The Effects of Exercise on Object and Spatial Memory Performance

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Abstract

The current study investigated differences between people participating in regular exercise (3 times a week for 30 minutes) versus people who did not participate in regular exercise on an Object Array and Spatial Memory Task. The Object Array used 2-dimensional arrays, and the Spatial Memory Task used 3-dimensional Vandenberg Mental Rotation Task. The regular exercise group had overall lower scores compared to the non-regular exercise group on all tasks. The sample size for this study was small and uneven, suggesting results are not conclusive and further research will be conducted.

Exercise is when someone takes part in an activity that requires a physical effort, carried out to sustain or improve health and fitness. There are different types of exercise such as aerobic, strength, balance, and flexibility. Aerobic exercise is the bases for overall training; it increases both your breathing and heart rate. Aerobic exercise includes activities such as walking, climbing, biking, dancing, and swimming. Strength exercise helps keep your muscles and bones healthy. Strength exercise involved lifting weights and using resistance machines to build your strength. Flexibility although isn't seen as the most traditional way of exercise but is helpful for a range of motion and usually involved activities like yoga.

It is known that as an individual age their memory does as well, along with their performance on tasks and thinking skills. This understanding of how the brain becomes less reliable over time has led the research community to focus a lot on ways to improve memory specifically in older adults. A lot of research has found exercise to improve memory and thinking skills. It was found that exercise is effective in helping your brain retain long term memory. Exercise is also known to increase the size of one's hippocampus; which is the part of the brain that is responsible for learning and memory.

The purpose of this study is studying the effects of regular exercise on a population of younger adult whose memory isn't already decreasing due to age. Ways of enhancing memory are critical to consider because it could lead to changes in the curriculum in schools; if results were to show with regular exercise cognition is enhanced, schools might implement more regular required gym hours.

Research shows that adults who started with higher fitness have a more significant benefit from acute exercise. Tsai, C., Huang, C., Wang, C., & Chu, I. (2015) experimented with older adults from Taoyuan County, Taiwan who were asked to complete a series of exercise protocols over two weeks. The participants were then asked to complete a cardiovascular fitness test. This study also used the Stroop test to see if fitness influences cognitive function through moderate aerobic exercise. The Stroop test scores improved in the older population of adults who participated in moderate aerobic exercise.

A study done by Carstensen, Hogan, and Mata in 2013 didn't want to look at older or younger adults but wanted to look at the potential age differences on cognitive functions. This study examined age differences after participants performed after a single bout of exercise. Participants ranging in age from 19-93 were randomly put into one of two groups. One was an exercise group who participated in moderate cycling for 15 minutes of, the other was a control group which completed ratings of neutral images. The Effect Assessment was used to test the powerful effects of exercise. Thirteen emotion words (angry, anxious/worried, sad, fatigued, bored, quiet, activated, enthusiastic, excited, calm, content, relaxed, happy) chosen by Barrett and Russell (1999) was used for this assessment. Participants viewed the words on a computer screen and were asked to report on a scale 1 (Very *little or not at all)* to 5 (Extremely*)* how much they were feeling each emotion. This assessment was given to the participants twice during this study.

They found that the exercise group was associated with high arousal positive affect (HAP). On the other hand, the control group was found associated with decreased levels of low arousal positive effect. In terms of age difference; younger adults were related to low-arousal

decisive (LAP) after they exercised. Overall throughout all age groups and in both the HAP and LAP condition participants were found to be more consistent.

Therefore, previous studies have concluded that exercise is beneficial for effective experience as well as cognitive performance. However, the effect of age may or not be a factor for these effects. Head, Singh, Bugg (2012) previously knew that stress hurts the hippocampal structure and function, which is also known to add to age decline. There is also evidence that says exercise is beneficial to older adults. This study specifically observed the effects of long term stress on hippocampal memory, the effects of stress on aging, and the effects of exercise on causes of stress. This experiment administered a questionnaire over the phone, and participants reported the number of workouts per week, average time per mile for each year in which they walked, ran, or jogged for ten years. They predicted that engaging in exercise would be associated with higher lifetime stress and an age-related decline in these variables. This study reported that long term exercise could prevent memory decline, and reduce the negative changes in the hippocampus.

