Mindful Meditation and Physical Exercise: Neuropsychological Effects

By

Emma Stein

****

Senior Honors Thesis

A thesis presented in partial fulfillment
of the requirements for the degree of
Bachelor of Science
Department of Psychology
Neuroscience Program

UNION COLLEGE

Schenectady, New York

June 2014

ABSTRACT

EMMA STEIN

Mindful Meditation and Physical Exercise: Neuropsychological Effects

Department of Psychology, June 2014

Neuroscience Program

ADVISOR: Cay Anderson-Hanley

An abundance of prior research has indicated the robust relationship between physical exercise and cognition (Colcombe & Kramer, 2003). More recent research has investigated the cognitive and stress-relieving benefits of mind-body exercise, involving a combination of mindful meditation techniques with physical movements (Wayne, et al., 2014). Among these two cognitively enhancing techniques, is “exergaming,” which provides interactive physical exercise with a virtual environment. Research on exergaming has found additional cognitive benefits of interactive mental and physical exercise compared to regular physical exercise (Anderson-Hanley, et al., 2012). However, it remains unclear as to which type of mental engagement is required during physical exercise in order to achieve the greatest cognitive benefits. Given the research suggesting some cognitive benefit of mindfulness meditation practiced independently (Zeidan, Johnson, Diamond, David, & Goolkasian, 2010), the current study investigated the efficacy of combining mindful meditation techniques with virtual reality enhanced exercise (cybercycle). Sixty-one undergraduate students were randomly assigned to one of four conditions: 1) cybercycle (interactive mental and physical exercise), 2) mindful cybercycle (mindful meditation and cybercycle), 3) physical exercise only (no mental component), or 4) mindful meditation only (no physical exercise component). Participants were administered neuropsychological tests of executive function before and after a twenty-minutes of an acute bout of exercise and/or meditation. There was a significant effect of mindful exercise on executive function as measured by the Color Trails, $F(1, 20) = 7.32$, $p = 0.01$, such that those in the mindful cybercycle group improved significantly more from pretest to posttest compared to the cybercycle group. No significant difference was found between any of the other conditions. These findings suggest combining mindful meditation with exercise may induce a greater degree of engagement and concentration, providing an enriched neural environment for cognitive enhancement. Future research should continue to explore the level and type of mental engagement/stimulation required during exercise that will produce the greatest cognitive benefits

TABLE OF CONTENTS

INTRODUCTION

Mindful meditation, once solely a Buddhist traditional practice (Nyanoponika, 1972), has recently become an everyday habit for many, with currently 9.4% of Americans (20 million) practicing some form of meditation (Barnes, Bloom, & Nahin, 2008). Mediation without religious associations began to serve a purpose to modern-day people who wished to relieve themselves of perceived stress and unknowingly improve their overall cognitive abilities. This increasingly popular custom has caused an abundance of literature to focus on the cognitive outcomes of the practice, of which an overwhelming majority has found beneficial outcomes (Chiesa & Serretti, 2010).

Mindful meditation practice is the cultivation of attention. The mindful state, which differs from mindful meditation practice, is achieved through the practice of observing sensations, mentally describing emotions and refraining from self-judgment (Holzel, Lazar, Gard, Schuman-Olivier, Vago, & Ott, 2011). Once practiced, the state of mind can be reached and one becomes more aware of their cognitive state, that is, one pays attention on purpose, in the present moment, and non-judgmentally (Raffone & Srinvasan, 2010). Previous research has found that with repeated focus of one’s thoughts and attention, a meditator can improve focus and more accurately retrieve available information from their working memory capacity (Chiesa & Serretti, 2010). Executive functions, which refers to the system that controls nearly all cognitive processes in the brain, has shown significant plasticity characteristics and therefore has been the target of many studies. Research investigating meditation has demonstrated how the practice can relieve stress and negative mood, while also (Lane, Seskevich, & Pieper, 2007) enhancing executive functions (Zeidan, Johnson, Diamond, David, & Goolkasian, 2010), visuospatial processing (Kozhevnikov, Louchakova, Josipovic, & Motes, 2009), and attentional processing (Chan & Woollacott, 2007). Mindful Meditation practice is encouraged more regularly in today's society, as the scientific community urges to find new ways to improve cognitive abilities, especially in the elderly. Physical exercise is one of the primary encouragements and it has been shown to illicit similar effects as meditation, including stress reduction (Lane, Seskevich, & Pieper, 2007) and cognitive enhancement (Colcombe S. J., et al., 2004).

In a relatively new approach for cognitive enhancement, mindfulness has recently been combined with physical exercise to assess the maximal benefit of both activities, such as yoga and Tai Chi (Chattha, Nagarathna, Padmalatha, & Nagendra, 2008). In a regular physical exercise session, the mind may be free to wander and attention free to focus on stressful events or activities in everyday life. Nonetheless, research provides solid suggestion that exercise alone delivers multiple cognitive benefits, more specifically, improvements in executive-control processing (Colcombe & Kramer, 2003). Thus far, it is evident how exercise and mediation alone may increase executive functions, however no research has examined the combined benefits. Merging exercise with mindful meditation requires individuals to focus on their movements during the activity and to develop an awareness of the connection between body and mind. If combining two cognitive-enhancing activities can yield an effect greater than either alone, mindful exercise could have enormous health benefits for the normative population. If executive functions can improve in healthy individuals, this combination could have large implications for various samples, including those who suffer from cognitive decline. Either way, the exploration of combining activities, which have both proved to improve cognition on their own, is important as it will provide a basis for which future research can develop the most cognitively enhancing activities for various groups of people. ...

With the lack of medications available to prevent the cognitive decline in the aging population, research has been heavily concentrated on practices or exercise that can slow this natural process (Colcombe, et al., 2006). Dementia, is an umbrella term encompassing multiple cognitive dysfunctions, all associated with a decline in memory, attention, focus, and various visual and auditory impairments. With increasing age, those suffering from dementia experience a drastic loss of neurons in the brain, causing decreased neuronal communication and thereafter, an impairment in a wide range of cognitive performances (Alzheimer's Association, 2014). Although there is no cure at the present time, preventative measures have been established. Research has demonstrated how regular physical exercise increases cognitive function (Heyn, Abreu, & Ottenbacher, 2004), and in addition, how meditation can improve neuronal connectivity in individuals with mild cognitive impairment (Wells et al., 2013). The current study hopes to contribute to this line of research by focusing on the benefits of high intensity mindful exercise (mindful meditation and exercise) in a healthy sample.

The Mental Effects of Meditation: Stress and cognition

The original motivation for individuals to pursue meditational practice was likely because initial stress-relief benefits were easily noticed. If people felt a general increase in mood or decrease in stress, meditation was reinforced, and the practice continued. If meditation can reduce stress, how can that affect other cognitive components? Mohan, Sharma and Bijlani (2011) investigated this question when they examined how meditation would affect stress-induced changes in cognitive function. If meditation produces a relaxation response (Mohan, Sharma, & Bijlani, 2011), and stress can produce impairment in cognitive abilities (Oei, Everaerd, Elzinga, Van Well, & Bermond, 2006), then perhaps meditation could act to meditate the impairments. Thirty-two undergraduate males with no meditation experience were recruited for the study. All subjects played various, difficult computer games, while their stress levels were monitored. The computer game that elicited the greatest level of stress was used as the stressor for that specific individual. The participants returned to the lab for a second time and were randomly assigned to four groups. All four groups played their specific computer game while being assessed on their level of stress. However, group one practiced meditation before the stressor, group three practiced meditation after the stressor, group two was assigned to wait before the stressor, and group four was assigned to wait after the stressor. The meditation consisted of brief instructions by a trained instructor and then a 20-minute session of mindful meditation. A prerecorded audio track, reinforcing focus and awareness of cognitive states during the 20 minutes helped the newly learned meditators to remain in the mindful state. In the control condition, participants waited in a room for 20 minutes with their eyes open. Six measurements of stress were used, which included; HR, phocardiography, electrical systole ratio, temple muscle EMG, sweat gland activity, and serum cortisol levels (Mohan, Sharma, & Bijlani, 2011). Cognitive function was then assessed by measuring: orientation, mental control, logical memory, attention, concentration, visual reproduction, and associative learning. Results indicated that meditation prior to exposure to a stressor produced significantly lower levels of stress compared to simply waiting prior to exposure to a stressor. In addition, meditation alone (group 1) produced a relaxation response and a decrease in acute stress after 20 minutes of meditation, which was not produced by simply sitting for 20 minutes (group 2). The memory quotient increased when meditation was practiced either before or after the stressor, suggesting that meditation may help to reduce stress in addition to helping maintain cognitive abilities (Mohan, Sharma, & Bijlani, 2011). This study demonstrates the efficacy of just 20 minutes of meditation in order to reduce stress. In addition, meditation may act to mediate stress-induced changes in cognitive function, representing its ability to inhibit stress from decreasing one's cognitive abilities.

The research dedicated to mindful meditation has become increasingly more apparent. This has led researchers to go beyond the relationship between meditation and mood/stress, and dig deeper into the cognitive benefits that may not be as evident to the meditator. Chiesa, Calati and Serretti (2011) conducted a systematic review of the neurological affects associated with mindfulness meditation training. Thirty-five studies were collected; however, 12 were excluded due to different concentrations, children samples, lack of control, or alternate mindful meditation definitions. A total of 23 adult studies were analyzed, of which eight were case-controlled, seven were randomized, and eight were controlled (Chiesa, Calati, & Serretti, 2011). The studies examined effects in healthy subjects, as well as subjects diagnosed with depression, chronic pain, TBI, or military personnel. The cognitive measurements assessed included attentional tests (internal switching task, stroop task, trail making test, etc.), memory tests (digit span backward and forward, operation span task), and tests of executive function (oral word association test, Hayling task, word production task). Researchers predicted an improvement in cognition based on a model that theorizes mindfulness allows disengagement from thoughts (attention switching) and direction of focus (selective attention; Chiesa, Calati, & Serretti, 2011). The results from all the studies were reviewed and summarized in order to determine the effects of each type of meditation training on attention, memory, executive functions and overall cognition (Chiesa, Calati, & Serretti, 2011). Results indicated preliminary evidence that suggest the mindfulness training improves selective and executive attention and to a greater extent in expert meditators. In addition, findings suggest mindfulness can improve working memory; however, these effects may be related to the amount of time spent practicing meditation. The few studies that did not yield significant effects were surmised null due to measurements not sensitive to effects of meditation. The use of varied measurements, mindfulness techniques and control conditions point to the need for more well controlled studies examining meditation. However, this review of previous research demonstrates the wealth of research with substantial preliminary evidence indicating mindful meditation alters and improves cognitive abilities.

Research involving meditation began by examining long-term Buddhist meditators (Chiesa & Serretti, 2010); so, much of the previous research encompasses long-term mindfulness meditation practice. Practice sometimes makes perfect, but some evidence demonstrates you may not need that much practice to reap the mindful meditation benefits. Zeiden and colleagues (2010) took a different approach by investigating how brief meditation would affect cognitive function and mood. Sixty-three undergraduate students took part in the study and were randomly assigned to the meditation or the control (book reading). Those in the meditation condition participated in four small-group training sessions where they were taught and practiced basic mindfulness techniques: the skills acquired involved focusing on the breath and bodily movements, noticing arising thoughts and then letting them go, and directing their attention back to their breathing (Zeidan, Johnson, Diamond, David, & Goolkasian, 2010). The control group listened to an audio recording in small groups for the same four sessions. All subjects were assessed using: a mindfulness inventory, anxiety measure, mood states survey, as well as cognitive assessments (example. working memory, sustained attention, visual coding, and verbal fluency). The results were consistent with research involving expert meditators, as mindfulness training produced an improvement in mood and various cognitive tasks. The mindfulness meditation group showed significantly greater improvements on the symbol digit modalities test, verbal fluency and hit runs on n-back, all of which measured sustained attention and executive function. The reduction in fatigue and anxiety may have contributed to the improvements in the cognitive tasks that involved speed of processing, allowing subjects to accurately complete the cognitive test in a shorter time. These findings appear to establish similar benefits in brief mindfulness training that have largely been found in long-term meditators.

It is evident that mood and cognitive improvements can be derived from the increasingly popular practice of meditation today. If these improvements are produced by alterations in brain chemistry, meditation could also benefit a sample of people under continual neuronal stress, such as in an aging sample of older adults. Gard, Hölzel, and Lazar (2014) conducted a systematic review of studies that examined how meditation could slow cognitive decline in older adults. Due to the fact that this area of meditation has not been well established, a total of 12 studies were used, after excluding 20 on the basis of poor eligibility (no aging focus, no cognitive measures, no meditation used, not original research; (Gard, Hölzel, & Lazar, 2014). The type of meditation practiced ranged from mantra-based meditation, mindful meditation, zen, mindful-based stress reduction (MBSR), and Buddhist based mindful meditation. Nearly all the studies consisted of subjects with poor to severe cognitive dysfunction and all studies measured a range of cognitive processes including: working memory, attention, executive function, and processing speed. In general, the researchers concluded that some studies suffered from bias, others from small sample sizes, and no distinct conclusion could be made. However, they do conclude, with caution, that the studies examined exhibit preliminary evidence that meditation may delay cognitive decline. In regards to specific cognitive domains, attention appeared to improve most after mindful meditation. Furthermore, older meditators were actually found to outperform younger non-meditators, suggesting that meditation can improve cognition as well as enhance attentional adeptness (Gard, Hölzel, & Lazar, 2014). This review on meditation and cognitive decline demonstrates that training the elderly to meditate is feasible, and specific meditation practices may be more effective than others.

It is evident that practicing meditation promotes an increase in certain cognitive functions (executive functions). What is less evident is the specific attentional networks that are most sensitive to meditation and therefore are enhanced with meditation practice. Chan and Woollacott (2009) examined whether long-term meditation improves the efficiency of orientational processes, and/or improves the efficiency of executive processes. Fifty meditators and ten non-meditators were recruited for the study. The meditators were split into groups specifying the type (transcending meditation vs. mindful meditation) and experience of meditation. All participants were administered the stroop task (measuring executive functioning) and the global-local letters task (measuring orientation attention). Results demonstrated that minutes of meditation per day were negatively correlated with improvement on stroop interference that is, more meditation led to faster performance on stroop (the test measuring executive control). The results also indicated no significant differences on the global-local letters task (the test measuring orientation network control). This suggests meditation experience leads to an increase in executive attention networks (Chan & Woollacott, 2007). In addition, no difference was found between the two types of meditations suggesting that either engage equally in executive control. This study differentiates between the attentional networks involved in meditation, suggesting that meditation practice can lead to improvements in executive function by increasing the ability to inhibit incorrect responses.

