The Performance of Females on Two Mental Rotation Tasks: A Possible Mediating Role of Female Hormones

Emma McIntosh
Department of Psychology

Submitted in partial fulfillment of the requirements for the degree of Bachelor of Arts, Honours

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University of Prince Edward Island
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Name of Author: Emma F. Mcintosh

Department: Psychology

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Name of Supervisor(s): Dr. Catherine L. Ryan

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Examining Board

____
Tracy Doucette, Ph.D.

____
Nia Phillips, Ph.D.

Thesis Advisor

____
Catherine Ryan, Ph.D.

April 20th, 2015
Date

Thesis by **Emma McIntosh**

entitled

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Abstract

Differences and similarities between the sexes has long been an area of curiosity and inquiry. Historically, research into sex differences in cognition has found differences favouring women in verbal tasks and men in visuospatial tasks. The visuospatial task that has consistently produced the largest and most robust sex differences favouring men has been the Mental Rotation Task.

One of the leading explanatory theories for this sex difference in visuospatial ability has been hormonal influences; particularly the influences' of testosterone and estrogen. Previous research has shown a strong positive testosterone and strong negative estrogen correlation to visuospatial performance, in particular mental rotation performance. Although Mental Rotation Task performance results typically favor males, the data are not altogether consistent across studies, with some failing to report this difference. One explanation for this inconsistency could be that many studies fail to report or investigate the possibility of performance differences between female oral contraceptive users and naturally cycling participants. Oral contraceptives inhibit monthly estrogen fluctuations that accompany the female menstrual cycle, thus hypothetically those participants on oral contraceptives should have enhanced performance on Mental Rotation Tasks in comparison to naturally cycling participants, a finding which could influence studies examining male-female differences.

The current study examined performance differences between oral contraceptive users and naturally cycling participants on two Mental Rotation Tasks: the Shepard and Metzler (1971) and the Vandenberg and Kuse (1978). The results failed to reveal a significant performance difference between these two groups on either of the two mental rotation tasks. However, when collapsed across groups, the data revealed a significant difference ($p < .01$) in performance as measured by correct responses between the two tasks, with participants performing worse on the Vandenberg and Kuse assessment compared to the Shepard and Metzler assessment. Further examination revealed a strong significant relationship between participant’s performances on both assessments while in the menstrual phase, but no relationship between assessments for participants in the luteal or follicular phase.

Continued research with respect to hormonal influences, oral contraceptive influence, and their relationship to sex and cognitive performance is needed. In addition, a more standardized version of the Shepard and Metzler mental rotation task should be developed in an effort to control for variability among conditions in future studies.

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1. Introduction

Differences and similarities between the sexes has long been an area of inquiry and curiosity. Much of this interest has been further fueled by the general finding of sex differences in standard tests of cognitive abilities. In particular, the majority of the literature suggests that men tend to exhibit a performance advantage in neuropsychological assessments of visuospatial ability, whereas women tend to exhibit a performance advantage in neuropsychological assessments of verbal ability.

In recent years, the validity of these cognitive sex differences has been questioned; specifically the magnitude and even further, the existence of these sex differences. Nonetheless much of the literature still strongly suggests prevalent sex differences favouring men in visuospatial abilities and women in verbal abilities (Linn & Petersen, 1985; Voyer, Voyer, Bryden, 1995; Weiss, Kemmler, Deisenhammer, Fleischhacker & Delazer, 2003a). While less debate now remains over the existence of these sex differences and much of the literature now suggests that these sex differences reliably appear in tests of these cognitive abilities, the data is still far from clear across a wide variety of cognition tests and testing sites. Much debate now focuses on the conditions that both contribute to the sex difference and the variability. Among the factors that may contribute to this data are the varying contributions of biological and social factors.

Many different biological and social factors have been examined in an attempt to gain a fuller understanding of the underlying processes causing these cognitive sex differences. Some of the social factors that have been hypothesized to influence these sex differences include: sex socialization differences, gender stereotyping and evolutionary theories. Some of the biological factors that have been hypothesized to influence these sex differences include: neuroanatomical differences and sex differences in lateralization, along with hormonal activational and organizational influences including possible influences of testosterone, estrogen and hormonal contraceptives (in the form of oral contraceptives) on cognitive performance. These theories and the evidence supporting them, or lack thereof, will be further addressed in detail in later sections.

2. Sex Differences in Cognitive Abilities

Sex differences in cognitive abilities have been and still are viewed as a well known research finding. However there have been many instances of this finding being questioned. Debate still remains over whether, real differences actually exist, in which cognitive abilities these differences may exist, and if they do exist is the cause environmental and biological? Questioning of whether or not these sex differences actually exist is further fueled by studies that report non-significant or small effect sizes in sex differences within cognitive abilities (Hugadhl, Thomsen & Ersland, 2006; Walletin, 2008).

Further debate on sex differences in verbal abilities resulted after a meta-analysis performed by Hyde and Linn (1988). In this analysis, the researchers assessed the magnitude of sex differences in verbal ability among 165 studies. They suggested that due to their result of a small effect size (d=0.11) that sex differences in verbal abilities do not exist, and if they do there is only a slight female advantage (Hyde & Linn, 1988). While earlier evidence (i.e. Hyde & Linn, 1988) suggested that sex differences do not exist in verbal abilities, more recent analyses of large-scale international assessments call for a revaluation of this suggestion. In a recent international analysis of data from 1.5 million children's reading performance and linguistic achievements, a large sex difference favouring females was found (Stoet & Geary, 2013). While there has been some question as to whether or not sex differences actually exist in other verbal abilities such as verbal fluency, speed of articulation, and accuracy of speech production, the majority of recent research still suggests that sex differences in some linguistic skills exist. (Halari et al., 2005; Hausmann, Schoofs, Rosenthal, & Jordan, 2009; Weiss et al., 2003a).

Similar to verbal abilities, the claim of sex differences in visuospatial abilities has been frequently questioned (Uecker & Obrzut, 1993; VanStrien & Bouma, 1990). In particular, one of the factors that has led to the questioning of differences in visuospatial abilities in the past, has been the lack of definition or a vague definition of what constitutes visuospatial abilities (Caplan, MacPherson, & Tobin, 1985). Prior to this, visuospatial abilities were defined primarily by a psychometric perspective that focused solely on categorizing abilities in terms of the assessments used to examine these skills. However because individuals may use different strategies in solving different items on the same test, a classification of the common psychometric tests of spatial ability cannot be achieved. Instead, research from the cognitive perspective sought to instead categorize visuospatial abilities by identifying the underlying processes used to solve these tasks (Linn & Petersen, 1985).

One of the first meta analysis performed to solely assess sex differences in visuospatial skills, Linn and Petersen (1985), not only assessed whether these differences in skills actually exist, but also attempted to regulate inconsistent definitions of what constitutes visuospatial abilities by defining what exactly constitutes visuospatial skills. Until this point, visuospatial abilities were loosely defined as: “Spatial ability generally refers to skill in representing, transforming, generating, and recalling symbolic, nonlinguistic information.” (Linn & Petersen, 1985, p.482). Linn and Petersen (1985) therefore divided visuospatial abilities into three distinct categories: spatial perception, mental rotation, and spatial visualization.

Linn and Petersen (1985) initially defined spatial perception as the ability to determine spatial relations, with respect to their own bodies, despite distracting information. One example is the Rod and Frame Test, in which participants must place a rod vertically while viewing a frame oriented at 22 degrees. They then defined mental rotation as the ability to rotate quickly and accurately two or three dimensional figures, mentally in one's imagination. This ability is commonly assessed using Mental Rotation Tasks, where participants are required to determine whether drawings of three-dimensional, asymmetrical assemblages of cubes are identical. Finally they defined spatial visualization as the ability to mentally manipulate complex spatial information when several stages are needed to produce the correct solution. Spatial visualization tasks often include Hidden Figures, Paper Folding, or Block Design assessments. By using this system of classification, Linn and Petersen (1985) suggest that visuospatial ability is not a unitary ability; instead it is a grouping of several different types of ability.

Through their analysis of 172 studies they found that sex differences existed across all three domains of visuospatial skills. While all three categories of visuospatial skills produced the expected sex differences, it was the mental rotation tasks that produced the largest and most robust sex differences that favoured males. Interestingly enough, although Linn and Petersen (1985) assessed studies that included participants prior to, after and during adolescence, they found that there was no clear age in which these sex differences began to manifest themselves. If there was a large sex difference present for the task it was present regardless of the age of participants.

This finding that mental rotation tasks revealed the largest sex differences among visuospatial skills was soon replicated in another analysis by Voyer, Voyer & Bryden (1995). Voyer et al. (1995) sought to examine the magnitude of sex differences but differently from Linn and Peterson (1985) the Voyer et al. analysis took into account the factors affecting the magnitude of sex differences along with the actual size of these differences. Additional factors were assessed for their influence on sex differences and focused on several different methods and variations of testing including: time constrictions, scoring variations, individual versus group testing, sex of the experimenter, selectivity of the sample and dimensionality of assessments.

Their analysis of 286 studies revealed significant sex differences in spatial abilities favoring males to be highly significant. They also found that of the three categories of visuospatial abilities, mental rotation tasks continued to reveal the largest and most robust sex differences favoring men. In addition, results from their analysis of other factors affecting the magnitude of sex differences showed that the Mental Rotations Test produces significant sex differences regardless of how it is scored, but sex differences become more pronounced when the task involved three dimensional versus two dimensional objects and when the testing procedure has strict time limits (Voyer et al., 1995).

Contrary to those findings of Linn and Petersen (1985), Voyer et al. (1995) claimed that there is an increase in the magnitude of sex differences in visuospatial abilities with age, with sex differences in mental rotation tasks beginning between the ages of 13-18. More dramatically and contrary to a previously report by Voyer et al. (1995), recent research has suggested that sex differences in visuospatial abilities, in particular mental rotation tasks, emerge as early as 3-5 months of age albeit in modified versions of standard mental rotation tasks (Moore & Johnson, 2011; Quinn & Liben, 2008; Quinn & Liben, 2013). As evidenced by these various examples there is still remaining debate on when in development these sex differences in visuospatial tasks, in particular mental rotation tasks, emerge. The presence of sex differences at this early in development complicate the ever present question as to why, and when, these differences emerge. Sex differences this early in development seem to suggest that there may be some biological mechanism at play, as this early in development social mechanisms may not exert a major influence over these differences. See Section 4 for a discussion of mental rotation abilities and the tasks used to assess these abilities

While many tests of visuospatial abilities have been consistently marked by a noted male superiority in relation to female performance, it is important to note that there is one visuospatial task in which females have a slight advantage in, namely remembering object locations (Voyer, Postma, Brake & Imperato-McGinley, 2007). In an analysis of 36 studies that produced 123 effect sizes, objection location memory and object identity memory skills were analyzed in female and male participants. Both types of object location and identity memory showed a small sex difference in favour of women. This finding aligns with small to moderate female advantage on other memory tasks including remembering object identities, faces, and lists of words and numbers (Voyer et al., 2007).

Many of different theories of the origin of these sex differences in cognitive abilities center on the age old debate of “nature” (theories of biological and hormonal nature) versus “nurture” (theories of social and evolutionary nature). Throughout the next sections I will address in detail how these different theories attempt to explain sex difference in cognitive abilities.

3. Causes/Influences of Sex Differences in Cognitive Abilities

Research into sex differences in cognitive abilities has looked to social influences as possible causes or explanations for why sex differences may exist in these tasks. Social influences on sex differences in cognitive abilities can be traced far back in our human evolution.