Further, a previous study done by Spirduso (1975) showed that older athletic adults had a shorter response time for reaction tasks compared to less active adults. Since this study, researchers have been looking at the relationship between different populations and cognitive measures. Lambourne (2011) look at the effects of short term exercise on long term memory; specifically the timing of exercise relative to the memory task. The experiment had participants listen to two paragraphs and summarize those 35 minutes after. Participants were assigned to three random groups; exercise before exposure, exercise after exposure, and no exercise. The groups that took part in the exercise had 30 minutes on a cycle ergometer. Results showed that

short term exercises positively influenced recall. They found no significance between the two exercise groups. However, they did find acute exercise positively influenced recall.

Smith and Hartley (1989) also conducted an experiment looking at the relationship between exercise and cognitive abilities in older adults. They hypothesized that people who exercised regularly would have a better working memory, and reaction time compared to those who spent most of their time inactive. This experiment had two groups; one with 62 men and women who exercised regularly, and 62 men and women who were inactive. The participants were tested in two sessions; the first being a vocabulary test, which measured working memory, and reaction time. The second test had three written tests of reasoning. Results were inconclusive, but researchers strongly believe physical exercise has an influence on older individual's cognition.

Overall findings suggest that exercise has significant benefits for both affective experience and cognitive performance regardless of age. Exercise also plays a role in motor affordances, as shown by Mechlinger, Gruenewald, Weiskopf, and Doeller (2016). They examined the role of motor affordances of objects for working memory retention processes. The participants had to retain the object in working memory for a comparison with an S2 stimulus, where brain activation was recorded. They found that retaining information about objects that had actions could easily be retrieved (manipulable objects) in working memory activated the hand region of the ventral premotor cortex (PMC) contralateral to the dominant hand. They believed that the motor programs for working memory would be similar to the motor programs for verbalized working memory. They also see that the motor representations along with other tasks support goal-oriented behavior.

The Mental Rotation Task uses hippocampal memory. The hippocampus supports Memory, specifically spatial memory. The hippocampus allows us to remember where the Location of the object. The hippocampus is the brain region that would help someone remember the Rotation of objects in the Mental Rotation Task (Shrager, Bayley, Bontempi, Hopkins, Squire (2007). In a study by Heidi Godman (2014), researchers found that regular aerobic and resistance exercise increases the size of the hippocampus.

According to previous research, women have an advantage in the Object Array Tasks while men have an advantage in the Mental Rotation Task. Sex differences in spatial cognition are well documented, which increasingly shows males usually outperform females on tasks dealing with mental rotation and spatial navigation. Research also often shows females outperform males on tasks dealing with object location, relational object location memory, or spatial working memory. Levin, Mohamed, and Platek (2005) conducted two experiments to examine behavior and neural sex differences in spatial abilities. In experiment 1 participants did both the mental rotation and spatial working memory tasks. In experiment 2 participants did the same task with a modification during the fMRI. There were two conditions; study condition and test condition. The study condition was the condition in which participants had to remember the location of pairs used in the spatial working memory task. The test condition had participants remember the differences between the two spatial working tasks.

The results for both of these experiments were the same as in the previous study, finding that males outperformed females on the mental rotation task, but that there was no behavioral sex difference on the Spatial Memory Task. Males showed more activation in the left Para hippocampal gyrus, right medial frontal gyrus, inferior parietal lobe, and inferior frontal gyrus in the mental rotation task, for the females showed activation in the left Para hippocampal gyrus

only. Females showed activation in left inferior frontal gyrus, while males activated left inferior parietal and medial frontal areas. For the test conditions, females showed activation in the right inferior frontal gyrus, left middle temporal gyrus, and left Para hippocampal gyrus. Males showed activation in the right medial frontal gyrus and inferior parietal lobe. This data shows behavioral and neutral sex differences that were supported with an evolutionary model; which suggests sexual selection might have favored sex-differences in these tasks.