The Neuropsychological Effects of Exercise and Exergaming: Stress and Cognition

Research has well established that regular physical exercise is efficient at enhancing cognition and reserving neuronal connections responsible for the brain's abilities (Colcombe S. J., et al., 2004). Colcombe and Kramer (2003) investigated the relationship between exercise and cognition in healthy older adults by conducting a meta-analysis. After exclusion of articles due to lack of random assignment, supervision, aerobic fitness, older sample, and a cross-sectional method, a total of 18 articles were left for analysis (Colcombe & Kramer, 2003). Several hypotheses were proposed according to the collection of literature, which attempt to explain the underlying mechanism linking cognition and exercise. Several biological mechanisms underly the following hypotheses, which include: neurogenesis, synaptogenesis and increased cerebral blood flow, controlled by molecular mechanisms such as brain-derived neurotropic factor (BDNF; Lista & Sorrentino, 2010) The first is the Speed Hypothesis, which indicates simple speed and reaction tests are most sensitive to fitness. This is likley due to an increase in cerebral oxygen, which is necessary for gluose metabolism as wlel as neurotransmission required for cognitive tasks (Dustman, et al., 1984). The visuosptial hypothesis states visuospatial skills are most vulnerable to aging and therefore fitness benefits should be seen in tasks that assess these skills. The controlled processing hypothesis indicates skills are formed when controlled processing progresses to automatic. Finally, the executive-control hypothesis states the central capacitor for cognitive control is associated with aging and therefore isy sensitive to fitness effects (Colcombe & Kramer, 2003). The results demonstrated a robust relationship, indicating aerobic fitness is beneficial to cognition in healthy adults. Exercise enhanced cognitive performance, regardless of the cognitive task, training method, or participants characteristics (Colcombe & Kramer, 2003). Speed, visuospatial, controlled-processing, and executive-control all benefited from aerobic fitness, with executive-control illustrating the largest improvement ($d = 0.05$). This literature review provides valuable evidence for the relationship between physical aerobic exercise and improved cogniton. A few years later Colcombe and collegues (2006) investigated the neuronal mechanism behind aerobic fitness in a randomized clinical trial. After either completing aerobic training or stretching for six months, significant increases in brain volume were observed in participants who took part in the aerobic exercise (Colcombe, et al., 2006). Cardiovascular fitness appears to be strongly associated with changes in brain volume, which may impact the maintanence of cognition in older adults.

It is evident that multiple practices and exercises can differentially affect and improve a variety of cognitive performance. However, it is important to understand the modality of physical exercises that produces the greatest changes in cognition. One integrative approach to combatting cognitive decline and increasing cognitive function, involves an activity that combines mental and physical exercise, which is known as exergaming. By combining mental and physical exercise in a cluster randomized clinical trial, Anderson and colleagues (2012) investigated how virtual reality enhanced exercise (exergaming) could improve cognitive abilitities in comparison to traditional exercise. Interactive gaming has been shown to increase the appeal of exercise, as well as promote mental stimulation in older adults. One hundred and two (79 randomized and 63 completed) participants were recuited from elderly living facilties to either participate in three months of cybercycling or riding on a stationary bike (Anderson-Hanley, et al., 2012). After one month of familiarizing themselves with the bikes, the participants rode an average three times a week for two months. In the exergame condition, a stationary bike is combined with an interactive videgame in which individuals steer the phsical bike in order to direct the virtual bike on the screen. Using handlebars for direction, they guid themselves through a 3D trail while competeing with other riders to finish the race. Steering through the trail and completeing the exercise requires full attention and illustrates the mental stimulation componenent of the biking. In the control group, participants rode a stationary bike without any interactive videogame. Cognition was assesed at baseline, one month, and three months and measured via executive function, attention, verbal fluency, verbal memory, and viduospatial skills. The results indicated that cybercycling produced a medium average effect size for executive function that was greater then the effect for traditional exercise (Anderson-Hanley, et al., 2012). In addition, the results demonstrated that both groups completed the exercises with equivalent physical effort, further indicating the advantage of cybercyling over traditional exercise. This study provides substantial evidence that combining physical and mental stimulation can increase executive function and decrease the rate of progression to mild cognitive impairment (MCI). It is likely that when physical exercise is cognitively challenging and/or has an additional mental component, the cognitive benefits are increased. This study illustrates that cycbercyling can produce greater cognitive advantages than traditional exercise, demontrating preliminarily that the combination of physical and mental stimulation may reduce the conversion to MCI.

In addition to the cognitive benefits of cybercycling, interactive video games and physical activity has been shown to increase adherence and participation. No matter how many studies accuraltey indicate the plethory of benefits produced by exercise and exergaming, motivation to perform these activities regularly remains a consistent problem. Mark et al (2010) revied literature exploring interactive video games and physical activity. A total of 19 studies were analyzed which all included physical activity interventions paired with some sort of virtual reality game. Outcomes included behavioral (attendenca, usage, adherence) and physiological (energy expenditure, oxygen uptake, heart rate). Several studies used the exercise induced feeling inventory to measure mood states, and found that virutal reality enhanced produced the greatest adherence and attitude levels, as well as decreased negative affect (Mark et al., 2010). This study suggests interactive videogames, as assessed by the exercise induced feeling inventory may produce significaly greater levels of affect and adherence compared to regular exercise. The increased interactive mental stimulation may increase the degree to which individuals are motivated to complete the intervention.

Effects of Mindful Exercise

Another mode of exercise that incorporates a mentally stimulating element, is known as mind-body exercise. Combining exercise with meditation dates back to ancient chinese Tai Chi (Koh, 1981), where physical, meditative, social, and cognitive components are merged into one activity. With more and more research suggesting physical exercise paired with some sort of mental stimulation can improve cognition, mind-body exercise has become increasingly popular (Van Schaik, Blake, Pernet, Spears, & Fencott, 2008). Tai Chi contains a heavy meditatoin component, in which mental attention is required to challenge the body physically and the mind mentally. In addition, (Wayne, et al., 2014) has shown to be safe and feasible exercise for older adults with limited flexibility. In a systematic review and meta-analysis, Wayne and collegeues (2013) evaluated the effects of Tai Chi on cognitive function in older adults. A total of twenty studies met the eligibility criteria, which included: randomized controlled (*n*=11), prospecitive nonrandomized controlled (n=1), prospective nonrandomized controlled (*n*=4), and cross-sectional studies (*n*=4). All studies measured cognitive outcomes associated with Tai Chi in either an impaired or nonimpaired sample and compaired to either a control or an active comparison group. Tai Chi interventions ranged from ten weeks to one year and individual sessions ranged from 20 to 60 minutes. For cognitively impaired adults, results indicated Tai Chi produced a significantly greater increase in cognitions for groups compared to both controls and active comparisons (such as western exercise). For the cognitively stable evaluations, the results were highly similar to the impaired subjects. The results from the study add to the growing body of literature that suggests Tai Chi is promising multimodal form of exercise to improve cognition and reduce the progression of cognitive impairments in adults. Futhermore, mind-body exercise seems to be a feasible exercise option for cognitive impaired as well as cognitively health adults who wish to practice safe exercise and improve their cognitive abilities.

Although it is evident that the mindful exercise, Tai Chi has certain cognitive benefits, less research has focused on how it compares to aerobic exercise, which has also proven to increase cognition. Mortimer and collegues (2012) investigated brain volume and cognitive changes after 40 weeks of Tai Chi, aerobic walking, social interaction, and no intervention. 120 older adults between the ages of 60 and 79 participated in the study. Participants were geiven neuropsychological battery tests at baseline, 20 weeks and 40 weeks (post intervention), which evaluated their overal cognitive abilities. In addition, participants received an MRI scan at baseline and post-intervention to assess changes in brain volume. The Tai Chi group performed Tai Chi exercises (plus warm up) with an instructor for 40 minutes. The walking group completed ten minutes of warmup and 30 minutes of brisk walking, followed by ten minutes of cooldown. The social interaction group took part in group-wide discussions on topics of their choice, and the fourth group received no intervention. The three intervention groups met three times a a week for 40 weeks. The MRI data analysis indicated a statistically significant increase in brain volume in both the Tai Chi and the social intervention groups in comparison to the no intervention group (Mortimer, et al., 2012). The neuropsychological results showed improvements in the Tai Chi group for multiple measures (trailmaking, dementia rating, auditory verbal learning) compared to no intervention, whereas the walking group showed no significant trends. However, when walking speed was considered, faster walkers experienced less brain tissue loss and greater cognitive improvements than slow walkers. Therefore suggests a more intense workout is related to greater cognitive benefits. Nevertheless, the results suggest that a less aerobic form of exercise (Tai Chi) can also have a greater effect on brain volume and cognitive abilites. Further, the study reiterates the benefits of mindful exercise, in which maintaining attention and focus during exercise can lead to equal or greater changes in cognitive functiong compared to moderate aerobic exercise.

An alternative mind-body approach to exercise, which is much more widely practiced than Tai Chi, is yoga. From 2008 to 2012 the number of Americans practicing yoga grew an extraordinary 29%, reaching a total of 20.4 million Americans (Sports Marketing Surveys USA, 2012). According to data collected by Sports Marketing Surveys USA, included in the top five motivational reasons for practice were stress relief (60%) and improvement in overall health (59%). The growth in yoga practice in the past few years has urged research to examine the health benefits of this mindful exercise.

In a randomized controlled trial, researchers investigated how yoga affects cognitive functions in a sample of women with climacteric syndrome (peri-menopausal women) (Chattha, Nagarathna, Padmalatha, & Nagendra, 2008). One hundred and twenty women ages 40 to 55 years old who were in a peri-menopause stage participated in the study. The participants were randomly assigned to either the integrated approach of yoga therapy (IAYT) group or the physical exercise group. IATY was created as a holistic yoga approach to physical and mental exercise and involves yogic postures, breathing practice; meditation combined with physical activity, and healthy lifestyle lectures (Chattha et al., 2008). The yoga session included 15 minutes of lecture, ten minutes of breathing with moderate aerobic physical excercises, ten minutes of 12 postures and breathing, and 25 minutes of meditation. The control group session consisted of 15 minutes of lecture, ten minutes of loosening/stretching practices, ten minutes of brisk walking, and 25 minutes of surpince rest (Chattha et al., 2008). Both interventions practiced for a total of one hour daily, five days a week for eight weeks. Participants symptoms were measured before and after intervention. In addition, six letter cancellation test (SLCT) was used to test cognitive functions and PGIMS (battery of ten memory tests) was administered before and after intevention. The results indicated that the yoga group showed significantly greater improvements on both the SLCT and the PGIMS than the control group ($p < 0.001$). More specifically, of the ten memory tests, those who practiced yoga had greater improvements in remote memory, mental balance, attention and concentration, delayed recall, immediate recall, visual retention, and recogntion. Betwenn both 1-hour sessions, the yoga and control group spent rougly the same amoutn of time doing physical activity (20 minutes each). Therefore, it is highly possible that the greater improvements in cognitive function seen in the yoga intervention group were due to the additional meditative component (on top of the physical exercise). Due to the fact that the control group also improved significantly (but significantly less than the yoga group), the findings suggest physical exercise is also a relaible technique to improving cognition. However, it is important to note that the yoga group also had significanly greater reduction in peri-menaupausal symptoms after the intervention, and therefore symptom reduction (hot sweats, night flushes, sleep disturbances) was a possible confound. Even so, as the researchers explain, previous research has demonstrated that improvement in perimenopausal symptoms is not related to improvements in cognitive functions. Thus, the aformentioned study indicates the superiority of yoga over moderate physical activity to improve cognitive functions, that may be attributed to the synchonization of breathing/meditating with exercise.

Neurobiological Mechanisms

The studies previously described have sought to examine the relationship between exercise or meditation and mental outcomes, such as perceived stress and executive function. An important component in understanding these relationships is to determine the neuropsychological mechanisms that underlie the practice of meditation and exercise. As Chan and Woollcott (2009) determined meditation's association with improved executive attention networks, more recent research has attempted to determine the brain structures involved (Xue, Tang, & Posner, 2011). Xue, Tang and Posner (2011) examined if and how short-term meditation could alter the topological properties of the anterior cingulate cortex, an area associated with the regulation of attentional networks. Thirty-two healthy undergraduate students with no previous meditation or relaxation experience were assigned to either the control group of the meditation group. The meditation group practiced integrative mind-body training (IMBT), which involves breathing and postural practices in a meditative state. The control group practiced muscle relaxation training (RT) for the same amount of time as the meditation group (30 min, 5 days a week, for 1 month). Before and after training, each participant underwent a MRI and fMRI in to examine the topographic properties of the brain. The various images were collaborated to analyze the resting-state efficiency of the integrated neuronal networks and the propagation of information across the networks (Xue, Tang, & Posner, 2011). The results indicated that after just one month of IMBT, the nodal efficiency in the left anterior cingulate cortex was significantly greater than one month of RT. Interestingly, they also found that the motor-related brain region of the RT group showed significantly greater efficiency than the IMBT group, suggesting that the incorporation of muscle movements may improve behavior planning and execution. Nevertheless, 11 hours of meditation produced changes in the anterior cingulate cortex, possibly strengthening the capacity to integrate higher order processes from multiple cortical areas. These findings provide neurophysiological evidence that could explain the improvements in executive functions due to meditation practice.

A systematic review of studies examining neurobiological mechanisms of meditation has also provided substantial evidence for the increasing cortical functioning, in addition to other neurological mechanisms (Chiesa & Serretti, 2010). The results indicated multiple cortical areas became activated, as shown by fMRI during meditation including the anterior cingulate cortex, along with the prefrontal cortex. In addition, cortical areas involved in attentional processes and executive functions were found to be significantly larger in mindful meditators compared to controls (Chiesa & Serretti, 2010). The brain regions involved in meditation may be similar to the brain regions associated with cardiovascular activity, implying that the two mechanisms may have similar cognitive consequences.

In a series of two studies, Colcombe and researchers (2003) examined how cardiovascular fitness affects attentional networks in the brain along with how physically active individuals demonstrate cortical activity in the areas dedicated to attention. The first study involved 41 healthy adults, who underwent physical activity assessments to determine their level of fitness. Then, all participants were administered cognitive tests (responding to central arrow cue embedded in other arrows) while being scanned with fMRI. In the second study (randomized clinical trial), 29 healthy adults were assigned to either an aerobic group or a stretching and toning group (control). Participants completed the sessions three times per week for 6 months. All participants underwent the same cognitive test with fMRI before and after intervention, along with a cardiorespiratory fitness test, post-intervention (Colcombe S. J., et al., 2004). The results showed that both the intervention and the cross-sectional study of aerobically active individuals performed better on tests of executive functioning. In addition, high levels of fitness gave rise to a reduction in the amount of activity in the anterior cingulate cortex (area associated with conflict). This reduction in activity is correlated with the reduced interference on the cognitive task seen in those who underwent the aerobic intervention or who came into the study with a high fitness level.

These findings relate to the findings from multiple meditation studies that examined brain regions (Chiesa & Serretti, 2010; Xue, Tang, & Posner, 2011). Presumingly, meditation and exercise both work to strengthen the nodes and therefore neural networrks in the anterio cingulate cortex. If meditation produced an increase in inter-nodal effecicency in the ACC, it is likely that there would be a reduction in task-related activity of the ACC. Sensitive to response conflict, the ACC has shown to become activated during certain cognitive tasks (flanker task and stroop task), with higher activity in response to higher levels of conflit

(Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999). By monitoring attention regularly during meditation, it is possible attentional networks of the ACC are enhanced, therefore producing greater ability to conflict opposing information during tasks such as the Stroop.