Some have proposed that sex differences in cognitive abilities are evolutionary representations of females' "gathering" status, and males' "hunting" status early in evolution. Some theories suggest that the early hunting and gathering division of labour selected for male reproductive strategies that stress mating effort and female strategies that emphasize parental investment. As a result, women were tasked with the low-risk job of gathering vegetation which was typically done closer to the "nest", whereas men were able to afford a higher risk of failure by hunting animals. Theorists suggest that this division of labour emphasized verbal skills in females, often associated with child rearing, and visuospatial skills in males, often associated with hunting large game (Bird, 1999). Debate remains on whether this division of labour resulted from biological causes or social causes, or from a biological attribution that favours this social division of labour. While there is a lack of concrete evidence in favour of this evolutionary theory other social theories have produced lively debate and theoretical explanations, including sex socialization differences, the idea of sex stereotype influence and stereotype threat (Hyde, 2014).

3.1 Sex socialization differences

Other research has suggested that experience and socialization patterns may play a role in the development of sex differences in visuospatial abilities. Previous research has suggested that practice is necessary for the development of visuospatial skills (Benninger & Newcombe, 1989), and that female children may suffer a relative "practice deficit," due to a lack of activities and experiences in their environment that provide relevant visuospatial practice opportunities (Connor, Schackman, & Serbin, 1978; Signorella, Jamieson, & Rupa, 1989). It has been reported that many spatial activities, such as block building and model constructing, are considered by both male and female individuals to be masculine-stereotyped activities. That is, they are generally considered to be more appropriate for male children than female children in western cultures. In addition, more male children than female children report participating in these types of activities (Newcombe, Bandura, & Taylor, 1983). Activities that predict strong visuospatial skills are also made more available to male children in their homes from infancy (O'Brien & Huston, 1985). As evidenced from the previous research listed, greater access to male sex-typed play materials may be a potential factor in the development of a male advantage on visuospatial tasks.

In a study by Serbin, Zelkowitz, Doyle, Gold & Wheaton (1990) researchers sought to examine the relationship between socialization factors and sex differences in cognitive abilities favouring males. To do so the researchers assessed 347 children, ranging in ages from five to eleven years old, on socialization factors as well as a measure of visuospatial ability.

Socialization factors that were examined included the sex typed division of labor in the household and the availability of sex-typed toys, and these factors were determined from parent completion of questionnaires. The Block Design subscale of Wechsler Intelligence Scales for Children (1974) was selected as a well standardized visuospatial test that could be administered across the age range of the young sample. Their results showed that access to stereotypical masculine toys and activities at home is a predictor of children's visuospatial ability for both sexes. With results indicating that male children tend to have enhanced performance on the Block design subscale, not surprisingly the results also revealed that male children had more access to masculine toys and activities at home (Serbin et al., 1990).

Other social factors that may influence the development of visuospatial skills include other familial influences, particularly the gender of siblings. Research has suggested that for young females in the family, there are two opposite potential effects of the presence of brothers in the family. Brothers may stimulate and enrich the spatial skills of their sisters by encouraging them to join in male stereotyped activities or they may have a negative, inhibiting effect by discouraging their sisters in regards to male stereotyped activities, therefore discouraging spatial skills in their sisters (Casey, Nuttall, & Pezaris, 1999).

3.2 Stereotype Threat

Stereotype threat is defined as the fear of conforming to a negative stereotype associated with a group membership (e.g. sex, race, ethnicity), which then results in an individual possibly behaving in accordance with this stereotype (Steele & Aronson, 1995). While stereotype threat research originally primarily focused on racial stereotypes, the effect has been found in a number of situations, including those associated with sex stereotypes.

Spencer, Steele and Quinn (1999) found that when a mathematics test was described as having previously shown sex differences, women underperformed compared to men. However, when participants were told that the test did not produce sex differences, women performed equally to men. Stereotype threat research suggests that knowledge of a stereotype (e.g. women have poorer performance in assessments of math ability) can affect the cognitive performance of an individual within that stereotyped domain. In addition, being reminded of a negative stereotype, be it explicitly reminded or being placed in the relevant situation, can affect cognitive performance as well. Stereotype threat is not unique to female performance; it has also been found for men when they are compared to women on stereotypically female domains (e.g. Koenig & Eagly, 2005; Leyens, Désert, Croizet & Darcis, 2000).

Previous research has examined the impact of positive and negative stereotypes on men and women’s performance on mental rotation tasks, and as previously discussed the mental rotation task is one that tends to consistently show a male performance advantage. When male participants received instructions emphasizing a female advantage on the assessment, this was found to led to poorer performance for them. Likewise when female participants received instructions emphasizing male superiority on spatial tasks, poorer performance in the female participants resulted (Wraga, Duncan, Jacobs, Helt & Church 2006; Wraga, Helt, Jacobs & Sullivan, 2007).

3.3 Link Between Stereotype Threat and Sex Hormones

Stereotype threat research has now further progressed onto examining stereotype threat as a mediator for another factor believed to be an important influence on sex differences in visuospatial skills: sex hormones (Please refer to Section 3.8 Hormonal Theories of Sex Differences in Visuospatial Abilities for more detail on sex hormones).

Recent research has suggested a possible link between sex stereotypes and sex hormones on their influence of sex differences in cognitive abilities. Josephs, Newman, Brown and Beer (2003) examined this relationship by measuring testosterone levels in both male and female participants who previously indicated that mathematics and math ability were very important to them. After saliva collection participants were informed that they would be taking a test of mathematical reasoning abilities. To activate stereotype threat conditions participants then completed a questionnaire designed to prime stereotype threat, control participants completed a control questionnaire featuring general questions about their university experience. Their results found that females with high and low testosterone levels respond differently to sex stereotypes. Results showed that females with high testosterone levels significantly underperformed in the stereotype threat condition compared to the control condition, while females with low testosterone levels did not differ on performance between conditions. This finding possibly suggests that stereotype threat effects are more pronounced for females who have higher testosterone levels. In contrast, no significant difference in performance was found between males of high and low testosterone (Josephs et al., 2003)

Josephs et al. (2003) conducted another scenario testing the opposite phenomenon of stereotype threat, stereotype lift. In these instances of stereotype lift, emphasis is placed on a positive stereotype about a particular group possibly leading to enhanced performance. Male participants were either given instructions that the test could only identify exceptional math ability, or poor math ability. In the exceptional condition, high testosterone males showed enhanced performance compared to that of low testosterone males. High testosterone males performed better in the exceptional condition compared to that of the weak abilities condition. Josephs et al. (2003) proposed that testosterone levels, of both men and women, may moderate the association between task performance and stereotype threat. Presumably, so too would be the case in alternative stereotyped domains like visuospatial skills.

Hausmann et al. (2009) sought to further examine the interaction between social and biological factors that may influence performance on cognitive tasks. Hausmann et al. (2009) chose to instead examine another stereotyped cognitive domain, visuospatial skills, in particular the mental rotation task. While Josephs et al. (2003) examined testosterone levels as a moderator of stereotype threat; they did not examine the effect of stereotype threat on testosterone, that is, whether a stereotype threat scenario would result in an increase in testosterone, compared to a control condition.

After collection of saliva samples, to activate gender stereotypes, a questionnaire was administered to the experimental group that referred to the cognitive tasks used. Participants were instructed to define whether the tasks were better categorized as a female or male task. The control group received an identical questionnaire but with only gender-neutral content. Their results showed that a male superiority in the Vandenberg and Kuse Mental Rotations Task (1978) was mainly driven by the stereotype-active group (i.e when participants were reminded of male superiority in the tasks males produced enhanced performance while females produced poorer performance). Interestingly, testosterone levels of the male stereotype-activated group were sixty percent higher than that of male controls. These results possibly suggest that sex hormones may mediate the effects of gender stereotypes on specific cognitive abilities (Hausmann et al., 2009).

As such evidence suggests that while social influences, including stereotype threat, may exert influence on sex difference in cognitive abilities, it is more likely that these influences work in conjunction with other factors to possibly produce this cognitive dichotomy.

3.4 Cultural Differences

Similar to stereotype threat, another source of evidence for a biological basis of the male advantage on visuospatial tests is its cross-cultural consistency. Sex differences reported for North American samples on a variety of spatial tasks, including mental rotation tasks, have been replicated in numerous different cultures and countries including: Japan (Silverman, Phillips & Silverman, 1996); Scotland (Berry, 1966; Jahoda, 1980); Ghana (Jahoda, 1980); India, South Africa, and Australia (Porteous, 1965); England (Lynn, 1992); and Sierra Leone (Berry, 1966). An interesting note is that despite these diverse cultures, and their different sex typed activities, results still consistently produced a male advantage in assessments of visuospatial ability. For example, as suggested by Jahoda (1980), both sexes at a young age in Ghana do not have access to building blocks, mechanical toys, or other male stereotyped activities that promote visuospatial skills. Yet despite this sex differences favouring males in the Vandenberg and Kuse (1978) mental rotation task was still found (Jahoda, 1980). As further support for a biological influence on sex differences in visuospatial assessments, several of these studies (Jahoda, 1980; Lynn, 1992) have shown that the magnitude of sex differences, as well as the direction, tends to be similar in culturally diverse groups (Silverman et al., 1996).

3.5 Biological Influences on Sex Differences in Cognitive Abilities

Well observed sex differences in spatial abilities is not a unique phenomenon to humans. Research from non human animal models has also suggested a robust sex differences in spatial abilities favouring males, including in rodent models (Gaulin & Fitzgerald, 1986; Roof, 1992; Spritzer et al. 2011) and in pigeon models as well (Cheng, Spetch, Kelly & Bingman, 2006). This has led to the idea that sex differences favouring males in spatial abilities is a very evolutionarily old and biologically based idea, as it is represented in many lower order animals. Gray and Buffery (1971) offer a possible evolutionary explanation for the superior performance of males on spatial-learning tasks: "It seems likely that, among rodents, this male superiority is connected with the fact that, in the wild, this sex has a larger home range than does the female ... [and that the] activity which is reflected in measurements of home range clearly involves the exercise of spatial ability" (Gray and Buffery 1971, p. 95). However, another interpretation is that the sex difference observed in many species may reflect differences in strategies to solve the problem, rather than absolute performance differences (Luine, 2014)

Due to the evidence for sex differences in visuospatial skills from animal models, research on the biological basis for sex differences in cognitive abilities has flourished in recent years. Many of these biologically based theories address lateralization theories and hormonal theories of sex differences in visuospatial skills.

3.6 Lateralization Theories of Sex Differences in Visuospatial Abilities

In an effort to further understand sex differences in cognitive abilities, researchers have turned to examining brain lateralization differences in these tasks between the sexes. Due to the differences observed behaviorally between the sexes on visuospatial and language tasks (Linn & Petersen, 1985; Weiss et al., 2003a), along with the general findings of hemispheric lateralization for language and visuospatial processing (Eagley, Beall, & Sternberg, 2004; Kimura, 2004), it has been hypothesized that possible differences in laterality for language and visuospatial processing contributes to the sex differences in these cognitive processes (Clements et al., 2006).

Hemispheric lateralization refers to functional specialization within the brain with certain skills and processes being processed primarily in one hemisphere, either the left or right hemisphere (Elias & Saucier, 2006). Many functional neuroimaging studies have suggested that, in both sexes, language processing takes place primarily in the left hemisphere and whereas visuospatial the right hemisphere is primarily responsible for nonverbal visuospatial processing (Eagley et al., 2004; Kimura, 2004; Springer & Deutsch, 1989). However, other findings suggest that instead women are more likely to have a bilateral hemispheric representation for language and that both hemispheres have the capacity to handle language tasks in women, but the role of the right hemisphere in language processing is still highly debated (Clements et al., 2006; Weiss et al., 2003c).

