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Using Differing Levels of Physical Activity as a Context Cue for Memory

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Abstract

The current study aimed to investigate the use of physical activity as a context cue for object location memory. The study included 49 undergraduate students who were asked to encode and recall a grid of 14 objects under three different physical activity conditions: rest, rolling a ping-pong ball, and pedaling on an exercise bike. It was expected that participants engaging in matching physical activity contexts at encoding and recall would have significantly higher rates of recall for object locations when compared to participants in the non-matching physical activity contexts. Results did not support my hypothesis as there was no evidence of a context effect of physical activity on object location memory. However, there was a significant advantage for participants identifying as White/Caucasian in the task over participants identifying as African American/Black. The failure to find a significant context effect is discussed in terms of an interference effect.

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Using Levels of Physical Activity as a Context Cue for Memory

The theory of context dependent memory (CDM) is based on the premise that a stimulus or physical environment can act as a context for retrieval if it is present at both encoding and recall. This implies that anything in the environment can be a context for memory: the room, bodily state, mood, physical action, etc. This phenomenon was first established in humans by Shuh Pan in 1926 who required participants to memorize pairs of words presented in a contextual situation and then tested their ability to recall the pairs of words in a contextual situation that was either the same in which they learned the pairs of words, altered, or absent. Pan found that participants recalled the pairs of words more accurately when the contextual situation was the same when participants were learning and when they were recalling the pairs of words. This phenomenon was found in many studies involving non-human animals before Pan's study. John B. Watson's 1907 study taught rats to run a maze and then the experimenter would rotate the maze to see if the change in environment orientation would have an effect on the rat's ability to run the maze. Watson's study found that the change in environmental context confused the rats. At the time, there were other studies that showed this phenomenon present in other animals. Walter Hunter's 1911 study showed the same phenomenon with pigeons in a maze, and earlier it was shown that the same phenomenon was present with sparrows in James Porter's 1906 study. The confusion that resulted from a change in the orientation of the maze in these studies is paralleled in human studies by a decrease in accuracy of memory recall.

The hypothesis most associated with CDM is the memory hypothesis. According to Smith (1979), the memory hypothesis attributes less accurate recall in nonmatching environments to participants associating the learned material with the environment. Therefore, upon recall participants use the environmental associations to remember the learned material.

This becomes a problem for participants when they are asked to recall the learned material in an environment different from the encoding environment, resulting in an inability to retrieve the learned material correctly.

The memory hypothesis of CDM is the most strongly supported one within the literature, as demonstrated by Metzger, Boschee, Haugen, & Schnobrich's 1979 study. Participants were students in an introductory geography class and the aim was to determine whether or not testing locations affected test scores. All participants were taught the course material and were tested over it in the same classroom for three weeks. However, during week four, half of the participants (Group A) were tested in a second classroom, but identical in color, lighting, type of desk, and seating alignment, while still learning the material in the first classroom. During week five, the groups were switched and the half of the students that were tested in the first classroom in week four (Group B) were then tested in the second classroom while still learning the material in the first classroom. Metzger et al (1979) found that when the groups learned the material and were tested in the same room, there were no differences in mean test scores. However, when one of the groups were tested in a different room, that group's mean test score was significantly lower than the group that was tested in the same room. Although the rooms were identical in their physical characteristics, the environmental associations of the room that participants had associated with the material were not the same, which resulted in poorer recall. These results support the memory hypothesis outlined in Smith (1979), reflecting that participants rely on environmental associations as retrieval cues for learned material.

The diversity of context-dependent memory is vast and ever-expanding into an umbrella term for many kinds of retrieval cue associations. Some researchers place state-dependent memory under this umbrella while some opt to leave it to stand on its own. State-dependent memory relies on internal cues to facilitate retrieval of learned material while context-dependent memory is reliant on external cues (Evans, Holness, Nichols-Lopez, Rose, & Furton, 2016). According to Eich (1980), state-dependent memory involves changing the individual's psychological or physiological state at both the encoding and the recall phases. Changing an individual's internal state can be as simple as changing someone's arousal state as Miles and Hardman (1998) did, or as controversial as changing one's psychological state with alcohol (Evans et al, 2010) or marijuana, methylphenidate, barbiturates, nicotine, or d-amphetamine (Eich, 1980). The changing internal state can also be the individual's emotional state as shown in Lang, Craske, Brown, and Ghaneian (2001) in which the internal states of fear and relaxation were used as cues, and in Bartlett and Santrock (1979) in which the mood states of happy and neutral were used as cues. These are all examples of repeatedly studied cues for state-dependent memory.

Matching Contexts

One of the most well-known studies of context-dependent memory is Godden and Baddeley's 1975 study that emphasized the importance of establishing matching contexts when testing participants' memory. This study emphasized the need for conditions that had matching contexts, and that context-dependent memory cannot be established nor claimed without those conditions. They used geographical location as the context cue for memory and required participants to learn and recall information in one of four conditions. The matching contexts conditions required participants to learn and recall a list of words while on land or learn and recall a list of words while under water. The non-matching contexts conditions required participants to learn the list of words while either on land or under water and then recall the list of words while in the opposite geographical context. Participants were trained scuba divers who would be comfortable completing a task under water (Godden & Baddeley, 1975). The results of the study were consistent with the theory of context-dependent memory and showed that participants who encoded the list of words on land or water and recalled the list of words in the matching context were more accurate than those participants who did not recall the list of words in a matching context. Godden and Baddeley's (1975) design of using matching and nonmatching contexts for encoding and retrieval has been present in all known CDM research to this date.