Flow

A possible mechanism that could explain the expected improvements in cognitive function after mindful cybercycle could be a great engagment in the activity, or a so-called flow expereince. When fully immersed in an activity and the demand of the activity meets the skill level of the individual, a flow sate of mind is reached (Payne, Jackson, Noh, & Stine-Morrow, 2011). This is what Csikszentmihalyi, the founder of the concept of flow, calls an optimal experience (Wong & Csikszentmihalyi, 1991). Although it has not been previously researched, the mindfulness state and the flow state share similar characteristics such as; effortless awareness, transformation of time, complete concentration. However, due to the fact that there is a difference between mindful meditation practice and the state of being mindful, flow may assess the mindful state more accurately. Especially because the mindful state takes practice, and unlike the expereince of flow, doesn't occur so automatically at first.

The flow questionnaire is of interest in order to explore whether the state of flow coincides with mindfulness and whether it can explain potential improvements in executive function. Despite previous research concentrating on physical exercise induced flow, it can be achieved in any mental or physical activity that meets the individuals level of skill (Dietrich, 2004). The attentional effort in flow may act to inhibit sensory distractions, allowing full concentration in the activity (and therfore the present moment), which may lead to an increase in attentional networks. By creating a channel in which explicit systems (conscious awareness) and implicit systems (expereice-based, normally not accessible to conscious awareness) are linked, the state of flow can cause an active disengagement from cognitive states and enables the one-poitedness of focus (Dietrich, 2004).

The Current Study

The current study attempts to provide preliminary evidence for stress reduction and cognitive enhancement by combing aerobic exercise and meditation. Prior research by Moore (2013) as well as Zelinger (2009) have demonstrated the benfits of combined physical and mental exercise compared to solely mental exercise (video game play). By increasing the amount of mental focus while exercising, the study hopes to show an increase in cognitive benefits which have already been demonstrated with the cybercycle. In addition, by increasing the amount of physical activity performed during meditation, the study hopes to increase the improvements that have previously been reported from meditation. In an attempt to modernize Tai Chi, a moderate aerobic exercise and meditation practice, the current study will involve an acute bout of exercise. This research will provide evidence for the benefits of combining two neurocognitive enhancing activities.

Various mechanisms have been proposed regarding meditation that are associated with certain components of meditation and related to specific behavioral and cognitive findings. Practicing mindful meditation involved attention regulation, body awareness, and emotion regulation (Holzel, Lazar, Gard, Schuman-Olivier, Vago, & Ott, 2011). The most sensitive of these to brief mindful meditation is the attention regulation, with a corresponding brain region of the anterior cingulate cortex (Xue, Tang, & Posner, 2011). Instructing individuals to remain attentive and return their thoughts back to the center, instigated enhanced performance on executive function tasks (Holzel et al., 2011). Another perspecitive regarding meditation surrounds the ability of meditation practice to reduce stress (Mohan, Sharma, & Bijlani, 2011). By reducing stress, neuronal reserve is more easily accessible and individuals are freed of any cognitive conflict. This study will thus examine executive function and stress as directly impacted by meditation and exericise, with stress and flow acting as potential moderators to changes in executive function.

Combing this meditative effect with exercise, in particular with exergaming (with a naturalistic mental component of navigating a scenic bike path), creates the potential for further increased mental focus. An increased focus on the task at hand and on cognitive states can result in a reduction of mindwandering and a greater engagment with the enriched environment provided by the cybercycle. The cybercycle combines mental and physical exercise and allows participants to steer the bike in order to complete the virtual tour. The cognitive improvements from the cybercyle are well established (Anderson-Hanley, et al., 2012), however the participants mind's were free to wander. This freedom of mind-wandering promotes no attention enhancement and the individuals may not be fully attentive in the activity. The current study will investigate how cybercycling and mindfulness meditation can be combined (mindful cybercycling) to increase the cognitive abailities achieved after meditation and cybercyling alone.

Hypotheses:

1. Executive functioning is expected to improve significantly more pre-test to post-test in the mindful cybercycling group compared to the cybercyling group.
    a. The greater improvement in the mindful cybercycling group (meditation + cybercycle) is hypothesized to be due to the the

integration of the cognitive processees, instead of practicing them seperately. By either greater engagement in the activity (as measured by flow), or a greater reduction in stress from pre-test to post-test (changed in PSM), cybercycling combined with a meditation will bring greater improvements in executive functions.

2. The mindful meditation group and mindful cybercycling group will demonstrate a significant decrease in stress levels from pre-test to post-test.

METHODS

Participants

The sample (n=61) consisted of Union College undergraduate students aged 18-22 years old (*M*= 19.39; *SD* = 1.46). Forty-five were Caucasian, eight were Asian, four were Hispanic, and three were African-American. All subjects were volunteers who were notified of the study through freud.union.edu, a Union College website that solicits student research studies. The subjects either received monetary compensation or course credit for participating in the research study. Each potential participant was made aware of the physical and mental effort required for the study and then signed an informed consent document approved by the Institutional Review Board at Union College.

Design

This experiment was part of a larger study investigating a broader topic of varying types of cognition and exercise. Two control groups were shared with the other study (n = 31) and students who volunteered were randomly assigned to one of seven conditions (n = 107), two of which belong to the other study (n = 30). The design was a randomized between-subjects independent group design. The independent variable was the exercise and/or meditation condition. The four different conditions examined in this study were: 1) mindful cybercycling (meditation and cybercycling), 2) cybercycling (bicycling with interactive bike tour), 3) regular bicycling (without virtual reality scenery; just blank screen) or 4) mindful meditation. All participants were randomly assigned to a condition depending on the order in which they signed up online. A Union College SRG (student research grant) provided funding for the research.

Participants in the first two conditions completed a twenty-minute acute exercise bout of cycling on the S3R Recumbent Bike (Interactive Fitness Holdings LLC). The third condition completed the same twenty-minute acute exercise bout on the same bike, but the screen (virtual reality display) was turned off (though all physical exercise groups could monitor their HR on the screen). The fourth condition completed twenty-minutes of guided mindful mediation sitting on the cybercycle. The dependent variables were stress and executive function, which was assessed using neuropsychological test that included: Color Trails 1B and 2B, Stroop Version 1 and Stroop Version 2, and Digit Span Backwards Version 1 and Digit span Backwards Version 2.

Measures

Color Trails 2 (D'Elia, Satz, Uchiyama, & White, 1996): Color Trails 2 was administered at pre and post condition to measure executive functioning. Available in validated and reliable alternate forms, Color Trails 2 are highly reliable and therefore provide a stable test for single bout studies (Strauss, Sherman, & Spreen, 2006). The pretest forms included: Color Trails 1A and Color Trails 2A. The post-test forms included: Color Trails 1B and Color Trails 2B. Different Color Trails were used (A and B) in order to guarantee there was no practice effect after the acute bouts. Color Trails include two separate tests, Color Trails 1 and Color Trails 2. Form 1 is administered first and acts as a practice for form 2. Form 1 displays a box with eight pink and yellow colored circles with numbers in them. The participants were instructed to take a pen and connect the circles in numerical order until they reach the end. They were also instructed to work as quickly as possible without lifting their pen from the paper. In addition, they were told to go through the center of each circle and to move back to the last correct circle if they made a mistake. The examiner pointed out any mistakes that went unnoticed by the participant. Once Color Trails 1 was completed, the participant was administered Color Trails 2, the test of executive function. Color Trails 2 displays the same box (but larger) as Color Trails 1, but there are a total of fifty pink and yellow circles with numbers in them. Participants had to connect the circles in numerical order until they reached twenty-five, while alternating colors (pink 1, yellow 2, pink 3, yellow 4). Participants were once again instructed to work as fast and as accurately as possible. This is a timed test, so performance was based on the amount of time it took to complete it (lower the score, greater the performance). Each individual trail has high reliability, and the composite score has a reliability coefficient of 0.90 for all ages (D'Elia, Satz, Uchiyama, & White, 1996).

Stroop Task C: Prosper version – 40 items (Van der Elst, 2006): The Stroop test is a historically valid and reliable neuropsychological test of executive function (Strauss, Sherman, & Spreen, 2006). All three parts of the test, Stroop A, Stroop B, and Stroop C, have demonstrated high reliability coefficients (*0.90, 0.83*, and *0.91* respectively) (Strauss, Sherman, & Spreen, 2006). The reliability within the three tests is moderate to high, suggesting they all assess similar, but not identical functions. Stroop A, administered first, includes 1 practice line and 4 test lines of 10 varied colored squares (red, green blue). Participants were instructed to read aloud the color of the blocks from left to right, all the way to the end of the fourth line. They were told to say the color as quickly as possible without making any mistakes (any mistakes were circled on examiner’s score sheet).

Stroop B was then administered similarly but the lines contained words of colors (red, green, blue) printed in black ink. Lastly, Stroop C is administered, a measures of executive functions because the individual must name the color of the ink, which does not correspond the what the word reads (ex. “blue” in red ink, or “green” in blue ink). The participant is instructed to say the color of the ink while ignoring what the word says. This is a test of one’s ability to interfere with cognitive information that is they must suppress the urge to read the word, and must say the color of the ink. Two different versions are administered before and after to reduce practice-effects; however, parallel form reliability (0.82) remains high. The less time it takes to complete the task reflects the individual’s ability to resolve and inhibit interfering information.

Digit Span Backward (Strauss, Sherman, & Spreen, 2006): The Digit Span test includes first the Digit Span Backwards and then the Digit Span Forwards. In completing the Digits Forward, participants were instructed to repeat a series of numbers, which progressively increase in length. For example, the examiner reads, “5-8-2” and the participant responds by repeating the number in the same order, “5-8-2”. The series of numbers starts with 2 and increases until there are 9 consecutive numbers. The participants have two trials for each series length, and as long as they get one correct, they move on to the next series length. If the participant gets both trials wrong for a single series length, the test is terminated. The two trials per series increase the reliability of the measure. For each trial, either a 0 or a 1 is scored, depending on whether they got it wrong or right, respectively. The total forward score was calculated by adding up the 1's for each trial (total score ranged from 0 to 16). The Digits Backward was then administered, which is the test of executive functions. Similarly to Digits Forward, participants must repeat a series of numbers, however they are instructed to do so backwards. For example, the examiner reads "9-7-2-3", and the participants must respond saying, "3-2-7-9". The length of the series of numbers ranged from 2 to 8, with a total of 14 trials and a maximum score of 14. The score for both the Digits Forward and Digits Backward were added together to make a total score, with a maximum of thirty. The greater the score, the greater the individual's performance on the task. For a normative sample, Digit Span backward and forward have high internal reliability (0.80 - 0.89) and adequate test-retest reliability (0.70- 0.79; Strauss, Sherman, & Spreen, 2006).

Demographic Questionnaire: A questionnaire was administered before the start of all acute bouts in order to assess standard demographics of the sample. The questionnaire was adapted from prior studies in our research lab. The form asked for basic information such as age, sex, height, weight, ethnicity, college major, and class year. It also asked for information regarding athletic history such as high school or college varsity athletic involvement (Table 1). Information concerning previous experience with a stationary exercise bike, with videogames, and with meditation was also collected (Table 1)

Exercise History Questionnaire (McAuley, et al., 2011): The exercise history questionnaire was used to assess the pattern and level of fitness performed by the participants. Individuals were instructed to check the box (corresponding to levels 1 through 5) that best reflects their usual pattern of physical activity. The fitness levels ranged from *1,"inactive or little inactivity other than usual daily activities"* to *5,"aerobic exercises at comfortable pace for over 3 hours per week."* The approximate length and intensity of a single session of exercise was also recorded. Participants also had to identify which type of exercise they normally participate in, such as "*strength/resistance exercise,"* or *"stamina and endurance exercise"* (Table 1).

Psychological Stress Measure (PSM-9): The PSM-9 is a questionnaire measuring the state of feeling stressed. It contains nine items, which have high content validity (0.95; Lemyre & Lalande-Markon, 2009). The stress measure has a normal distribution, which makes it very sensitive to change, and is therefore well suited to document progress in repeated measures (Lemyre & Lalande-Markon, 2009). The questionnaire was administered at pre and post testing to assess the participants' levels of perceived stress. Participants indicated the degree to which statements applied to them, on an 8-point scale, rooted with *"not at all" (1)* and "*extremely"(8).* Some of the statements include, "*I feel calm,*" *"I feel preoccupied, tormented or worried,"* and *"I feel stressed."*

Calculating Target Heart Rate: Target heart for each participant in the exercise conditions was calculated using the Karyonen equation (Haddock, et al., 2012). Before the cycling began, the participant was asked to place their hands on the handlebars so a resting heart rate could be recorded. Using age and resting heart rate, the target heart rate was calculated and the participant was instructed to maintain it. This was done to ensure the participants were getting the maximum benefits of the 20 minutes of exercise. The individuals whose maximum heart rate did not reach their calculated target heart rate, were later dropped form the sample because they were considered as not having completed the session to the best of their ability. Heart rate was not monitored for the meditation only condition because they did not use the cybercycle.

Target Heart Rate = [(220 - age) – (Resting Heart Rate)] x 60% + Resting Heart Rate

Exercise Performance Data Sheet: During the twenty-minute acute bout of exercise, the cybercycle bike monitored the total time, distance, power, heart rate, miles per hour, and the calories burned of the session. This information was recorded from the bike screen after the exercise was complete.

Flow Questionnaire (Payne, Jackson, Noh, & Stine-Morrow, 2011): The flow state questionnaire is administered at post-testing to measure the degree to which the participant was fully immersed in the activity. The questionnaire was used to assess whether the experience of a psychological flow state is related to cognitive outcomes. The 16-item questionnaire asks participants to rate their level of agreement on a five-point scale, rooted with 1, *strongly disagree* and 5, *strongly agree.* The statements assess the level of flow the individual reached during the session. A flow state involves focused concentration, merging action and awareness, loss of reflective-self consciousness, control of actions, and distortion of time. The flow questionnaire contains five subscales all with high internal consistency. These include, merging actions and awareness (MAA, a = 0.83), concentration at task at hand (CO, a = 0.81), challenge skill balance (CS, a = 0.76), transformation of time (TT, a = 0.89), and autotelic experience (AE, a = 0.71). Flow can be assessed by the individual flow constructs or a unitary construct. Some items include, "*My attention was focused entirely on what I was doing"* (CO), *"I lost my normal awareness of time"* (TT), and "*I performed automatically, without thinking too much"* (MAA). Fluid ability is positively related to flow for cognitively demanding activities and negatively related to flow for non-cognitively demanding activities (Payne, Jackson, Noh, & Stine-Morrow, 2011). The five factors have high factorial validity (*CFA* =0.92), and all adequately measuring the flow experience in a variety of activities (Payne, Jackson, Noh, & Stine-Morrow, 2011).

Exercise Induced Feeling Inventory (EIFI; Gauvin & Rejeski, 1993): EIFI is a measure of how an individual is feeling at the exact time. It includes 12 adjectives such as "*Refreshed", "Calm", "Fatigued", "Energetic", "Revived",* and "*Worn-out"*. The participant is asked to rate the degree to which the word describes how they feel, on a five point scale, rooted with 0, "*Do not feel"* and 4, "*Feel very strongly"*. The EIFI consists of 4 subscales; positive engagement (PE), Revitalization (REV), tranquility (TQ), and Physical exhaustion (PHY). All four of the factors demonstrate excellent internal consistency, with alpha coefficients equal to 0.94 (PE), 0.86 (REV), 0.91 (PHY), and 0.84 (TQ). The inventory is scored by adding together the questions that belong to each subscale.

