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Temporal Effects of Acute Moderate Intensity Physical Activity on Working Memory Performance in Young Adults

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Temporal Effects of Acute Moderate Intensity Physical Activity on Working Memory Performance in Young Adults.

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Abstract

An ample amount of research suggests that increases in physical activity in young adults could help improve memory and cognitive functions which may aid in academic success (Johnson & Loprinzi, 2019; Perini et al., 2016). A sufficient working memory is critical to learning because it allows us to temporarily store and compare multiple informational items at one time to form a new concept or solve a problem (Cowan, 2013). The purpose of this study was to examine the temporal effects of acute moderate intensity physical activity on working memory in young adults. This study utilized a within-groups (repeated measures) cross-over experimental design. Each participant completed three different protocols on three separate visits. The three visits included the following protocols: (1) a control visit with no physical activity prior to working memory testing, (2) 15 minutes of moderate intensity physical activity immediately (5 min) prior to working memory testing, (3) 15 minutes of moderate intensity physical activity 30 minutes prior to working memory testing. Physical activity intensity was measured by monitoring participants heart rate and rate of perceived exertion (RPE) throughout the testing protocol. Participants walked at a brisk pace on a treadmill for 15 minutes. Working memory was assessed using the automated version of the operation span task. A total of 20 participants were recruited for this study. Participants ranged from 19 to 34 years of age, with the average being 22.20 years. The proportion of male and female participants was equal, with 10 males and 10 females. A one-way within-subjects RM-ANOVA was conducted to compare the temporal effects of physical activity on working memory. The results of the RM-ANOVA showed that no significant differences in working memory scores were found for the three protocols. Previous research suggests acute moderate intensity physical activity has a positive effect on working memory performance. However, the bulk of these studies utilized between

subjects designs and varied the type of working memory test conducted. Further research should focus on within subjects designs and should consider including all three working memory span tasks (operation, counting, and reading) to assess working memory performance. If future research, with more standardized designs, finds that acute physical activity does have an effect on working memory, it could provide evidence as to when or if people should perform moderate intensity physical activity to improve working memory capacity.

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Introduction

It is well known that regular physical activity can improve overall physical health (US Department of Health and Human Services [HHS], 2018). However, evidence suggests that increases in physical activity can improve cognitive functioning as well (Stillman et al., 2016). Recent neuroimaging studies suggest that individuals who are more physically fit show increased brain function efficiency compared with individuals who a less physically fit (Felez-Nobrega, Hillman, Cirera, & Puig-Ribera, 2017). While changes in overall cognitive performance and learning can be linked to a variety of external factors and can be hard to examine, changes in memory performance can be more specifically assessed. Due to the known connection between memory and cognitive performance and learning, researchers often measure changes in memory performance to examine the effects of physical activity on cognition and learning (Cowan, 2013; Perini et al., 2016; Titz & Karbach, 2014). Furthermore, Stillman et al. (2016) suggests that improvements in cognitive performance gained after physical activity are highly associated with improved memory performance. Recent research indicates that increases in overall (chronic) physical activity can improve memory performance (Ruscheweyh, 2011). Research also suggests that even a single bout of physical activity can have a positive effect on memory performance (Haynes, Firth, Sng, & Loprinzi, 2019; Labban & Etnier, 2011; Yanes & Loprinzi, 2018). Exactly how physical activity affects memory performance is still up for some debate (Ruscheweygh et al., 2011). Coles and Tomporowski (2008) suggest that physiologic changes in cardiorespiratory, hormonal, and metabolic processes that accompany physical activity could explain how it affects memory performance. Some of these physiologic changes that may affect memory performance include increases in blood flow, increases in the release of neurotransmitters, and reduction in oxidative stress in hippocampal structures during physical activity (Ruscheweyh et al., 2011).

One thing to consider when using changes in memory performance to examine the effects of physical activity on cognition and learning is the type of memory being evaluated. Researchers in the field of memory and psychology break down memory into primary (short-term and working) and secondary (long-term) memory (Rose, Myerson, Roediger, & Hale, 2010). Primary memory involves a limited amount of sensory information that is brought to our immediate attention and is preserved for a matter of seconds (Estes, 2014; Sprenger 1999). The information in primary memory is either forgotten or turned into secondary memory through retrieving and rehearsal (Estes, 2014; Rose et al., 2010). Working memory uses short-term memory storage to carry out the rehearsal process (Hall, Jarrold, Towse, & Zarandi, 2015). Titz and Karbach (2014) suggest that working memory allows us to temporarily store newly obtained information, process un-related cognitive tasks, then recall the information. Working memory performance is a crucial component of cognitive tasks such as learning (Chalmers & Freeman, 2018; Smith et al., 2013). Moreover, several studies have found differences in working memory capacities to be related to cognitive function and learning (Cowan, 2013; Rathore & Lom, 2017; Rose et al., 2010; Titz & Karbach, 2014). Therefore, researchers have begun measuring working memory performance to examine the effects of physical activity on cognition and learning. Recent studies suggest that acute and chronic physical activity may improve working memory performance of healthy adults (Lopriniz, 2018; Rathore & Lom, 2017; Titz & Karbach, 2014). However, the available research is limited and varies in design and methods such as acute vs. chronic physical activity, the levels of intensity of physical activity, the target population, and working memory measurements.

For instance, some studies have shown that moderate intensity physical activity is more effective at improving memory and cognitive function than low or high intensity physical activity (Frith, Sng, & Loprinzi, 2017; Rattray & Smee, 2016; Smith et al., 2013; Yanes & Loprinzi, 2018). However, only a few studies have examined the effects of acute moderate intensity physical activity on working memory specifically. There is also limited research on the temporal effects of acute physical activity on memory, specifically working memory. Some research has been conducted to determine whether working memory performance is improved more when physical activity is performed prior to, during, or after memory encoding. Memory encoding occurs when sensory input is converted into information capable of processed into memory (American Psychological Association, n.d.). While the verdict is still out due to the varying research designs and methods, evidence indicates that physical activity performed prior to memory encoding may be more effective at improving working memory performance than when performed during or after memory encoding (Firth et al., 2017; Haynes et al., 2019; Labban & Etnier, 2011; Smith et al., 2013; Sng, Firth, & Loprinzi, 2017). However, there is still no conclusive evidence as to when physical activity should be performed prior to memory encoding. Is physical activity performed immediately before or 20 minutes before memory encoding more likely to improve working memory performance than 30 minutes or longer before memory encoding?

Overall, current research indicates acute exercise is linked to enhancements in learning and memory. However, the verdict is still out on a specific exercise protocol to follow to gain these benefits (Smith et al., 2013). Further research needs to be done on how the timing of acute physical activity influences working memory performance. Furthermore, subsequent research should utilize more specific and standardized designs and measures to determine the temporal effects of acute physical activity on working memory. More specific and standardized research designs and measures could provide more conclusive results as to whether the timing of acute moderate intensity physical activity influences working memory capacity in young adults.

Purpose of the Study

Increases in physical activity in young adults could help improve memory and cognitive functions, which may aid in academic success (Johnson & Loprinzi, 2019; Perini et al., 2016). The purpose of this study was to examine the temporal effects of acute moderate intensity physical activity on working memory in young adults. The results of this study attempted to answer the following questions. Does acute moderate intensity physical activity enhance working memory performance? Does the timing of acute physical activity influence its effect on working memory performance?

Hypotheses

Hypothesis #1: Acute moderate intensity physical activity performed 30 minutes prior to memory encoding enhances working memory performance in young adults more than it would if performed immediately (5 min) before memory encoding.

Hypothesis #2: Acute moderate intensity physical activity performed immediately (5 min) before and 30 minutes before memory encoding enhances working memory performance in young adults more than no physical activity prior to memory encoding.