A study done by Jancy Mathew observed the sex differences in adolescent male and female rats and their influence changes in non-spatial learning and working memory. This study found the effect of ethanol on working memory and non-spatial learning of adolescent male and female rats treated with saline or binge ethanol. The experiment put rats into a secluded area that had two identical objects; they were then reintroduced to those objects after three hours. There were 3 groups with different levels of Ethanol, first had control saline, the second had 1.75 g/kg, and the third group had 3.0 g/kg of ethanol. For all the group's females spent more time exploring the objects during the first five minutes of the trial. There was also a more significant effect was for the Ethanol treated animals. In male rats, there was no difference between time exploring and when the test conditions were manipulated. The data shows there are sex differences in non-spatial learning following ethanol pretreatment in adolescent rats.

A study done by Hayes, Ryan, Schnyer, Nadel (2004) tested participants for the memory of object, spatial, and temporal-order information (while fMRI). This study had 16 participants that watched videotaping of a house tour that showed objects in their specific locations. From the fMRI, researchers found there to be activation in the right Para hippocampal gyrus during the spatial-location tasks. Spatial location and temporal order were associated with activation in the right dorsolateral prefrontal cortex. These findings show the importance of frontal and medial

temporal regions during episodic retrieval. It also indicates an essential role for the hippocampal in the retrieval of spatial-location information.

The present study will examine the effects of regular exercise on cognition in young adults. A majority of past research focused on how short term exercise influenced older adult's memory and ability to perform on various tasks. Therefore this study will look at variables that affect memory through exercise that haven't been examined together before; regular exercise and population of young adults. This will be the first study to examine the effects of regular exercise on cognition in young adults using the Object Array and a Mental Rotations Task. The purpose of this study is to determine if regular exercise affects object memory and spatial abilities. It has been demonstrated that any type of exercise enhances cognition in older adults (Clarkson-Smith, Hartley 1989). It has also been hypothesized that any bouts of exercise compared to no exercise will improve memory (Labban, Etnier 2011). Therefore, I hypothesize that people who exercise three times a week for 30 minutes or more will have enhanced cognitive functions on these tasks.

Method

Participants

Participants were undergraduate students from a public, northeastern college. There were Thirty-four students in psychology classes recruited through email. Participants ranged from ages 19-24. there were twenty-five females (75%), and seven males (25%). There were nine people in the regular exercise group, and 24 in the no exercise group. The criterion for people who were in the regular exercise group exercised three times a week for 30 minutes or more.

Materials

Personal Information Questionnaire. A questionnaire asked participants about their exercise routines, as well as other personal information like age, sex, and race. **(See Appendix A)**

Object Array Task. The Object Array Task has 31 objects drawn in black and white. (Levy, L. J., Astur, Frick (2005). This task has three conditions: Object-Exchange condition, Object-Shift condition, and Novel Object condition. The object-exchange and the object-shift condition has seven objects change positions. The participants were asked to circle the objects that switch positions. The object-shift condition has 14 of the objects move to positions that weren't occupied in the original array. Participants are then asked to circle shifted objects. The last condition is the novel object condition which has 17 of the original objects in their original positions and 14 new objects in the same positions as the old objects. Participants are asked to circle the new objects as previously described (Levy, Astur, Frick 2005). **(See Appendix B)**

Mental Rotation Task. The Mental Rotation Task measures spatial ability (Vandenberg, S. G., & Kuse, A. R. (1978). Participants are shown a target object and have to circle two of the four objects that are rotated versions of the target object. The goal is for the participants to identify which two of the four rotated objects match the target object. **(See Appendix C)**

Procedure

Participants were asked to sign an electronic consent form, which included risks to subjects, purpose, and procedure. Participants were given a link to Qualtrics where they filled out the personal information questionnaire. At the end of this questionnaire, participants were given

a subject number and asked to bring that number to the experiment so that the experimenters could identify them. The participants came to the lab at their scheduled time and were instructed on how to complete the object array and mental rotation task. After they completed these tasks, they were debriefed.