Procedures

The intervention period lasted approximately one-hour, which included the pre and post testing along with the 20-minute exercise and/or meditation session. Participants who signed up were designated a time-period to come to the Neuropsychology Healthy Aging Lab. Participants were randomly assigned to one of four conditions. Participants first signed an Informed Consent Document outlining the their participation agreements and the confidentiality of the study. Participants completed the Demographic Questionnaire, the Exercise History Questionnaire, and the Psychological Stress Measure. Then the participants were administered the three pretest neuropsychological evaluations (Color Trails IA and IIA, Stroop A, B, C, Digit Span Forward and Backward). The examiner read all instructions off of a script to ensure no information was left out and that instructions were consistent throughout the study.

Two of the four conditions used the cybercycle bike for the exercise component. The term “cybercycle” refers to a stationary bike with a video screen that displays interactive virtual game components. It is equipped with a seat and handle bars that the participant uses to steer through the trail. All conditions used the same beginner-level bike trail, called “Evening Bliss.”

Following the testing, the participants then completed the assigned condition. In the first condition, mindful cybercycling, the participants sat on the bike and were taught how to control and maneuver the cybercycle using the handlebars. They were also told they were also going to be listening to a guided meditation track while they were cycling and to listen and do as the recording said. Their target heart rate was calculated and they were further instructed to do their best to maintain it by monitoring their heart rate on the screen.

The second condition, cybercycling, consisted of the same protocol as the first condition, without the guided meditation track. The third condition, regular cycling, involved cycling on the same bike, but with the screen turned off. The only thing displayed on the screen in front of them was their heart rate, distance, speed, and time. In the last condition, meditation only, the participants sat on the cybercycle seat and listened to the guided meditation track (Appendix B). The meditation track was created using mindful meditation techniques, such as reminding the listeners to regard passing thoughts, but to let them go. All four conditions exercised or meditated for twenty minutes.

In regards to the mindful cybercycle condition, the regular cycling condition, and the cybercycle condition, the Karyonen equation was used to calculate the target heart rate for each participant. If the individual did reach their target heart rate (at any point during the acute bout), the intensity would be equal to or above that recommended by the American College of Medicine and the CDC (Haddock, et al., 2012). For this reason, those who didn't reach their target were dropped from the sample.

After the 20-minute acute bout was complete, the participants were given a glass of water. Then they completed the Exercise-Induced Feeling Inventory (EIFI), the Flow Questionnaire, and the Psychological Stress Measure (PSM-9). Lastly, they were administered alternate forms of the three neuropsychological tests in the same order (Color Trails B, Stroop Task, Digit Span Forward and Backward). Participants were then given a debriefing form explaining the purpose and hypotheses of the study and then were compensated for their participation (either $8 or 1 hour of course credit).

Statistical Analysis

Data collected was analyzed using Microsoft Excel and the Statistical Package for the Social Sciences (SPSS v. 12.0). Repeated measures ANOVAs were conducted to evaluate time x group interaction for the primary dependent variables (executive function measures) specified in the hypotheses above. A repeated measure ANOVA was also conduced to assess the time x flow score interaction, in order to explore the potential mechanism behind the increase in executive function scores. In addition, paired t-tests were performed to evaluate the differences between stress measured at pre-test and stress measured at post-test.

RESULTS

There were sixty-one participants who completed the study. Subjects included thirty-six females and twenty-five males with a mean age of 19.39 (*SD = 1.46*). Forty-five were Caucasian, eight were Asian, four were Hispanic, and three were African-American. All but five participants were right-handed.

There were forty participants who indicated on the exercise history questionnaire that they were a level four or level five, and therefore deemed fit. The remaining twenty-one participants completed the exercise history questionnaire with a level of three or below, and therefore were deemed unfit. Nine of the fit participants were in the cybercycle condition, ten in the regular cycling condition, thirteen in the mindful meditation condition, and eight in the mindful meditation condition. The mean BMI score was 23.68, falling in the normal weight category (18.5 – 24.9), as specified by the National Institute of Health (Health, 2014). The demographic characteristics of the participants are illustrated in Table 1 in the appendix. There was no significant difference in demographics for any of the groups. The average pre-test and post-test scores are illustrated in Table 2.

To reach their target heart rate, participant's maximum heart rate must have reached their calculated target. Thirty-six of the forty-four participants in the exercise conditions reached their target heart rate, whereas seven did not. Heart rate was not recorded for the participants who were in the meditation only condition (n = 16). The physiological data for the forty-four participants assigned to one of the exercise conditions is illustrated in Table 3. There was no difference in any of the physiological characteristics among the four groups at pre-test, as seen in table 3.

Comparing The Effects of Mindful Cybercycling on Executive Function

The Cybercycle condition and the Mindful Cybercycle condition, the two primary groups of interest were compared on all measures of executive function. Participants whose maximum heart rate did not reach their target heart rate (n = 4) were removed from the analyses, as they did not successfully complete the minimum requirements for the exercise session. Participants in the Mindful Cybercycle group who indicated a one, on a scale from one to five, they had “no experience with/never done meditation” (n = 5), were also removed from analyses. The concern was that the combination of meditation with the Cybercycle would proved to be too difficult of a task for those participants who had never done any form of meditation. Although the rest of the group were still considered beginners meditators, with three participants reporting a two, “very rarely done”, six reporting a three, “occasionally done”, one reporting a four, “done pretty regularly”, and zero reporting a five, “done almost daily”. The sample consisted of subjects from the mindful cybercycle condition (n = 9) and the cybercycle condition (n = 11) who had done meditation at least once in the former group, and those who reached their target heart rate in either group.

A repeated measures ANOVA was performed in order to compare the pretest scores and posttest scores for all three executive function measures. The multivariate test showed that the effect of exercise condition on executive function was non-significant, $F(3, 18) = 2.2$, $p = 0.12$. The univariate results were still analyzed, as executive function is a broad category and the individual tests measured slightly different components of executive function.

The effect of mindful exercise on executive function as measured by Color Trails 2 was non-significant, $F(1, 20) = 0.28$, $p = 0.60$, participants in the mindful cybercycle group (M = -7.2) did not improve more pre-test to post-test, compared to the cybercycle group (M =

-9.7). The negative means indicate that the participants improved at post-test, taking less time to complete the task (Table 5).

The effect of mindful exercise on executive function as measured by Digit Span Backwards was non-significant, $F(1, 20) = 0.98$, $p = 0.33$, participants in the mindful cybercycle group ($M = 1.67$) did not perform better pre-test to post-test, compared to the cybercycle group ($M = 0.69$; Table 5).

The effect of mindful exercise on executive function as measured by Stroop C was significant, $F(1, 20) = 7.32$, $p = 0.01$, participants in the mindful cybercycle group ($M = -9.22$) improved more pre-test to post-test compared to the cybercycle group ($M = -5.1$). The negative means indicate that the participants improved at post-test, taking less time to complete the task (Table 5).

When all four of the groups were analyzed using a repeated measures ANOVA, the multivariate test was non-significant, $F(3, 132.0) = 0.95$, $p = 0.48$. However, the univariate test measuring executive function as measured by the Stroop C task was significant, $F(3, 44) = 2.88$, $p = 0.04$ (Figure 2). Post hoc tukey tests revealed no significant differences between the four groups (Table 3).

The Effect of Psychological Flow State on Executive Function

A repeated measures ANOVA was performed to see if reaching a greater level of flow predicted performance on the Stroop C task in the mindful cybercycle group and the cybercycle group. A median split was first performed for the total flow score in order to categorize the subjects for analysis. Those who scored below 23.5 were categorized as having not reached the flow state, and those who scored above 23.5 were categorized as having reached the flow state. Among the mindful cybercycle group and the cybercycle group, thirteen participants reached the flow state, of which seven were in the cybercycle group, and six were in the mindful cybercycle group. A total of nine participants did not reach the flow state, of which six were in the cybercycle group and three were in the mindful cybercycle group. The multivariate test for time x total flow was non-significant, $F(1, 20) = 3.82$, $p = 0.06$, those who reached a flow state did not perform significantly better pre-test to post-test on the executive function, measured by Stroop C (Table 7). However, the results did indicate a trend toward significance, with those rating higher levels of flow performing better on Stroop C at post-test ($M = 26.05$) compared to those who rated lower levels of flow ($M = 30.98$).

An additional analysis was done to evaluate if one of the questions on the flow questionnaire could explain the differences in stroop scores between the mindful cybercycle group and the cybercycle group. The question states, "I had total concentration" ($a = 0.77$) and is part of the concentration on task at hand subscale (CO). The entire subscale was not used, as several facets of it would not pertain to individuals who are not expert meditators, such as "I had no difficulty concentrating". It is likely there was some degree of difficulty on concentrating, but what's more important is whether or not they did feel entirely concentrated, as this would likely predict the degree to which they were in a mindful meditative state. A median split was done, categorizing those with a score of one, two, or three as not concentrated, and those with a score of four or five as fully concentrated. A total of thirteen were concentrated, eight in the mindful cybercycle group and six in the cybercycle group, and a total of nine were not concentrated, seven in the cybercycle group and two in the mindful cybercycle group. The multivariate test for time x concentration was significant, $F(1, 20) = 5.24$, $p = 0.03$, those who reported full concentration after the exercise session, improved significantly more on the Stroop C task compared to those who reported little concentration (Table 7).

The Effect of Stress Levels on Executive Function Measures

A repeated measures ANOVA was performed to determine whether or not a reduction in stress predicted performance on the executive function measures among the mindful cybercycle group and the cybercycle group. A median split was done to categorize participants as either improved stress (n=11), of which seven were in the cybercycle group and four were in the mindful cybercycle group, or non improved stress ($n=11$), of which five were in the cybercycle group and six were in the mindful cybercycle group. The multivariate tests revealed no significant difference between the improved and not improved stress, $F(3, 19) = 2.79$, $p = 0.07$. The univariate test for Digit Span backward was non-significant, $F(1,20) = 0.14$, $p = 0.71$ and the univariate test for Stroop C was non-significant, $F(1,20) = 1.18$, $p = 0.29$ (Table 8). However, the univariate test for Color Trails 2 was significant, $F(1,20) = 5.23$, $p = 0.03$, the individuals who were considered to have improved stress, performed significantly better from pretest to posttest on the Color Trails 2 (Table 8).

The Effect of Meditation on Reduction in Stress

A Paired t-test was performed for each group to determine if stress, measured at post-test was significantly different from stress, measured at pre-test. Results indicated no significant change in stress from pre-test ($M = 26.1$) to post-test ($M = 25.4$) for the mindful cybercycle group, $t(8) = 0.175$, $p = 0.86$, and no significant change in stress from pre-test ($M = 33.5$) to post-test ($M = 29.6$) for the meditation only group, $t(13) = 1.13$, $p = 0.27$. However, when the individuals who reported at pretest to have low levels of stress ($n = 6$), the paired t-test was significant, $t(14) = 2.65$, $p = 0.02$, among the meditation conditions, there was a significant difference in pre-test stress ($M = 33.0$) and post-test stress ($M = 27.1$).

A repeated measures ANOVA was performed to determine if there was any significant differences in stress from pre-test to post-test among the four groups. The multivariate test was non-significant, $F(3, 43) = 0.35$, $p = 0.79$. Post Hoc Tukey tests revealed no significant differences in changes in stress between the four groups (Table 6).

DISCUSSION

Previous research has demonstrated the cognitive benefits of physical exercise (Colcombe & Kramer, 2003) as well as mindful meditation (Chiesa & Serretti, 2010). Research has also begun to look at different variations of mindful exercise (meditation + physical exercise) (Wayne, et al., 2014), but it is remains a mystery as to which type and level of mental engagement and activity is required to yield the greatest cognitive benefit when combined with physical exercise. In addition, little to no research has examined the effects of combining mindful meditation with a more cardiovascular intense form of physical exercise, such as cycling. The current study attempted to examine how the direction of attention during exercise, as induced by mindful meditation practice, could increase performance on executive function measures. The current study was part of a larger research project (n = 107) with a total of seven conditions, investigating how varied cognitive exercises would affect cognitive function. The purpose of the current study was to investigate whether two cognitively enhancing activities could be feasibly combined and whether this specific type of mental activity (meditation) would be a sufficient level of cognitive engagement. It was hypothesized that the mindful cybercycling condition (meditation + virtual reality enhanced exercise) would improve significantly more pre-test to post-test than the regular cybercycling condition. Sixty-one Union College undergraduate students participated in the study and were randomly assigned to one of four conditions; cybercycle (biking + virtual reality enhanced tour), mindful cybercycle (mindful meditation + cybercycle), mindful meditation alone (no exercise), or biking alone (nothing shown on screen). The current findings set the stage for future research in mindful exercise and found that meditation combined with cybercycling offers some additional cognitive benefit compared to cybercycling alone.

The primary hypothesis was that the mindful cybercycle group would improve significantly more from pre-test to post-test on the executive function measures compared to the cybercycle group (hypothesis 1). The purpose was to explore what additional benefits could be gained from adding a mentally stimulating component to the already, cognitively enhancing cybercycle. Results demonstrated that group by time interaction for exercise condition and executive function scores were non-significant. However, one of the three univariate tests measuring executive function, as measured by Stroop C was significant (p = 0.02), which led us to only partially support the primary hypothesis. The Stroop task however, as part of the executive network, has demonstrated high sensitivity to mindful meditation practice compared to tasks measuring the orientation network (Chan & Woollacott, 2007). The immediate effects of meditation practice are likely related to what is taught in the track; teaching participants to acknowledge wandering thoughts and then to bring their attention back to the meditative present moment. By continually maintaining attention and focus (on cognitive states and the present) and pushing other distractions aside (wandering thoughts), one could increase attentional efficiency. This practice is very similar to what's required mentally when completing the stroop task, in which individuals must maintain focus on the task at hand (naming the color of the word) and oppose conflicting information (reading the word).

These findings suggest some additional benefit of directing attention and focusing on the present moment, which may free up cognitive space, allowing for greater allocation of attentional resources. Because the findings for one of the executive function measures was significant, more research is necessary to investigate which tests are most sensitive to meditation and exercise. In addition, the small sample size further encourages more research to examine a larger group of individuals as well as a longer lasting intervention period. The sample was composed of relatively all novice meditators and novice cybercyclists, perhaps hindering the maximal benefits that could be achieved from the intervention. Nevertheless, the current findings suggest some preliminary evidence for an underlying benefit of combining aerobic exercise with meditation.

Currently, no research has found cognitive gains from just twenty minutes of meditation, and it therefore seems unlikely that this was enough time to not only teach mindful meditation practice, but to reap the benefits. Although, previous research in our Neuropsychological and Aging Lab at Union College has documented the benefits of an acute bout of cybercycling compared to mental stimulation (Moore, 2012). Even when individuals had never used the cybercycle before, the majority could easily master it within an acute bout of exercise. However, learning to meditate for the first time while using the cybercycle seemed to be more difficult, as when those individuals were dropped from the sample, we were able to see an effect on executive function measures. A study that did examine how one session of meditation for novices could affect cognition and mood, found that twenty-five minutes of meditation was not sufficient enough to significantly improve cognition (Johnson, Moses, David, & Currier, 2013).