Significance of the Study

Increases in physical activity in young adults could help improve memory and cognitive functions and improve learning, which may aid in academic success (Johnson & Loprinzi, 2019; Perini et al., 2016). The purpose of this study was to determine whether the timing of acute moderate intensity physical activity has an effect on working memory in young adults, utilizing standardized measures of moderate intensity physical activity and working memory capacity, and a standard physical activity modality. The results of this study could provide more conclusive results as to whether the timing of acute moderate intensity physical activity influences working memory capacity in young adults. If the results of this study provide evidence as to when young adults should perform moderate intensity physical activity to improve working memory capacity, it could provide a protocol for them to follow if they would like to improve their working memory and cognitive function.

Definition of Terms

Cognition – thinking skills, including language use, calculation, perception, memory, awareness, reasoning, judgment, learning, intellect, social skills, and imagination (Venes & Taber, 2009, p.481).

Intelligence – the capacity to comprehend relationships; the ability to think, solve problems, and adjust to new situations

Intensity of physical activity - the rate at which the activity is being performed or the magnitude of the effort required to perform an activity or exercise" ("What is moderate-intensity and vigorous-intensity physical activity?", n.d.)

Learning – a change in behavior or skill acquired by experience and practice (Venes & Taber, 2009, p.1310).

Memory – the mental registration, retention, and recollection of past experiences, sensations, or thoughts (Venes & Taber, 2009, p. 1437)

Memory Consolidation - the neurobiological processes by which a permanent memory is formed following a learning experience (American Psychological Association, n.d.)

Memory encoding – the conversion of a sensory input into a form capable of being processed and deposited in memory (American Psychological Association, n.d.)

Moderate intensity physical activity - that "requires a moderate amount of effort and noticeably accelerates the heart rate" ("What is moderate-intensity and vigorous-intensity physical activity?", n.d.)

Neuroplasticity – the ability of nerve cells to grow and form new connections to other neurons (Venes & Taber, 2009, p. 1579)

*Operation Span Task – "*a widely used task to assess working memory capacity, in which participants try to remember sequentially presented words in their correct order while simultaneously solving simple math equations" (American Psychological Association, n.d.)

Physical activity – any bodily movement produced by skeletal muscles that require energy expenditure (Donnelly et al., 2016)

Temporal - of or pertaining to time or its role in some process (American Psychological Association, n.d.)

Working memory – immediate memory system, in which a limited amount of information can be stored temporarily, while un-related complex cognitive tasks are processed (Baddeley, 2006).

Assumptions

For this study, it is assumed that the participants answered the background information, pre-screening, lifestyle/activity level, and PARQ+ questionnaires truthfully and correctly follow the instructions that are given to them throughout the course of the study. It is assumed that participants gave maximal effort during working memory (operation span) testing.

Limitations

While the G*power analysis showed that only 16 participants were necessary for the study to achieve sufficient statistical power, this study was limited by a somewhat small sample size.

Delimitations

This study took place at a university campus, which narrowed the participants to those who are also academically inclined. The site for the study was a university in northeastern Oklahoma. Therefore, any findings may not be generalized to populations of healthy young adults in other geographical locations or settings. Also, this study evaluated only two time periods for physical activity prior to memory assessments and only utilized one working memory span task, the operation span task, to assess working memory performance. It is possible that the use of different memory tasks might produce different results.

Review of Literature

Memory

There are many different components of memory, all of which play key roles in our day-to-day activities and throughout our lives. According to Bristow, Daines, and Cowley (1999), “the primary process of memory is recognition” (p. 3). We go through life recognizing information as new or familiar. The new information gets processed through our memory and is either forgotten or becomes familiar. All the information we take in overtime builds on the memories we create, which together generate the context of our lives (Bristow et al., 1999). Most researchers place the different types of memory into two main categories with several subcategories. Hall et al. (2015) breaks memory down into primary and secondary memory systems, while other researchers describe the two main categories of memory as short term and long-term memory (Estes, 2014).

Primary memory involves a fixed amount of sensory information gathered from our conscious awareness, in other words what grabs our immediate attention (Estes, 2014). The information residing in primary memory is either forgotten or turned into secondary memory through the process of rehearsal (Estes, 2014). Secondary memory contains memories from the recent or distant past that are retrieved when recalled (Rose et al., 2010).

Consistent with other researchers in the field, Rose et al. (2010), breaks the primary memory system down into short-term memory and working memory. According to Sprenger (1999), short-term memory is only preserved for a matter of seconds and can consist of visual, auditory, or kinesthetic information. Each type of information item is processed and temporarily stored in the associated cortex of the brain (i.e., visual information is stored in the occipital lobe, auditory in the temporal lobe, and kinesthetic in the motor cortex) (Sprenger, 1999). However, these areas of the brain have a limited capacity and cannot store information for long especially at a young age. Nevertheless, as we age our capacity to store short-term items increases. Sprenger (1999) suggests that adults can store around seven items in short-term store depending on the attention given to and the prior knowledge of the information being obtained. This information can range from abstract thoughts and theories to concrete observations and processes (Cowan, 2013).

Hall et al. (2015) relates short-term memory to working memory, which uses short-term memory storage to carry out its process. According to Sprenger (1999), when new information enters the brain, it is sent to short term memory storage areas in each lobe to be examined. If that information is focused on and connects to new or existing information, it is sent to working memory located in the prefrontal cortex where it can be examined for hours. Bristow et al. (1999) note the process of examining information involves an increase in focus and effort to remember, wherein information is either preserved in our conscious attention or brought back to consciousness frequently. Bringing information back to our conscious attention or remembering is also known as recall (Bristow et al., 1999).

While short-term and working memory are limited to maintaining recently obtained information, long-term memory can integrate information over an indefinite amount of time (Miner, Schurgin, & Brady, 2019). For this to occur, information sent to long term memory should follow certain implicit or explicit memory system lanes (Sprenger, 1999). Implicit memory is mainly involuntary and involves responses to stimuli and situations. Explicit memory is more voluntary and is developed when we try to remember words, facts, and places. Sprenger (1999) notes there are two memory lanes for explicit memory, episodic and semantic, and three memory lanes for implicit memory, procedural, automatic, and emotional. Each memory lane has its own gateway located in different areas of the brain. These gateways are used to access the information that has been stored in long term memory (Sprenger, 1999).

Episodic memory involves personal experiences obtained throughout our lives within certain spatiotemporal contexts (Schendan, 2012). Episodic memory provides contextual information about the information obtained such as time, place, and even physical and emotional feelings (Martin & Simmons, 2008). Semantic memory contains our main store of knowledge and is concerned exclusively with meaning (Schendan, 2012). One of the major benefits of semantic memory is that it is almost limitless. This is due to being stored in the hippocampus, which has the capacity to store unlimited amounts of new information (Sprenger, 1999). Semantic memory includes information regarding facts, events, ideas, and concepts obtained from tasks such as reading and listening (Martin, 2009). Furthermore, Grossman and Koenig (2002) propose semantic memory is modality-neutral, meaning it can be visual, auditory, or kinesthetic and can include actions, and manners of thought. These components of semantic memory indicate why it plays such an important role in learning. However, for learning to occur via the semantic memory lane, the memory must be stimulated by similar information and repeated several times (Sprenger, 1999).

Working Memory

In 1974, Baddeley and Hitch proposed a model of working memory that described the presence of an immediate memory system, in which a limited amount of information can be stored temporarily while un-related complex cognitive tasks are processed (Baddeley, 2006). Titz and Karbach (2014) suggest that working memory allows us to recall recently obtained information while continuing to take in and process new information. For example, Cowan

(2013, p. 199) explains it as "doing simple arithmetic in your head, if you want to add 24 and 18, you may need to find that 4+8=12, retain the 2 while carrying the 1 over to the tens column to make 2+1+1=4 in the ten's column, and integrate with the ones columns to arrive at the answer, 42." During this process you are recalling information recently stored in your working memory while adding new information to it. You may even continue the working memory task by taking the answer of 42, retaining it in working memory and applying it to say the price of items you wish to purchase while shopping. That information can be stored in working memory for several hours while you repeat the process with different items in the store to decide which of the items has the best price associated with it. Without a good working memory capacity, this process would be difficult to perform.