Practical Applications

It is important to note that although Godden & Baddeley (1975) set an important precedent for context-dependent memory research, the study itself is hard to replicate and apply to a practical or real-life scenario. Although studies similar to Godden & Baddeley (1975) such as Thompson, Williams, L'Esperance, and Cornelius (2001) that involved videos of skydiving are important to the diversity of studies on context-dependent memory, the practical applications of CDM needed to be explored. One practical application of context-dependent memory is its use in eyewitness testimony. Eyewitness testimony is very controversial as eyewitness memory is not reliable (Smith & Vela, 1992). For years, psychologists have been researching various ways to apply their research in memory in a practical way for law enforcement to use in their procedures. Smith and Vela (1992) were interested in the implication that eye witness facial recognition may depend environmental context reinstatement, i.e., matching contexts. They staged a live event involving confederates for participants to watch, after which participants were tested on facial recognition of the confederates either in the same location as the event or in a different location, such as a police department. Consistent with context-dependent memory, the participants who were tested on facial recognition of the confederates in the same location at which they saw the confederate (the matching context) showed significantly higher rates of accurate recall when compared to participants who were tested on facial recognition of the confederates in a different location than they first saw they confederate (non-matching context). This research has had major impact on the view of how context-dependent memory can be applied to the world.

Context-dependent memory also has major implications for the classroom, such as with Metzger et al. (1979) that brings attention to the issue of testing students in a room that is different from where they learned the material. Eich (1985) reaffirms these findings with their test of learning object names in one distinct room and being tested in either the same room or another distinct room. Van Der Wege and Barry (2008) is another example of this. Participants were students that were about to take their scheduled final exam and were given the choice of either taking the exam in the same classroom that they had been in throughout the semester or taking the exam in an entirely different room. The results showed that participants had significantly higher test scores when they took the final exam in the same classroom that they had been in all semester. These same results were replicated in Jensen, Harris and Anderson (1971) that used participants from grades two through twelve. The results of these studies could have major impact on the way that students are tested in various majors such as chemistry, engineering, and biology where students are usually tested in a separate classroom from which they are taught course material, sometimes even at a different time of day.

Physical Activity as a Context for Memory

Although the research on context-dependent memory is extremely diverse and ever-expanding, the literature is lacking on studies that use physical activity as the context cue. This makes Miles and Hardman's (1998) research especially important. In this study, participants learned a list of words while either performing aerobic exercise (riding an exercise bike) or at rest while having their heart rates monitored. Over the course of the study, four different word lists, each consisting of 36 three-syllabic words, were used during the encoding phase. There were four different conditions that each participant would participate in over the course of four consecutive days. The conditions were: rest at encoding and rest at recall, rest at encoding and exercise at recall, exercise at encoding and exercise at recall, and exercise at encoding and rest at recall. Participants were required to reach and sustain a heart rate between 120 bpm and 150 bpm during the exercise condition. In this study, the context is both the physical activity and the physiological arousal (Miles & Hardman, 1998). They expected their results to align with the context-dependent memory theory, meaning that when the participants' heart rates were the same at both encoding and recall, there would be significantly higher recall accuracy. Their hypothesis was supported by their findings.

Although Miles & Hardman (1998) stands out as the study to have shown physical activity as a context cue, it is important to note the other studies have used physical activity as their cue. Clark, Milberg, and Ross (1983) and Schramke and Bauer (1997) are two other examples of this. In both studies, participants were required to learn a list of words after either engaging in exercise or rest and then were required to engage in either the opposite or matching activity before recalling the list of words. The results of both of these studies support the Miles & Hardman (1998) findings that an individual's physiological arousal can be a cue for memory. It is important to note that these two studies vary from Miles & Hardman (1998) as participants were instructed to engage in the activity before encoding and recalling the list of words rather than during encoding and recall. In both Clark, Milberg, and Ross (1983) and Schramke and Bauer (1997), it seems that the context is the arousal itself rather than the physical activity.

Hammond, Murphy, Silverman, Bernas, and Nardi (2018) is the most recent study to my knowledge to attempt to replicate the findings of Miles & Hardman (1998). This study was broken up into two experiments. In each experiment, participants' heart rates were measured at four individual times. In the first experiment, participants were required to learn the location of 28 objects on a grid while either walking or standing on a health walker. At recall, participants were shown each of the 28 objects they had encoded individually while either walking or standing on the health walker and were asked to indicate verbally where they believed the individual object belonged on a blank grid. The experimenter provided no feedback and the objects were not placed on the grid. However, this experiment yielded no results to show evidence of the presence of context-dependent cues. In the second experiment, the 28-object grid was split into two 14-object grids. In the first encoding phase, participants were required to either walk or stand on the health walker while learning the location of 14 images of common objects on a 4 row by 7 column grid. Immediately following the encoding phase, participants were given a rehearsal period while still engaging in the assigned physical activity (Hammond et al, 2018). The participant was shown a blank numbered grid and the experimenter individually showed the participant the 14 objects one by one and verbally named each object. The participant was asked to indicate verbally where they thought the object belonged on the grid. The participants were given verbal feedback and one by one the images of the objects were placed onto the grid according to the participant's response. After all of the objects were on the grid, participants were given time to study the completed grid (Hammond et al, 2018). Following a cool-down period, participants were guided through the same encoding process again while completing the opposite physical activity (walking or standing) and while learning a new 14-object grid. At recall, participants were asked to either walk or stand on the health walker (depending on the condition) and then were guided through recalling each of the 28-objects while looking at a blank numbered grid. Again, no feedback was given, and the objects were not placed on the grid. However, just like in the first experiment, there were no significant findings of context-dependent cues.