Results on lateralization of visuospatial measures are generally less consistent compared to that of language processing lateralization (Gur et al., 2000; Kimura, 2004; Unterrainer, Wranek, Stafen, Gruber & Ladurner, 2000). During the mental rotation task, certain studies have suggested greater bilateral activation in the inferior parietal lobe in men when compared to women (Gur et al., 2000; Weiss et al., 2003b); however, not all studies have produced consistent results with these reported differences. Unterrainer et al. (2000) suggest that bilateral activation in the parietal lobe and frontal regions is not linked with sex differences, but instead is linked to differences in speed and accuracy of mental rotation task performance.

Unterrainer et al. (2000) found that participants who exhibited poorer performance on a mental rotation task showed bilateral representation in both the frontal and parietal lobes, while those who exhibited better performance had increased left frontal and right parietal lobe activity. In addition other studies have found no differences in cortical activity between the sexes during the mental rotation task (Dietrich et al., 2001), or significantly different activation patterns in frontal and parietal activation during the mental rotation task (Thomsen et al., 2000). Thus, as clearly indicated by these studies and their inconsistent findings, inconsistency is prevalent when examining cortical differences between the sexes on mental rotation, and visuospatial, tasks.

Due to these inconsistencies, Jordan, Wüstenberg, Heinze, Peters, and Jäncke (2002) sought to examine in depth, the cortical activation of women and men who exhibited similar performance in mental rotation tasks, thus gaining the ability to evaluate the factor of sex differences in lateralization, independent of differences in performance levels. For their analysis, Jordan et al. (2002) used the Shepard and Metzler (1971) mental rotation task. Their results indicated that women exhibited significant bilateral activations in the following areas: intraparietal sulcus, the superior and inferior parietal lobule, the inferior temporal gyrus and the premotor areas. Men showed significant activation in the following areas: right parieto-occitpital sulcus, the left intraparietal sulcus and the left superior parietal lobule. Both men and women showed activation of the premotor areas, but men also showed an additional significant activation of the left motor cortex. These results suggest that, contrary to the findings of Unterranier et al. (2000), there are genuine sex differences in cerebral activation patterns during mental rotation task even when performances are similar among the participants (Jordan et al., 2002).

Numerous neuroimaging studies have reported activation in the parietal cortex during performance on mental rotation tasks similar to those findings of Jordan et al. (2002) (e.g. Tagaris, Kim, Strupp & Anderson, 1996). In addition, these results indicated an increased activation in the inferior parietal lobule in males compared to females. The findings that females showed increased activations in frontal lobe and fusiform areas (Jordan et al., 2002) was soon replicated by Weiss et al. (2003b) and Hugdahl et al. (2006).

Extending the findings of Jordan et al. (2002), Hugdahl et al. (2006) examined cortical activity during the Shepard and Metzler (1971) mental rotation task using functional magnetic reasoning imaging (fMRI) technology. The fMRI activation data for both sexes showed significant increases in neuronal activation bilaterally in the superior parietal lobule, although predominantly in the right hemisphere. This finding is in agreement with previous studies on lateralization of mental rotation tasks (Jordan et al., 2002; Tagaris et al., 1996). The parietal lobule thus seems to be important in mental rotation tasks, which as suggested by Hugdahl et al. (2006) may tap into the dorsal pathway of the visual processing system. These results suggest that the role of the right parietal lobe, furthermore, seems to be the same for males and females, since the main sex difference was observed for frontal lobe activations (Hugdahl et al., 2006).

To further examine the neural correlates of sex differences in visuospatial tasks, Halari et al. (2006) examined behavioural performance and blood-oxygenation- level-dependent (BOLD) regional brain activity, using functional magnetic resonance imaging, during a computerized three-dimensional mental rotation task. As expected, male participants demonstrated enhanced performance on the mental rotation task compared to that of female participants. Men and women activated areas in the right superior parietal lobe and the bilateral middle occipital gyrus in association with the rotation condition. In addition, men activated the left middle temporal gyrus and the right angular gyrus (Halari et al., 2006).

Thus, although bilateral activations typically are found in brain imaging studies, numerous studies have consistently reported the right parietal lobule as involved in mental rotation, suggesting a right hemisphere processing dominance. Other studies have, however, reported bilateral parietal lobule activation (Tagaris et al., 1996) or inconsistent laterality across subjects (Dietrich et al., 2001). Thus, the issue of hemispheric asymmetry in brain activation studies of mental rotation remains unsolved.

3.7 Handedness

Neuroimaging studies are not the sole tool used in an attempt to further understand sex differences in lateralization and therefore sex differences in cognitive abilities. Another factor that has been examined in an attempt to better understand cerebral laterality of these cognitive skills has been handedness. Conclusions about lateralization are often inferred from behavior, specifically from hand dominance. Handedness refers to the hand a person is more skilled with and prefers to use, although handedness commonly refers to the hand used to write (Elias & Spencer, 2006; Thilers, Macdonald & Herlitz, 2007).

Previous research has focused on the differences and similarities between left handed and right handed individuals, reporting physiological differences in hormone levels including the finding that right handed individuals have higher free testosterone levels compared to left handed men (Moffat & Hampson, 1996). Left handed individuals also tend to show atypical patterns of lateralization compared to right handed individuals, including less consistent left hemispheric language processing (Knetcht et al., 2000, Thilers, Macdonald & Herlitz, 2007).

To further examine the role of handedness on sex differences in cognitive abilities, Thilers, Macdonald & Herlitz (2007) investigated the pattern of sex differences in cognitive performance and free testosterone levels in samples of right handed and non-right handed participants. In particular, they hypothesized that the right handed group would show expected sex differences favoring men on a visuospatial task. Further, based on previous findings suggesting a differential representation of language functions in non right-handers (Knecht et al., 2000), it was hypothesized that such a hemispheric organization would negatively affect the non right handed men's visuospatial performance, but positively influence their verbal performance, resulting in sex differences of lesser magnitude as compared to groups of right handed individuals (Thilers et al., 2007).

Results showed the expected sex differences in the right handed group, whereas differences were unreliable in the non-right handed group. These results suggest a more bilateral representation of language functions in non-right handed men, possibly affecting their visuospatial performance negatively and their verbal performance positively, thereby reducing cognitive sex differences. Interestingly, the non-right handed women tended to have higher visuospatial performance and had lower verbal fluency performance as compared to right handed women. Thus, supporting the previous hypothesis that right-handed individuals are more likely to show the typical pattern of left hemisphere dominance for language tasks and right hemisphere dominance for perceptual and spatial tasks (Elias & Saucier, 2006; Thilers et al., 2007).

3.8 Hormonal Theories of Sex Differences in Visuospatial Abilities

An important area to consider when examining sex differences in cognitive abilities, specifically visuospatial abilities, is hormonal influences on performance. Hormonal influences begin when human sexual differentiation begins at approximately 7-8 weeks of gestation. At this point in development, the testes develop in male fetuses and begin secreting testosterone (Francis & Gardner, 2004). Testosterone, estrogen, and progesterone are produced mainly in the gonads (the testes and the ovaries). Two other important hormones, luteinizing hormone (LH) and follicle-stimulating hormone (FSH) stimulate the gonads into secreting sex hormones. LH and FSH are secreted from cells in the anterior pituitary gland, and are called gonadotropins due to their role in stimulating the gonads (Francis & Gardner, 2004). The principle regulator of LH and FSH secretion is gonadotropin-releasing hormone (GnRH), which is secreted from the hypothalamus. GnRH stimulates secretion of LH and FSH, which in turn stimulates gonadal secretion of the sex hormones testosterone, estrogen and progesterone (Francis & Gardner, 2004).

It is believed that development during critical periods can be affected by varying amounts of these endogenous sex hormones, estrogen and testosterone, resulting in certain sex-typed behaviours and cognitive patterns or differences later in development (Csathó, Osváth, Bicsák, Karádi, Manning & Kállai 2003). Though both sexes are exposed to estrogen and testosterone during prenatal development, the fetal testes in males and adrenal glands in both sexes generally expose males to higher levels of testosterone while females are exposed to higher levels of estrogen during early prenatal development (Csathó et al., 2003).

3.8.1 Organizational Effects

During critical periods early in development, androgens and their metabolites have an organizational effect on the brain to produce lifelong effects on a variety of reproductive and non-reproductive sexually dimorphic behaviours. The organizational-activational hypothesis, first proposed by Pheonix, Goy, Gerall and Young in 1959, changed the way sexual differentiation of the brain is viewed, and therefore the sexual differentiation of behaviour as a result. Phoenix et al. (1959) in their study, through the use of a guinea pig model, suggested that sex differences in the brain and behaviour were permanently sexually differentiated by testosterone during an early critical period of development.

This was the first study that placed the brain together in a class with other major sexually dimorphic tissues, and proposed an integrated hormonal theory of sexual differentiation for all of these non-gonadal tissues (Pheonix et al., 1959). The authors described an apparent dichotomy between hormonal effects on behaviour. First they described organizational (also referred to as "differentiating") effects as the effects of prenatal testosterone interpreted to have changed the response to gonadal hormones that activate behaviors in adulthood. As they went on to explain, administered prenatally, androgens and their metabolites have an organizing action on the tissues mediating mating behaviour (Pheonix et al., 1959).

In the years since the original Pheonix et al. (1959) article describing the dichotomy of organizational and activational hormonal effects, research has moved past traditionally examining the organizational and activational hormonal effects of sexual reproduction before and onto more generally sex differentiated behaviour. Research has suggested that it may be that prenatal levels of certain organizational hormones not only have a permanent effect on later cognitive patterns but also affects the responsiveness and sensitivity to later circulating (activational) levels of similar hormones (Sanders, Sjodin & de Chastlaine, 2002). Research has suggested that organizational effects impinge on neural structures and behaviors beyond those related to reproduction (de Vries & Södersten, 2009).

Evidence shows that the early presence of organizational effects in the form of androgens may organize the male brain to enhance certain spatial functions. The most noted evidence of this phenomenon comes from individuals with a genetic condition called congenital adrenal hyperplasia (CAH). Congenital adrenal hyperplasia is a genetic condition in which there is an overproduction of androgens in development due to an andrenal enzyme deficiency. Research has shown that female patients with congenital adrenal hyperplasia exhibit enhanced performance on some spatial tasks, including mental rotation tasks, compared to the performance of unaffected female participants (Hampson, Rovet & Altmann, 1998; Resnick, Berenbaum, Gottesman & Bouchard, 1986). When female participants with congenital adrenal hyperplasia and their unaffected sisters' performance on spatial tasks were compared, affected CAH females still exhibited enhanced spatial ability (Hampson et al., 1998). As evidenced by the research listed above, evidence from individuals with congenital adrenal hyperplasia suggests that hormonal influences contribute to sex differences in visuospatial abilities.

3.8.2 Activational Effects

Other hormonal influence research has turned to examining activational hormonal influences. Fluctuations in the levels of these hormones in adulthood, referred to as activational influences, may alter the likelihood that different cognitive patterns will occur. Contrary to organizational effects, activational effects are those hormonal effects that take place during adulthood when the neural tissues mediating mating, and other, behaviour respond to androgens or to estrogens to produce that sex typed behaviour. Essentially, Phoenix et al. (1959) first explained that during the prenatal period testosterone acts to organize tissues so that they respond differently to gonadal hormones in adulthood. In adulthood, the hormones therefore activate those tissues organized prenatally (Phoenix et al., 1959).