The ability to recall recent information while also processing new information through working memory is a critical component in cognitive tasks such as learning, comprehension, and reasoning (Chalmers & Freeman, 2018; Smith et al., 2013). Felez-Nobrega et al. (2017) propose that an individual's capacity for working memory can predict performance on higher order capabilities. An improvement in working memory capacity may aid in improving vocational and academic performance as well as the development of life skills.

While information in working memory can be stored longer than information in short-term memory, working memory can still only hold a limited amount of information for a limited amount of time (Cowan, 2013). The accumulation of complex tasks such as reading comprehension and arithmetic can at times overburden the working memory system causing information to be lost (Hall et al., 2015). Information that is unable to form meaningful connections to existing memories or information that is not recalled or focused on enough will be forgotten (Sprenger, 1999). Cowan (2013) proposes that one can avoid overburdening the working memory system by only presenting a few pieces of information at one time, unless they are all connected to one another and can be integrated into one collected piece of information. Unintegrated information held in working memory for a prolonged period of time has an increased risk of being forgotten (Cowan, 2013). According to Sprenger (1999), if the information in working memory is meaningful, able to form connections, and recalled enough, it will be transferred to long-term memory where it can be stored for an indefinite amount of time.

Effects of Working Memory on Learning

Working memory allows for the temporary storage and manipulation of information required to perform a range of cognitive tasks such as learning, comprehension, and reasoning (Rathore & Lom, 2017; Rose et al., 2010). Learning occurs when new informational items are combined with other new or already existing informational items within working memory to form entirely new concepts (Cowan, 2013). According to Rose et al. (2010), differences in working memory capacity may be related to differences in higher order cognition including complex learning. Cowan (2013) argues that sufficient working memory is critical to learning because it allows us to temporarily store and compare multiple informational items at one time to form a new concept or solve a problem. While we may be able to memorize informational items brought into our short-term memory, without having a good working memory we may not be able to build on or understand the underlying concepts of the information being obtained (Cowan, 2013).

There is some controversy between researchers on whether intelligence is the main factor of learning or if working memory holds the key to complex learning (Titz & Karbach, 2014). However, measures of working memory may be a better indicator of academic ability than measures of intelligence (Titz & Karbach, 2014). Specifically, working memory has been linked to achievement in numeracy and literacy (Chalmers & Freeman, 2018). Furthermore, Titz & Karbach (2014) assessed the contribution of working memory to academic achievement showed support of working memory being a contributing factor in learning.

Physical Activity

The World Health Organization defines physical activity as "any bodily movement produced by skeletal muscles that requires energy expenditure ("Physical activity," 2018)". Regular physical activity can improve health-related quality of life by improving overall physical and mental health (HHS, 2018). The WHO ("What is moderate-intensity and vigorous-intensity physical activity?", n.d.) suggests adults should perform moderate to vigorous-intensity physically activity for at least 150-300 minutes a week to gain the related health benefits. Some examples of moderate physical activity include brisk walking to jogging, doing household chores, dancing, or participating in recreational sports. The intensity of physical activity is the amount of physical effort required to perform an activity or exercise. Moderate intensity physical activity is physical activity that requires a moderate amount of physical effort and should be difficult, but not hard to perform ("What is moderate-intensity and vigorous-intensity physical activity?", n.d.).

One way to measure the intensity of physical activity is through energy expenditure. Energy expenditure is calculated in METs or metabolic equivalent of task (HHS, 2018). Energy expenditure is around 1 MET while at rest, roughly 3 METs during light-intensity activity, 3 to 6 METs during moderate-intensity activity, and 6+ METs during high-intensity/vigorous activity (HHS, 2018). Another way to measure the intensity of physical activity is through perceived exertion or how hard it is to physically perform the activity. The Borg Rating of Perceived Exertion (RPE) measures physical activity intensity based on the level of fatigue and increases in heart rate, breathing rate, and sweating (Perceived exertion (Borg rating of perceived exertion scale)," 2020). The Borg scale starts at a rating of 6, which is means the activity takes minimal effort or involves no perceived exertion, to 20 meaning the activity requires maximal effort and involves maximal perceived exertion. Typically, a rating of 12-14 or "somewhat hard" is associated with moderate-intensity activity (Perceived exertion (Borg rating of perceived exertion scale)," 2020).

Effects of Physical Activity on Memory

Participating in regular moderate to vigorous-intensity physical activity may improve cognitive functioning as well as improving physical health (Stillman et al., 2016). Multiple studies have demonstrated a positive relationship between physical activity, memory function and cognitive performance (Haynes et al., 2019; Labban & Etnier, 2011; Yanes & Loprinzi, 2018). Increased cognitive performance has also been linked to higher education levels and well-educated individuals tend to lead healthier lifestyles (Perini et al., 2016). This link has made it difficult for researchers to isolate the effect physical activity has on cognitive performance, although research suggests that increased working memory performance is highly associated with cognitive improvements (Cowan, 2013; Titz & Karbach, 2014). The association between working memory performance and cognitive improvements has allowed researchers to better isolate the effect of physical activity on cognitive performance.

In 2011, Ruscheweyh et al. found that increases in overall physical activity results in improved memory performance. The study involved 62 healthy older adults (aged 50-72 years) who were predominantly sedentary (less than two exercise sessions per week). Participants baseline memory performance and fitness levels were assessed prior to being put into one of three intervention groups (low-intensity aerobic exercise, moderate- intensity aerobic exercise, and no exercise control). There were no significant differences in memory performance or fitness levels at baseline between the three groups. After 6 months of the exercise interventions, the participants were tested on memory performance. Both exercise groups had increased memory performance scores while the control group showed no change. The results of this study indicate that an increase in physical activity may lead to improved memory performance in older individuals, with no significant difference between the low and moderate intensity exercise interventions (Ruscheweyh et al., 2011). Furthermore, Felez-Nobrega et al. (2017) found that 3 hours per week of moderate physical activity was associated with higher working memory capacity, suggesting that adults should engage in at least 3 hours per week of moderate physical activity to boost working memory capacity.

Recent research also indicates that acute physical activity may have a positive effect on memory (Loprinzi, 2018). Loprinzi conducted a systematic review to evaluate the effects of acute exercise on memory function including, whether the intensity of exercise, the type of memory assessed, as well as the temporality of the acute exercise bouts affect the role acute exercise plays in memory function. The initial search revealed 526 articles related to the topic, however only nine articles met the study criteria (published in English, conducted on humans, employ experimental design, have acute exercise independent variable, include a cognitive-related memory assessment, and not include a stress-induced neurotoxicity paradigm). Overall, the findings suggest that acute physical activity may improve memory performance. However, these results are not conclusive due to the variations in exercise intensity, timing of acute physical activity, memory type assessed, and methods of assessing memory between the articles. More research needs to be conducted to evaluate the interrelationships of physical activity intensity and timing on different types of memory (Loprinzi, 2018).

