potential stressor that increases arousal. As such, light to moderate exercise should increase arousal to a level optimal to in turn increase resources available to perform a cognitive task. Over arousal, a result of over taxation of cognitive resources, results in detriment to performance. It is possible that the younger media-multitasking generation may feel comfortably stimulated reading a screen while walking on a treadmill where older generations may feel over stimulated within this dual task resulting in inferior performance. Fortunately, these possible learning impairments can be ameliorated with regular exercise and possibly through repeated exposure to dual task exercise learning itself. Furthermore, Schmidt-Kassow et al. (2014) reports that simultaneous exercise enables low performers to increase their performance to a level comparable to high performers. Therefore, future longitudinal random control trials are needed to decipher mechanistic differences and long-term benefits of exercise learning on retention and brain health. Additionally, these proposed studies do not require a minimum level of cardiovascular fitness as our results have
indicated no influence of such on learning performance, nor on emotional affect toward the intervention.

Data supports our second hypothesis as immediate retention scores proved significantly better than delayed retention scores regardless of age. This result aligns with previous mechanistic research, finding that increased BDNF expression elicited by exercise dissipates quickly, with potential learning benefits dissipating synchronously (Szuhany, 2014). Lack of significant increases in BDNF levels found in previous dual task exercise learning research may be a result of delayed blood sampling post intervention and warrants further investigation. Change scores in immediate to delayed posttests did not significantly differ between age groups, though mean change (number of definitions forgotten) was slightly elevated for the elder two age groups. This shows that though younger adults retained a greater number of definitions, retention rates of what was learned 24-hours post intervention was consistent across age groups. This result coincides with results from our unpublished study utilizing an identical vocabulary encoding protocol, which also found significant delayed retention benefits in young adults following exercise learning.

Our third hypothesis was partially supported as perceived retention was correlated to both immediate and delayed retention scores. Interestingly, utilization was the single qualitative perception to differ significantly between age groups. This difference was centralized to 46-55 year olds as they reported an overall feeling of indifference toward retention level. As age decreased agreement toward retention increased. Promisingly to the broader picture of translation, level of enjoyment and likelihood to utilize exercise learning remained similar to that of all other age groups regardless of the suppressed perceived retention in the eldest age group.
This warrants further investigation into the psychological perceptions of participants, particularly as it pertains to exercise adherence. Soliciting exercise learning as means in which to effectively increase physical activity while simultaneously consolidating information to memory could aid in uptake and utilization within a busy population.

Differences in walking speed and exercise intensity were found between the 26-35 and 46-55 age groups. According to ACSM guidelines, all age groups 15-45 exercised at light intensity while the 46-55 age group walked at a moderate intensity. This difference creates speculation that the elevated workload in this age group may have mediated other significant differences, such as perceived retention and learning performance. This slight elevation in walking intensity with the concurrent cognitive task may have resulted in overstimulation as discussed by Tomporowski et al (2010).

Overall, this was a pilot study to determine if differences exist across the age span in learning performance following an acute bout of dual task exercise learning. Limitations exist. Foremost, control groups and therefore random assignment were not utilized. However numerous aforementioned studies indicate that dual task exercise and encoding results in significantly better performance than sedentary study. Adding to our justification is unpublished research utilizing an identical protocol, which indicated significantly better retention in the walking while encoding group compared to jogging while encoding and sedentary encoding. This research also lacked neuroendocrine mechanistic measures (such as BDNF and cortisol). Repeated measures of such in extant research failed to find significant correlation to performance results, though may have been a result of mistiming in collection. Blood sampling immediately following an exercise learning bout may provide alternative results. It is also possible that
mechanistic responses may differ among age groups as did performance and warrant investigation. Overall, conclusions as to why differences exist between age groups following an acute bout of dual task walking and visual media encoding remains speculative, requiring further elucidation.

**Conclusion**

People age 18-35 may benefit more from engagement in dual task exercise and visual media encoding than older generations. Though perceived retention may be less in older adults, enjoyment and likelihood of utilization remains consistent across the age span. Based on these findings, random control trials comparing exercise learning to age categorized control groups of traditional sedentary learning, where performance and mechanistic changes are measured is warranted.