Results

An independent t-test was conducted to look at the differences between the two groups. In the Object exchange condition the regular exercise group (M=4.11, SD=4.31) did not perform as well as the nation regular exercise group (M=6.46, SD=3.02); t (31) = 1.76, p = 0.087. This was consistent for the other two Object Array conditions. The object shift exercise group (M=4.00, SD= 2.44) had lower scores compared to the non-exercise group for the object shift non exercise group (M=4.46, SD= 2.06); t (31) = .540, p= .593. This was also the same for the novel object exercise group (M=9.22, SD= 3.73) had lower scores compared to the novel object no exercise group (M=10.08, SD= 2.30); t (31) =.803, p= .428. In the Mental Rotation task, there was a significant difference in the scores for the regular exercise group (M=6.44, SD= 3.64) and non-exercise group (M=10.67, SD=5.15); t (31) = 0.032, p=2.24.

Discussion

This study investigated how regular exercise affects performance on the Object Array and Mental Rotation tasks. It was hypothesized that people who exercised regularly would outperform those who do not exercise regularly. This study used the Object Array task which measured object memory through the object shift, object exchange, and novel object conditions. This study also used the Mental Rotation task which examined spatial memory.

The results of previous studies Labban and Etnier (2011) and Chu (2015) have found improvements in different populations of adults who participated in the exercise. The current research is inconsistent with these previous findings because the participants who exercised regularly did not have enhanced performance on the Object Array and Mental Rotation tasks. In the study by Labban and Etnier (2011) found that short term exercises positively influenced recall. In another study done by Chu (2015) used the Stroop test which found overall improvements in the older population of adults who participated in aerobic exercise. An increase in older adults who took part in aerobic exercise was also found in a study done by Parks (2014). This article also found there to be a positive relationship between aerobic fitness and memory function. Individuals with higher cardiorespiratory fitness exhibited better implicit memory performance and better long-term memory retention.

There could be many reasons for these conflicting results. One may have been having a small sample size of only 34 students who participated overall. There was also an uneven sample; having only nine students who identified as exercising regularly. Having such an uneven group of participants led to a lack of consistency with prior research. If the number of students who exercised regularly was larger, it might decrease variability in the sample.

The present study also examined the effects of lifestyle exercise on cognitive performance and compared people based on their self-reported exercise habits. This in itself is also a limitation. For our experiment, we didn't assign a specific amount of exercise for the two groups. Therefore we didn't have any control over the main manipulated variable; exercise. Another reason why having a larger sample size is important because having a larger sample size would allow any results to be more indicative of a whole group, instead of results from a group of 9 people who exercise regularly to characterize people who exercise regularly as a whole.

Other studies used intervention methods that specified the amounts of exercise subjects experienced. Our research suggests that people who do regular exercise might have impaired performance for both. Another reason for our conflicting results may be because our subjects were all undergraduate college students, who may feel sleep deprived and stressed from added extracurricular activities like exercise; which may not be ideal for studying the effects of exercise.

Reference

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Ohia-Nwoko, O., Montazeri, S., Lau, Y., & Eriksen, J. L. (2014). Long-term treadmill exercise attenuates tau pathology in P301S tau transgenic mice. Molecular Neurodegeneration, 9, 17.