According to Rathore and Lom (2017), acute and chronic physical activity intervention studies have yielded significant increases in the working memory performance of healthy adults. Rathore and Lom (2017) conducted a systematic review using meta-analysis of randomized controlled trials investigating the effects of physical activity on working memory. The systematic review was conducted according to PRISMA guideline recommendation PICOS, which pre-defines and identifies Population, Intervention, Comparator group, Outcome, and Study design. Of the 15 randomized control trials included in the review, five of eight chronic physical activity studies and five of seven acute physical activity studies showed improvements in working memory performance. Though Rathore and Lom's meta-analysis revealed significant positive outcomes for chronic physical activity improving working memory, it did not reveal significant positive outcomes for acute physical activity improving working memory. This may be due to the considerable heterogeneity between the seven acute physical activity studies. The acute physical activity studies had differences in age groups, working memory test protocols, and intensities of physical activity. Rathore and Lom recommend further research on the effects of acute physical activity on working memory that adheres to recommended guidelines by credible organizations. More specific research based off set guidelines would allow for more conclusive and significant results in determining the effects of acute physical activity on working memory performance.

Studies also suggest that acute physical activity may also facilitate learning (Perini et al., 2016; Sage et al., 2016). Acute exercise has been shown to influence the rate of acquisition and retention, information processing and cognitive function (Sage et al., 2016). Perini et al. (2016) examined the effects of acute exercise on learning. The study involved 84 healthy male participants split into two experimental groups. Then the experimental groups were then split into subgroups consisting of a control group (minimal to light intensity) and moderate intensity exercise groups. The light intensity group participated in a computerized orientation discrimination task and the moderate intensity group participated in a motor task. The researchers had the participants perform a pre-learning task, associated with their experimental group, prior to a 30-minute aerobic exercise bout at their subgroup's intensity level. Immediately following the exercise bout, participants completed either orientation discrimination tasks or the motor tasks depending on their experimental group. The results indicated a lower learning rate in the light intensity group than in the moderate intensity exercise group. Furthermore, the moderate intensity exercise group outperformed the light intensity group on the motor task. These findings suggest acute bouts of moderate intensity aerobic exercise may facilitate basic learning mechanisms and could promote brain plasticity in both motor and non-motor areas (Perini et al., 2016).

Exactly how physical activity influences cognition and memory is still up for some debate (Ruscheweygh et al., 2011). However, the changes in cardiorespiratory, hormonal, and metabolic processes that accompany physical activity could explain how they affect memory and cognition on a physiological level (Coles & Tomporowski, 2008). Some of these changes that may affect memory and cognition are the increases in blood flow, increases in the release of neurotransmitters, and reduction in oxidative stress in hippocampal structures during physical activity (Ruscheweyh et al., 2011). Studies have also shown that physical exercise enhances neuroplasticity, which has a direct effect on cognitive function (Perini et al., 2016).

Additional research suggests exercise leads to an increase in proliferation and connectivity of neural connections between the hippocampus and prefrontal cortex, which contributes greatly to memory performance (Frith et al., 2017; Perini et al., 2016; Stillman et al., 2016). Yanes and Loprinzi (2018) propose that exercise enhances neuronal excitability as well as attentional resource allocation, which could support memory encoding. This increase in attention may be due to the modulation of dopamine and norepinephrine during and shortly after exercise (Frith et al., 2017; Loprinzi, 2018, p.256; Ruscheweyh et al., 2011). These neurobiological changes have also been linked to improved memory retention and learning success (Sage et al., 2016).

Effects of Intensity of Physical Activity on Memory

The positive effects of acute physical activity on memory have been well documented. However, little research has been done on how different levels of exercise intensity affect memory functions (Loprinzi, 2018). It is imperative to evaluate the intensity levels of physical activity when assessing the effect physical activity has on memory functions (Labban & Etnier, 2011). Low, medium, and high intensity levels of physical activity may affect memory functions differently (Ruscheweyh et al., 2011).

In a study done by Firth et al., (2017), high intensity exercise had a positive effect on memory and cognitive function. However, additional studies have shown that short bouts of light to moderate physical activity are more effective at improving memory and cognitive function than high intensity physical activity (Felez-Nobrega et al., 2017; Frith et al., 2017; Labban & Etnier, 2011; Rattray & Smee, 2016; Yanes & Loprinzi, 2018). Labban and Etnier (2011) and Smith et al. (2013) note that enhancements in memory and cognitive function can occur even after short 10-minute bouts of moderate intensity exercise (Labban & Etnier, 2011; Smith et al., 2013).

The study conducted by Rattray and Smee (2016) examined the effects of different exercise intensities on memory. Twenty healthy and active participants (10 male and 10 female) completed four different exercise protocols (constant/moderate), low intensity, and high intensity exercise) on four different occasions plus a control/no exercise occasion. Immediately following each exercise protocol, participants completed a cognitive task to assess memory recognition. Rattray and Smee found that response time for the cognitive task was faster for all exercise groups compared to the control, with the moderate intensity exercise group being the fastest. They suggest that the effect of physical activity on memory and cognition follows an inverted-U, where moderate intensity exercise is most effective and low and high intensity exercise are less effective. While the exact physiology behind this result is unknown, Rattray and Smee suggest this may occur due to peak oxygenation of the frontal lobe occurring with moderate intensity exercise.

Temporal Effects of Physical Activity on Memory

Another key component of acute physical activity that needs to be evaluated is the temporal effect on memory and cognition (Labban & Etnier, 2011). Further research needs to be conducted to determine whether memory and cognition are enhanced more if memory encoding and consolidation occur before, during, or after physical activity (Sng et al. 2017). Memory encoding occurs when sensory input is converted into information capable of processed into memory. Memory consolidation occurs when information from a recent memory is processed and forms a permanent memory (American Psychological Association, n.d.).

Though there is limited research, a few studies have shown changes in the effects of acute physical activity on memory and cognition in regard to the timing of physical activity (Frith et al., 2017; Haynes et al., 2019; Labban & Etnier, 2011; Sng et al., 2017). Physical activity before memory encoding may improve memory by increasing attention while physical activity after memory encoding may enhance memory consolidation (Frith et al., 2017; Sage et al., 2016). A study conducted by Sng et al. (2017) evaluated the effects of acute moderate intensity walking exercise on memory function. The study consisted of 88 healthy male and female college students. Memory function was assessed using the Rey Auditory Verbal Learning Test (RAVLT). The RAVLT measures "a person's ability to encode, combine, store and recover verbal information in different stages of immediate memory (Khosravi Fard et al., 2016, p. 27)." Therefore, many researchers use this assessment tool to study short term memory, long term memory, and learning.

The 88 participants were split up into four experimental groups with 22 participants per group, including a control group, exercise prior to memory encoding group, exercise during memory encoding, and exercise during memory consolidation. The exercise groups participated in 15 minutes of moderate intensity walking on a treadmill either prior to or during memory encoding or during memory consolidation. The exercise prior to and during memory encoding groups completed the RAVLT to assess learning and memory after exercise or during exercise respectively. The exercise during memory consolidation group completed the RAVLT recall 20 minutes and 24 hours after exercise. According to Sng et al. (2017), the exercise prior to memory encoding group scored better than all other groups on the RAVLT as well as the 20 minute and 24-hour recalls. These results indicate exercising prior to memory encoding is most effective when it comes to improving memory and cognition (Sng et al., 2017).

Firth et al. (2017) also noted that exercising during memory encoding can be linked to decreased memory performance. This result is likely due to the shift of metabolic resources from the regions in the brain where memory is developed and stored to motor regions that produce and sustain bodily movement (Frith et al., 2017). In addition, Van Dongen et al. (2016) suggest acute exercise enhances memory consolidation when performed four hours after memory encoding but showed little to no effect when performed immediately after memory encoding.

Current evidence indicates that acute physical activity performed prior to memory encoding and consolidation may be more effective at improving memory and cognition when compared to during or after (Frith et al., 2017; Haynes et al., 2019; Labban & Etnier, 2011; Smith et al., 2013; Sng et al., 2017). However, this evidence stems from studies using varying physical activity intensities and modalities, age groups, and working memory measures. Furthermore, little to no research has been conducted on the timing of acute exercise prior to memory encoding. For instance, future research should determine whether physical activity performed immediately before, 20 minutes before, or an hour before memory encoding is best at eliciting improvements in memory (Haynes et al., 2019).