Physical Effort and Cognition

The perspective of embodied cognition is the idea that the nervous system, the surrounding, and the body all play a role in our cognition and that any change made to one of these three results in a change in all of them (Wilson, 2002). Embodied cognition is the perspective that is most found in CDM literature. This is in contrast to the previous perspective that cognition is basically disembodied and that our surroundings and physical body have no effect on our cognitive processes (Lakoff, 2012). The literature has shown much evidence to support the theory of embodied cognition and the link between physical effort and spatial cognition. There are many studies that examine participants' perception of space while wearing a heavy backpack (increased physical effort) or while not wearing a heavy backpack (decreased physical effort). Participants who are wearing a heavy backpack judge the distance in front of them to be greater than while not wearing the backpack (Proffitt, Stefanucci, Banton, & Epstein, 2003). This has also been shown in how participants judge the steepness of hills. Bhalla and Proffitt (1999) asked participants to judge the steepness of hills while wearing a heavy backpack and while not wearing the backpack. Their results showed that participants who were wearing the heavy backpack judged the hills to be steeper than the participants who did not wear the backpack.

Although there is an abundance of literature regarding the effect of physical effort on the perception of space, there is little literature showing the effect of physical effort on memory.

Normally, the amount of energy used is proportional to the distance traveled; however, there is evidence to show that this is not how we remember it. The results of Cohen, Baldwin, and Sherman (1978) suggest that the more effort it takes to cover a distance, the more our memory tends to overestimate the effort. Cohen, Baldwin, & Sherman (1978) required participants to judge the distance they had walked on a path. The participants who walked the path with more hills or environmental barriers tended to overestimate the distance when asked later in comparison to participants who had walked the same distance but without any hills or barriers. Okabe, Aoki, and Hamamoto (1986) required participants to walk several different routes with varying levels of difficulty (number of slopes, and hills). Consistent with Cohen, Baldwin, & Sherman (1978), they found that participants overestimated the distance of the routes they took that were more difficult in comparison to routes that were relatively level.

Failure to Replicate

As shown with the results of Hammond et al (2018), physical activity does not always provide the needed evidence for context cues in studies. The most varied in results and possibly the most tested kind of physical activity is chewing gum. Baker, Bezance, Zellaby, and Aggleton (2004, p. 207) was a study completed to test the "general belief that chewing gum can aid concentration and, thereby, influence cognition." It should be noted that it is the action of chewing the gum, not the actual chewing gum (such as the flavor of mint) that is serving as a context in this experiment. The researchers did not use complete matching contexts, however, sorting their participants into two groups, the first of which chewed gum during both encoding and recall and the second that chewed gum during encoding, but not during recall. This could have some effect on the validity of the experiment when comparing it with other context dependent memory studies as they did not have four counterbalanced conditions (Gum-Gum,

Gum-No Gum, No Gum-No Gum, and No Gum-Gum). However, the study did result in the finding that participants who chewed gum both during encoding and recall had higher scores than those who only chewed gum during encoding which is consistent with CDM (Baker et al, 2004). Although there are similar studies that managed to replicate these results, it should be noted that there are just as many studies that failed to replicate (Miles & Johnson, 2007; Anderson, Berry, Morse & Diotte, 2005; Johnson & Miles, 2008; Miles, Charig, & Eva, 2008). These discrepancies could be due to the type of memory task used at recall and the varying levels of delay. The mixed literature leaves it unclear whether or not it is actually the taste of the gum rather than the action of chewing that acts as the context-cue in these studies.

In sum, there is a link between physical activity/effort and the way space is represented in our memory, but the limited amount of research on physical activity as a context cue hinders the conclusions that we can draw from it. There also is a lack of replication of the studies that do show evidence for physical activity being a context cue for memory. Although studies such as Miles & Hardman (1998) show the effect of context-dependent memory in line with that of Godden & Baddeley (1975), other studies that have attempted to replicate this effect fall short, possibly due to a lack of distinctly separate contexts during encoding and recall. In studies such as Metzger et al (1979) this was simply changing identical classrooms, but in Godden & Baddeley (1975) the geographical locations were complete opposites. Miles & Hardman (1998) echo this by having a large difference between rest and an elevated state of physical activity. More recent studies such as Hammond et al (2018) do not show such a dramatic change. The goal of the current study is to compare the performance of participants under two different levels of physical activity to further explore the magnitude of the effect of physical activity as a context-dependent memory cue.

The Current Study

The current study aimed to replicate the findings of Miles & Hardman (1998) and to investigate a possible limitation to context-dependent memory found in recent studies: the lack of a dramatic change in physical activity between encoding and recall contexts. This study intended to enhance our current understanding of context-dependent memory, and physical activity as a context cue for spatial memory. The context effects of physical activity on memory have only been explored in two studies: Miles & Hardman (1998) and Hammond et al. (2018), with Hammond et al. (2018) being the only study to examine the effect on object location memory. The current study examined level of physical activity as a context-dependent memory cue for remembering the location of images on a poster board. The study overcomes limitations in recent studies (Hammond et al., 2018) that did not employ such a dramatic change in physical activity.

There are three hypotheses for the current study. First, that participants will recall the location of the objects on the grids more accurately when the encoding context matches the recall context. Second, participants engaging in a high level of physical activity (pedaling on an exercise bike) will have better recall overall than participants in a low level of physical activity (rolling a ping-pong ball in their hands). Third, participants will have better recall overall in contexts where physical activity is present compared to baseline.

Method

Participants

Participants were undergraduate students at Eastern Illinois University who were enrolled in an Introduction to Psychology course and received research participation credit for participating in the current study. Participants were recruited through the online SONA system where they were able to view a brief description of the study and choose an individual time slot to sign up for. A total of 49 participants participated. In total, there were 35 females and 14 males; 24 participants identified as African American, 16 identified as White, 5 identified as Hispanic/Latino, 2 identified as Asian, and 1 identified as Native American.

Materials

Object memory task. Three stimulus grids were prepared. The first consisted of a 7 column x 4 row grid on a 51 x 76 centimeters poster board, containing 14 images of objects (see Figure 1). The second consisted of a 7 x 4 grid on a 51 x 76 centimeters poster board, containing 14 images of objects that were different than the first (see Figure 2). Both sets of 14 objects were adapted from a grid of 28 objects from Hammond et al (2018) that was adapted from a stimulus array created by Silverman and Eels (1992) (See Figure 3). The third consisted of a 7 x 4 grid on a 51 x 76 centimeters poster board with blank numbered boxes (1-28) (see Figure 4). The poster board was set on top of a desk against the wall (see Figure 5) during both encoding and recall for all conditions except when participants were riding the stationary bike. When riding the bike, the poster board was raised higher off the ground to be at eye level.