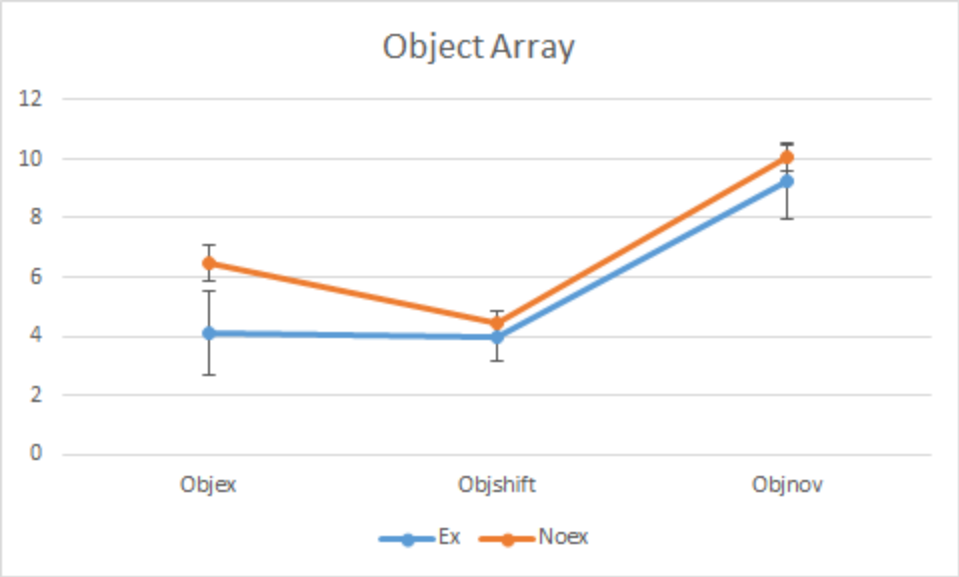


Figure 1: Object Array Task

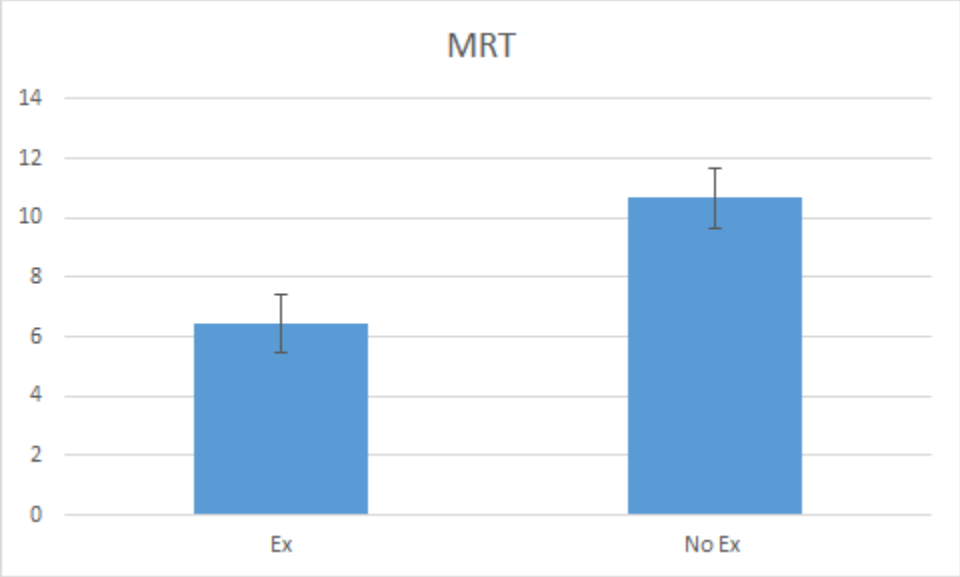


Figure 2: Mental Rotation Task

Appendix A
Informed Consent

Informed Consent Form
Name of Study: The Effects of Exercise, Nicotine and Exogenous Hormone Use on Object Memory and Mental Rotation in Young Men and Women
Researchers: Principal Investigators: Kathleen Beach, Ethan Sua, Lily Otto, Nadia Shadi
Sponsor: Harburger
Contacts: Lauren.harburger@purchase.edu
Sponsor Email: Lauren.harburger@purchase.edu
Purpose: We would like permission to enroll you as a participant in a research study. This study investigates how multiple variables affect cognitive performance.
Procedure: In this experiment, you will be asked to complete a personal information questionnaire. The questionnaire will ask you personal questions ranging from drug and exercise habits to questions about your hormones. After the personal information questionnaire you will be asked to complete two cognitive performance tests. All information collected will be kept anonymous. The study should take approximately 60 minutes.
Costs, risks, and discomforts: This study has minimal risks. The personal information questionnaire may evoke some discomfort from reporting any personal information that one does not wish to share. This study is not mandatory and you can opt out at any time. Your identity will not be reported and will remain anonymous.
Benefits and compensation: The general benefit of participating in scientific research is the satisfaction that comes from contributing to science and the pursuit of knowledge. If applicable, participation in this research will allow college student participants to be compensated through class credit.
Confidentiality: The results of this study may be published in a scholarly book or journal or used for teaching purposes. However, your name and other identifiers will not be used in any publication or teaching materials. Your data will never be associated with your name or any other information that would make it possible to identify you.
Refusal or withdrawal of participation: You do not have to participate in this study. If you decide to participate, you can change your mind and drop out of the study at any time without affecting your present or future interactions with the experimenters and with no loss of credit for