It was also hypothesized that this additional benefit in the mindful cybercycle group would be due to either a greater engagement in a psychological flow state or a greater reduction in stress from pre-test to post-test (hypothesis 1a). The former was based on prior research examining flow states during cognitive tasks, which found that those with higher fluid abilities experienced higher levels of flow during the tasks (Payne, Jackson, Noh, & Stine-Morrow, 2011). The flow state of mind may predict how much individuals can get out of a cognitive activity. When a median split was performed on total flow score and then used to assess changes in the stroop c scores, the p value was close to significance (p = 0.06). This suggests, combining mindful meditation with exercise may make it easier for individuals to reach that flow state and reap the benefits of the exercise session. Csikszentmihalyi, the founder of flow has stated that yoga (a type of mindful exercise) is likely the oldest and most systematic method to engage in a flow experience (Wong & Csikszentmihalyi, 1991).

An important facet of the flow questionnaire is having total concentration, which, in the current study, was significantly related to performance on the Stroop C task (p = 0.03). These results demonstrate that those who were categorized as having high levels of concentration during the intervention, performed significantly better than those who were not concentrating well. Having total concentration implies that the mind is not wandering, which has previously been shown to be the mediator for the cognitive benefits produced by mindful meditation practice (Mrazek, Franklin, Phillips, Baird, & Schooler, 2013). In this recent study, individuals were asked to rate the degree to which they were entirely concentrated during the meditation practice. Not only did the mindful meditation group improve more on the GRE and in working memory capacity compared to an active control, but also they also had significantly lower levels of mind-wandering (Mrazek et al., 2013). They found that mind wandering mediated the effect of meditation on performance, with individuals improving more pretest to posttest if they were entirely focused, and therefore possessing low levels of mind wandering. fMRI data has supported these findings, indicating that executive networks in the prefrontal cortex were highly active during the sustained attention components of meditation and that the default mode networks were active during mind-wandering (Hasenkamp, Wilson-Mendenhall, Duncan, & Barsalou, 2012).

The second mechanism, which was predicted to mediate the changes in executive function scores, is a greater reduction in stress from pre-test to post-test. A median split was performed for the reduction in stress score, categorizing individuals as either improved stress or not improved stress. In the mindful cybercycling and cybercycling groups, the repeated measures ANOVA indicated a significant difference for one of the executive function measures. Individuals who had improved stress, improved significantly more on Color Trails 2 compared to individuals whose stress level did not improve ($p = 0.03$). This could serve as a potential mechanism underlying the differences in executive function scores from pretest to posttest. Brief mindful meditation has been shown to reduce stress (Lane, Seskevich, & Pieper, 2007), and a reduction in stress could allow for a more efficient allocation of resources. A review of acute stress on cognition has found that elevated stress levels can impede performance on cognitive tasks, specifically a reduced working memory capacity (Shaozheng, Hermans, van Marle, Luo, & Fernandex, 2009). Acute stress was shown to produce less activity in the working memory-related cortical networks, suggesting that it caused a reallocation of neural resources. This implies that individuals, who have a greater reduction in acute stress, are able to allocate neural resource more efficiently from pre-test to post test and improve more in executive attention.

The second hypothesis predicted that individuals in the mindful meditation group and the mindful cybercycling group would demonstrate a significant decrease in levels of stress from pre-test to post-test. This hypothesis was based on prior research that indicated even brief meditation can improve perceived stress, however the “brief” referred to a minimum of four twenty minutes sessions within one week (Lane, Seskevich, & Pieper, 2007; Tang, et al., 2007). A paired samples t-test indicated that there was no significant change in stress from pretest to posttest in the conditions with a meditation component (either alone or with cybercycle) (p = 0.31). However, when the individuals were removed from the two groups who had low levels of stress at pre-test (n= 6), there was a significant difference in changes in stress levels (p = 0.006). If individuals began the study with a low stress level, it may be hard to see any improvement post intervention, due to the ceiling effect. This suggests that meditation may benefit those the most with higher levels of stress.

Strengths

The methodologies used in the current study were consistent with previous research examining cognitive benefits of exercise. In addition, the executive function measures used are similar to those used in studies examining cognition in exercise and cybercycling (Colcombe & Kramer, 2003; Anderson-Hanley, et al., 2012). The Psychological Stress Measure (PSM-9) has also demonstrated validity in the general population and serves as an accurate assessment of the state of feeling stressed (Lemyre & Lalande-Markon, 2009). The PSM-9 measures acute stress and is therefore sensitive to short intervention periods, like twenty minutes of exercise or meditation. The Karyonen equation, measuring target heart rate is a reliable measurement to ensure adequate intensity (Haddock, et al., 2012). The flow questionnaire was also a reliable measure of full engagement, and has been shown in previous studies to accurately depict the degree of concentration in exercise tasks (Bendiks, 2013).

Another strength of this study that was not evident in previous research examining brief meditation is that the mindfulness meditation session was controlled and consistent across all participants. Unlike other studies, which teach mindfulness meditation techniques and then allow the participants to practice on their time, this study provided a controlled environment in which they all listened to the same recorded track (Tang, et al., 2007). The mindful meditation only condition sat in the chair of the cybercycle, without the bike turned on. Another strong indication of control across groups is that both the mindful cybercycle and the cybercycle conditions utilized the same beginners virtual reality track on the Expresso cybercycle. The cybercycle bike aims to provide an environment similar to an outdoor cycling experience, therefore implying these findings to other mentally stimulating forms of cycling.

The sample was a well-represented undergraduate group of individuals. In addition, the participants recruited were not aware of the meditation component before signing up. Previous research on brief mindful meditation used a sample of people who were interested in learning mindful meditation techniques. Therefore, the sample was not completely random, and the motivation behind signing up could have lead to a hypothesis predictions. The current study offered psychological course credit as well as monetary compensation, therefore recruiting individuals outside of the psychology field, who may have been well versed in the executive functions measures. Last, due to the fact that mindful meditation and cybercycling have never been examined before, it is sensible that the initial investigation include a small sample size. The current study hopes to set the stage for increasing research examining mindful exercise, providing a basis for which large-scale interventions can be explored.

Limitations

There are multiple limitations that could have influenced the outcome of the study as well as the statistical analyses. First and foremost, the study was composed of a small sample size, which evidently effects the maximal implications, generalizability, and statistical power that can be achieved. The available funds and time limited the number of participants in each condition. In addition, the four conditions used in the current study were part of a larger investigation, which had seven conditions, so total number of participants had to fill more than the conditions in this study. Besides reducing the generalizability and accuracy of a representative sample, the small sample size makes it harder to drop participants who didn't meet general exercise and meditation requirements. When those who didn't reach their target heart rate were dropped, the sample size dropped significantly, and with that the statistical power dropped as well. The sample was composed of participants who had a relatively wide range of meditation experience, and it would have been interesting to examine the differences between the groups. However, there were not enough people in each level of experience in order to statistically analyze them. The bigger the sample size, the more likely a significant effect could have been found, assuming there is a real world effect.

The duration of the intervention is also a primary concern, which could have directly impacted the results in this study. In the mindful cybercycle and mindful meditation conditions, many participants had to learn how to meditate during the acute bout, instead of being taught before hand. Without adequate knowledge of mindful meditation techniques, twenty minutes may not likely be enough time to learn and enter a mindful state. Meditation is not an easy practice to master and participants may have had higher levels of flow if they were taught techniques before the twenty minutes. In addition, the majority of previous research has indicated the benefit of longer interventions and previous meditation experience in order to improve in executive functions (Chiesa & Serretti, 2010). For the exercise conditions, twenty minutes may not be enough to obtain the cognitive effects, especially for those who are unfit and don't regularly practice physical exercise. There may have been significant differences between all four of the groups but the short amount of time spent performing each session may not have been enough to make those differences significant.

Another limitation is the lack of construct validity associated with the Flow questionnaire in measuring mindfulness. Although Flow measures the degree to which one is fully immersed in the activity, it has previously been used for athletic activities only (Payne, Jackson, Noh, & Stine-Morrow, 2011). Another validity limitation is the fact that the meditation track was prerecorded and not taken from any previous research. Although it was created using valid measures of mindfulness (Mindful Attention Awareness Scale; ref?), the actual prerecorded track had unproven/unknown content validity because it had never been used before.

The final limitation regards the various experimenters who ran the subjects. Including the leading researcher, there were a total of five students who assisted in running subjects. Their lack of extensive experience in the protocol and administration of the executive function measures may have influenced the results of the study. They were not monitored each time they ran a subject through the study; so possible issues may have arisen of which the researchers were not made aware of. In addition, they have left out some important instructions while administering the measures, resulting in either an advantage or disadvantage for the respective participants. Despite protocol training, the research assistants did not have extensive knowledge or experience in administering the tests and utilizing the cybercycle.

Future Research

There is an abundance of potential future research that could follow-up the current study and advance the concept of mindful exercise. Due to the fact that mind-body exercises that have been researched involve primarily Tai Chi and yoga, various exercises should be explored. The type and level of physical activity should be further explored to determine the intensity required to achieve cognitive benefits. In addition, the level of activity that matches one's skill level is important in order to reach the optimal experience of flow. Future research should explore the combination of mindful meditation with regular cycling, as cybercycling and meditation may have been too difficult of a task to master for the first time. In regards to beginners, it is also important for future research to focus on teaching mindful meditation techniques before the intervention so that beginners have an idea of what to expect before the exercise session.

If time and money were in one's favor, it would be highly beneficial to recruit more individuals for the study and include a longer intervention period. Several more sessions of mindful exercise and cybercycling would likely yield more cognitive benefits than a 20 minute acute bout. Especially because executive function outcomes after meditation have shown to be highly related to the time spent practicing each day (Chiesa & Serretti, 2010).

Exergaming, involving some sort of mental stimulation combined with physical exercise has demonstrated significant improvements in executive function measures (Anderson-Hanley, et al., 2012). However, the type of mental stimulation required to maximize the enriched neural environment provided by the cybercycle and by physical exercise has yet to be determined. It is still unknown whether a type of stimulation is even required, as the current research has demonstrated the benefits of mental focus or attention.

Future research should therefore explore whether mental stimulation of executive attention networks or mental focus on cognitive states and disengaging from others will lead to greater cognitive benefits. If our attentional resources are already present, is it enough to practice efficient allocation of those resources in order to improve their quality? Or is it possible to strengthen the neural connections of our executive function networks in order to increases the quantity of resources available? The direction and allocation of cognitive resources during physical exercise should be further researched in order to establish the optimal combination of integrative mind and body exercise to improve cognition.

Conclusion

The purpose of this study was to investigate the potential benefits of adding mindful meditation, a type of mental engagement to the already cognitive enhancing cybercycle. Although the primary hypothesis was not entirely supported, as only one of the executive function measures proved to be significant, the present research suggests the cultivation of attention through meditation may provide an even more enriched environment than exercise alone. Additionally, there are certain aspects of a psychological flow state that are required during mindful meditation and may serve as a moderator for an improvement in executive functions. As methods to improve cognition become even more popular, this research looks to set the stage for a more engaging type of physical exercise in which the most benefits can be achieved. The literature conducted on mindful meditation had shown us the power of the mind, in which humans possess the ability to alter neuronal connections and improve cognitive processes. It just up to the future of scientific research to determine the best way to maintain and even improve our cognitive abilities.

ACKNOWLEDGEMENTS

1. Many thanks to all Union College Participants
2. Thank you to my advisor, Cay Anderson-Hanley, PhD.
3. Thank you to the research assistants, Julie Warren, Astrid Vargas, Dean Constant, Nancy Pace, and Shannon Hughes from Professor Hanley's lab who assisted with the study
4. Thank you to the Student Research Grant (SRG) of Union College for providing funds for this study

References

Alzheimer's Association. (2014). 2014 Alzheimer's disease facts and figures. *Alzheimer's and Dementia , 10* (2).

Anderson-Hanley, C., Arciero, P. J., Brickman, A. M., Nimon, J. P., Okuma, N., Westen, S. C., et al. (2012). Exergaming and older adult cognition. *American Journal of Preventative Medicine , 42* (2), 109-119.

Botvinick, M., Nystrom, L. E., Fissell, K., Carter, C. S., & Cohen, J. D. (1999). Conflict mointoring versus selection-for-action in anterior cingulate cortex. *Nature , 402*, 179-181.

Chan, D., & Woollacott, M. (2007). Effects of level of meditation experience on attentional focus: is the fficiency of executive or orientation networks improved? *The Journal of Alternative and Complementary Medicine , 13* (6), 651-65713.

Chattha, R., Nagarathna, R., Padmalatha, V., & Nagendra, H. (2008). Effect of yoga on cognitive functions in climacteric syndrone: a randomised control study. *BJOG: An international Journal of Obstetrics & Gynaecology , 115*, 991-1000.

Chiesa, A., & Serretti, A. (2010). A systematic review of neurobiological and clinical features of mindfulness meditations. *Psychological Medicine , 40*, 1239-1252.

Chiesa, A., Calati, R., & Serretti, A. (2011). Does mindfulness training improve cognitive abilities? A systematic review of neuropsychological findings. *Clinical Psychology Review , 31*, 449-464.

Colcombe, S. J., Kramer, A. F., Erickson, K. I., Scalf, P., McAuley, E., Cohen, N. J., et al. (2004). Cardiovascular fitness, cortical plasticity, and aging. *Proceedings of the National Academy of Sciences of the United States of America , 101*, 3316-3321.

Colcombe, S. K., Erickson, K. I., Scalf, P. E., Kim, J. S., Prakash, R., McAuley, E., et al. (2006). Aerobic exercise training increases brain volume in aging humans. *The Journals of Gerontonolgy Series A: Biological Sciences and Medical Sciences , 61* (11), 1166-1170.

Colcombe, S., & Kramer, A. (2003). Fitness effects on the cognitive function of older adults a meta-analytic study. *Psychological Science , 14* (2), 125-130.

D'Elia, L. G., Satz, P., Uchiyama, C. L., & White, T. (1996). *Color Trails Test.* Odessa FL: Psychological Assessment Resources.

Deshmukh, V. D. (2006). Neuroscience of Meditation. *The Scientific World Journal , 6*, 2239-2253.

Gard, T., Hölzel, B. K., & Lazar, S. W. (2014). The potential effects of meditation on age-related cognitive decline: a systematic review. *Analysis of the New York Academy of Sciences , 1307* (1), 89-103.

Gauvin, L., & Rejeski, W. J. (1993). The exercise-induced feeling inventory: Development and initial validation. *Journal of Sport & Exercise Psychology , 15*, 403-423.

Heyn, P., Abreu, B. C., & Ottenbacher, K. J. (2004). The effects of exercise training on elderly persons with cognitive impairments and dementia: a meta-analysis. *Archives of Physical medicine and Rehabilitation , 85* (10), 1694-1704.

Holzel, B. K., Lazar, S. W., Gard, T., Schuman-Olivier, Z., Vago, D. R., & Ott, U. (2011). How deos mindfulness meditation work? Proposing mechanisms of action from a conceptual and neural perspective. *Perspectives on Psychological Science , 6*, 537-559.