**Table 1. Participant demographics by age group.**

<table>
<thead>
<tr>
<th>Age Group</th>
<th>15-25</th>
<th>26-35</th>
<th>36-45</th>
<th>46-55</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>21.1±3.0</td>
<td>31.1±3.5</td>
<td>39.5±4.0</td>
<td>50.7±3.7</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>67.2±3.5</td>
<td>66.8±5.6</td>
<td>68.5±6.6</td>
<td>66.6±2.8</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>73.2±13.3</td>
<td>73.3±25.0</td>
<td>78.1±32.0</td>
<td>74.5±21.4</td>
</tr>
<tr>
<td>Sex (M;F)</td>
<td>2;6</td>
<td>2;6</td>
<td>3;5</td>
<td>2;7</td>
</tr>
</tbody>
</table>
**Figure 1. Learning performance by age group.** This figure illustrates differences between age groups on immediate (5-minute) and delayed (24-hour) retention scores.

* Indicates significant difference compared to 46-55 age group at the 0.05 significance level.

** Indicates significance difference compared to 36-45 and 46-55 age groups at the 0.05 significance level.

**Figure 2. Correllational relationship between age and immediate (5-minute) vocabulary retention scores.** This figure illustrates a significant negative correlation between age and immediate learning performance ($r = -.51$, $p = .002$).
**Figure 3.** Correlational relationship between age delayed (24-hour) vocabulary retention scores. This figure illustrates a significant negative correlation between age and delayed learning performance ($r = .525$, $p = .002$).

**Table 2.** Mean scores across age groups for immediate retention, delayed retention and change scores.

<table>
<thead>
<tr>
<th>Retention Test</th>
<th>Age Group</th>
<th>15-25y</th>
<th>26-35y</th>
<th>36-45y</th>
<th>46-55y</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate (5min)</td>
<td></td>
<td>20.6±8.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>23.6±5.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>15.2±5.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.44±5.6&lt;sup&gt;a, b&lt;/sup&gt;</td>
<td><strong>0.003</strong></td>
</tr>
<tr>
<td>Delayed (24h)</td>
<td></td>
<td>19.13±7.3&lt;sup&gt;c&lt;/sup&gt;</td>
<td>21.5±7.0&lt;sup&gt;d&lt;/sup&gt;</td>
<td>12.13±6.9&lt;sup&gt;d&lt;/sup&gt;</td>
<td>9.56±4.9&lt;sup&gt;c, d&lt;/sup&gt;</td>
<td><strong>0.002</strong></td>
</tr>
<tr>
<td>Change Score</td>
<td></td>
<td>-1.75±2.4</td>
<td>-2.13±3.0</td>
<td>-3.13±2.1</td>
<td>-2.89±2.6</td>
<td>0.672</td>
</tr>
</tbody>
</table>

Significant group differences at the 0.05 alpha level are **bolded**. Superscript letters indicate differences between groups according to post-hoc analyses at the 0.05 significance level.

**Table 3.** Mean scores per age group for factors of psychological affect.

<table>
<thead>
<tr>
<th>Perceived Affect</th>
<th>Age Group</th>
<th>15-25y</th>
<th>26-35y</th>
<th>36-45y</th>
<th>46-55y</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enjoyment</td>
<td></td>
<td>4.50±.76</td>
<td>4.63±.52</td>
<td>4.00±1.3</td>
<td>4.22±.97</td>
<td>0.546</td>
</tr>
<tr>
<td>Retention</td>
<td></td>
<td>4.63±.74</td>
<td>4.88±.35&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.00±1.3</td>
<td>3.44±1.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td><strong>0.016</strong></td>
</tr>
<tr>
<td>Utilization</td>
<td></td>
<td>4.50±.76</td>
<td>4.50±.76</td>
<td>4.00±1.3</td>
<td>3.56±1.1</td>
<td>0.190</td>
</tr>
</tbody>
</table>

Significant group differences at the 0.05 alpha level are **bolded**. Superscript letters indicate differences between groups according to post-hoc analyses at the 0.05 significance level.
**Figure 4. Mean walking speed per age group.** This figure illustrates significant differences between age groups in treadmill walking speed during dual task walking and learning ($F_{3, 29} = 4.9, p = .007$).
* Indicates specific significant differences between groups as determined by post-hoc analyses at the 0.05 significance level.