participation.
Signature: I confirm that the purpose of the research, the study procedures, the possible risks and discomforts, as well as potential benefits
that I may experience have been explained to me. All my questions have been answered. I have read this consent form. My signature below
indicates my willingness to participate in this study. I understand that I may contact the chair of the Institutional Review Board if I experience
any problems during this experiment or have concerns about the ethics of this research [**irb.chair@purchase.edu**].
Type in your full name as your signature:

Appendix B

Personal Information Questionnaire

Q2

Personal Information Questionnaire

Age:

Q3

Sex:

· Male

· Female

· Non-Binary

Q4

Assigned sex at birth:

· Male

· Female

Q5

Race (Choose all that apply):

· White/Caucasian

· African-American/Black

· Mexican-American

· Asian-American/Asian

· Puerto-Rican American

· Pacific-Islander

· Middle-Eastern

· American Indian

· Other Latino/Hispanic Origin

· Other

Q6

Relevant Background Information

What were your scores on the SAT? (Type N/A if not applicable)

14

EXERCISE ON OBJECT AND MEMORY PERFORMANCE

Reading and Writing

Q7

Math

Q8

What was your score on the ACT? (Type N/A if not applicable)

Page Break

Q9

How many times per week do you exercise? (If none, type 0):

Display This Question:

If How many times per week do you exercise? (If none, type 0): Text Response Is Greater Than 0

Q10

How many minutes do you spend doing each type of exercise per week?

Stretch Exercise (examples: yoga, any type of dance, zumba)
Resistance Exercise (example: weight lifting)
Cardiovascular Exercise (examples: running, swimming, biking)

Q11

Are you currently part of a sports club, sports team or a dance program?

· Yes
· No

Page Break

Q12

Do you use (or have you used) any Nicotine products?

· Yes
· No

If Do you use (or have you used) any Nicotine products?

· Yes
· No

Q13

What forms of nicotine delivery do/did you use? (Choose all that apply):

· Cigarette/Cigar Smoking
· Vaping
· E-Cig
· Hookah/Water Pipe
· Nicotine Gum
· Nicotine Patch
· Chewing Tobacco
· Other

If Do you use (or have you used) any Nicotine products?

· Yes
· No

Q14

How long have you been a nicotine user? (Amount in years, months, weeks, or days):

If Do you use (or have you used) any Nicotine products?