Kozhevnikov, M., Louchakova, O., Josipovic, Z., & Motes, M. A. (2009). The enhancement of visuospatial processing efficency through Buddhist Deity meditation. *Psychological Science* , *20* (5), 645-653.

Lane, J. D., Seskevich, J. E., & Pieper, C. F. (2007). Brief meditation training can imrpove perceived stress and negative mood. *Alternative Therapies in Health and Medicine* , *13* (1), 38-44.

Lemyre, L., & Lalande-Markon, M.-P. (2009). Psychological stress measure (PSM-9): integration of an evidence-based approach to assessment, monitoring, and evaluation of stress in physical therapy practice. *Physiotherapy Theory and Practice* , *25*, 453-453.

Mark, R., Rhodes, R., Warburton, D. E., & Bredin, S. (2010). Interactive video games and physical activity: a review of the literature and future directions. *The Health & Fitness Journal of Canada*, *1*(1), 14-24.

McAuley, E., Szabo, A. N., Mailey, E. L., Erickson, K. I., Voss, M., White, S. M., et al. (2011). Non-exercise estimated cardiorespiratory fitness: Associatations with brain structure, cognition, and memory complaints in older adults. *Mental Health and Physical Activity* , *4*, 5-11.

Mohan, A., Sharma, R., & Bijlani, R. L. (2011). Efeect of meditation on stress-induced changed in cognitive functions. *The Journal of Alternative and Complementary Medicine* , *17*, 207-212.

Mortimer, J. A., Ding, D., Borenstein, A. R., DeCarli, C., Guo, Q., Wu, Y., et al. (2012). Changes in brain volume and cognition in a randomized trial of exercise and social interaction in a community-based sample of non-demented chinese elders. *Journal of Alzheimer's Disease , 30*, 757-766.

Oken, B., Kishiyama, S., Bourdette, Z. D., Carlsen, J., Haas, M., Hugos, C., et al. (2004). Randomized controlled trial of yoga and exercise in multiple sclerosis. *62*, 2058-2064.

Raffone, A., & Srinvasan, N. (2010). The exploratin of meditation in the neuroscience of attention and consiousness . *Cogn Process , 11*, 1-7.

Sports Marketing Surveys USA. (2012). *Yoga in America.* San Francisco: Yoga Journal.

Strauss, E., Sherman, E. M., & Spreen, O. (2006). *A Compendium of Neuropsychological Tests: Administration, Norms, and Commentary* (3 ed.). New York, NY, USA: Oxford University press.

Van der Elst. (2006). *The Stroop Version 1 40 items and The Stroop Version 2 Alternate Form 40 items.*

Van Schaik, P., Blake, J., Pernet, F., Spears, I., & Fencott, C. (2008). Virtual augmented exercise gaming for older adults. *CyberPsychology & Behavior , 11*, 103-106.

Wayne, P. M., Walsh, J., Taylor-Piliae, R. E., Wells, R. E., Papp, K. V., Donovan, N. J., et al. (2014). Effect of tai chi on cognitive performance in older adults: systematic review and meta-analysis. *Journal of American Geriatrics , 62*, 25-39.

Wells, R., Yeh, G., Kerr, C., Wolkin, J., David, R., Dossett, M., et al. (2013). Meditation's impact on default mode network and hippocampus in mild cognitive impairment: a pilot study. *Neuroscience letters , 556*, 15-19.

Xue, S., Tang, Y.-Y., & Posner, M. I. (2011). Short-term meditation increases network effieciency of the anterior cingulate cortex. *Cognitive Neuroscience and Neuropsychology* , *22*, 570-574.

Zeidan, F., Johnson, S. K., Diamond, B. J., David, Z., & Goolkasian, P. (2010). Mindfulness meditation improves cognition: evidence of brief mental training. *Consciousness and Cognition* , *19*, 597-60

Table 1. Demographic and Fitness Characteristics.

Variable	Mean (SD)				p values					
	Con. 1: Cybercycle (*n* = 15)	**Con. 2: Regular Cycling (*n* = 15)**	**Con. 3: Mindful Cybercycling (*n* = 15)**	**Con. 4: Mindful Meditation (*n* = 16)**	**Con. 1 v. Con 2.**	**Con. 1 v. Con. 3**	**Con. 1 v. Con. 4**	**Con. 2 v. Con. 3**	**Con. 2 v. Con. 4**	**Con. 3 v. Con. 4**
Age, years	18.1 (1.5)	19.1 (1.1)	19.8 (1.6)	19.9 (1.3)	0.92	0.23	0.18	0.58	0.50	0.99
Females (n)	11	7	8	10						
Males (n)	5	7	6	5						
Height, inches	67.2 (3.8)	67.6 (3.9)	68.5 (3.4)	65.4 (4.1)	0.99	0.78	0.54	0.93	0.37	0.12
Weight, lbs	149.2 (23.8)	165.5 (38.0)	154.2 (20.9)	146.3 (27.7)	0.38	0.96	0.99	0.69	0.27	0.87
BMI	23.1 (2.6)	24.9 (3.7)	23.0 (2.6)	23.8 (3.2)	0.32	1.0	0.91	0.31	0.74	0.89
Fitness:										
Level of Activity (1-5)	3.7 (1.5)	3.7 (1.5)	4.6 (0.74)	3.6 (1.2)	1.0	0.21	0.99	0.26	0.99	0.15
Exercise Intensity (1.3)	2.3 (0.47)	2.3 (0.59)	2.6 (0.49)	2.2 (0.56)	0.99	0.33	0.94	0.24	0.98	0.13

Table 2. Pre-test and Post-test Executive Function Scores for all Participants.

Pre-test Executive Function Scores:	**Cond. 1: Cybercycle (*n* = 16)**	**Cond. 2: Regular Cycling (*n* = 15)**	**Cond. 3: Mindful Cybercycle (*n* = 15)**	**Cond. 4: Mindful Meditation Only (*n* = 15)**	**P value Con. 1 v. Con. 2**	**P value Con. 1 v. Con. 3**	**P value Con. 1 v. Con. 4**	**P value Con. 2 v. Con. 3**	**P value Con. 2 v. Con. 4**	**P value Con. 3 v. Con 4**
Color Trails II – A, seconds	58.19 (16.60)	62.09 (18.38)	54.12 (9.73)	61.94 (20.81)	0.53	0.42	0.58	0.15	0.98	0.19
Stroop C, seconds	37.3 (8.13)	34.9 (5.22)	32.39 (4.65)	35.79 (6.92)	0.40	0.05	0.58	0.24	0.75	0.11
Digit Span Backwards, string of numbers	6.94 (2.69)	7.00 (2.60)	7.13 (1.81)	7.53 (1.75)	0.95	0.81	0.87	0.87	0.93	0.91
Post-test Executive Function Scores										
Color Trails II-B, seconds	50.32 (13.76)	49.68 (10.78)	45.61 (7.59)	50.28 (13.35)	0.89	0.25	0.99	0.24	0.89	0.24
Stroop C alt., seconds	31.78 (7.91)	30.11 (4.89)	25.05 (2.80)	30.06 (5.90)	0.49	0.004	0.50	0.001	0.99	0.005
Digit Span Backwards alt., string of numbers	7.378(3.34)	7.53 (2.20)	8.60 (2.23)	7.73 (2.91)	0.87	0.59	0.75	0.20	0.83	0.37

Table 3. Pre-test and Post-test Executive Function Scores for Improved Sample.

Pre-test Executive Function Scores:	**Cond. 1: Cybercycle (*n* = 13)**	**Cond. 2: Regular Cycling (*n* = 11)**	**Cond. 3: Mindful Cybercycle (*n* = 9)**	**Cond. 4: Mindful Meditation Only (*n* = 16)**	**P value Con. 1 v. Con. 2**	**P value Con. 1 v. Con. 3**	**P value Con. 1 v. Con. 4**	**P value Con. 2 v. Con. 3**	**P value Con. 2 v. Con. 4**	**P value con. 3 v. Con. 4**
Color Trails II – A, seconds	56.22 (17.4)	63.02 (20.3)	53.97 (9.96)	58.75 (17.4)	0.91	0.73	0.74	0.24	0.62	0.52
Stroop C, seconds	35.84 (7.34)	33.06 (5.74)	33.5 (3.6)	34.14 (5.25)	0.39	0.39	0.52	0.84	0.64	0.76
Digit Span Backwards, string of numbers	7.54 (2.6)	7.09 (3.05)	7.33 (2.0)	7.54 (2.6)	0.99	0.84	0.53	0.84	0.93	0.66
Post-test Executive Function Scores										
Color Trails II-B, seconds	46.57 (12.2)	50.64 (11.1)	45.67 (8.94)	47.3 (11.9)	0.98	0.98	0.88	0.39	0.49	0.89
Stroop C alt., seconds	30.76 (8.07)	29.20 (4.47)	24.18 (1.48)	29.05 (5.15)	0.83	0.02	0.54	0.005	0.94	0.13
Digit Span Backwards alt., string of numbers	8.23 (3.0)	7.45 (2.29)	9.0 (1.80)	7.75 (2.4)	0.99	0.51	0.67	0.12	0.76	0.21

Table 4. Physiological Characteristics of Participants in Physical Exercise Conditions.

	Mean (SD)	Mean (SD)	Mean (SD)	p-value		
Physiological Measures	**Condition 1: Cybercycle (*n* = 15)**	**Condition 2: Regular Cycling (*n* = 15)**	**Condition 3: Mindful Cybercycle (*n* =15)**	**Con. 1 vs. Con. 2**	**Con. 1 vs. Con. 3**	**Con. 2 vs. Con. 3**
Target Heart Rate (bpm)	153.5 (3.01)	153.3 (6.45)	151.5 (6.57)	0.99	0.59	0.65
Average Heart Rate (bpm)	149.3 (13.37)	140.9 (16.19)	142.4 (17.12)	0.53	0.45	0.96
Maximum Heart Rate (bpm)	166.88 (14.48)	165.23 (16.17)	167.8 (21.48)	0.97	0.99	0.92
Distance (miles)	4.46 (0.52)	4.59 (0.82)	4.57 (0.53)	0.84		
Average Power (watts)	105.94 (25.44)	94.71 (30.29)	103.79 (20.37)	0.41	0.97	0.63
Maximum Power (watts)	443.81 (144.56)	317.54 (133.32)	373.93 (124.17)	0.5	0.35	0.54
Average Speed (mph)	13.03 (1.52)	12.68 (2.16)	13.24 (1.53)	0.86	0.94	0.67
Maximum Speed (mph)	21.33 (4.01)	18.7 (3.53)	19.32 (3.21)	0.15	0.29	0.89

Table 5. Neuropsychological outcomes following Exercise/Meditation Condition

	Mean Difference Score (from pretest to posttest):		
	Condition 1: Cybercycle	**Condition 3: Mindful Cybercycle**	**p value**
All Participants	***n* = 15**	***n* = 15**	
Color Trails 2	-7.87	-8.47	0.87
Stroop C	-5.56	-7.33	0.19
Digit Span Backwards	0.44	1.47	0.23
Only participants who reached target HR and have meditated before	***n =13***	***n = 9***	
Color Trails 2	-9.69	-7.22	0.58
Stroop C	-5.08	-9.22	0.01
Digit Span Backwards	0.69	1.67	0.33

Table 6. Psychological Stress Measure (PSM) Scores at pre-test and and post-test.

PSM Scores (SD)	Cond. 1: Cybercycle (*n* = 13)	Cond. 2: Regular Cycling (*n* = 11)	Cond. 3: Mindful Cybercycle (*n* = 9)	Cond. 4: Mindful Meditation Only (*n* = 16)	P value Con. 1 v. Con. 2	P value Con. 1 v. Con. 3	P value Con. 1 v. Con. 4	P value Con. 2 v. Con. 3	P value Con. 2 v. Con. 4	P value con. 3 v. Con. 4
Pre-test PSM Score (9-72)	29.54 (8.62)	31.36 (13.64)	26.11 (6.79)	33.5 (8.86)	0.69	0.33	0.46	0.30	0.85	0.12
Post-test PSM Score (9-72)	22.77 (6.41)	26.82 (8.0)	25.44 (7.89)	29.64 (9.10)	0.18	0.39	0.03	0.70	0.42	0.27

Table 7. Differences in Stroop C scores among levels of flow and concentration.

Stroop C Score (SD)	High Flow Score (*n=13)*	Low Flow Score (*n* = 9)	p value High flow vs. Low flow
Pretest Score:	34.34 (4.55)	35.85 (8.03)	0.54
Posttest Score:	26.05 (4.85)	30.98 (8.79)	0.15
	High Concentration (*n* = 13)	**Low Concentration (*n* = 9)**	**P value high con. Vs. low con.**
Pretest Score:	34.34 (4.38)	35.67 (8.21)	0.62
Posttest Score:	25.99 (4.87)	31.07 (8.72)	0.14

Table 8. Differences in executive function between improved stress levels and unimproved.