Participants were given 90 seconds to learn the 14-object grid. The participants then entered a 5-minute rest period in which they were given a Where's Waldo? book as a distractor task. During recall, participants were shown each of the 14 objects that they had learned earlier, and while looking at a blank grid numbered 1-28, indicated where they thought the object belonged on the grid. Participants were asked not to point at the empty grid box, but to verbally state the number of the box they believed the object belonged in. Participants were given no feedback and the objects were not placed on the grid.

Two dependent variables were measured: the number of correct responses given and the accuracy of the responses. Correct responses (recalling an object in the correct box in the grid) were coded as zero points, while incorrect responses were given a score between -1 (one box away) and -6 (six boxes away), based on distance from the correct object location. The number of correct responses at baseline recall and experimental recall were calculated for each participant.

Exercise Condition. A 15-1306 Stamina Indoor Pro-Cycle stationary ergometer was used for participants in the exercise condition (See Figure 6). The Pro-Cycle was placed in the back center of the room and approximately 71 centimeters away from the poster board. The poster board was positioned approximately 114 centimeters above the ground. When pedaling on the bike, participants were instructed to reach and keep a pace represented on the digital screen on the bike as the number 6.5 for 2-minutes before encoding or recall would begin in order to raise the heart rate to target levels (60-75% of maximum heart rate). During the 90 second encoding phase and during the untimed recall participants were also engaged in pedaling on the exercise bike.

Ping-pong ball condition. Participants were instructed to sit at the desk with their elbows either on or off the table, whichever they were comfortable with, and steadily roll a standard ping-pong ball in between their palms in a vertical motion as demonstrated by the experimenter. Participants in the condition requiring them to roll the ping-pong ball between their palms were given 15 seconds to practice before the encoding or recall began. During the 90 second encoding phase and during the untimed recall participants were also engaged in rolling the ping-pong ball.

Pulse rate. Participants' pulse rates were measured using a ReliOn™ Wrist Blood Pressure Monitor BP300W. This provides a digital representation of both heart rate and blood pressure. Pulse rates were measured after the 2-minute pedaling session or after the 15-second practice with the ping-pong ball, immediately before encoding and recall.

Procedure

The current study followed the guidelines of the American Psychological Association and was approved by the IRB. All participants were tested individually after providing informed consent. The experiment consisted of six phases: baseline encoding, delay 1, baseline recall, encoding, delay 2, and recall. Before each encoding and recall phase, the participant's heart rate was taken. During both delay periods, participants sat at the same desk as they had during the baseline memory task while completing the distractor task (Where's Waldo search).

Participants completed the baseline memory task (no physical activity) and then were assigned to one of four conditions, in which the memory task was repeated while engaging in either a high (exercise bike) or low (ping-pong) level of physical activity during the encoding and recall periods. Thus, the four experimental conditions were:

1) Encoding and recalling the picture grid while riding a stationary bike.
2) Encoding the picture grid while riding on a stationary bike but recalling the grid while rolling a ping-pong ball between their hands.
3) Encoding and recalling the picture grid while rolling a ping-pong ball between their hands
4) Encoding the picture grid while rolling a ping-pong ball between their hands but recalling the grid while riding the stationary bike.

The order of pedaling on the exercise bike or rolling a ping-pong ball at encoding and recall was counterbalanced. Overall, the whole experimental session lasted approximately 40 minutes.

Results

A 2 (within subjects: performance at baseline and experimental recall) x 4 (between subjects: physical activity at encoding/recall) mixed factorial analysis of variance was used to analyze responses using hit or miss scoring. At an alpha level of .05, the main effect of time on the number of correct responses at baseline recall and at experimental recall was not statistically significant, $F(1, 45) = 0.56$, $p = 0.46$, $\eta_p^2 = 0.01$. Participants recalled relatively the same number of correct object locations at baseline recall as they did at the experimental recall. Furthermore, the main effect of time on the accuracy of responses (distance from correct location) was also not statistically significant $F(1, 45) = 3.53$, $p = 0.07$, $\eta_p^2 = .07$. Participants recalled object locations with relatively the same accuracy at both baseline recall and experimental recall.

Crucially, the interaction between time and the type of encoding/recall activity on number of correct responses was not statistically significant $F(3, 45) = 1.67$, $p = 0.18$, $\eta_p^2 = 0.10$. Participants' average number of correct object locations for the first condition, learning while pedaling on the exercise bike and recalling while pedaling on the exercise bike, was relatively similar at baseline recall, $M = 6.31$ ($SD = 3.64$) and at experimental recall, $M = 6.77$ ($SD = 4.40$). Participants' average number of correct object locations for the second condition, learning while pedaling on the exercise bike and recalling while rolling the ping-pong ball, was also relatively similar at baseline recall, $M = 7.92$ ($SD = 2.81$) and at experimental recall, $M = 8.17$ ($SD = 3.04$). Participant's average number of correct object locations for the third condition, learning while rolling the ping-pong ball and recalling while rolling the ping-pong ball, was the most dissimilar between baseline recall, $M = 8.50$ ($SD = 3.42$) and at experimental recall, $M = 6.67$ ($SD = 2.28$).

Participants' average number of correct object locations for the fourth condition, learning while rolling the ping-pong ball and recalling while pedaling on the exercise bike, was also relatively similar at baseline recall, *M* = 7.00 (*SD* = 3.36) and at experimental recall, *M* = 6.92 (*SD* = 3.70).