More specific research using standardized methods should be conducted to obtain more conclusive evidence on the temporal effects of acute physical activity on working memory (Firth et al., 2017; Haynes et al., 2019; Loprinzi, 2018; Rathore and Lom, 2017). Future research should incorporate a standard measure for working memory, a specific physical activity modality, and focus on moderate intensity physical activity to determine the temporal effects of physical activity on acute working memory in young adults.

Method

Participants

The target group for this study was healthy young adults ages 18-35. The number of participants needed to achieve a-priori power of 0.80 was calculated in G*Power (v.3.1), using a one-way repeated measure analysis of variance (RM-ANOVA) with the following settings: medium effect size (0.25), Type I error rate (alpha) = 0.05, 3 repeated measurements (protocols), and a medium high correlation (0.70) among measures (Faul, Erdfelder, Lang, & Buchner, 2007). Therefore, 19 participants were needed to obtain sufficient statistical power.

Participants were recruited via a convenience-based, non-probability sampling approach (classroom announcements, word-of-mouth, flyers, and emails). This study was approved by the Institutional Review Boards (IRBs) from the University of Arkansas (UA) and Northeastern State University (NSU), and participants provided written consent prior to participation. Due to the physical demands of this study, participants had to pass a health screening and show no contraindications on a physical activity readiness questionnaire (PARQ+; see Appendix A) to be eligible for participation. Prior to participation, participants also completed a lifestyle/physical activity level (See Appendix B) and pre-screening/demographic questionnaire (See Appendix C). All three questionnaires were emailed to participants prior to arranging the first lab visit, though all paperwork was signed in person during their first lab visit. This eliminated participants from having to come into the lab if they were ineligible for the study. Participants were ineligible for this study if they reported any of the following on their pre-screening questionnaire: current smoker, concussion within the past 30 days, diagnosed with attention deficit or attention deficit hyperactivity disorders, diagnosed with a learning disability, are pregnant, currently under the influence of alcohol, marijuana, or illicit substances.

A total of 20 participants were recruited for this study with 10 males and 10 females. Participants ranged from 19 to 34 years of age, with the average being 22.20 years with a standard deviation of 3.33.

Measures

Physical Activity Intensity

Physical activity intensity was measured by monitoring participants heart rate and rate of perceived exertion (RPE), throughout the testing protocol. Participants walked at a brisk pace on a treadmill at for 15 minutes. During this time participants were instructed to increase their pace until their heart rate (HR) is at 65-75% of their estimated heart rate max, which corresponds to moderate intensity physical activity (Liguori, Feito, Fountaine, & Roy, 2022). Each participant's heart rate was assessed continuously throughout the protocol using a chest strapped monitor. The goal was to have participants reach and sustain 65-75%% max HR after the first 5 minutes of walking. An RPE of 3-4 on a scale of 1-10 is considered moderate intensity (Liguori et al., 2022). Participants' RPE was taken at minutes 5, 10, and 15 of the treadmill walking protocol. Walking speeds were adjusted to maintain 65-75% max HR and 3-4 RPE. Heart rate and RPE were also assessed immediately before working memory testing to measure physiological arousal.

Working Memory Performance

Although there is no one specific measurement tool to assess working memory capacity, several studies have used working memory "span" tasks to successfully measure working memory performance (Conway et al., 2005; Felez-Nobrega et al., 2017; Hall et al., 2015; Hilbert et al., 2015; Rathore & Lom, 2017). Working memory span tasks, used to measure working memory capacity, were designed based on Baddeley and Hitch's (1974) model of working memory (Conway et al., 2005). Working memory span tasks entwine the presentation of to-be-remembered information with the presentation of a complex cognitive processing tasks (Conway et al., 2005). In a working memory span task, the to-be-remembered information can be digits, words, phrases, or images and the cognitive processing tasks can be anything from simple arithmetic to reading comprehension, depending on the specific span task. The three working memory span tasks commonly used in research are the reading span, operation span, and counting span tasks. All three working memory span tasks have been used in hundreds of independent studies and show a high degree of reliability and validity (Conway et al., 2005).

The specific span task that was used for this study was the operation span task in which participants were required to solve basic mathematical problems while trying to remember the letters that were shown to them before each problem. The operation span task has been administered to thousands of subjects in hundreds of studies to analyze working memory performance. No two tasks or mini tasks are the same for the operation span task. Each task includes different letters and different basic math problems every time each task is done. Therefore, there are no order (practice) effects expected with the operation span task. The operation span task also has adequate consistency reliability. Consistency reliability reflects the consistency of participants' responses across a test's items at one point in time. A coefficient alpha of 1 defines a perfect correlation. In 2004, Kane at al. observed coefficient alphas of 0.80 for the operation span task. Furthermore, Conway et al. observed test-retest correlations of 0.70 to 0.80 for the operation span task (2005). The operation span task also shows considerable construct validity (Conway et al., 2005), meaning the operation span task predicts performance on a wide array of tasks for which control of attention and thought are important. Operation span tasks also show convergent validity in that operation span tasks correlate extremely well with each other and with performance on tests of more complex cognition that depend on working memory (Conway et al., 2005). Operation span tasks do not predict performance on tasks that appear to reflect automatic processing or basic recall in the absence of interference, that is, the operation span tasks only tests working memory, not short-term or long-term memory, which shows discriminant validity (Conway et al., 2005).

For this study, working memory was assessed using the automated version of the operation span task produced by Psychology Experiment Building Language (PEBL), an open-source software system for designing and running psychological experiments. During this task, participants sat at a computer and were shown a series of letters intertwined with basic math problems. Participants were instructed to read each letter as they saw it and answer the math problems as they came up. At the start of each mini task, participants were shown a letter. After each letter they were shown a math problem they needed to quickly solve in their head. This continued 3-5 times depending on the computers randomly selected task length. After the 3-5 mini tasks, the participants were instructed to click on the letters they saw in the correct order. If the participant did remember a specific letter in the order, they were instructed to hit the blank button, which kept the place of the unknown letter. The whole process was repeated three times to obtain an average score, which was based off the number of letters the participant got correct in the correct order for each mini trial.

Prior to beginning the scored operation span task, participants took a practice test. The practice test determines the average time it takes a participant to answer the math problem. If the participant went over their average time to solve a math problem in the actual task, the program showed the letter to be remembered without the participant having to solve the problem and the program marked it as a math error. Since this test was not trying to assess math skills and was used only to distract the participant, the math errors were not counted against the final score of letters remembered.

Research Design and Procedures

This study utilized a within-subjects (repeated measures) cross-over experimental design. The advantages of this design could reduce error variance associated with individual differences and would provide more robust indications of any causal effects of acute moderate intensity physical activity on working memory performance (Maxwell & Delaney, 2004). Each participant completed three different protocols on three separate visits to the exercise physiology lab at NSU. Participants were instructed to come into the lab around the same time of day for each of the three necessary visits. Each visit lasted approximately 1-1.5 hours and occurred at least 24 hours after the previous visit to allow for a wash-out period and minimize carry-over effects (Maxwell & Delaney, 2004). To control order effects, a Latin Square Counterbalanced Design was utilized to randomize the protocol conditions (Figure 1). Working memory was assessed after each protocol utilizing an automated version of the operation span task produced by Psychology Experiment Building Language (PEBL), an open-source software system for designing and running psychological experiments.

Figure 1

Latin Square Counterbalanced Design.