**Figure 5. Mean percentage of heart rate max per age group during exercise learning session.** This figure illustrates significant differences between age groups in exercise intensity as determined by age estimated heart rate during a 10-minute walking and learning session ($F_{3, 29} = 3.1, p = .041$).
* Indicates specific significant differences between groups as determined by post-hoc analyses at the 0.05 significance level.
Figure 6. Correlational relationship between exercise heart rate and vocabulary retention score. This figure illustrates trends toward significant correlation strength between exercise intensity and vocabulary retention at immediate (5-minute) and delayed (24-hour) retention tests ($r = -0.28$, $p = .114$ and $r = -0.31$, $p = .076$ respectively).

Acknowledgements: Thank you Dr. James Navalta and Dr. Jack Young for your expertise.

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References


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CHAPTER 5

Overall Dissertation Conclusions

The overarching purpose of this dissertation was to examine the physiological, neurological and psychological benefits of exercise bouts aimed at increasing cognitive function and replacing otherwise sedentary behavior. Three successive yet individual study designs were implemented in addressing this purpose. Though protocols varied in exercise intervention, centralized interdisciplinary themes were found throughout. Each study examined physiological data pertinent to corresponding intervention. Fitness4Finals looked at stress hormones (Chapter 2 and Appendix I) while the dual task exercise and learning studies examined speed, exercise intensity (Chapter 3 and 4) and fitness level (Chapter 4). Neurological findings were studied via translational results as opposed to mechanistic measures, particularly learning performance through retention as the focus of the dual task studies. Finally, psychological perceptions of academic stress and self-efficacy were measured during the F4F protocol, while perceptions of enjoyment, usefulness, and likelihood of utilization were measured across studies.

Cumulative results of this dissertation solidify the purpose that measurable interdisciplinary positive effects can be elicited through brief, acute bouts of exercise. Perhaps the most prominent and promising finding within this dissertation is the unanimous affect of enjoyment across interventions and age groups (Chapter 4). This fact remains constant regardless of participant perception of usefulness and likelihood of utilization, both of which varied between and within protocols. Positive affect continued as a trend across studies as F4F
participants reported feelings of increased motivation and productivity following participation and strongly disagreed with the notion that their time could have been better used for studying (Chapter 2, Table 4). University students showed positive affect for walking (Chapter 3; walking group vs. sedentary group enjoyment \( r = 1.056, p = .05 \)) and jogging equally, regardless of perceived level of retention; the sedentary study group did not share this sentiment. Strikingly similar results were found across age groups when engaged in walking and learning,. Regardless of perceived retention, participants showed high positive affect for enjoyment as well as likelihood of utilization, with an average enjoyment rating of 4.33 out of 5 across age groups and utilization 4.14 out of 5 (Chapter 4, Table 3). However, across the adult lifespan, perceived retention was moderately correlated to both immediate and delayed retention \( r = .56, p = .001 \) and \( r = .60, p < .01 \) respectively. These results show promise as positive psychological affect is found to be a key component to exercise uptake and adherence.

Exercise intensities varied across protocols, however what remained consistent was the participant’s ability to choose their intensity. F4F participants chose which exercise activity in which to participate in each day, ranging from yoga to stair climbs. Treadmill joggers and walkers were instructed to find a pace comfortable for them. Providing participants with a sense of autonomy throughout these dissertation studies may have mediated the consistent result of positive affect toward the intervention. Even the smallest amount of autonomy has been shown to increase investment endeavor. It’s possible that autonomy may also influence the cognitive benefits of exercise, all of which warrant future investigation.