	Mean Difference Scores (SD)		
Executive Function:	**High Improved Stress (*n* = *11)***	**Low Improved Stress (*n* = 11)**	**p value**
Color Trails 2	-13.18 (9.77)	-4.18 (8.43)	0.87
Stroop C	-7.64 (4.47)	-5.91 (3.56)	0.34
Digit Span Backwards	1.27 (2.53)	0.91 (2.07)	0.03

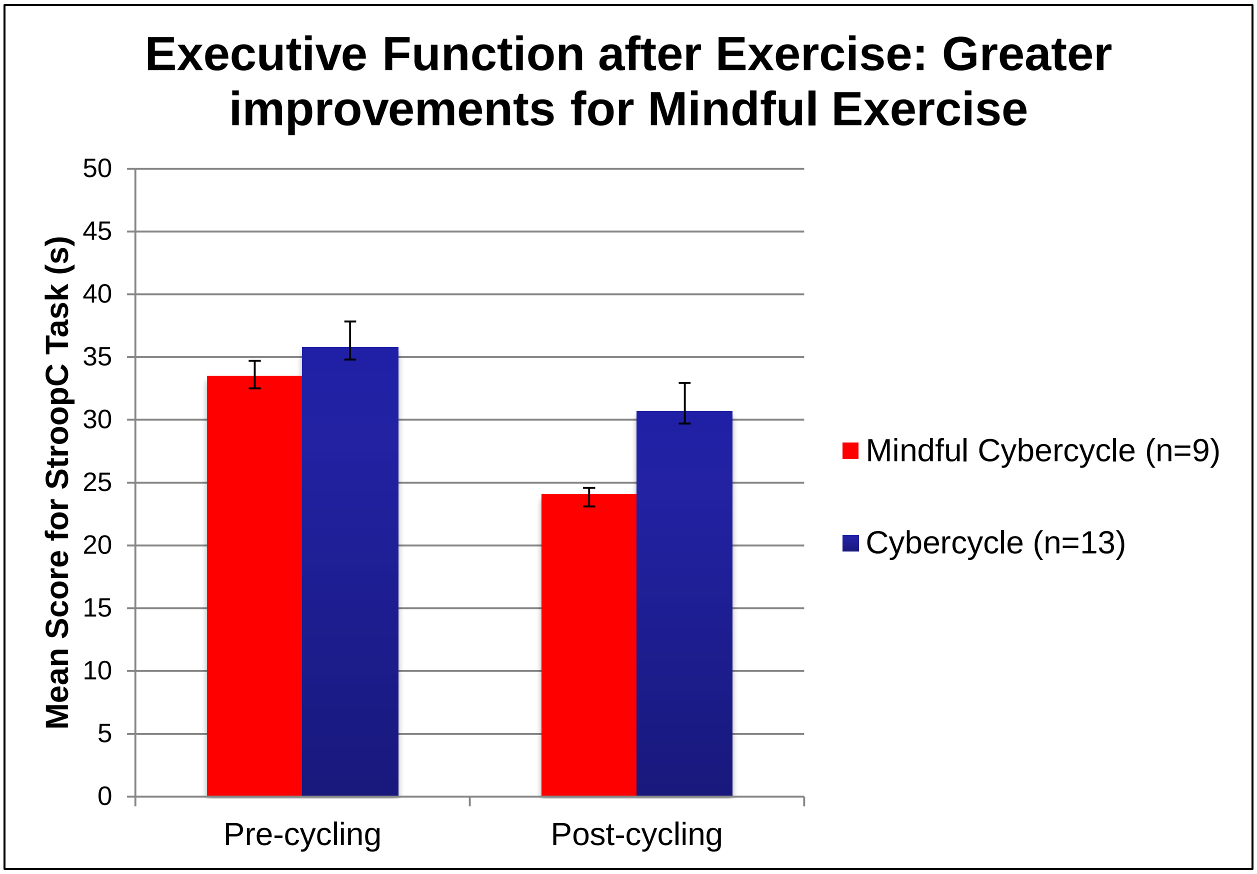

Figure 1. The graph above illustrates the effect of adding a meditation component to physical exercise on the cybercycle. The graph only utilized participants whose maximum heart rate reached their calculated target heart rate, as well it excluded several participants (*n = 4)* who indicated they had never done meditation before. The scores that were used were the Stroop C scores at pretest and posttest. The x-axis shows the time at which the participants completed the executive function measure (before and after the intervention). The y-axis shows the time it took for the participants to complete the task, with a higher score illustrating a longer completion time in seconds. There was no significant difference in the pre-test Stroop C score between the two conditions, p =0.39. There was a significant difference in the post-test Stroop C scores, p = 0.02, with the mindful cybercycling group significantly outperforming the cybercycle group after the acute bout of exercise. This data suggest an additional meditation component can benefit executive function scores when combined with cybercycling.

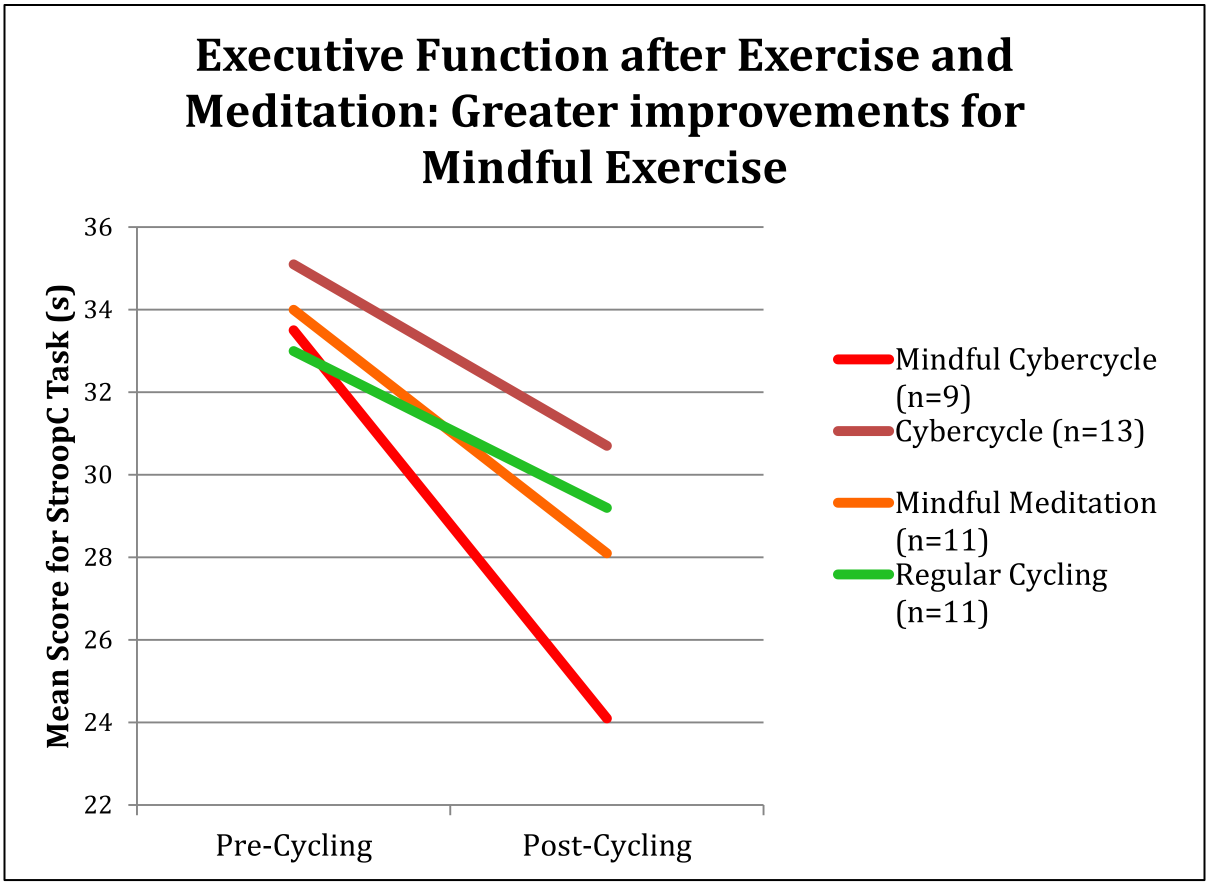

Figure 2. The graph above illustrates all four of the groups performance on Stroop task. The graph only utilized participants whose maximum heart rate reached their calculated target heart rate, as well it excluded several participants (*n = 4)* who indicated they had never done meditation before. The scores that were used were the Stroop C scores at pretest and posttest. The x-axis shows the time at which the participants completed the executive function measure (before and after the intervention). The y-axis shows the time it took for the participants to complete the task, with a higher score illustrating a longer completion time in seconds. There was a significant difference in the post-test Stroop C scores, $p = 0.04$, but tukey test revealed no significant difference between any of the four groups. This data suggest an different variations of cognitive engagement influence improvements in executive functions.

APPENDIX A

Protocol Instructions

______Welcome participant to the study.

______ Give participant a copy of the Informed Consent Form.

Please read this Informed Consent form carefully and sign at the bottom. If you have any questions, do not hesitate to ask.

______ Administer Demographic Questionnaire and Exercise History Questionnaire

Please fill out these questionnaires to the best of your ability. Remember that all answers will remain confidential.

______Administer Psychological Stress Scale (PSM -9; Lemyre et al., 2009) & FLOW Questionnaire

Please fill out these questions to the best of your ability. All answers will remain confidential.

_____ Administer Color Trails A (time to complete if less than 60 sec or stop participant at 60 sec and record # correct)

Be sure to be ready with the stopwatch, even a one second difference in recording time can be significant..

PRACTICE: Color Trails A-1
In this box are different colored circles with numbers in them. When I say "begin," I want you to take this pen and connect the circles by going from 1 *(point to the 1),* **2** *(point to the 2),* **3** *(point to the 3)***, and so on, until you reach the end. I want you to connect the circles in the correct order as quickly as you can, without lifting the pen from the paper. If you make a mistake, I will point it out. When I do, I want you to move the pen back to the last correct circle and continue from there. The line that you draw must go through the circles and must do so in the correct order. Do you have any questions? Okay, let's practice. Put your pen here where this hand tells you to start. When I say "begin," connect the circles in order as quickly as you can until you reach the circle next to the hand telling you to stop. Ready? Begin.** *(Begin timing as soon as you detect movement toward the first circle.)*

TEST: Color Trails A-2
Now I have a sheet with several more numbers and circles. Connect the circles in order like you did just a moment ago. Again, work as quickly as you can, and do not lift the pen from the paper as you go. Make sure that your lines touch the

circles. *Point to the first circle and say the following:* **You will start here, where the hand tells you to start, and end where the hand tells you to stop. Ready? Begin.** *(Begin timing as soon as you detect movement toward the first circle. Be sure to record # of dot just completed at 60 seconds, as well as time to complete all).*

Record circle color and number at 60 seconds: **_____**

Record time to complete (in seconds): **_____**

_____ Administer the Stroop Task (PROSPER version – 40 items)

Before showing the examinee any of the cards, say:

COLOR BLOCKS:
I am going to show you a few different pages. On this first page, there are some colored blocks. Please tell me the names of the colors you see on this top, sample row (point to the row)**.**

If necessary, clarify that the names to use are: red, blue & green. If the examinee cannot distinguish the colors, perhaps due to color-blindness, move on to the next task. If the examinee completes the sample line successfully, say:

Good. Now I want you to tell me the names of each color block starting here and going as quickly as you can, without making mistakes, across the row and down to the next line and across, etc., until you finish all the rows (point to the end)**. Are you ready? Go.** (Be sure to start & stop the timer precisely. Mark all answers on your record sheet so that you can tally the number of errors later. Examinee can self-correct, but do not prompt for corrections)**.**

BLACK WORDS:
Ok good, on the next page you will see that the task is similar, but slightly different. Here, read the words as quickly as you can. Please try the sample line (point)**.**

Fine. Now I want you to start here (point) **and read across as quickly as you can without making mistakes. Again, go across each row and then down until you finish all the rows** (point to the end)**. Are you ready? Go.**

COLORED WORDS (incongruous/interference):
Good. On this last page, your task is to tell me the color of the ink and ignore the written word. (Feel free to empathize if the examinee laughs, gasps, etc. – e.g., say something like: **I realize this is getting more challenging, but do the best you can). Please try the sample line.**

Fine. *(If not, please explain again and repeat practice until clear understands, or abandon task).* **Start here** (point) **and read across and then down as quickly as you can without making mistakes until the end** (point)**. Are you ready? Go.**

_____ Administer Digit Span (digits forward)

Read numbers at rate of one second per number, with downward intonation at end. Be sure to record all responses whether right or wrong. Discontinue after 2 failures of the same length of digits.

I am going to say some numbers. Then when I am through, I want you to repeat them right after me. For example, if I say 8-9 you will say 8-9. You'll just say exactly what I say.

_____ Administer Digit Span (digits backward).

Read numbers at rate of one second per number, with downward intonation at end. Be sure to record all responses whether right or wrong. Discontinue after 2 failures of the same length of digits.

Now I am going to say some more numbers. But this time when I stop, I want you to say them backward. For example, if I say 7-9, what would you say?

______ **EXERCISE CONDITION 1**: **CYBERCYCLE & TRAIL**

INSTRUCTIONS FOR CYBERCYCLE:
You will be completing 20 minutes of biking on a trail. To go forward and move around the course you start pedaling. The bars on either side of you are what you will use to steer. To steer right, you will lift the left handlebar and push down the right. To steer left you will lift the right handlebar and push down the left. Increasing the gear is going to make you move faster on the course and also raise your heart rate. To change the gears of the bike use to two red buttons located on the handlebars. To increase the gear you press down on the left red button. To decrease the gear you press down on the right red button. The gear indicator is located on the bottom right corner (point to where it is located). **Do you have any questions?**

______ Measure resting heart rate and calculate the participants target heart rate.
Before we begin, please hold on to the handlebars so that we can get a reading of your resting hear rate. Record it on this sheet and on the attached exercise table.

THR = (220 – age – RHR) x .60 + RHR (record on the attached exercise table)

Ok. During this exercise session, we want you to try to reach and maintain an exercise intensity equal to 60% of your heart rate reserve during a 20 min

exercise bout. In order to achieve this, try your best to exercise at a pace so that your heart rate is around _________ beats per minute .To help reach and maintain your target heart rate, you may adjust the gears to change pedaling resistance. Remember that increasing the gear will help raise heart rate, make you go faster in the game. The bottom right of the screen tells you which gear you are on. I will incrementally let you know if you have reached your target heart rate and will further instruct you to maintain your heart rate, or to increase the resistance of the bicycle or pedal faster to raise your heart rate.

Let me know when you are ready to begin. Once participant says they are ready:

- Select the trail course from the cybercycle menu (Called Evening Bliss)

Now you can begin exercising. (Start stopwatch for 20 mins)

______ EXERCISE CONDITION 2: STATIONARY BIKE WITH BLANK SCREEN

INSTRUCTIONS FOR STATIONARY BIKE: **Here is the stationary bike that you will be using to exercise. Please sit on the bicycle and adjust the seating using the red bar in front of the seat so that you are comfortable. The bars on either side of you are the handlebars. The red buttons on the handlebars change the gears of the bike, and the gear indicator is located in the bottom-right corner of the screen. For both handlebars, the right red button decreases the gear and the left red button increases the gear.**

______ Measure resting heart rate and calculate the participants target heart rate.
Before we begin, please hold on to the handlebars so that we can get a reading of your resting hear rate. Record it on this sheet and on the attached exercise table.

THR = (220 – age – RHR) x .60 + RHR (record on the attached exercise table)

Let me know when you are ready to begin.

(Start stopwatch for 20 mins)

___EXERCISE CONDITION 3: MINDFUL CYBERCYCLING

INSTRUCTIONS FOR CYBERCYCLE: **You will be cycling for 20 minutes and steering through a trail. Please sit on the bicycle and adjust the seating using the red bar in front of the seat so that you are comfortable. The bars on either side of you are the handlebars. The red buttons on the handlebars change the gears of the bike, and the gear indicator is located in the bottom-right corner of the screen. For both handlebars, the right red button decreases the gear and the left red button increases the gear. To steer right, you will lift the left handlebar and push down the right. To steer left you will lift the right handlebar and push**

down the left. Increasing the gear is going to make you move faster on the course and also raise your heart rate. Do you have any questions?