As Gerall (2009) later went on to describe in further research on the organizational-activational hypothesis, unlike organizational effects activational actions are temporary. Their duration of action is dependent upon their current presence either in the blood stream or in the tissue substrate. Organizational action or effect refers to the ability of hormones to alter the tissue itself and thereby, permanently modifying the behavioral characteristics that could be manifested by that animal (Gerall, 2009).

The term activational effect is used to refer to the influences that circulating gonadal steroids may exert on cognition (Hampson & Kimura, 1992; Kimura, 1999). To examine activational influences on cognition, many studies have used the menstrual cycle as a tool to look at estrogen and progesterone whereas others have looked at testosterone across its seasonal cycles. Both of these phasic influences on cognition will be discussed further in Section 3.8.4 (Estrogen) and Section 3.8.4(Testosterone).

3.8.3 Testosterone

In research on sex difference in cognitive abilities the two endogenous sex hormones that have been extensively examined for their effect on sex differences in cognitive abilities have been estrogen and testosterone (Phillips & Silverman, 1997; Silverman, Kastuk, Choi & Phillips, 1999). Studies examining both organizational and activational hormonal effects generally show a decrease in spatial abilities with increased estrogen levels, consistent with observed sex differences. In addition, research has suggested that levels of testosterone within the average adult-male range are accompanied by a male advantage on spatial tasks (Hausmann et al., 2009; Phillips & Silverman, 1997; Silverman et al., 1999).

In a study by Yang, Hooven, Boynes, Gray and Pope (2007), the authors reviewed studies assessing the relationship between mental rotation performance and testosterone in men in an attempt to further understand the relationship between testosterone and spatial performance, and if higher levels of testosterone are associated with a male advantage in spatial tasks. Their review produced inconsistent results; they found evidence for positive relationship (Gordon & Lee, 1986; Silverman et al., 1999) negative (Moffat & Hampson, 1996), and no relationship between testosterone levels and spatial performance (Gouchie & Kimura, 1991; Halari et al., 2005). As Yang et al. (2007) went on to further clarify, these inconsistencies could possibly result from a variety of different methodological limitations and differences between studies. While there are many inconsistencies within the research, and the methodology of research, Yang et al. (2007) only assessed a small sample of studies that solely looked at the relationship between testosterone and male performance on visual spatial tasks.

Research into the relationship between testosterone and spatial performance has also examined the effects of testosterone on female spatial performance. In a study by Aleman, Bronk, Kessels, Koppescharr and van Honk (2004), the researchers administered 0.5 mg of sublingual testosterone to female participants in an attempt to understand whether this testosterone administration would improve visuospatial ability in healthy young women on the Vandenberg and Kuse (1978) mental rotation task, a test that has consistently been associated with male performance superiority. All participants were tested twice in a placebo-controlled design. For fourteen of the subjects, the injection order was testosterone followed by a placebo, and in the other twelve participants the order was placebo followed by a testosterone. The two measurements were conducted on separate days, within ten days after their last menstruation. Participants completed the mental rotation task between four and five hours after receiving sublingually 0.5 mg testosterone or placebo (Aleman et al., 2004)

Their results suggested that compared to the results of a placebo control group, female participants who received a single administration of testosterone, had improved visuospatial skills after a testosterone administration. It is important to note that the female participants, who received a testosterone administration, still had significantly improved performance after controlling for learning effects due to repeated testing by including the variable of ‘order of administration’ as a grouping factor in the repeated measures ANOVA analysis (Aleman et al., 2004).

Due to inconsistency in results of testosterone’s influence on sex differences in visuospatial skills, many researchers suggest an inverted U-shaped curvilinear relationship between testosterone levels and visuospatial abilities (Kimura, 1996). This inverted U-shaped curvilinear relationship is referring to the finding that either very low or very high levels of testosterone leads to poorer performance in visuospatial tasks. This inverted U-shaped curvilinear relationship places young healthy males at optimum levels of visuospatial performance, consistent with the results of many studies on sex differences in visuospatial abilities (Aleman et al., 2004**).**

Another interesting factor important to consider when examining testosterone influence on sex differences in visuospatial differences is seasonal differences. Research has suggested that there are in fact seasonal differences in cognitive performance in men, seemingly related to variations in testosterone levels (Kimura & Hampson, 1994). Previous research has shown that male participants with testosterone levels below the median, performed better on visuospatial assessments than those male participants with levels above the median. Such studies suggest that there is some optimum level of testosterone for spatial ability, and that this level is above the level of the average female, but below the level of the average male (Gouchie & Kimura, 1991).

In the northern hemisphere, testosterone levels are higher in men in autumn than in spring, this is thought to be an evolutionary remnant related to optimal mating and offspring production times (Gouchie & Kimura, 1991). If lower testosterone levels within the normal range are associated with better spatial ability, one might expect men's scores on spatial tasks to be higher in spring than in autumn (Gouchie & Kimura, 1991). This indeed turned out to be the case in a study by Kimura and Touissant (1991). Men performed better on tasks with a male advantage, in this case the Vandenberg and Kuse (1978) mental rotation task, in the spring compared to males tested in autumn.

3.8.4 Estrogen

Another sex hormone that has been heavily investigated for its influence on sex differences in visuospatial abilities has been estrogen. One easy and non-invasive method used for studying estrogen's influence on visuospatial performance is by examining female participants at different phases in the menstrual cycle. The female menstrual cycle is divided into three primary phases: menstrual phase (also known as menses), follicular phase, and luteal phase. Within the follicular phase is the ovulatory phase where when an egg (ovule) is released from the ovaries (Rosenthal, 2012). In terms of hormonal fluctuations during the menstrual cycle, the menstrual phase is marked by low levels of both estrogen and progesterone; the follicular phase is marked by the highest levels of estrogen and progesterone while the luteal phase is marked by moderately high levels of estrogen and progesterone (Tortora & Derrickson, 2011). Figure 1 showcases hormonal fluctuations during the average menstrual cycle.

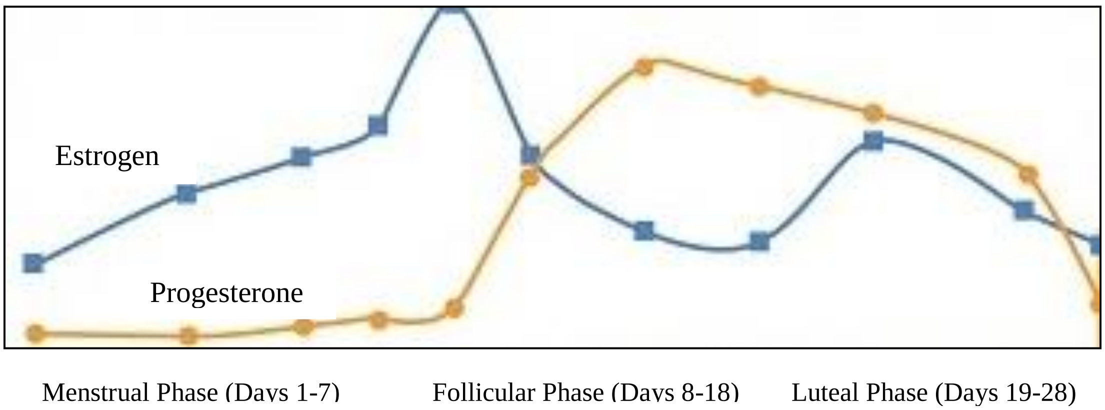

Figure 1: Estrogen and Progesterone levels during an average 28 day menstrual cycle. Adapted from Dzugan (2006).

Evidence has shown that high levels of ovarian hormones may facilitate certain skills that show a female advantage (tests of verbal ability), while being detrimental to skills that show a male advantage (tests of visuospatial ability) (Kimura & Hampson, 1994). The research team of Doreen Kimura and Elizabeth Hampson have published numerous studies investigating this relationship between menstrual cycle hormone fluctuations and visuospatial skills. Hampson & Kimura (1988) administered a battery of neuropsychological assessments including sexually dimorphic tasks to female participants, with a portable version of the Rod-and-Frame test used to assess visuospatial abilities, at numerous different points in the participants' menstrual cycle. Their results provided support for the hypothesis that the high levels of gonadal steroids present at the luteal phase of the menstrual cycle may facilitate skills favouring females, but be detrimental to skills favouring males. Female participants performed poorer on assessments of visuospatial abilities at the midluteal phases of the menstrual cycle (Hampson & Kimura, 1988).

In a follow-up study by Hampson (1990b), a group of normally cycling women were assessed using a battery of cognitive and motor neuropsychological assessments during menses and during the late follicular phase of the menstrual cycle. Once again, a portable version of the

Rod-and-Frame test used to assess visuospatial abilities. By testing female participants at these phases of the menstrual cycle, this allowed the researchers to gain a greater understanding of the influence of not only estrogen but progesterone as well. Progesterone is another endogenous hormone similar to estrogen that plays a role in regulation of the menstrual cycle and pregnancy (Tortora & Derrickson, 2011). Women's menstrual phase (menses) performance, when both estrogen and progesterone levels are low, was compared with their performance a day or two before ovulation (late follicular phase), when estrogen levels are extremely high, but progesterone levels are still relatively low.

The results showed enhanced performance on tests of articulatory and fine motor skills during the late follicular phase, while performance on tests of visuospatial ability, on a portable version of the Rod-and-Frame, were poorer at that time, compared with performance during menses. In addition, participants exhibited enhanced performance on visuospatial assessments during the menstrual phase compared to that of the follicular phase (Hampson, 1990b).

This study provided further evidence for cognitive changes due to hormonal fluctuations, in particular across the menstrual cycle, among some sexually differentiated skills including visuospatial skills. These results again revealed reciprocal changes among abilities that show sex differences favoring males versus females. High levels of estrogen alone did appear to be associated with variation in motor and visuospatial skills, suggesting that is indeed estrogen that exerts stronger effects over performance in visuospatial skills (Hampson, 1990b).

The research team of Kimura and Hampson were not alone in their research on hormonal fluctuations and their influence on sex differences in cognitive abilities, in particular visuospatial abilities. Irwin Silverman and Krista Phillips have replicated many of the findings of Kimura and

Hampson (1988) and Hampson (1990a, 1990b) but using a different spatial measure, the Vandenberg and Kuse Mental Rotations Task (1978). In a study conducted by Silverman and Phillips (1993), women showed significantly better spatial performance during the menstrual phase of the cycle, compared with their performance during the early luteal phase, similar to the findings of Kimura and Hampson (1988).

Specifically Silverman and Phillips (1997) next examined differences in the relationship of menstrual cycle phase to spatial performance on two- and three-dimensional mental rotation tasks. Their results replicated those findings of Hampson (1990a, 1990b) along with Kimura and Hampson (1988) with female participants performing better during the menstrual phase as compared to midluteal phase of the menstrual cycle. Interestingly, menstrual cycle phase differences in the form of poorer performance during the midluteal phase of the menstrual cycle, was found for all three-dimensional, but not two-dimensional tests (Silverman & Phillips, 1997).They hypothesized that compared to the two-dimensional tests, the three dimensional tests provide a purer measure of spatial processing, that they possess greater ecological validity, and are more representative of the common spatial stimuli we are presented with in reality. Another proposed hypothesis is that the two types of tasks, two dimensional versus three dimensional, are mediated by different neural processes, with only three dimensional tasks being influenced by hormonal processes.