Cognitive benefits due to underlying neurological mechanism were present throughout the range of studies. F4F participants showed significant decreases in academic stress while
steadily increasing for academic self-efficacy as exams approached. The next step of which is to determine if these changed translate to increased academic performance on final exams. Young adults appear to receive the greatest learning benefit during simultaneous exercise and learning. However, Schmidt-Kassow et al. (2014) showed evidence that dual task exercise learning can illicit such a neurophysiological response as to see traditionally “low performers” then retain as much as traditionally “high performers.” This notion has vast reaching possibilities for those with learning disabilities as well as the aging population. Our results showed that while older adults did not perform as well overall as younger adults in learning performance, change scores between the 5-minute and 24-hour retention tests did not significantly differ. If baseline differences exist in level of comfort for walking while reading from a screen as hypothesized, older adults could then be considered “low performers” and had therefore performed up to the higher standard at the 24-hour retention test. Such data was not measured but certainly warrants further investigation.

Overall, it can be concluded that adults across the age span enjoy exercise as a means in which to increase cognitive function and largely look to utilize such behavior in their everyday lives. Whether it is breaking university students away from the constant studying from a computer screen or convincing the population at large to bring those screens with them to the gym, the population appears to enjoy the idea of movement to increase cognitive performance. In a world where time is of the essence, people may find the idea of simultaneously increasing physical health, brainpower and emotional stability to be incredibly empowering. The research presented in this dissertation in conjunction with extant literature gives justification to the solicitation of exercise as having a trifecta positive effect on learning, health and emotional
wellbeing. Fitness professionals, coaches and healthcare providers should solicit exercise as such and remain open to changes in the digital age and beyond, always looking for the positive spin on what may appear to be the next roadblock.
APPENDIX

University-Driven Exercise Event

Reduces Student Stress Prior to Final Exams

By

Tessa L. Koschel, John C. Young and James W. Navalta

Introduction

A surge in literature has emerged examining the relationship between exercise and cognition, largely concluding that exercise benefits cognitive performance. Prior research has shown an increase in academic achievement as a result of exercise, which may be moderated by the positive effect of physical activity on memory consolidation, stress and self-efficacy. These correlations give cause for a PA intervention nearing final exams. Accordingly, UNLV implemented F4F, a 3-day, on-campus PA intervention to reduce final exam stress levels. The program is held the week preceding final exams with light to vigorous intensity exercise options. Previous research by Koschel, Young & Navalta (2017) examined effectiveness of Fitness4Finals in relieving physiological and psychological stress in students. Quantitative results were inconclusive while qualitative results indicated a unanimous positive affect and perceived stress reduction from participants engaged in F4F. Improved measures of physiological and psychological stress were warranted in explaining qualitative data. This study was therefore conducted as a follow-up to previous results. The purpose of this study was implementation of improved acute stress measurements to determine the effect of Fitness4Finals.
on end-of-semester physiological stress (measured by salivary α-amylase), perceived academic stress and academic self-efficacy in college students. Secondary measures include correlation between physiological stress and academic stress and perceived psychological affect toward the intervention.

**Methods**

24 participants volunteered for this study and were grouped by intent to participate in F4F (F4F, n=9) or not participate (Non F4F, n=15). Institutional approval was granted and informed consent signed prior to participation. A short demographic questionnaire was completed following consent signing.

In place of cortisol, used in the previous F4F examination, acute physiological stress was measured through salivary α-amylase. Evidence shows the biomarker salivary α-amylase as a valid marker of sympathetic nervous system activation and correlates to sympathetic activity during stress (Backes, Horvath & Kazial, 2015; Rashkova, Ribagin, & Toneva, 2012; Robles et al. 2011). Furthermore, Backes, Horvath & Kazial, (2015) found salivary α-amylase levels to be non affected by fluid consumption, which is not so for cortisol.