INSTRUCTIONS FOR MINDFUL MEDITATION: **You will be listening to a pre-recorded audio meditation track. It's objective is to guide you into a meditative state and into a deeper level of mind. Try your best to follow the track. Relax, and if you notice your thoughts start to wander, acknowledge the thoughts, and bring yourself back to the guided meditation. Focus on the trail and do your best to steer while following the guided meditation. Do you have any questions?**

EXERCISE CONDITION 4: MINDFUL MEDITATION

INSTRUCTIONS FOR MINDFUL MEDITATION: **You will be listening to a pre-recorded audio meditation track. It's objective is to guide you into a meditative state and into a deeper level of mind. Sit comfortably on the bike and relax your body. Try your best to follow the track. Relax, and if you notice your thoughts start to wander, acknowledge the thoughts, and bring yourself back to the guided meditation.**

___EXERCISE CONDITION 5: COGNITIVE TRAINING + CYBERCYLING

INSTRUCTIONS FOR CYBERCYCLE: **You will be cycling for 20 minutes and steering through a trail. Please sit on the bicycle and adjust the seating using the red bar in front of the seat so that you are comfortable. The bars on either side of you are the handlebars. The red buttons on the handlebars change the gears of the bike, and the gear indicator is located in the bottom-right corner of the screen. For both handlebars, the right red button decreases the gear and the left red button increases the gear. To steer right, you will lift the left handlebar and push down the right. To steer left you will lift the right handlebar and push down the left. You will be cycling through a trail called evening bliss. Do your best to keep within the perimeter of the trail by adjusting the handlebars. Increasing the gear is going to make you move faster on the course and also raise your heart rate. Do you have any questions?**

INSTRUCTIONS FOR COGNITIVE TRAINING: **You will be given a cognitive task to complete while CyberCycling through the Evening Bliss trail. A sign only qualifies as a sign if it is facing you on the trail. When you are biking on the trail and come to either a lamppost or a sign, say outloud "Right" or "Left" based on the side of the trail in which they appear. While you are doing this, also try to keep track in your head how many lampposts and signs you have seen. When you reach ten of these items, say outloud "ten"… "twenty" … "thirty" … etc. Do your best to keep track of how many are appearing. This is a difficult task, so try your best not to get discouraged. Do you have any questions?**

___EXERCISE CONDITION 6: COGNITIVE TRAINING ALONE

INSTRUCTIONS FOR COGNITIVE TRAINING: **You will be asked to sit on the stationary bike and you will be given a cognitive task to complete. A sign only qualifies as a sign if it is facing you on the trail. When you are biking on the trail and come to either a lamppost or a sign, say outloud "Right" or "Left" based on the side of the trail in which they appear. While you are doing this, also try to keep track in your head how many lampposts and signs you have seen. When you reach ten of these items, say outloud "ten"… "twenty" … "thirty" … etc. Do your best to keep track of how many are appearing. This is a difficult task, so try your best not to get discouraged. Do you have any questions?**

___EXERCISE CONDITION 7: VIDEOGAME ALONE

INSTRUCTIONS FOR COGNITIVE TRAINING: **You will be asked to sit on the stationary bike and you will be given a videogame to complete. Your task will be to get a high score. You will pedal and steer toward a coin, once through it, you can follow the arrow to find a matching color dragon. Avoid the water and remember you can down-shift if you hit a hill. Do you have any questions?**

______ Offer participant a glass of water & Administer Attentional Focus Questionnaire.
--------- Administer the Psychological Stress Scale (PSM -9; Lemyre et al., 2009) & FLOW
Please fill out these questionnaires to the best of your ability.

All Conditions:
You will now take the same neuropsych tests you completed earlier. After we are done with the evaluations, we will move on to the final part of the study. Do you have any questions?

_____ Administer Color Trails B (time to complete if less than 60 sec or stop participant at 60 sec and record # correct)

Be sure to be ready with the stopwatch, even a one second difference in recording time can be significant..

PRACTICE: Color Trails B-1
In this box are different colored circles with numbers in them. This time I want you to take the pen and connect the circles in order by going from *this* color 1 *(point to the pink 1)***, to *this* color 2** *(point to the yellow 2)***, to *this* color 3** *(point to the pink 3)***, and so on, until you reach the last number next to the hand telling you to stop.** *Take the pen and point to the example below the box as you say the following:* **Notice that the color changes each time you go to the next number. I want you to work as quickly as you can. Do not lift the pen from the paper once you have started. If you make a mistake, I will point it out. When I do, I want you to move the pen to the last correct circle and continue from there. As before, the line you draw must go through the circles in the correct order. Do you have any questions? Okay, let's practice. Put your pen here next to the**

hand telling you to start. When I say "begin," connect the circles in order as quickly as you can, changing from one color to the next, until you reach the hand telling you to stop, Ready? Begin. *(Begin timing as soon as you detect movement toward the first circle.)*

TEST: Color Trails B-2

Now I have a sheet with several more numbers and colored circles. Connect the circles like you did just a moment ago. Again, work as quickly as you can. *Point to the first circle and say the following:* **You will start here, where the hand tells you to start, and end where the hand tells you to stop. Ready? Begin.** *(Begin timing as soon as you detect movement toward the first circle. Be sure to record # of dot just completed at 60 seconds, as well as time to complete all).*

Record circle color and number at 60 seconds: **_____**

Record time to complete (in seconds): **_____**

_____ Administer the Stroop Task (PROSPER version 2-alternate form – 40 items)

Before showing the examinee any of the cards, say:

COLOR BLOCKS:

I am going to show you a few different pages. On this first page, there are some colored blocks. Please tell me the names of the colors you see on this top, sample row (point to the row)**.**

If necessary, clarify that the names to use are: red, blue & green. If the examinee cannot distinguish the colors, perhaps due to color-blindness, move on to the next task. If the examinee completes the sample line successfully, say:

Good. Now I want you to tell me the names of each color block starting here and going as quickly as you can, without making mistakes, across the row and down to the next line and across, etc., until you finish all the rows (point to the end)**. Are you ready? Go.** (Be sure to start & stop the timer precisely. Mark all answers on your record sheet so that you can tally the number of errors later. Examinee can self-correct, but do not prompt for corrections)**.**

BLACK WORDS:

Ok good, on the next page you will see that the task is similar, but slightly different. Here, read the words as quickly as you can. Please try the sample line (point)**.**

Fine. Now I want you to start here (point) **and read across as quickly as you can without making mistakes. Again, go across each row and then down until you finish all the rows** (point to the end)**. Are you ready? Go.**

COLORED WORDS (incongruous/interference):
Good. On this last page, your task is to tell me the color of the ink and ignore the written word. (Feel free to empathize if the examinee laughs, gasps, etc. – e.g., say something like: **I realize this is getting more challenging, but do the best you can). Please try the sample line.**

Fine. *(If not, please explain again and repeat practice until clear understands, or abandon task).* **Start here** (point) **and read across and then down as quickly as you can without making mistakes until the end** (point)**. Are you ready? Go.**

_____ Administer Digit Span Alternate Form (digits forward)

Read numbers at rate of one second per number, with downward intonation at end. Be sure to record <u>all</u> responses whether right or wrong. Discontinue after 2 failures of the same length of digits.

I am going to say some numbers. Then when I am through, I want you to repeat them right after me. For example, if I say 8-9 you will say 8-9. You'll just say exactly what I say.

_____ Administer Digit Span Alternate Form (digits backward).

Read numbers at rate of one second per number, with downward intonation at end. Be sure to record <u>all</u> responses whether right or wrong. Discontinue after 2 failures of the same length of digits.

Now I am going to say some more numbers. But this time when I stop, I want you to say them backward. For example, if I say 7-9, what would you say?

______ Debrief and compensate participant.

Give the participant the debriefing form and tell them to read through it. At the end please thank them for their participation.

APPENDIX B

Mindful Meditation Track Script
Recording Script (time = 20 minutes)

"Welcome to your mindful mediation experience, for the next 20 minutes I will guide you through a session of meditation in order to reach a deeper state of mind and allow yourself to become aware of your sensations cognitions. I want you to begin by finding a comfortable position on the seat and gently closing your eyes.
Being by taking a slow and deep breathe in through your nose, filling your lower abdomen. Feel your lungs slowly expand and your chest rise. Think of the air flowing into your mouth and into your lungs. Now breathe out through your mouth.
Take another deep breath, in through your nose, filling your lungs, and out through your mouth. Concentrate on each breath you take and follow the path it takes in and out of your body I am going to count down from 10 and when I do you will slowly reach a deeper and more relaxed state of mind.
Continue to breath, and as you do, each breath will release any stress of worries.
10, 9, 8, 7, 6, 5, 4, 3, 2, 1. I want you to try and focus on the following things while you reach this deeper state of mind:

- The up-and down movement of your abdomen as the air you breathe enters and exits your body
- The feeling of air moving through your nose as you breathe in and out through it
- The present moment how you are feeling at the exact moment

Gather all your attention on the center of your body. Try to real in all thoughts, and let the outside world melt away, dissolving into empty space
Try to relax your mind and your body. If you feel your thoughts start to drift, or start to worry, acknowledge the worries as normal thoughts and bring yourself back to this relaxing and center state of mind.

Begin to notice the density of your body sitting in the seat. Bring your attention to the natural flow of your breath, notice how your stomach rises and then contracts. This breathing is completely effortless. Notice the effortlessness of diaphragm breathing. Now id like you to follow the path of the breath, through your nostrils, down into your lungs, feeling your stomach rise. Notice the pause between the inhale and the exhale. Bring the attention to the top of your head – notice any sensations you feel at the top of your head, not trying to change or alter your body in anyways, just become aware

Move your attention down to your forehead noticing any sensations or feelings. Focus on the temples and the forehead, imaging any tension, headache or pain dissolve away. Disappearing as you concentrate on this part of the body. Imagine any tension draining down your body into the ground. Become aware of the eyes, the cheeks, your jaw and tongue, became aware of the throat and the neck and the sensations in these areas. Bring your attention gently to the shoulders, noticing any feelings that arise, and move your attention to the arms, the hands, the fingers, just noticing any sensations and any feelings.

Try to relax your mind and your body. If you feel your thoughts start to drift, or start to worry, acknowledge the worries as normal thoughts and bring yourself back to this relaxing and center state of mind.

Not gently bring your awareness to the front of the body, to the chest, the rib cage, the lungs and the abdomen. Sense our own heart beat, and continue to breathe, in through your nose out through your mouth.

Notice the rise and fall of each breath, now gently shift your attention to the back of the body. Notice the feeling of your spine, move your awareness to your shoulder blades, your middle back, and finally the lower back region. Try to release all the tension in these areas, feel the stress melt away. Move your attention to your seat, your waist and hips, the pelvis, and slowly move your attention to your legs and your thighs, your hamstrings, and down to your knees. Slowly bring your attention to your calves and shins, noticing any sensations that may arise, move your attention down to your feet, the arches, the heels, the balls of the feet, notice the feelings of your feet in your shoes. Bring your attention to the toes, noticing any sensations that may arise, notice any tingling or the temperature of the toes

If you notice any thoughts appear, simply let it go and bring your attention back to the sensations of your body. Finally bring attention to the entire body as a whole system, becoming present with the entire system, as you become fully present. Allow yourself to feel completely relaxed, yet maintain your attention the present moment. When you feel ready slowly begin to wiggle your fingers and toes, gently allow your eyes to open and trying to maintain this feeling of being fully connected to the present moment”

APPENDIX C

Exercise History Questionnaire

Participant ID# ____________________

Which one of the five physical activity categories reflects your usual pattern of daily physical activity? Please check the box next to each level of physical activity.

- □ **Level 1**: Inactive or little activity other than usual daily activities.
- □ **Level 2**: Regular (>5 days/week) participation in physical activities for at least 10 min at a time that require low levels of exertion resulting in only slight increases in breathing and heart rate.
- □ **Level 3**: Engage in aerobic exercises (e.g. brisk walking, joggning or running, cycling, swimming, or vigorous sports) at a comfortable pace for 20-60 min per week.
- □ **Level 4**: Participate in aerobic exercises at a comfortable place for 1-3 hour per week.
- □ **Level 5**: Participate in aerobic exercises at a comfortable pace for over 3 hours per week.

Please answer the following questions to the best of your ability.

1) Approximate length (min) of a single session of exercise ________________

2) Identify which type(s) of exercise of which you typically participate.

- □ Strength/Resistance Exercise (e.g. weightlifting)
- □ Flexibility Training/Exercise (e.g. static or dynamic stretching)
- □ Stamina and Endurance Exercise (e.g. cardiovascular exercise, all types of aerobic exercise)
- □ Balance Exercise (e.g. Yoga)

3) Rate the intensity at which you typically exercise:

Low Intensity   Moderate/Self-Paced Intensity   High Intensity

4) What is your reason for exercising? (please circle all that apply)

To loose weight   To stay healthy   Because it is enjoyable   Other

If other, please specify:____

APPENDIX D

Psychological Stress Measure (PSM-9)

Participant ID# ____________________

Mark the number that best indicated the degree to which each statement applies to you recently.

Not at all	Not really	Very Little	A Bit	Somewhat	Quite a bit	Very Much	Extremely
1	2	3	4	5	6	7	8

1. I feel calm	1 2 3 4 5 6 7 8
2. I feel rushed; I do not seem to have enough time	1 2 3 4 5 6 7 8
3. I suffer from physical aches and pains: sore back, headaches, stiff neck, stomach aches	1 2 3 4 5 6 7 8
4. I feel preoccupied, tormented or worried	1 2 3 4 5 6 7 8
5. I feel confused; my thoughts are muddled; I lack concentration and I cannot focus my attention	1 2 3 4 5 6 7 8
6. I feel full of energy and keen	1 2 3 4 5 6 7 8
7. I feel a great weight on my shoulders	1 2 3 4 5 6 7 8
8. I have difficulty controlling my reactions, emotions, moods or gestures	1 2 3 4 5 6 7 8
9. I feel stressed	1 2 3 4 5 6 7 8

APPENDIX E
Demographic Questionnaire

Participant ID#______________

1) Age: ___________

2) Sex: M F

3) Height:___________________(ft/in) Weight:___________________(lbs.)
(*Note: Remember that all information will remain confidential. Please write your height and weight as accurately as possible or to the best of your knowledge.*)

4) Class Year:____________________

5) Major/Minor:__________________________

6) Ethinicity (circle as many as apply):

Caucasian/White African-American/Black
Hispanic-American Asian-American
Native American Other: _______________

7) Did you participate in any varsity athletic team(s) in high school? Yes No

If yes, please specify:____

8) Have you participated in any varsity athletic team(s) in college? Yes No

If yes, please specify:____

Which hand do you write with? ____________________________________

Which hand do you use to throw a ball? ____________________________________

At this time, how much experience have you had with a <u>stationary exercise bike</u>?

1	2	3	4	5
none never used one	very rarely used	occasionally used	used pretty regularly	lots used almost daily

At this time, how much experience have you had with <u>videogames</u>?

1	2	3	4	5
none never used one	very rarely used	occasionally used	used pretty regularly	lots used almost daily

At this time, how much experience have you had with **<u>Meditaion?</u>**

1	2	3	4	5
none never used one	very rarely used	occasionally used	used pretty regularly	lots used almost daily

APPEDIX F

Flow Questionnaire

Date: ___________ ID#: _________

Please consider your most recent study exercise session in rating each of the below statements. Place a checkmark ÷ to indicate your level of agreement with each statement.

1	2	3	4	5
strongly agree				strongly disagree

1 I performed automatically, without thinking too much.

2 I was challenged, but I believed my skills would allow me to meet that challenge.

3 The experience was extremely rewarding.

4 I did things spontaneously and automatically without having to think.

5 Things just seemed to happen automatically.

6 I had total concentration.

7 The experience left me feeling great.

8 Time seemed to alter (i.e., to either slow down or speed up).

9 It was no effort to keep my mind on what was happening.

10 I really enjoyed the experience.

11 I felt just the right amount of challenge.

12 My attention was focused entirely on what I was doing.

13 I lost my normal awareness of time.

14 The way time passed seemed to be different from normal.

15 I had no difficulty concentrating.

16 The challenge and my skills were at an equally high level.

(Payne et al., 2012; 5 subscales - MAA, CO, CS, TT, AE)