These research findings of females showing lower mental rotation performance during the follicular or midluteal phase, which corresponds hormonally to high estrogen and progesterone levels, and higher mental rotation scores during menses, corresponding to low estrogen and progesterone levels, has been replicated by numerous other researchers using the same experimental paradigm (Maki, Rich & Rosenbaum 2002; Moody, 1997; Schöning et al., 2007). The results of these studies and others examining menstrual cycle fluctuation and the corresponding cognitive performance are presented in Table 1.

Similar to those findings of Silverman and Phillips (1997), Hausmann, Slabbekoorn, Van Goozen, Cohen-Kettenis & Gunturkun (2000) found menstrual cycle related differences in a three dimensional version of the mental rotation task, with higher scores during the menstrual phase than during the midluteal phase. In this study, mental rotation task performance was positively and negatively related to testosterone and estrogen levels, respectively. This finding has further been supported by Maki et al. (2002) who also found higher mental rotation task scores during the menses than midluteal phase, and also found estrogen levels to be negatively related to mental rotation task performance. Additionally, they found a positive relationship between estrogen levels and verbal fluency (Maki et al., 2002).

As evidenced by the various research studies listed above, the evidence suggests that there is a negative relationship between estrogen levels and performance on visuospatial assessments. Estrogen is not the only hormone implicated in performance on tests of visuospatial abilities; testosterone has a positive relationship with performance. Strong evidence suggests that hormones and their organizational and activational effects have a significant influence on participants’ performance on assessments of visuospatial skills.

Study	Assessment	Menstrual Cycle Phase Corresponding to Poorest Performance	Menstrual Cycle Phase Corresponding to Enhanced Performance
Kimura & Hampson (1988)	Battery of cognitive and motor tests	Midluteal Phase	Menstrual Phase
Hampson (1990a)	Battery of cognitive and motor tests	Late Follicular Phase	Menstrual Phase
Hampson (1990b)	Battery of cognitive and motor tests	Late Follicular Phase	Menstrual Phase
Phillips & Silverman (1993)	Vandenberg and Kuse Mental Rotation Task	Midluteal Phase	Menstrual Phase
Phillips & Silverman (1997)	Vandenberg and Kuse Mental Rotation Tasks	Midluteal Phase	Menstrual Phase
Maki et al. (2002)	Vandenberg and Kuse Mental Rotation Task	Midluteal Phase	Menstrual Phase
Moody (1997)	Vandenberg and Kuse Mental Rotation Task	Midluteal Phase	Menstrual Phase
Schöning et al. (2007)	Vandenberg and Kuse Mental Rotation Task	Midluteal Phase	Menstrual Phase
Hausmann et al. (2000)	Vandenberg and Kuse Mental Rotation Task	Midluteal Phase	Menstrual Phase

Table 1: Table detailing numerous referenced studies and their results when examining menstrual cycle influences on assessments of visuospatial ability.

3.8.5 Oral Contraceptive Usage

In recent years, research has now turned to examining further hormonal influences on cognitive abilities through examining the influence of oral contraceptives on cognitive performance. One of the most common types of hormonal contraceptives is oral contraceptives. Oral contraceptives act centrally (mainly at the hypothalamic level) and peripherally to inhibit follicular growth, reduce overall endogenous sex steroid levels and prevent monthly hormonal fluctuations (Gordon & Lee, 1993; Rosenthal, 2012). Nearly all previous studies examining hormonal influences in female participants, particularly those that examined menstrual cycle fluctuations in performance, did not address or evaluate oral contraceptive usage in participants (Hampson 1990a, 1990b; Maki et al., 2002; Phillips & Silverman, 1993, 1997; Schöning et al., 2002)

As previously mentioned, research has suggested that performance on assessments of cognitive ability are sensitive to fluctuations in hormone levels, in particular testosterone and estrogen. With oral contraceptives, the level of sex hormones can be suppressed, as evidenced in Figure 2. However, the data about the effect of this relatively short-term and reversible change in hormonal levels on cognitive functions caused by oral contraceptive usage are sparse and contradictory (Gordon & Lee, 1993; Mordecai, Rubin & Maki, 2008; Rosenberg & Park, 2002). An important note is that with many of the few studies that examined oral contraceptive usage's influence on cognitive performance, their hypotheses were not centered on examining the influence of oral contraceptive usage on cognitive performance. Instead, in these studies, oral contraceptive usage was examined as an additional demographic and variable to include in the analysis.

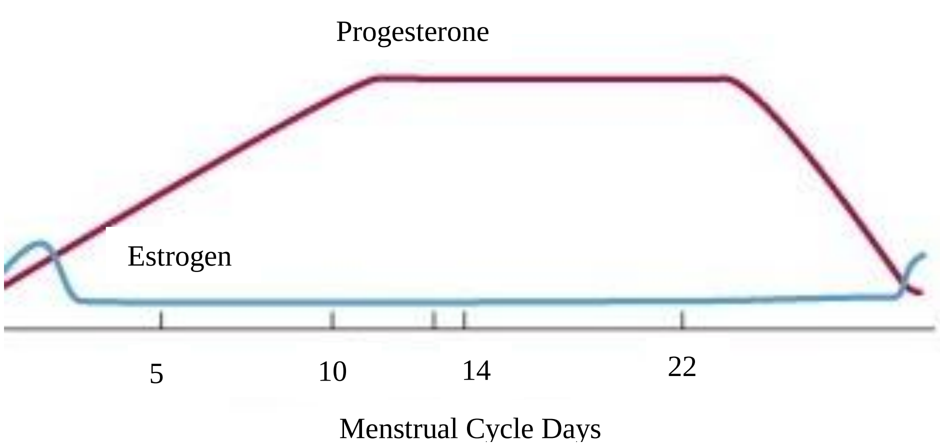

Figure 2: Hormonal regulation of the menstrual cycle in oral contraceptive users. Adapted from Alvergne & Lummaa (2006)

In a recent study by Griksiene and Ruksenas (2011), researchers sought to examine oral contraceptive usage and its influence on mental rotation and verbal fluency abilities. Participants' performance on mental rotation and verbal fluency tasks was investigated in oral contraceptive users and non-users during two phases of the menstrual cycle: the follicular and luteal phases of the menstrual cycle.

Their results showed that naturally cycling women performed better on a verbal fluency task as compared to oral contraceptive users. Surprisingly, the mental rotation and verbal fluency scores did not vary depending on the phase of menstrual cycle (Grieksiene & Ruksenas, 2011). Given that oral contraceptive users have lower levels of estrogen, the poorer performance for oral contraceptive users is not as surprising as there is a general consensus that there is a positive relationship between estrogen and verbal ability performance (Hausmann et al., 2009**)**. In addition, oral contraceptive users demonstrated significantly longer response time in the mental rotation task compared to naturally cycling participants. This finding was inconsistent with the previous studies that assessed oral contraceptive performance on mental rotation tasks that found no differences in performance between naturally cycling participants and oral contraceptive users. But this could be partially attributable to the researchers' use of a non-standard Mental Rotation Task (Rosenberg & Park, 2002).

More recent research has examined not only the behavioural differences among naturally cycling and oral contraceptive users, but is now beginning to examine neuroanatomical differences between these two populations as well. Pletzer, Kronbichler and Kerschbaum (*In press*) in one of the first research studies examining neuroanatomical differences, found that relative gray matter volumes were significantly larger in oral contraceptive users compared to naturally cycling participants in the following areas: bilateral fuisform gyri, fusiform face area, parahippocampal place area, and cerebellum. In addition, many of these cortical areas were significantly larger the longer the duration of oral contraceptive use. These findings suggest possible differential effects of oral contraceptive usage on brain structure, but as this is a new area of research, further investigation is need to confirm these differential effects on brain structure.

As evidenced above, similar to the influential effects of hormone fluctuations on cognitive performance, oral contraceptive usage influences cognitive performance as well. As this is a relatively new foray into research on hormonal influences on cognitive performance, and inconsistencies remain within the research, further investigation is needed to confirm oral contraceptive usage's influences on cognitive performance.

4. Mental Rotation Task

One of the most commonly used measures of visuospatial skills is the mental rotation task. The mental rotation task was first introduced into cognitive science in by Roger Shepard and Jacqueline Metzler in 1971. In their well known experiment Shepard and Metzler sought to study the phenomenon of how human subjects are often able to determine that two different two-dimensional images portray objects of the same three-dimensional shape despite that these objects are depicted in very different orientations (Shepard & Metzler, 1971).

4.1 Shepard and Metzler (1971) Mental Rotation Task

In the original Shepard and Metzler mental rotation task participants are presented with pairs of drawings of three-dimensional, asymmetrical assemblages of cubes. In each pair of drawings, the right picture either shows an assemblage identical to that shown on the left, but rotated from the original position by a certain degree, or it shows an assemblage that was not only rotated, but was also the mirror image of the one to the left. The purpose of the experimental task is to determine, as rapidly as possible if the two objects depicted were in fact identical (except for rotation), or were mirror images (Shepard & Metzler, 1971). Figure 2 illustrates a standard pair of drawings presented in the Shepard and Metzler mental rotation task.

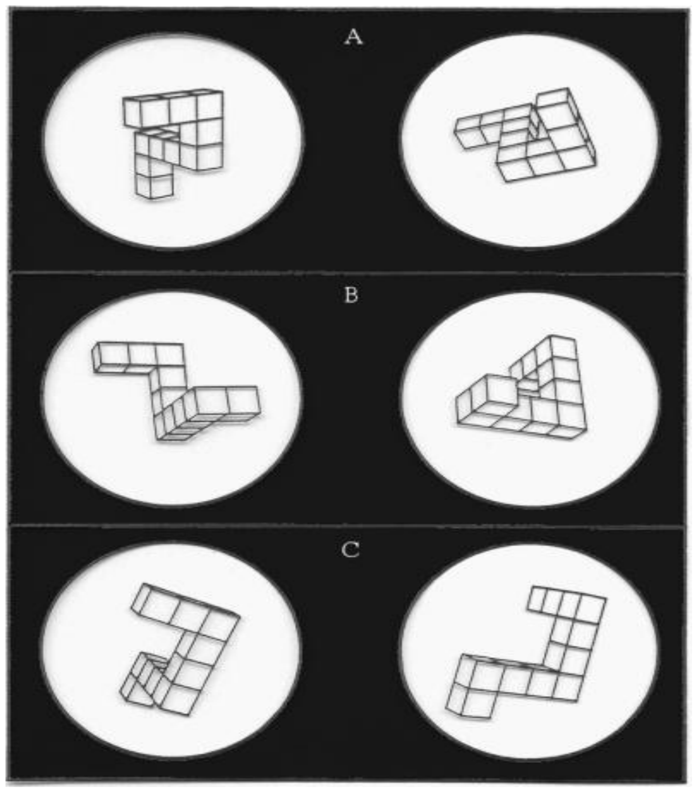

Figure 3: The Shepard and Metzler (1971) mental rotation task.

The original Shepard and Metzler (1971) results showed that the time required to recognize that the two perspective drawings portray objects of the same three-dimensional shape was found to be influenced by two main things. First, an increasing of the angular difference in the portrayed orientations of the two objects resulted in longer response time in the participants. Thus they found that response time was a linear function of the angular difference between the two three-dimensional objects portrayed. Secondly, there were no significant differences in response to corresponding to a rigid rotation of one of the two-dimensional drawings in its own picture plane than for differences corresponding to a rotation of the three-dimensional object in depth. Interestingly, sex differences in the mental rotation task were not observed in the Shepard and Metzler (1971) study.