Academic stress was again measured but done so in combination with academic self-efficacy as to bridge the gap between psychological affect and perceived stress. Perceived academic stress and self-efficacy were measured through a modified version of the Perceived Academic Stress and Self-Efficacy Survey (Zajacova, Lynch & Espenshade, 2005). These scales were created and validated by Zajacova et al. in 2005 with high reliability and are shown to have moderate negative correlation. The scales have been modified to include 11 tasks from the
original scale, which are exam and coursework specific. Examples of these include: preparing for exams, studying, and managing time efficiently. The instrument measures levels of perceived psychological stress associated with college-related tasks and perceived self-efficacy in which to cope with these stressors. Participants rated their level of perceived stress for each task from 0 (not stressful) to 10 (very stressful). Participants also rated their level of perceived self-efficacy for each task from 0 (not confident) to 10 (very confident).

Psychological affect toward the event in terms of perceived usefulness was measured through survey questions created by the research team and crosschecked by an unbiased party for transparency. Following their chosen activity each day of the three-day event, F4F participants used the provided Likert scale to indicate the degree to which they agreed or disagreed with the statements shown in Figure 1.
Figure 1. Daily post-participation survey for Fitness4Finals participants. This figure illustrates the questions asked and likert scale utilized in determining perceived usefulness of the event.

In addition to changes in instrumentation, changes in timing of collection were also implemented. Across groups, salivary $\alpha$-amylase and academic stress were measured at three time-points: the Friday prior to study week (Base), the Friday prior to exam week (Post F4F) and prior to student’s first final exam (Pre-Exam). Affect toward usefulness was measured in F4F participants following the completion of each event in which they participated. Data were analyzed using multiple mixed-measures ANOVAs, at the $p<0.05$ significance level.
Results

A significant group difference was found for perceived academic stress at Post F4F ($F_{(1,19)} = 4.403, p = .049$) (Table 1, Figure 2). Though not significant, mean scores also revealed lower salivary amylase for the F4F group across all time points. F4F group showed lower academic self-efficacy at baseline, surpassing the Non F4F group at Post F4F and Pre-Exam time points, while Non F4F remained unchanged (Table 1, Figure 3). Salivary $\alpha$-amylase and academic stress trended toward significant correlation at Base ($r = -0.388, p = 0.091$). Means and standard deviations between groups, across time points can be found in Table 1.

![Figure 2](image1.png)

**Figure 2. Group differences in perceived academic stress across time-points.** This figure illustrates significantly lower perceived academic stress in the F4F group immediately following the F4F event.

![Figure 3](image2.png)

**Figure 3. Group differences in mean academic self-efficacy across time-points.** This figure illustrates the gradual increase in academic self-efficacy in the F4F group, compared to relatively constant scores of the nonF4F group.
Table 1. Physiological stress, psychological stress and self-efficacy across collection time points.

<table>
<thead>
<tr>
<th></th>
<th>BASE</th>
<th>POSTF4F</th>
<th>PRE-EXAM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>F4F</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salivary Amylase</td>
<td>155.4±159</td>
<td>226.2±239.2</td>
<td>219.2±188</td>
</tr>
<tr>
<td>Academic Stress</td>
<td>77±15.4</td>
<td>67.3±18.2*</td>
<td>68.6±9.8</td>
</tr>
<tr>
<td>Self Efficacy</td>
<td>68.29±12.9</td>
<td>74.14±18.9</td>
<td>78.14±14.4</td>
</tr>
<tr>
<td><strong>NonF4F</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salivary Amylase</td>
<td>219.2±188</td>
<td>242.3±232.6</td>
<td>233.8±288.5</td>
</tr>
<tr>
<td>Academic Stress</td>
<td>81.2±14.8</td>
<td>82.6±14.5*</td>
<td>75.4± 16.8</td>
</tr>
<tr>
<td>Self Efficacy</td>
<td>69.93±14.6</td>
<td>70.29±17.3</td>
<td>69.93±19.8</td>
</tr>
</tbody>
</table>

* Indicates significance at the 0.05 significance level.