Participant	Visit 1	Visit 2	Visit 3
1	Protocol 1	Protocol 2	Protocol 3
2	Protocol 2	Protocol 3	Protocol 1
3	Protocol 3	Protocol 1	Protocol 2
4	Protocol 1	Protocol 3	Protocol 2
5	Protocol 2	Protocol 1	Protocol 3
6	Protocol 3	Protocol 2	Protocol 1
7	Protocol 1	Protocol 2	Protocol 3
…	…	…	…

During the first visit to the lab, participants were asked to read and sign a written informed consent form approved by both the NSU and UA IRBs. They were also asked to complete a PARQ+, lifestyle/physical activity level and demographic questionnaires. Once all preliminary screening and assessments were completed, participants were assigned one of the three protocols depending on the Latin Square protocol for their participant number. If the participant was assigned Protocol 1, they rested for 20 minutes before completing the automated operation span task for working memory assessment. If the participant was assigned Protocol 2, they walked on the treadmill at a moderate intensity for 15 minutes and then rested for 5 minutes before completing the automated operation span task for working memory assessment. If the participant was assigned Protocol 3, they walked on the treadmill at a moderate intensity for 15 minutes and then rested for 30 minutes before completing the automated operation span task for working memory assessment. The automated operation span task included a pre-test given immediately prior to the actual tested task to familiarize participants with the test. The rest periods consisted of watching an episode of the TV show “Friends” to allow for controlled distraction and rest. The 5-minute and 30-minute rest periods were chosen based on previous research and physiologic changes after physical activity. Previous research indicates measuring memory performance after 5 minutes of rest to determine “immediate” effects of physical activity on memory (Firth et al., 2017; Perini et al., 2016; Rattray and Smee, 2016; Sng et al., 2017). Furthermore, physical activity during memory encoding and/or assessment has been linked to decreased memory performance, which may be due to the shift of metabolic resources from memory regions of the brain to motor regions of the brain (Firth et al., 2017). Therefore, participants rested for 5 minutes before completing the memory assessment to allow time for the body to pull those resources back to regions of the brain more specific to memory and cognitive function. Previous research has mainly focused on the effects of physical activity on memory when performed immediately before, during, or after memory encoding. The 30-minute rest period was chosen for this study to determine if an extended rest time between physical activity and working memory testing has an effect on working memory performance.

Statistical Analysis

The statistical package for the social sciences software (SPSS) version 25 was used to perform all data management and analyses. Following preliminary descriptive analysis, model assumptions were checked before further analysis. Second, a univariate analysis of variance (ANOVA) was used to evaluate if there is an order effect on protocols. Third, a one-way within-subject ANOVA was conducted with the factor begin three moderate-intensity physical activity protocols [no physical activity, physical activity immediately before (5 min), and 30 minutes before working memory testing] and the dependent variable being the working memory performance, measured by the automated operation span task. Finally, previous studies (Hill et al., 2014; Li et al., 2010) indicated males and females performed differently on working memory tasks. Therefore, disregarding whether the main effect (i.e., from the previous one-way within-subject ANOVA) was significant, a further exploratory analysis was conducted using a two-way repeated-measures ANOVA (a mixed-design with one within-subject and one between-subject) to investigate the gender effects.

Results

The purpose of this study was to examine the temporal effects of acute moderate intensity physical activity on working memory in young adults. A RM-ANOVA was conducted to compare the temporal effects of physical activity on working memory. As mentioned previously, working memory performance was measured using an automated operation span test. A univariate analysis of variance conducted on protocol order was not significant at the .05 level, $F(2,17) = 0.009$, $p = .99$, showing there were no order effects. The means and standard deviations for the operation span tests scores are presented in Table 1.

Table 1

Means and Standard Deviations for Working Memory Test Scores ($N = 20$).

Operation Span Test	*M*	*SD*
Protocol 1	10.30	3.33
Protocol 2	10.05	2.98
Protocol 3	10.60	3.94

The results of the one-way within-subject ANOVA indicated that the effect of the physical activity protocols on working memory scores was not significant, Wilks' $\Lambda = .845$, $F(2,38) = 2.095$, $p = .137$. There were no differences between the three moderate intensity physical activity protocols (i.e., no physical activity and a 20-minute rest, 15-minute physical activity with a 5-minute rest, and 15-minute physical activity with a 30-minute rest). The effect size was medium to large ($\eta^2 = 0.099$).

Because males and females have been shown to differ on memory tasks (Hill et al., 2014; Li et al., 2010) a follow-up exploratory analysis was conducted with a mixed-design ANOVA. The gender by protocol interaction was not significant, $F\ (2, 36) = 2.19$, $p = .127$, nor was the main effect for gender, *F* (1, 18) = 0.49, *p* = .493. Not surprisingly, the effect for protocols remained nonsignificant, *F* (2, 36) = 0.42, *p* = .657 (see Table 2 for detail).

Table 2.
ANOVA Summary of Exploratory Analysis for Gender by Protocols

Source	*df*	*SS*	*MS*	*F*
Between Subjects				
Gender (A)	1	14.02	14.02	0.49
Residual between within Subjects	18	515.63	28.65	
Within Subjects				
Protocol (B)	2	3.03	1.52	0.42
A×B Interaction	2	15.63	7.82	2.19
Residual within	36	128.67	3.57	

Discussion

The purpose of this study was to examine the temporal effects of acute moderate intensity physical activity on working memory in young adults. Specifically, this study examined the effects of acute moderate intensity physical activity on working memory performance in young adults as well as the effects of the timing of acute moderate intensity physical activity (5 minutes before or 30 minutes before memory encoding). Previous research suggests that even a single bout of physical activity can have a positive effect on memory performance (Haynes, et al., 2019; Labban & Etnier, 2011; Yanes & Loprinzi, 2018) and that acute physical activity may improve working memory performance of healthy adults (Lopriniz, 2018; Titz & Karbach, 2014; Rathore & Lom). Therefore, the main hypothesis for this study was that acute moderate intensity physical activity enhances working memory performance in young adults. Prior research also suggests that the timing of physical activity may have an effect on memory performance (Firth et al., 2017). For instance, previous research indicates that physical activity performed before memory encoding and consolidation may be more effective at improving memory and cognition when compared to during or after (Frith et al., 2017; Haynes et al., 2019; Labban & Etnier, 2011; Smith et al., 2013; Sng et al., 2017). Linking together the results of previous studies, it was hypothesized that acute moderate intensity physical activity performed 30 minutes prior to memory encoding enhances working memory performance in young adults more than it would if performed immediately (5 min) before memory encoding. It was also hypothesized that acute moderate intensity physical activity performed immediately (5 min) before and 30 minutes before memory encoding enhances working memory performance in young adults more than no physical activity prior to memory encoding. However, the results of this study contradict the theory that acute moderate intensity physical activity has an effect on working memory performance. The data also suggests that the timing of acute moderate intensity physical activity does not have an effect on working memory performance.

Previous research suggests there may be some gender differences when it comes to working memory (Hill et al., 2014; Li et al., 2010). Gender differences in working memory have been attributed to differences in types of working memory in which males and females differ. According to Hill (2014), males tend to be better at mathematical, spatial, and object working memory while females are better at verbal and writing skill working memory. Therefore, possible gender effects were also analyzed to determine if physical activity's effect on working memory score varied by gender. However, the results of the interaction analysis between gender and working memory scores were also not significant.