The Shepard and Metzler study was one of the first research studies that gave us insight into the ongoing cognitive processes occurring during this assessment. How was it that the participants could determine whether or not the two objects matched despite their differing orientations? The subjects in Shepard and Metzler's study (1971) claimed that to make the required comparison they first had to imagine one object as rotated into the same orientation as the other and that, since they perceived the two-dimensional pictures as objects in three-dimensional space, they could imagine the rotation around whichever axis was required with equal ease.

4.2 Vandenberg and Kuse (1978) Mental Rotation Task

As previously mentioned, sex differences in the mental rotation task were not observed in the Shepard and Metzler study (1971), however in another well known study and assessment of mental rotation Vandenberg and Kuse (1978) sex differences were indeed found. Steven G. Vandenberg and Allan R. Kuse conducted a similar experiment to that of Shepard and Metzler's (1971) original mental rotation study. The modified Vandenberg and Kuse mental rotation task was different from Shepard and Metzler's original task as it was a paper-and-pencil test of spatial visualization, and the images used for the test were constructed from India ink drawings.

In the Vandenberg and Kuse mental rotation task (1978) each original stimulus was a two-dimensional projection of one of five three-dimensional objects. Each stimulus was shown in a different orientation after it had been rotated a specified amount around the vertical axis. The

Vandenberg and Kuse Mental Rotations Test contains 20 items in five sets of four items. Each item consists of a criterion figure, two correct alternatives, and two incorrect one or "distractors". Figure 3 illustrates the Vandenberg and Kuse mental rotation test. The participant is required to indicate which of the four figures are identical to the criterion figure. Thus while the original Shepard and Metzler task and the modified Vandenberg and Kuse task are similar measures of visuospatial ability, there are distinct differences between the two versions.

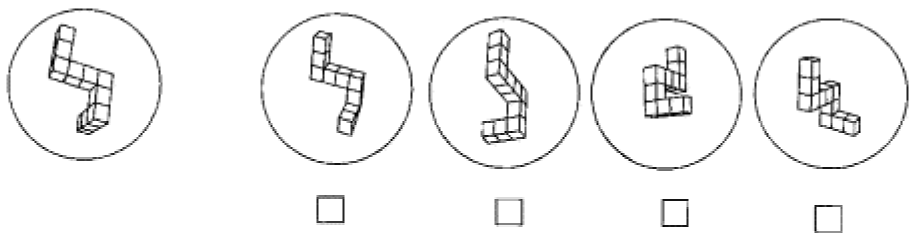

Figure 4: The Vandenberg and Kuse (1978) mental rotation task.

4.3 Sex Differences in Mental Rotation Tasks

As previously mentioned, sex differences in visuospatial abilities are most prominent in tests of mental rotation ability (Linn & Petersen, 1985; Maccoby & Jacklin, 1974; Voyer et al., 1995). Evidence suggests that both versions of the Mental Rotations Test produce significant sex differences regardless of how they are scored. However, the magnitude of sex differences is largest when the test is scored out of 20 instead of 40 and smallest when it is administered in an unconventional format (i.e. with no time restrictions) (Voyer et al., 1995).

Both the Shepard and Metzler and Vandenberg and Kuse types of mental rotation tasks yield consistent sex differences across ages, although the magnitude of the difference depends on the test used (Linn & Petersen, 1985; Voyer et al., 1995). In fact, evidence has suggested that there are larger effects at all ages for the Vandenberg and Kuse (1978) version of the Shepard and Metzler Mental Rotation Test than for the other measures of mental rotation (Linn & Petersen, 1985).

An important aspect to consider when comparing mental rotation tasks is the aspect of dimensionality. In the traditional Shepard and Metzler and Vandenberg and Kuse versions of the mental rotation task, participants are presented with two dimensional prints of three dimensional objects. In earlier studies of mental rotation ability, Shepard and Cooper (1982) found no effect of dimension when rotation of two- and three-dimensional objects was compared. Further research has suggested that mental rotation tasks consisting of two dimensional prints of three dimensional objects produce the largest sex differences favouring males (Linn & Petersen, 1985; Phillips & Silverman, 1997). Researchers have suggested that these three-dimensional tasks represent valid representations of the spatial world and as such are sensitive measures of biological influences on spatial ability (Phillips & Silverman, 1997)

In more recent research, this phenomenon of a male advantage on three dimensional mental rotation testing has been challenged. Results from a study performed by McWilliams, Hamilton and Muncer (1997) have suggested that the male advantage with three dimensional testing is significantly reduced when the rotation task is presented in the form of true three-dimensional models, as compared to presenting the traditional two dimensional prints of three dimensional objects (McWilliams et al., 1997).

This finding was soon replicated by Roberts and Bell (2003) who analyzed sex differences in brain activation patterns on a two dimensional as well as a three dimensional mental rotation task. Male participants showed more right hemispheric activation than females in the two dimensional task while both sexes showed more right hemispheric activation in the three dimensional task. Interestingly, sex differences favouring males in performance, in this case differences in response time, resulted only in the two dimensional task, not the three dimensional task (Roberts & Bell, 2003).

In a more recent analysis of this phenomenon, Neubauer, Bergner and Schatz (2010) sought to examine further the sex differences shown to emerge only for two dimensional presentations of three dimensional objects versus authentic three dimensional objects. As the previous research and their hypothesis predicted, once again, sex differences were more prominent on the two dimensional versions of the task compared to those results of the three dimensional task. Neubauer et al. (2010) observed a general facilitating effect of three dimensional presentation (compared to that of the two dimensional presentation), both with respect to accuracy scores as well as for response time.

While the evidence suggests that there is a clear sex difference present in two dimensional tasks but not in three dimensional tasks, Neubauer et al. (2010) sought to expand on this further and develop possible explanations for the mechanisms behind this phenomenon. Three dimensional presentation of the three dimensional figures seems to ‘release’ the information processing load for all individuals, but more significantly for females.

A possible explanation for this phenomenon emerged in a prior meta analysis performed by Voyer et al. (1995). They hypothesized that certain spatial tasks require transforming a spatial problem presented in two dimensions to a solution in three dimensions, a phenomenon they called ‘dimensionality crossing’. The authors suggested that this phenomenon of dimensionality crossing could be responsible for sex differences favoring males in mental rotation tasks, in particular in two dimensional tasks. McWilliams et al. (1997) extended this hypothesis further by arguing that usage of real three dimensional objects reduced task complexity for females because their problems with cross-dimensionality may be resolved, leading to an overall decrease in sex differences. Based on these and other findings some researchers are hypothesizing that the female disadvantage in mental rotation tasks may lie within the derivation of a three dimensional image representation versus that of a two dimensional representation (Neubauer et al. 2010; Parsons et al., 2004).

With increasing technological advances, researchers have begun to examine if there are any differences between the traditional pen and paper tests of mental rotation and tests in virtual environment. Virtual environment testing is described as an advanced computer program that allows humans to become immersed within a computer-generated simulated environment (Parsons et al., 2004). In one of the first studies examining this difference, Parsons et al. (2004) employed virtual reality spatial rotation tasks and compared those to the classic paper and pencil version and, while replicating the sex difference in the paper and pencil version, they found no sex effects in the virtual environment (Parsons et al., 2004).

Parsons et al. (2004), when explaining this disappearance of a sex difference with virtual reality mental rotation tasks, argued that virtual reality objects do not require the creation of three dimensional cognitive representations from two dimensional drawings (a phenomenon coined dimensionality crossing by Voyer et al. [1995]).

As previously mentioned, Neubaeur et al. (2010) sought to examine further the sex differences shown to emerge only for two dimensional presentations of three dimensional objects versus authentic three dimensional objects, this research study utilized both a paper and pencil version of the mental rotations test and a virtual environment. Their results replicated these sex differences traditionally seen on paper-and-pencil measures, while no sex effects were observed in the virtual environment.

As evidenced above there are many differences between versions of mental rotation tasks, including the specific assessment used (Shepard & Metzler or the modified Vandenberg & Kuse), dimensionality, and presentation of the assessment (pen and paper or virtual environment). All of these factors are important in understanding the prevalence and underlying causes of sex differences in mental rotation tasks.

5. Current Study

While debate still remains on the primary cause of sex differences in cognitive abilities, many different theories have emerged attempting to gain a deeper understanding as to why these sex differences emerge. One area of research that has received attention has been hormonal influences on cognitive sex differences. Two of the primary endogenous hormones that have been examined for their effects on cognitive performance are estrogen and testosterone. Evidence has shown that for visuospatial performance there is a positive testosterone and negative estrogen relationship.

While testosterone and estrogen have been examined for their effect on sex differences in cognitive abilities, particularly visuospatial abilities, one area of sex hormonal influence on mental rotation tasks that has yet to be examined in depth is the role of oral contraceptives on females' performance. Only one study, Griksiene and Ruksenas (2011), has directly examined performance differences between oral contraceptive users and naturally cycling participants on a mental rotation task. They found that oral contraceptive users had significantly longer response times, but no significant differences in correct answer scores on the Shepard and Metzler mental rotation task.

However, this has yet to be examined on another mental rotation task: Vandenberg and Kuse (1978), another popular mental rotation task that is reported by some to be more sensitive to hormonal process (Voyer et al., 1995). As previously discussed, there are many differences between these two versions of the mental rotation task and previous research has noted that the Vandenberg and Kuse three-dimensional model of the original Shepard and Metzler two-dimensional mental rotation task has produced larger sex differences along with increased sensitivity to hormonal processes (Phillips & Silverman, 1997; Voyer et al., 1995).

The purpose of the current study was to determine whether the variability in sex differences reported in the literature could be influence by the possibility that female performance variability could be the result of some females using oral contraceptives. To this end, the current study examined whether or not performance differences between oral contraceptive users and naturally cycling women would be manifested in two separate versions of a mental rotation task, the Vandenberg and Kuse (1978) and the Shepard and Metzler (1971) mental rotation tasks. Additionally the possible effect of phase of the menstrual cycle on performance measures in these two mental rotation tasks was also investigated, along with possible performance differences between the assessments .

6. Methods

6.1 Participants

A total of 50 participants were recruited, with 25 participants in each group (naturally cycling or oral contraceptive user). One participant's data from the naturally cycling group was discarded due to menstrual cycle irregularity. In addition, another participant's data was discarded from the oral contraceptive group as that participant has been diagnosed with a genetic disorder known to influence levels of sex hormones, including estrogen (Francis & Gardner, 2004). Thus in statistical analysis 24 participants were included in each group, oral contraceptive users and naturally cycling participants. Participants were primarily recruited from Psychology courses and social media advertising via a post made to the UPEI Psychology Arts and Science Society's Facebook page. Participants were compensated for their participation with entry into a $50 cash prize. The mean age of participants was 21.5, and they ranged in ages from 18 to 44, with a Standard Deviation of 4.75.

6.2 Apparatus & Procedure

Participants first filled out a questionnaire detailing standard and noninvasive questions regarding their menstrual cycle and oral contraceptive usage (see Appendix A). Naturally cycling participants were asked to indicate the date their last menses began. The participants information was then used to determine what phase of the menstrual cycle (e.g., menstrual, luteal, or follicular) the participant was in. Participants on oral contraceptives were required to have been on oral contraceptives for over a month to be included in the oral contraceptive users group. If a participant indicated they were on oral contraceptives for less than a month, their data was discarded. No questions as to why participants were taking oral contraceptives were asked on the questionnaire as this information was not relevant for the study. In addition, participants completed a separate contact information card that was kept in a locked storage box separate to their menstrual cycle/oral contraceptive questionnaire to ensure anonymity.