Qualitative results regarding positive affect toward F4F can be found in Table 2. Twenty-four of 27 expected post-F4F activity surveys measuring usefulness affect were completed, with overwhelmingly positive results. While cumulative data responses can be found in Figure 2, we will highlight larger results. 54% of F4F participants agreed that their level of productivity and motivation to accomplish an academic task had increased. 54% of respondents also disagreed with the statement “I do not feel that participation in this activity will influence my academic performance.” The largest result came in response to the statement “I feel that time spent on this activity would have been better used for study time,” in which 58% of F4F participants disagreed.
Table 2. Perceived effectiveness and usefulness of Fitness4Finals.

<table>
<thead>
<tr>
<th>Statements of affect toward F4F</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I feel that my level of personal stress has decreased after having participated in this activity.</td>
<td>41.67%</td>
<td>45.83%</td>
<td>12.50%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>I feel that my level of academic stress has decreased after having participated in this activity.</td>
<td>25.00%</td>
<td>41.67%</td>
<td>20.83%</td>
<td>12.50%</td>
<td>0.00%</td>
</tr>
<tr>
<td>I feel that time spent on this activity would have been better used for study time.</td>
<td>0.00%</td>
<td>4.17%</td>
<td>12.50%</td>
<td>58.33%</td>
<td>25.00%</td>
</tr>
<tr>
<td>I feel that my motivation to accomplish academic tasks has increased after participation in this activity.</td>
<td>20.83%</td>
<td>54.17%</td>
<td>12.50%</td>
<td>12.50%</td>
<td>0.00%</td>
</tr>
<tr>
<td>I feel that my level of productivity has increased after having participated in this activity.</td>
<td>20.83%</td>
<td>54.17%</td>
<td>20.83%</td>
<td>4.17%</td>
<td>0.00%</td>
</tr>
<tr>
<td>I feel that my level of stress will be lower going into final exams due to participation in this activity.</td>
<td>37.50%</td>
<td>41.67%</td>
<td>8.33%</td>
<td>12.50%</td>
<td>0.00%</td>
</tr>
<tr>
<td>I do not feel that participation in this activity will influence my academic performance.</td>
<td>0.00%</td>
<td>4.17%</td>
<td>25.00%</td>
<td>54.17%</td>
<td>16.67%</td>
</tr>
</tbody>
</table>

Discussion

Participation in F4F eases academic stress, albeit temporarily. F4F participants displayed lower physiological and psychological stress overall and increased academic self-efficacy as they neared final exams. Furthermore, participants largely perceived F4F to be a useful and effective use of their time in combating end-of-semester pressures. These results support qualitative findings from pilot F4F research. Lack of correlation between acute physiological stress markers and reported academic stress was continuous across studies and warrants further investigation.

Conclusion

Overall, an end-of-semester, university-driven exercise program such as F4F is effective at combating climatic stress through physical activity offerings. Universities should seek to implement similar interventions to ease peak stress levels in student population approaching final exams.
References


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Curriculum Vitae

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Education

Ph.D.  **Interdisciplinary Health Sciences, Exercise Physiology emphasis.** School of Allied Health Sciences. University of Nevada, Las Vegas.

M.S.  **Applied Health Sciences.** School of Health Sciences and Wellness. Northwest Missouri State University.

B.A.  **Psychology.** Western State Colorado University.

Affiliations/Memberships

- American College of Sports Medicine 01/2015 - Present
- American College of Sports Medicine, Southwest Chapter 01/2015 - Present
- Professional Association of Therapeutic Horsemanship 04/2013 – Present
- National Strength & Conditioning Association 10/2011 - Present
  - Certified Strength & Conditioning Specialist
- USATF Level 1 10/2007 - Present
- CPR/AED American Heart Association 08/2010 - Present

Teaching Experience

- Guest Lecturer, Miami Beach JCC 08/2017 - present
- Letter of Appointment, Lecturer, Univ. of Nevada, Las Vegas 08/2015 – 05/2016
  - Theories of Strength & Conditioning, Kinesiology 308
  - Social Psychology and Physical Activity, Kinesiology 250
  - Physical Activity & Health, Kinesiology 175
- Part Time Instructor, Univ. of Nevada, Las Vegas 01/2015 – 07/2015
• Physical Activity & Health, Kinesiology 175
  o Lecturer, Northwest Missouri State University 01/2011 – 05/2011
  o Theories of Strength and Conditioning, HPER 529
• Instructor, Northwest Missouri State University 08/2008 – 12/2011
  o Fundamentals of Track & Field, HPER 283