One limitation of this study was that the interaction analysis for gender on working memory scores was under power. Statistical power for the interaction was calculated in G*Power (v.3.1), using a repeated measure analysis of variance within-between interactions with the following settings: effect size = 0.16, Type I error rate (alpha) = 0.05, number of measurements = 3 (protocols), total sample size = 20, number of groups = 2, and a medium high correlation (0.70) among measures (Faul, Erdfelder, Lang, & Buchner, 2007). The power analysis resulted in a power of 0.49. Therefore, sufficient statistical power for the interaction was not achieved. While the G*power analysis showed that only 16 participants were needed for the study to achieve sufficient statistical power, a larger sample size was needed to get more power when analyzing the interaction and may have rendered more support for the hypotheses. A delimitation of this study is the homogenous sample of only healthy young adults. The target population for this study was healthy young adults. However, the study took place at a university campus, which narrowed the participants to those who are also academically inclined. Therefore, any findings may not be generalized to populations of healthy young adults in other geographical locations or settings.

Future Research

Future research should consider evaluating a more diverse group of young adults and eventually, children, older adults, and those with memory impairments or cognitive deficits. This study also only evaluated two time periods for physical activity prior to memory assessments and two time periods for acute physical activity prior to the working memory assessment. Future research should assess shorter and longer durations of rest between physical activity and memory assessments (Haynes et al., 2019). For example, no rest, 10 minute rest, 45 minute rest, or one or more hours of rest between physical activity and memory assessments.

This study only utilized one working memory span task, the operation span task, to assess working memory performance. The automated version of the operation span task produced by Psychology Experiment Building Language (PEBL) was used to assess working memory performance, which may not have been sensitive enough to determine an effect of physical activity on working memory. Although the operation span task has a high degree of reliability and validity in assessing working memory performance, using all three of the working memory span tasks may provide more conclusive evidence of any changes in working memory performance (Conway et al., 2005). The three working memory span tasks include the operation, reading, and digit span tasks. While this study focused on working memory performance, more research should also continue to be conducted to evaluate the interrelationships of physical activity intensity and timing on different types of memory (Loprinzi, 2018).

Previous research suggests acute moderate intensity physical activity has a positive effect on working memory performance. However, the bulk of these studies utilized between subjects designs and varied on the type of working memory test conducted. The within subjects design and the type of working memory test used in this study may have controlled more extraneous variables, making the results less sensitive to differences. Further research should focus on within subjects designs and should consider including all three working memory span tasks (operation, counting, and reading) to assess working memory performance. In addition, more specific research using standardized methods should be conducted to obtain more conclusive evidence on the temporal effects of acute physical activity on working memory (Firth et al., 2017; Haynes et al., 2019; Loprinzi, 2018; Rathore and Lom, 2017). Future research should incorporate a standard measure for working memory, a specific physical activity modality, and focus on moderate intensity physical activity to determine the temporal effects of physical activity on acute working memory in young adults. If future research, with more standardized designs, finds that acute physical activity does have an effect on working memory, it could provide evidence as to when or if people should perform moderate intensity physical activity to enhance working memory performance.

Conclusion

In conclusion, the purpose of this study was to examine the temporal effects of acute moderate intensity physical activity on working memory in young adults. The results of this study failed to support the hypotheses that acute moderate intensity physical activity improves working memory performance in young adults and that the timing of the physical activity has an effect on working memory performance. According to the results of this study, there is no difference in working memory performance based on whether physical activity was performed prior to working memory testing, specifically 5 minutes or 15 minutes before memory testing. Overall, more research should be conducted to develop more standardized measures of physical activity and working memory capacity. For instance, more research could determine which level of physical activity intensity is best for working memory performance, what the best testing procedure or combination of testing procedures is for working memory performance, and what the best physical activity modality is to improve working memory performance. In conclusion, more standardized research may provide more conclusive evidence as to whether acute moderate intensity physical activity and/or the timing of physical activity influences working memory capacity in young adults.

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Appendices

Appendix A

2021 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1) Has your doctor ever said that you have a heart condition ☐ **OR** high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** ____________	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** ____________	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it **does not limit your current ability** to be physically active. **PLEASE LIST CONDITION(S) HERE:** ____________	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Please sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow Global Physical Activity Guidelines for your age (https://www.who.int/publications/i/item/9789240015128).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

PARTICIPANT DECLARATION
If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for its records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME ____________________ DATE ____________

SIGNATURE ____________________ WITNESS ____________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ____________________

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at www.eparmedx.com before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

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FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1. Do you have Arthritis, Osteoporosis, or Back Problems?

If the above condition(s) is/are present, answer questions 1a-1c — If **NO** ☐ go to question 2

1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	YES ☐ NO ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	YES ☐ NO ☐

2. Do you currently have Cancer of any kind?

If the above condition(s) is/are present, answer questions 2a-2b — If **NO** ☐ go to question 3

2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck?	YES ☐ NO ☐
2b.	Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)?	YES ☐ NO ☐

3. Do you have a Heart or Cardiovascular Condition? This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm

If the above condition(s) is/are present, answer questions 3a-3d — If **NO** ☐ go to question 4

3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)	YES ☐ NO ☐
3c.	Do you have chronic heart failure?	YES ☐ NO ☐
3d.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	YES ☐ NO ☐

4. Do you currently have High Blood Pressure?

If the above condition(s) is/are present, answer questions 4a-4b — If **NO** ☐ go to question 5

4a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
4b.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	YES ☐ NO ☐

5. Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes

If the above condition(s) is/are present, answer questions 5a-5e — If **NO** ☐ go to question 6

5a.	Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?	YES ☐ NO ☐
5b.	Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.	YES ☐ NO ☐
5c.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet?	YES ☐ NO ☐
5d.	Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?	YES ☐ NO ☐
5e.	Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?	YES ☐ NO ☐

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6. Do you have any Mental Health Problems or Learning Difficulties? This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome

If the above condition(s) is/are present, answer questions 6a-6b — If **NO** ☐ go to question 7

6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
6b.	Do you have Down Syndrome **AND** back problems affecting nerves or muscles?	YES ☐ NO ☐

7. Do you have a Respiratory Disease? *This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure*

If the above condition(s) is/are present, answer questions 7a-7d — If **NO** ☐ go to question 8

7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	YES ☐ NO ☐
7c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	YES ☐ NO ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	YES ☐ NO ☐

8. Do you have a Spinal Cord Injury? *This includes Tetraplegia and Paraplegia*

If the above condition(s) is/are present, answer questions 8a-8c — If **NO** ☐ go to question 9

8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	YES ☐ NO ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	YES ☐ NO ☐

9. Have you had a Stroke? *This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event*

If the above condition(s) is/are present, answer questions 9a-9c — If **NO** ☐ go to question 10

9a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
9b.	Do you have any impairment in walking or mobility?	YES ☐ NO ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	YES ☐ NO ☐

10. Do you have any other medical condition not listed above or do you have two or more medical conditions?

If you have other medical conditions, answer questions 10a-10c — If **NO** ☐ read the Page 4 recommendations

10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	YES ☐ NO ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	YES ☐ NO ☐
10c.	Do you currently live with two or more medical conditions?	YES ☐ NO ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE: ______________________

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

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If you answered NO to all of the FOLLOW-UP questions (pgs. 2-3) about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:
You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME ______________________________ DATE ______________________________

SIGNATURE ______________________________ WITNESS ______________________________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________________

For more information, please contact
www.eparmedx.com
Email: eparmedx@gmail.com

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The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the BC Ministry of Health Services.

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PRINT FORM RESET FORM

Appendix B

Lifestyle/Physical Activity Level Questionnaire:

Questions:

1. Name: First and Last

2. What exercise activities do you currently take part in (e.g., running, weightlifting, group exercise, etc.)?

3. How many days per week do you get at least 60 minutes of moderate-intensity exercise?

4. On a scale of 0-10, how important is maintaining a physically active lifestyle to you?

5. What is your occupation?

6. Does your occupation require extended periods of sitting? (If yes, please explain.)

7. Do you partake in any recreational physical activities (golf, swimming, hiking, etc.)? If yes, please explain.)

8. Do you have any additional hobbies that require you to be physically active (gardening, fishing, dancing, etc.)? (If yes, please explain.)