The interaction between time and the type of encoding/recall activity on accuracy of responses was also not statistically significant $F(3, 45) = 1.39$, $p = 0.26$, $\eta_p^2 = 0.08$. Participant's average score for the first condition, learning while pedaling on the exercise bike and recalling while pedaling on the exercise bike, was relatively similar at baseline recall, *M* = -13.69 (*SD* = 8.64) and at experimental recall, *M* = -16.31 (*SD* = 12.13). In fact, participants in this condition were the least accurate at experimental recall overall which did not support my hypothesis that participants would recall object locations more accurately when engaged in the higher level of physical activity. Participant's average score for the second condition, learning while pedaling on the exercise bike and recalling while rolling the ping-pong ball, was also relatively similar at baseline recall, *M* = -9.42 (*SD* = 7.39) and at experimental recall, *M* = -9.33 (*SD* = 5.74). Participants in this condition were the most accurate at experimental recall overall, which did not support my hypothesis that participants would be more accurate at recalling object locations when engaged in the matching physical activity as they were at encoding. Participant's average score for the third condition, learning while rolling the ping-pong ball and recalling while rolling the ping-pong ball, was again the most dissimilar between baseline recall, *M* = -8.67 (*SD* = 6.41) and at experimental recall, *M* = -13.67 (*SD* = 8.44). Participant's average score for the fourth condition, learning while rolling the ping-pong ball and recalling while pedaling on the exercise bike, was also relatively similar at baseline recall, *M* = -12.00 (*SD* = 6.73) and at experimental recall, *M* = -12.08 (*SD* = 8.98).

An independent samples t-test was conducted to compare the performance (number of correct responses and accuracy of responses) of participants who identified as male or female in a preliminary demographic questionnaire given after informed consent was received. This independent samples t-test showed no statistical significance for number of correct responses at baseline recall, $t(47) = 1.17, p = 0.25$; nor for number of correct responses at experimental recall, $t(47) = 1.17, p = 0.25$; nor for the accuracy score at baseline recall, $t(47) = 1.19, p = 0.24$; and not for the accuracy score at experimental recall, $t(47) = 0.26, p = 0.80$ (See Figures 9 & 10). Previous research indicated that there may be some sex differences in object location memory, but this is not supported by the data collected for the current study.

Discussion

As previously stated, my central hypothesis was that participants who encoded and recalled object locations in matching physical activity contexts would have higher rates of recall than participants who encoded and recalled object locations in different physical activity contexts. For example, a participant who encoded a grid under the condition of pedaling on the exercise bike and then recalled that grid while pedaling on the exercise bike would show higher rates of recall than a participant who encoded a grid under the condition of pedaling on the exercise bike and then recalled that grid while rolling a ping-pong ball. This context effect would entail a significant interaction between time and group on the number of correct responses and the accuracy of the responses. However, when analyzing the data, there was no significant interactions.

The outcome of the current study conflicts with the results of Miles and Hardman (1998) which was the basis for this study, but it does coincide with the results of Hammond et al (2018) which is the basis for this thesis. Given these conflicting results, it is important to discuss the differences between these studies and my own. In Miles and Hardman (1998), participants were asked to learn a list of 36 words that were provided to them auditorily, while in the current study participants were asked to learn a total of 28 object locations (14 at a time) that were provided to them visually. Despite this finding, the literature suggests that there are comparable effects from auditory and visual stimuli on physical and cognitive tasks (Woodham, Billinghurst, & Helton, 2016). However, both Miles and Hardman (1998) and the current study used similar modes of physical activity as both used a stationary ergometer (exercise bike) and both had a comparable condition of rest. The current study included the condition of rest as a baseline for spatial location memory while Miles and Hardman (1998) included this as an experimental condition. In the current study a lower level of physical activity, rolling a ping-pong ball, was used as an experimental condition instead of rest. Miles and Hardman (1998) also engaged participants in a free recall period where participants listed off the words they could remember from the lists they had learned, but the current study did not include this and opted to stick to a more structured recall.

Although the current study does coincide with the results of Hammond et al (2018), there are some important differences between the two studies. The current study engaged in different levels of physical activity than Hammond et al (2018) which used walking and standing on a health walker as their conditions with no tested rest condition. The current study used pedaling on an exercise bike and rolling a ping-pong ball as the levels of physical activity with a designated comparable rest condition. The current study used the same hit or miss scoring as Hammond et al (2018) as well as the same object location grids, and even had a similar number of participants. The current study did not replicate the finding in Hammond et al (2018) that found a sex difference in recall levels. Hammond et al (2018) found a significant interaction between the sex of the participant and the activity performed at recall and showed that female participants recalled significantly more object locations than male participants. This finding was supported by the literature which shows a female advantage in object location memory (Eals & Silverman, 1994; Silverman & Eals, 1992; Lejbak, Vrbancic, & Crossley, 2008; and Neave, Hamilton, Hutton, Tildsley, & Pickering, 2005). A theory explaining this female advantage is known as the Gathering Hypothesis (Neave et al, 2005). The theory states that in the past the males were typically hunters while females were placed into the role of gathering and foraging, and that this division of the labor resulted in a difference in spatial skills where males have an advantage in navigational skills, but females have an advantage in object location memory. Although my results do not show this difference in a statistically significant way, this could be explained as due to the proportion of males and females in the study: 71.4 percent of participants identified as female while only 28.6 percent of participants identified as male.