· Yes

· No
Q15
How many times a day do you use nicotine?
Display This Question:
If Do you use (or have you used) any Nicotine products? Yes Is Selected
Q16
How many times a week do you use nicotine?
If Do you use (or have you used) any Nicotine products? Yes Is Selected
Q17
When was the last time you used nicotine? (Amount in minutes, hours, days, weeks, months, or years)

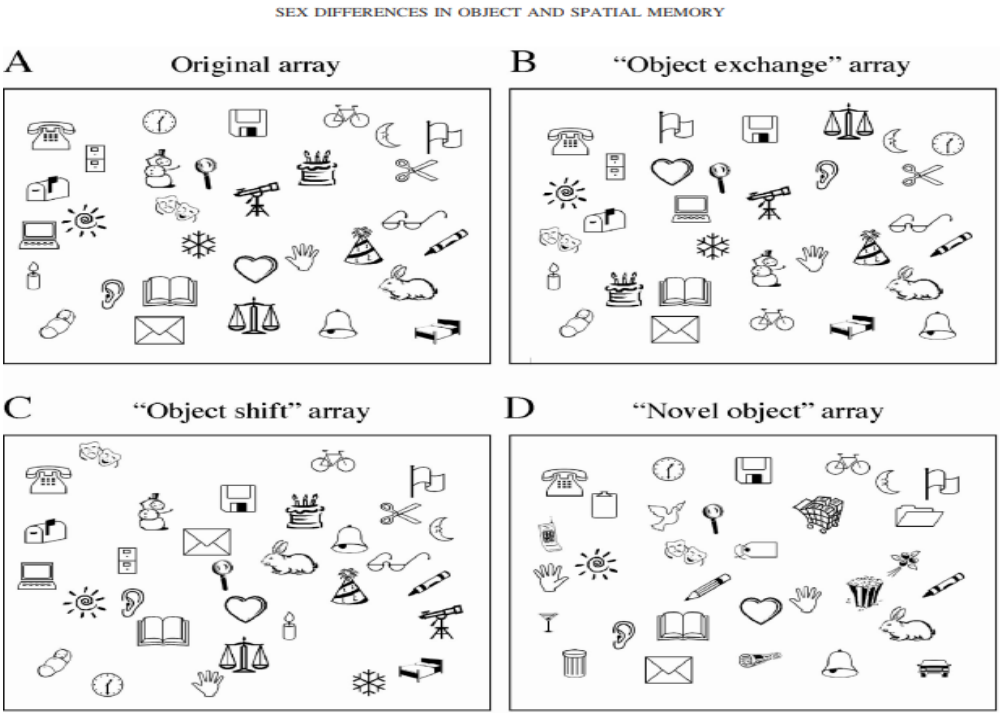
If Assigned sex at birth:
Q18
Females Only:
What was the date of your last menstrual period? (Type N/A if you prefer not to answer):
Display This Question:
If Assigned sex at birth: Female Is Selected
Q19
Are you currently menstruating?
· Yes
· No
· Prefer not to answer
Display This Question:
If Assigned sex at birth: Female Is Selected
Q20
Do you have regular menstrual cycles?
· Yes
· No
· Prefer not to answer
Display This Question:
If Assigned sex at birth: Female Is Selected
Q21
Are you currently pregnant?
· Yes
· No
· Prefer not to answer

If Assigned sex at birth: Female Is Selected
Q22

Are you currently taking any type of birth control that uses artificial hormones including birth control pills or patch, Norplant, Depo Provera, or
others?
· Yes
· No
· Prefer not to answer
Display This Question:
If Are you currently taking any type of birth control that uses artificial hormones including birth…
· Yes
· No
Q23
If so, what type and brand?
If Assigned sex at birth: Female Is Selected
Q24
Are you currently taking any type of estrogen and/or progesterone as prescription hormone therapy?
· Yes
· No
· Prefer not to answer
Display This Question:
If Are you currently taking any type of estrogen and/or progesterone as prescription hormone therapy? Yes Is
Selected
Q25
If so, what type and brand?

Appendix C

Object Array Task



Appendix D
Mental Rotation Task