Participants completed both the Shepard and Metzler (1971) and the Vandenberg and Kuse revised (1978) paper and pen versions of the mental rotation task (see Appendix B & C).

The order of presentation of the Shepard and Metzler assessment or the Vandenberg and Kuse assessment first was counterbalanced. The Vandenberg and Kuse redrawn MRT-A assessment was provided by Dr. Michael Peters (Peters, 1995) and the images used to create the Shepard and Metzler assessment was provided by Drs. Michael Peters and Christine Battista from the "Library of Shepard and Metzler type mental rotation stimuli'' (Peters & Battista, 2008). Participants were given a three minutes break between assessments.

The Shepard and Metzler task required participants to determine whether two drawings of three-dimensional, asymmetrical assemblages of cubes were identical (See Appendix B for a copy of the entire task). This task consisted of 20 sets of rotated cubes, with two sets of rotated images per page, and with a 7 minutes time limit. The images of ten white cubes in a white background with black borders around the cubes were used. Participants indicated if the two images were mirror images by marking below the images with an "X". Participants indicated if the two images were the same image but at a different rotation by marking below the images with a checkmark. This assessment consisted of 10 mirror images and 10 identical images. Both the participant's total response time and answers were recorded. All of the stimuli were rotated in 5 degree steps from a reference stimulus orientation (0 degrees), from 0 to 360 degrees. Each of these stimuli was rotated around the vertical axis "z" (i.e. dancer spinning around vertical axis).

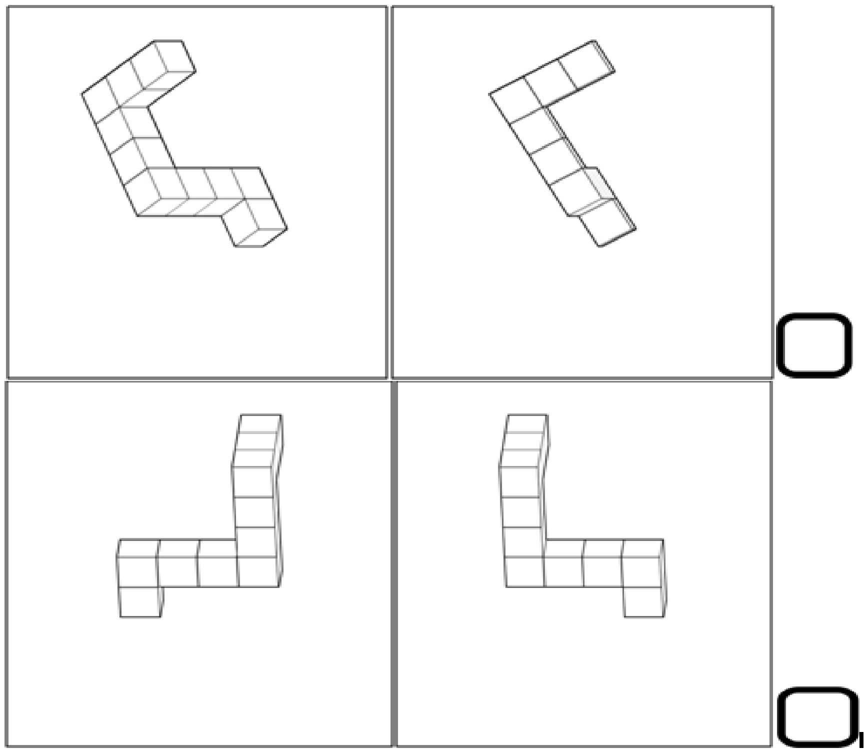

Figure 5: An example of a mirror image presentation (above row) versus a rotated image (bottom row) presentation in the Shepard and Metzler mental rotation task

The second task, the redrawn Vandenberg and Kuse task, required participants to determine which two of four drawings of three-dimensional asymmetrical assemblages of cubes were identical to the criterion figure (See Appendix C for a copy of the entire task). The Vandenberg and Kuse redrawn task used is referred to as the MRT-A assessment, and was developed by Dr. Michael Peters et al. (1995). Each row of images consisted of a criterion figure, two correctly rotated images, and two distractor images. This task required participants to complete a 24 item set with a time limit of 6 minutes. Participants indicated which two of the four images were the correctly rotated images by marking the images with an "X". Both the total response time and answers were recorded. Participants received a score of 1 only if they correctly identified both correctly rotated images, thus for this assessment the maximum score was 24. Similar to the Shepard and Metzler task, the images used in the Vandenberg and Kuse task were composed of ten white cubes on a white background with black borders around the cubes.

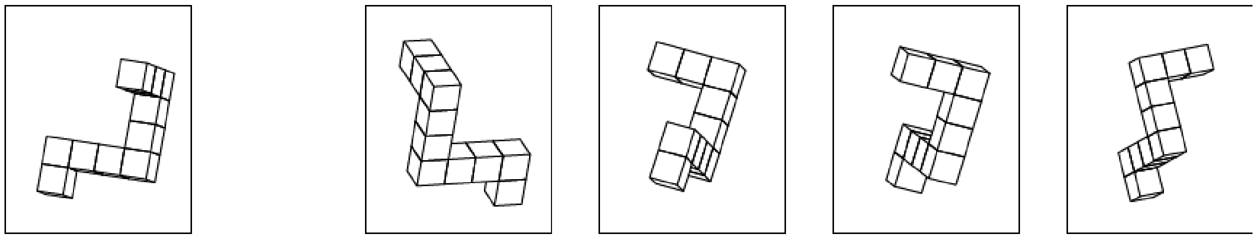

Figure 6: An example of a question in the Vandenberg and Kuse redrawn mental rotation task. On the far left is the target image. The first and third images (from the left) are the correctly rotated images, with the other two images acting as distractors.

6.3 Data Compilation

All analyses were run in SPSS Statistics 21, version 21.0.0 (SPSS, Inc., Chicago, IL, USA). Oral contraceptive users were given a nominal label of 1, while naturally cycling participants were given a label of 2. Those naturally cycling participants that were in the menstrual phase were given a nominal label of 1, while those in the follicular phase were given a label of 2, and those in the luteal phase were given a label of 3.

To compare overall performance differences between the Shepard and Metzler assessment and the Vandenberg and Kuse assessment all correct answers were converted into percentage values.

6.4 Data Analysis

The dependent measures for both MRTs were the test score, defined as the number of correct responses, and the latency to complete the entire test. In the case of the Vandenberg and

Kuse response time, the majority of the participants (42 of 48) failed to complete the task in the time allotted and received a score of 6 minutes as the completion time, therefore resulting in truncated latency data. All analyses computed on this data, used nonparametric analyses.

For the comparisons of overall performance differences between groups on, the Shepard and Metzler and Vandenberg and Kuse tests, test scores were converted to percentages and t-tests and Pearson's r correlations were conducted on the score percentages. To further examine the relationship between menstrual phase and mental rotation performance for both groups, participants were divided into three categories corresponding to the three phases of the menstrual cycle (menstrual, follicular and luteal) regardless of contraceptive status, and Pearson's r correlations were conducted on MRT scores and the Shepard and Metzler response times. Spearman's rho was used to investigate the relationship between menstrual phase and response times on the Vandenberg and Kuse response time.

7. Results

7.1 Oral Contraceptive Usage, Menstrual Cycle Phase and Mental Rotation Performance

Three separate 2-way ANOVAs (with grouping variables of oral contraceptive status and menstrual cycle phase) on the dependent measures of test score (number of correct responses) and latency were conducted on the Shepard & Metzler correct score, Shepard & Metzler response time, and Vandenberg &Kuse correct score. A Mann-Whitney U test and Kruskal-Wallis test was conducted for each grouping variables on the Vandenberg and Kuse response time data.

For the Shepard Metzler test score, there were no significant effects of oral contraceptive usage, (*F* (1,42) = .051, *p* = .822), and menstrual cycle phase (*F* (2,42) = .440, *p* = .647), and no significant interaction effect for oral contraceptive usage and menstrual cycle phase (*F* (2,42) = .273, *p* = .762). On the dependent measure of time to complete the test, there were no significant effects for oral contraceptive usage (*F* (1, 42) = .212, *p* = .648), menstrual cycle phase (*F* (2,42) = .069, *p* = .934) or interaction effect of oral contraceptive usage and menstrual cycle phase (*F* (2,42) = 2.04, *p* = .143).

On the Vandenberg and Kuse test, for the analysis of test score, there were no significant effect for oral contraceptive status (*F* (1,42) = .534, *p* = .469.) or menstrual cycle phase (*F* (2,42) = .761, *p* = .473), nor a significant interaction effect of oral contraceptive usage and menstrual cycle phase, (*F* (2,42) = 1.15, *p* = .325). On the measure of response time, using an independent samples Mann-Whitney U, there were no significant effect of oral contraceptive usage , *p* = .986. For the independent sample Kruskal-Wallis test for response time, no significant effect of menstrual cycle phase was found, *p* = .458.

See Table 2 for means with standard deviation for all dependent measures.

Table 2
Descriptive Statistics

	Hormonal Contraceptive			
	Oral Contraceptive		Naturally Cycling	
Dependent	**Mean**	**SD**	**Mean**	**SD**
SHEPARD & METZLER SCORE	15.71	3.75	15.88	3.52
SHEPARD & METZLER RESPONSE TIME	184.38	77.30	199.17	87.99
VANDENBERG & KUSE SCORE	7.21	3.58	8.00	4.56
VANDENBERG & KUSE RESPONSE TIME	351.83	25.74	351.75	29.32

Means and standard deviations of all dependent measures: Shepard & Metzler MRT score, Shepard & Metzler MRT response time, Vandenberg & Kuse MRT score and Vandenberg & Kuse MRT response time, divided by hormonal contraceptive usage.

7.2 Performance Differences Between Vandenberg and Kuse MRT and Shepard and Metzler MRT

As there were no significant effects revealed for either oral contraceptive usage or menstrual cycle phase, data was collapsed across the variables. A paired-samples t-test was conducted on test percentage scores to compare overall performance on the Shepard & Metzler mental rotation task and the Vandenberg and Kuse mental rotation task. There was a significant difference in percentage score, $t(47) = 14.38$, $p = .001$, with participants performing better on the Shepard and Metzler task (see Figure 7).

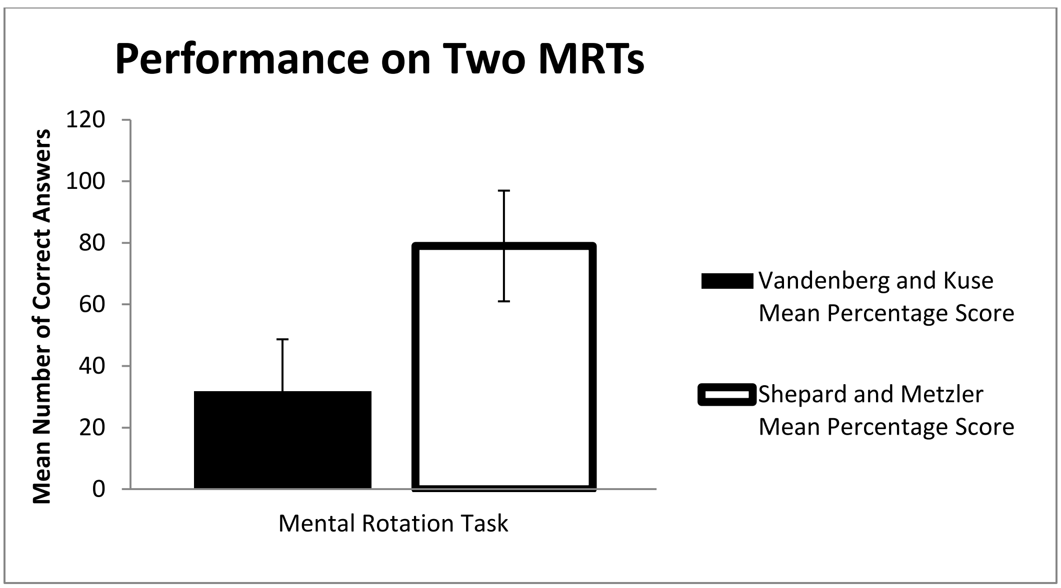

Figure 7: Mean Percentage Score for the Vandenberg and Kuse MRT and the Shepard and Metzler MRT.