My central purpose for this study was to address what seemed to be a limitation on context-dependent memory which was the need for dramatic change in physical activity levels. I had hypothesized that because Miles and Hardman (1998) compared such different physical activity levels (rest and pedaling on an exercise bike) that this was the reason for their success in showing context effects for physical activity. No other study had managed to replicate these results. I also wanted to show physical activity as a context for spatial location memory as the only other study to address this (Hammond et al, 2018) had not found significant results. However, my results have shown to be more in line with the interference effect of physical activity. The interference effect is impairment of working memory due to the result of the strain of higher levels of physical activity. It has been proposed by both Hammond et al (2018) and

Miles and Hardman (1998) that a higher level of physical activity may do more harm than good in context-dependent memory. The lack of power in the current study should also be noted. As there were four conditions and only 49 students, that meant that there were only about 12 participants in each condition. With more participants perhaps, a significant result may have been found, however due to a time limit this was not able to be achieved. In future studies where this is the case, researchers could combine the two matching conditions together and the two non-matching conditions together and then run the analysis to determine a context-dependent effect.

Conclusion

As previously stated, to the best of my knowledge, only one study has systematically addressed the use of physical activity as a context cue for memory (Miles & Hardman, 1998) and there is currently only one study to address context-dependence related to spatial location memory (Hammond et al, 2018). The current study is the only study, to my knowledge, to utilize dramatic changes in physical activity as a context for object location memory.

Although the current study did not find evidence supporting context effects of physical activity on object location memory, it did show more evidence for an interference effect of physical activity on memory retrieval. Future studies should address whether this is due to the grid used (different grids used at baseline recall and experimental recall), the interference effect of physical activity, or perhaps an issue with spatial memory. Future studies may also want to consider using a different type of physical activity.

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Table 1 ANOVA Summary Table

Sources of Variance	*SS*	*df*	*MS*	*F*	*p*	*Partial Eta Squared*	*Power*
Between Groups Effects							
Activity at Recall	32.89	3	10.96	0.53	0.66	0.03	0.18
Within Groups Effects							
Performance (Number Correct)	2.22	1	2.22	0.56	0.46	0.01	0.08
Performance (Number Correct) x Activity Condition	19.97	3	6.66	1.67	0.18	0.10	0.56

Table 2 ANOVA Summary Table

Sources of Variance	*SS*	*df*	*MS*	*F*	*p*	*Partial Eta Squared*	*Power*
Between Groups Effects							
Activity at Recall	415.92	3	138.64	1.22	0.31	0.07	0.40
Within Groups Effects							
Performance (Accuracy Score)	88.69	1	88.69	3.53	0.07	0.07	0.40
Performance (Accuracy Score) x Activity Condition	104.38	3	34.79	1.38	0.26	0.08	0.46

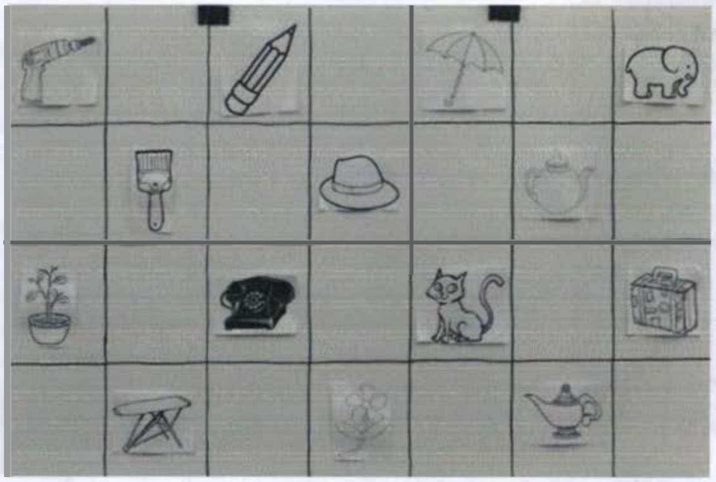

Figure 1. Picture of 14-object grid used in the baseline encoding and recall.

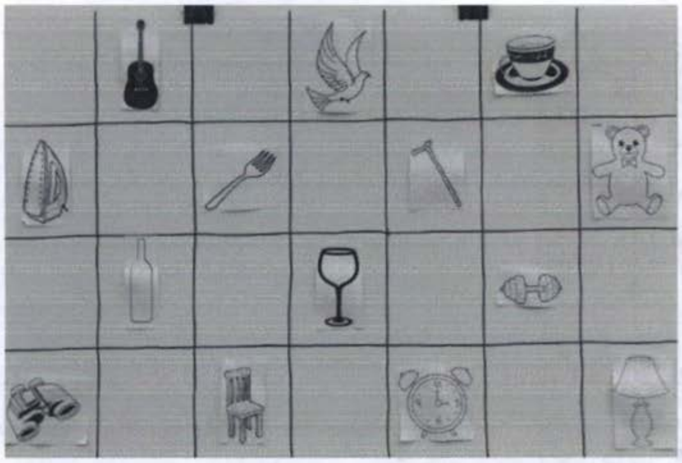

Figure 2. Picture of the 14-object grid used in the experimental encoding and recall.

Figure 3. Picture of 28-object grid that the two separate 14-object grids used in the experiment were derived from.

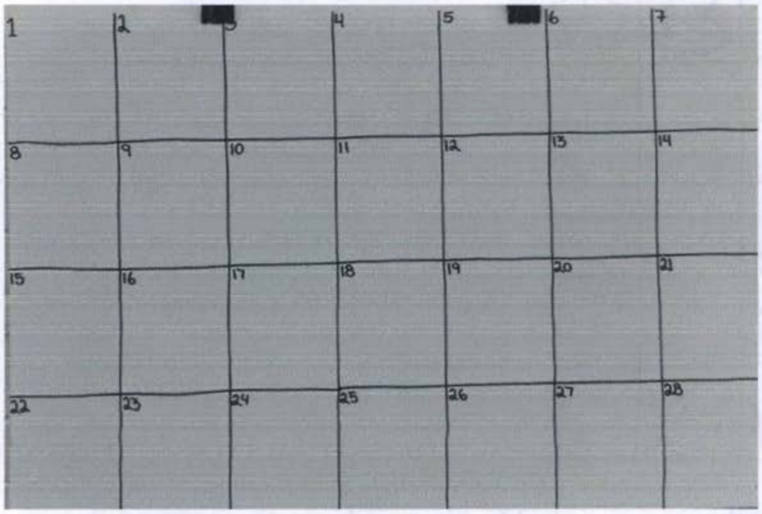

Figure 4. Picture of the blank numbered grid used in both the baseline recall and the experimental recall.