9. Do you consume caffeinated beverages such as coffee, tea, soda, and/or energy drinks? If so, how many per week?

Appendix C

Pre-screening Questionnaire:

Questions: Demographic Information

1. Name: First and Last

2. What is the highest degree or level of school you have completed? (If you're currently enrolled in school, please indicate the highest degree you have *received.*)
    a. Some High school
    b. High School degree or equivalent
    c. Some college, no degree
    d. Associates degree (e.g. AA, AS)
    e. Bachelor's degree (e.g. BA, BS)
    f. Master's degree (e.g. MA, MS, Med)
    g. Doctorate degree (e.g. PhD, EdD)

3. Are you a current smoker?

4. Have you had a concussion within the past 30 days?

5. Have you been or are you currently diagnosed with attention deficit or attention deficit hyperactivity disorders?

6. Have you been diagnosed with a learning disability?

7. Are you pregnant?

8. Have you been under the influence of alcohol, marijuana, or illicit substances in the last 24 hours?

9. Have you exercised in the last 5 hours?

10. Have you had caffeine in the last 5 hours?

Appendix D

UNIVERSITY OF ARKANSAS

Temporal Effects of Acute Moderate Intensity Physical Activity on Working Memory Performance in Young Adults

Consent to Participate in a Research Study
Principal Researcher: Kimberly Loy-Seibold
Faculty Advisor: Cathy D. Lirgg

INVITATION TO PARTICIPATE
You are invited to participate in a research study about how the timing of acute physical activity influences working memory performance. You are being asked to participate in this study because you are an apparently healthy individual aged 18-35.

WHAT YOU SHOULD KNOW ABOUT THE RESEARCH STUDY

Who is the Principal Researcher?
Kimberly Loy-Seibold, M.S
Assistant Professor-Kinesiology
Northeastern State University
loyk@nsuok.edu
kl032@uark.edu

Who is the Faculty Advisor?
Cathy D. Lirgg. Ph.D.
Professor-Kinesiology
University of Arkansas
clirgg@uark.edu

What is the purpose of this research study?
The purpose of this study is to examine the temporal effects of acute moderate intensity physical activity on working memory in young adults.

Who will participate in this study?
Twenty-five apparently healthy individuals between the ages of 18 and 35 will be recruited for this study. Due to the physical demands of this study, participants must pass a health screening and show no contraindications on a physical activity readiness questionnaire (PARQ+) to be eligible for participation. Participants will also be ineligible for this study if they report any of the following on their pre-screening questionnaire: current smoker, concussion within the past 30 days, diagnosed with attention deficit or attention deficit hyperactivity disorders, diagnosed with a learning disability, are pregnant, currently under the influence of alcohol, marijuana, or illicit substances.

What am I being asked to do?
Your participation will require the following:

> You will set up a time to meet with the researcher for the paperwork, familiarization, and protocol at the exercise physiology lab at Northeastern State University (NSU). Each visit to the lab will last approximately 60-90 minutes. The first meeting will consist of completing the informed consent and health history and 1 of the 3 activity protocols. During the first visit to the lab, you will be asked to read and sign this written informed consent form approved by both the NSU and the University of Arkansas (UA) institutional review boards. You will also be asked to complete a PARQ+, lifestyle/physical

activity level and demographic questionnaires. Once all preliminary screening and assessments have been completed, you will be assigned 1 of the 3 physical activity protocols.

If you are assigned protocol 1, you will rest for 20 minutes before completing the automated operation span task for working memory assessment. If you are assigned protocol 2, you will walk on the treadmill at a moderate intensity for 15 minutes and then rest for 5 minutes before completing the automated operation span task for working memory assessment. If you are assigned protocol 3, you will walk on the treadmill at a moderate intensity for 15 minutes and then rest for 30 minutes before completing the automated operation span task for working memory assessment. You will complete 1 of the last 2 remaining protocols on your second visit to the lab. You will complete the last remaining protocol on your 3rd (last) visit to the lab.

You will be asked to report back for the second and third round of testing within one week after the first testing protocol. Participants will be able to stop testing at any time if they feel any discomfort.

What are the possible risks or discomforts?
The movements involved in testing are not strenuous but may be aerobically taxing during the 15 moderate intensity protocols. Even though you will complete a physical activity readiness questionnaire and a health screening prior to participation, abnormal responses to aerobic physical activity are possible. These responses may include, but are not limited to joint pain, chest pain, dizziness, and irregular heartbeat. Any abnormal responses will result in an immediate termination of the test. The primary investigator (PI) of the study is CPR/AED certified and will be present for every test.

What are the possible benefits of this study?
Upon completion of all 3 visits to the lab you will receive a $25 visa gift card! You must complete all 3 visits and physical activity protocols to be eligible for the $25 visa gift card. There could also be benefits for society. If the results of this study provide evidence as to when young adults should perform moderate intensity physical activity to improve working memory capacity, it could provide a protocol for you to follow if you would like to improve your working memory and cognitive function.

How long will the study last?
You will be asked to visit the lab on 3 separate occasions. Each visit/protocol will last approximately 60-90 minutes.

Will I receive compensation for my time and inconvenience if I choose to participate in this study?
Yes, upon completion of all 3 visits to the lab you will receive a $25 visa gift card! You must complete all 3 visits and physical activity protocols to be eligible for the $25 visa gift card.

Will I have to pay for anything?
No, there will be no cost associated with your participation.

What are the options if I do not want to be in the study?
If you do not want to be in this study, you may refuse to participate. Also, you may refuse to participate at any time during the study. Your job, your grade, your relationship with the University, etc. will not be affected in any way if you refuse to participate.

How will my confidentiality be protected?
All information will be kept confidential to the extent allowed by applicable State and Federal law. Confidentiality will be maintained by coding all information with individual identification numbers. The master

list containing identifying information will be shredded upon completion of the study; the coded data will be stored separately from the master list throughout the study and kept in a locked filing cabinet in the PI's office and on a password protected USB drive.

Only qualified research personnel and the University of Arkansas and Northeastern State University Institutional Review Boards (IRB) will have access to the study data. The master list will be stored in the PI's office in a locked filing cabinet and on a password protected USB drive. The signed consent forms will be kept for 3 years per federal guidelines. Data will not be linked to participants. The data will be stored on a password protected USB drive that will be locked in the PI's office. Once demographic data of the participants are put into the database, the questionnaires will be shredded. Also, all information from individuals who do not meet inclusion criteria will be shredded.

Will I know the results of the study?
At the conclusion of the study you will have the right to request feedback about the results. You may contact the faculty advisor, Cathy D. Lirgg (clirgg@uark.edu) or Principal Researcher, Kimberly Loy-Seibold (loyk@nsuok.edu / kl032@uark.edu). You will receive a copy of this form for your files.

What do I do if I have questions about the research study?
You have the right to contact the Principal Researcher or Faculty Advisor as listed below for any concerns that you may have.

Kimberly Loy-Seibold, loyk@nsuok.edu, kl032@uark.edu

Cathy D. Lirgg, clirgg@uark.edu

You may also contact the University of Arkansas Research Integrity and Compliance office listed below if you have questions about your rights as a participant, or to discuss any concerns about, or problems with the research.

Ro Windwalker, CIP
Institutional Review Board Coordinator
Research Integrity and Compliance
University of Arkansas
109 MLKG Building
Fayetteville, AR 72701-1201
479-575-2208
irb@uark.edu

I have read the above statement and have been able to ask questions and express concerns, which have been satisfactorily responded to by the investigator. I understand the purpose of the study as well as the potential benefits and risks that are involved. I understand that participation is voluntary. I understand that significant new findings developed during this research will be shared with the participant. I understand that no rights have been waived by signing the consent form. I have been given a copy of the consent form.

____