Work Experience

• Fitness and Wellness Coordinator, MBJCC, Miami Beach, FL 12/2016 - Present
• Lecturer, University of Nevada Las Vegas 08/2014 – 05/2016
• Therapeutic Riding Instructor, Dream Therapies, Las Vegas, NV 09/2012 – 08/2013
• Professional Research Assistant, University of CO, Denver 07/2011 – 07/2012
• Director, Youth Track & Field Camp, Maryville, MO 07/2008 – 07/2011
• Assistant Director, Youth Speed & Agility Camp, Maryville, MO 07/2008 – 07/2011
• Collegiate Coach, Track & Field, Northwest MO State Univ. 07/2008 - 07/2011
• Collegiate Coach, Track & Field, Western Illinois Univ. 08/2007 – 06/2008

Publications, Professional Presentations and Refereed Published Abstracts


• Koschel, T.L., Young, J.C., Navalta J.W. University-driven exercise event reduces student stress prior to final exams. Annual Meeting of the American College of Sports Medicine, Denver, CO. June 2017

• Koschel, T.L., Navalta J.W. Exer-Study: for the brain, for the body. Walking while studying proves more effective than sedentary study. Southwest American College of Sports Medicine, Costa Mesa, CA. October 2016

• Koschel, T.L., Navalta, J.W. Examining the impact of a University-driven exercise event on end-of-semester stress in students. University of Nevada, Las Vegas School of Nursing Interdisciplinary Research Scholarship Day, Las Vegas, NV. March 2016

• Koschel, T.L., Manning, J.W., Tacad, D.K., Montes, J., Tanner, E., McCune, D., Tovar, A., Taylor, J., Young, J.C., DeBeliso, M., Navalta, J.W. Moderate Altitude Acclimation has no Effect on


Grants

- UNLV Exercise Physiology Travel Grant, $400.00 10/2016
- UNLV Exercise Physiology Travel Grant, $400.00 10/2015
- UNLV Graduate & Professional Student Association Research Grant, $625.00 08/2016
- UNLV Graduate & Professional Student Association Research Grant, $625.00 02/2016

Research Experience

- Doctoral Student Researcher, *Age mediates learning performance but not enjoyment during dual task treadmill walking and digital vocabulary memorization.* UNLV 05/2017 - Present

• Doctoral Student Researcher, *Exer-Study: for the brain, for the body. UNLV* 08/2015 – 08/2016


• Professional Research Assistant, *Exenatide improves diastolic function and attenuates arterial stiffness but does not alter exercise capacity in individuals with type 2 diabetes, UC Denver* 07/2011 – 07/2012

• Professional Research Assistant, *Dissociation of local and global skeletal muscle oxygen transport metrics in type 2 diabetes* 07/2011 – 07/2012

• Master’s Student Researcher, *Gender differences in motivation to participate in collegiate athletics. NWMSU* 08/2009 – 05/2010

**Research Interests**

• Utilization of population technology adaptions to increase physical activity and memory.

• Interdisciplinary approach to teaching and incorporating lifestyle medicine in medical schools.

• Role of exercise in stress reduction, self-efficacy and academic performance.

**Professional Development and Service**

• Reviewer, *International Journal of Exercise Science* 2/2016 - Present

• Speaker, *MBJCC Adult Education Series* 12/2016 - Present

• Co-course developer, *Kinesiology 172 (in progress)* 08/2015 – Present

• Co-course developer, *Kinesiology 175 (in progress)* 08/2015 – Present
• Co-author, “Introduction to Kinesiology” textbook (in progress) 05/2015 – Present
  o Chapter: Physical Activity & Mental Health

• Fitness4Finals Development Committee 01/2015 – Present

• Center for Women’s Health Research, Research Advocate 07/2011 – 07/2012
  o University of Colorado, Denver

References

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