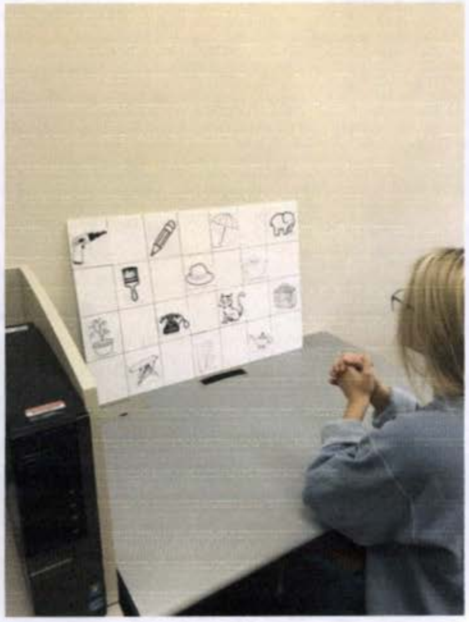

Figure 5. Picture of set up for baseline.

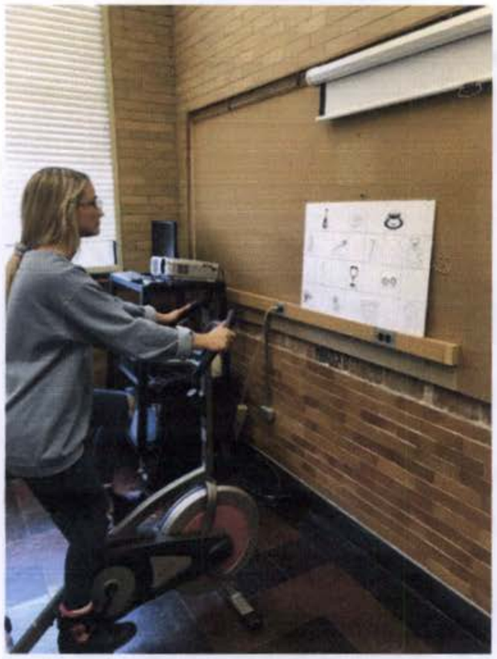

Figure 6. Picture of experimental set up and the 15-1306 Stamina Indoor Pro-Cycle.

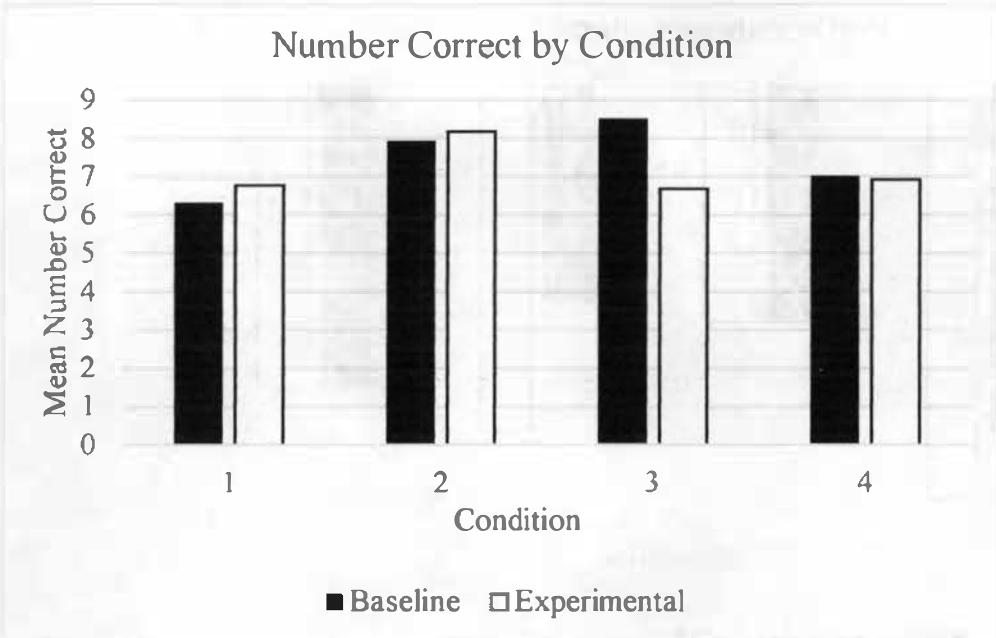

Figure 7. Graph showing the nonsignificant interaction between time and type of activity at encoding/recall on number of correct responses. Condition 1 represents the matching exercise bike condition, condition 2 represents the nonmatching condition of pedaling on the exercise bike at encoding and rolling the ping-pong ball at recall, condition three represents the matching ping-pong ball condition, and condition four represents the nonmatching condition of rolling the ping-pong ball at encoding and pedaling on the exercise bike at recall.

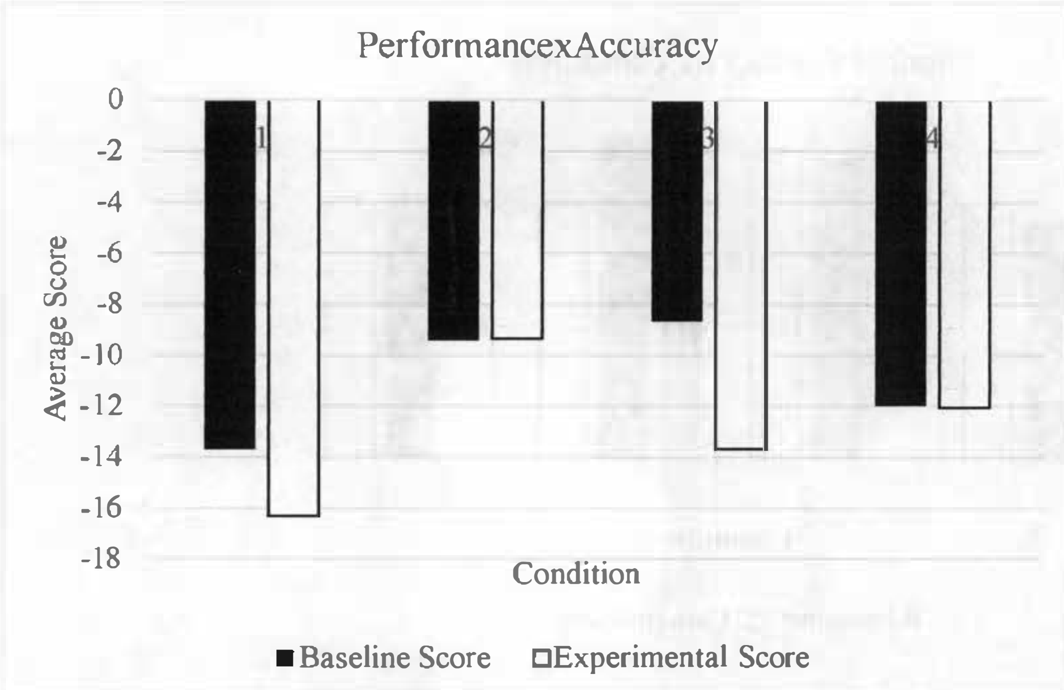

Figure 8. Graph showing the nonsignificant interaction between time and the type of activity at encoding/recall on Accuracy. Condition 1 represents the matching exercise bike condition, condition 2 represents the nonmatching condition of pedaling on the exercise bike at encoding and rolling the ping-pong ball at recall, condition three represents the matching ping-pong ball condition, and condition four represents the nonmatching condition of rolling the ping-pong ball at encoding and pedaling on the exercise bike at recall.

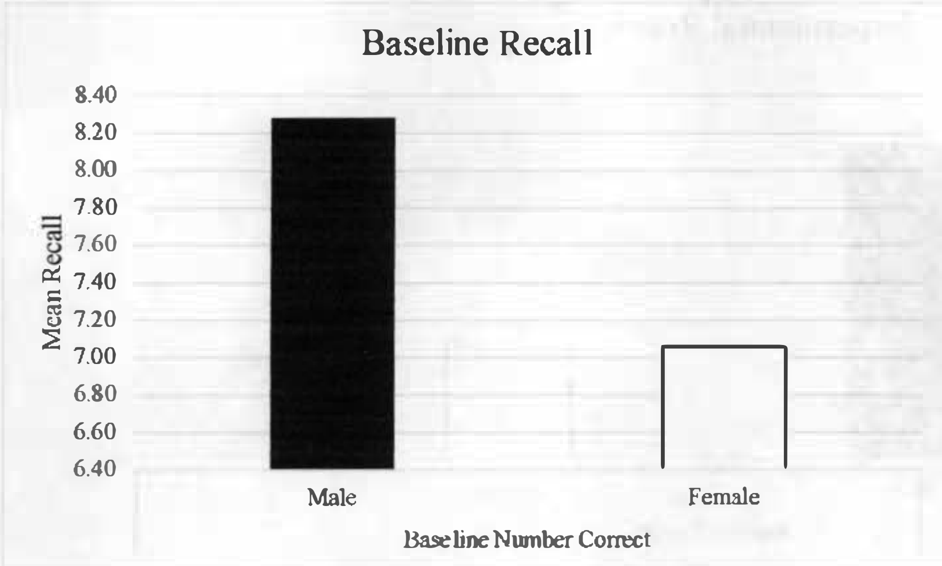

Figure 9. Graph showing the mean number of correct baseline recall responses for male and female participants averaged across conditions.

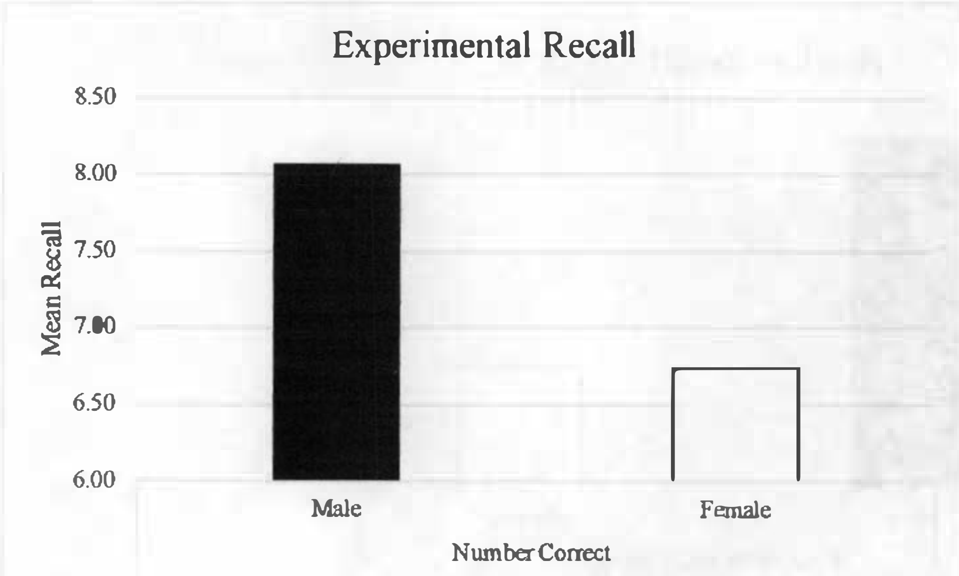

Figure 10. Graph showing the mean number of correct experimental recall responses for male and female participants averaged across conditions.