Interestingly, there was no significant relationship found between percentage on the Shepard and Metzler MRT and score percentage on the Vandenberg and Kuse MRT, $r = .151$, $p = .305$.

7.3 Relationship Between Performance on MRTS and Phase of Menstrual Cycle

In order to further examine possible relationships between task performance on the Shepard and Metzler MRT and the Vandenberg and Kuse MRT, the relationship between test scores (percentage correct) for the two MRTs was evaluated separately for each of the three menstrual cycle phases (menstrual, follicular or luteal), using Pearson r correlations. There was a significant relationship found between percentage scores on the Shepard and Metzler MRT and on the Vandenberg and Kuse MRT, for those participants in the menstrual phase, r = .619, p = .018. There was no significant relationship found between percentage scores on the Shepard and Metzler MRT and on the Vandenberg and Kuse MRT, for those participants either in the follicular phase, (r = .289, p = .245), or in the luteal phase , (r = -.322, p = .224).

To investigate a possible relationship between the latency scores on the two MRTs, three Spearman rho calculations were conducted (one for those in each of the three phases of the menstrual cycle). No significant relationships were revealed.

For a list of all correlations conducted see Table 3.

Table 3

Correlations between overall performance on both MRTs and phase of menstrual cycle

Phase of M.C.	SM score & VK score	VK response time & SM response time
Menstrual	.619*	.119
Follicular	.289	.248
Luteal	.-.322	.232

* p <.05

8. Discussion

Contrary to previous studies examining the difference between oral contraceptive users and naturally cycling participants (Grieksiene & Ruksenas, 2011), no differences between these two groups were found in the current study, on either the Shepard and Metzler mental rotation task nor the Vandenberg and Kuse mental rotation task. While this was not the expected result, and is somewhat contradictory to previous studies on the subject, it is consistent with the variability often reported from study-to study. One potential source of this variability in the literature on oral contraceptive usage's influence on female performance, and in the current study, is the fact that there was no control for the brand of contraceptives, and therefore control of fluctuations in estrogen levels that may accompany different brands/types of oral contraceptives.

In comparison to previous literature, participants in the current study had similar performance on the Shepard and Metzler (1971) task (Grieksiene & Ruksenas, 2011). However, participants had lower scores on the Vandenberg and Kuse (1978) task than is commonly observed in the current literature (Peters et al., 1995; Voyer et al., 1995). There are no current theories as for why the current sample had lower scores in this assessment than what is usually reported in the literature. However, these lower scores may account for the failure to find a significant effect of oral contraceptive use on this task.

Previous studies examining the influence of sex hormones on sex differences in visuospatial skills, particularly mental rotation tasks which show the largest and most robust sex differences in performance, have mainly examined estrogen and testosterone for their influence on visuospatial performance. Many studies have shown a strong positive testosterone influence on both male and female performance on visuospatial measures, on both the Shepard and Metzler and Vandenberg and Kuse versions of the mental rotation task (Phillips & Silverman, 1997; Silverman et al., 1999; Aleman et al., 2004). While testosterone has shown to be a positive contributor in relation to performance on mental rotation tasks, the opposite can be said for estrogen. Many previous studies have suggested a negative estrogen correlation in relation to female performance (Kimura & Hampson, 1994; Hampson, 1990a; Silverman & Phillips, 1997), leading to the influence of sex hormones becoming a main theory to further explain sex differences in visuospatial skills.

One of the main research methods that has been employed for examining estrogen's influence on female visuospatial performance has been examining participants at different phases in the menstrual cycle. Because the menstrual cycle is divided into three primary phases, menstrual, luteal and follicular, that are each accompanied by varying estrogen levels, this has allowed researchers to gain insight into estrogen's influence on performance. Numerous studies have reported that the follicular and luteal phases, marked by the highest levels of estrogen throughout the cycle, are accompanied by a decrease in female performance on mental rotation tasks. While the menstrual phase (also known as menses), marked by the lowest levels of estrogen throughout the cycle, is accompanied by an increase in female performance (Hampson 1990a; Hampson 1990b; Kimura & Hampson, 1988).

While the current study did not find any significant differences among naturally cycling participants across the menstrual cycle, it is important to note that the 24 naturally cycling participants were not equally distributed among the three different phases of the cycle. Which therefore could have possibly lead to the current findings. However, further examination of the influence of the menstrual cycle phase for both groups (naturally cycling and oral contraceptive) revealed a positive significant correlation between Vandenberg & Kuse percentage score and Shepard & Metzler percentage score. This positive relationship between performances on these assessments during the menstrual phase is consistent with the previous literature that has noted an increase in female visuospatial performance during the menstrual phase, accompanied by the lowest levels of estrogen throughout the menstrual cycle.

Not all studies examining differences in performance among the different menstrual phases have found significant differences among participants in the different phases (Grieksiene & Ruksenas, 2011). Thus, while performance differences among the phases have been reported in some studies, it has failed to be replicated in others. This observed difference in performance between the menstrual cycle phases is perhaps not an all-or-none phenomenon, with some variability remaining in the literature and in the current study. This variability among estrogen's influence in visuospatial performance during the menstrual cycle may lead to questions about the relative influence of activational hormonal effects on visuospatial performance. Perhaps the inconsistent findings suggest that it is instead, organizational effects that have a larger influence on visuospatial performance. As further evidenced by studies examining sex differences in visuospatial performance in young participants prior to puberty, when hypothetically activational effects have yet to begin. (Moore & Johnson, 2011; Quinn & Liben, 2008; Quinn & Liben, 2013). However, it might also be the case that activational effects are more variable due to the vast individual differences in plasma circulating levels of estrogen and the variability of phase of cycle, even with respect to where in each of the three phases of the cycle an individual may be, when tested (Jasienska & Jasienski, 2006). As well, seasonal variations in estrogen levels have also been reported (Bjovnevem et al., 2006) which may also need to be considered.

In recent years research on estrogen's influence on female performance in visuospatial measures has turned to examining, in essence, a natural control group: oral contraceptive users. Oral contraceptives inhibit follicular growth, reduce overall endogenous sex steroid levels and prevent monthly hormonal fluctuations (Gordon & Lee, 1993; Rosenthal, 2012). Thus, females on oral contraceptives do not have the strong monthly estrogen fluctuations that normally accompany the menstrual cycle, acting as a great control comparison to naturally cycling participants. Many earlier studies examining estrogen's influence on visuospatial performance often did not take into account oral contraceptive usage (Hampson 1990a; Hampson 1990b; Kimura & Hampson, 1988), possibly influencing the results. Of the recent studies comparing naturally cycling participants and oral contraceptive users the evidence has been sparse and contradictory. With some studies reporting no statistically significant difference between these groups on both verbal and visuospatial measures (Gordon & Lee, 1993; Rosenberg & Park, 2002; Mordecai, Rubin & Maki, 2008); and others reporting significant differences between these groups on both verbal and visuospatial measures (Grieksiene & Ruksenas, 2011). Previous research has reported that oral contraceptive users demonstrate significantly longer reaction times in the mental rotation task compared to naturally cycling participants (Grieksiene & Ruksenas, 2011).

This variability between studies could partially be attributed to the researchers' use of a non-standard Shepard and Metzler style Mental Rotation Task. Thus in the current study participants were tested on both a Shepard and Metzler style mental rotation task and also the standardized Vandenberg and Kuse mental rotation task as differences between these groups on the Vandenberg task has yet to be studied in the literature. Although, as previously mentioned, there were no statistically significant differences between the groups on both mental rotation tasks, many previous studies examining female performance on mental rotation tasks did not take into account oral contraceptive usage. Then, the contradictory research suggests that this may not be a contributing factor to female performance on mental rotation tasks anyways.

While the Vandenberg and Kuse mental rotation task has yet to be used to examine performance differences between oral contraceptive users and naturally cycling participants, one would expect a larger difference between these groups on this assessment as research has previously noted that it is this assessment that is more sensitive to hormonal processes (Voyer et al., 1995). Contrary to this suggested increased hormonal sensitivity in the current study no statistically significant differences were found for these groups on the Vandenberg and Kuse assessment. While no statistically significant effects were found for the Shepard and Metzler assessment in the current study as well, previous studies have found significant differences on the Shepard and Metzler assessment. In particular oral contraceptive users have been suggested to have longer response times on the Shepard and Metzler assessment than naturally cycling participants (Grieksiene & Ruksenas, 2011). Perhaps in fact, it is the Shepard and Metzler assessment that is more sensitive to possible significant differences between these groups, and not the Vandenberg and Kuse assessment as previously suggested.

After initial analysis of the two dependent measures, response time and correct answers/score on both MRTs, lead to no statistically significant results, analyses were then conducted comparing performance differences for both groups on the Shepard and Metzler mental rotation task versus the Vandenberg and Kuse mental rotation task. Student's t-test analyses revealed significant differences ($p = .01$) with participants performing poorer on the Vandenberg and Kuse assessment compared to performance on the Shepard and Metzler assessment. This raises the question: Are both of these assessments measuring the same cognitive ability?

Currently most Shepard and Metzler tasks used in the literature are developed from the images created by Drs. Michael Peters and Christine Battista from the "Library of Shepard and Metzler type mental rotation stimuli". Unlike the standardized redrawn Vandenberg and Kuse assessment, also developed by Dr. Michael Peters, the images chosen for the Shepard and Metzler assessment vary from researcher to researcher. Thus, there is the possibility of variability in these Shepard and Metzler tasks as a result, or researchers using different stimuli for study to study. The use of a non-standardized Shepard and Metzler task could potentially account for inconsistent data in the literature surrounding sex differences in visuospatial and mental rotation measures, and further in the literature surrounding hormonal influences' on these sex differences.

There were certain limitations to the current study that could have potentially influenced the results. Having a larger number of participants, and naturally cycling participants equally distributed between the three phases of the cycle (menstrual, follicular, luteal), would allow for more statistical power regarding performance differences among the phases. In addition, while hormonal assays were not within the scope of the current study, having a measure of circulating estrogen would allow for making a more direct connection between estrogen's influences with respect to performance on both mental rotation tasks. A direct measure of a participant's circulating estrogen levels could also allow the accurate tracking of the menstrual cycle phase a naturally cycling participant was in, rather than relying on self-report measures. There was a lot of variability among the participants as to how they tracked the date of their last menses, with many relying on a calendar but others relying on smart phone application or tracking based on their oral contraceptive pills. This is problematic as studies have shown that self-report measures are often not an accurate measure of menstrual cycle phase (Wideman, Montgomery, Levine, Beynoon & Shultz, 2013). A physiological measure of estrogen levels would also allow for the control of fluctuations in estrogen levels that may accompany different brands/types of oral contraceptives.

Another limitation to the current study was the measure of response time. Other studies examining female performance in mental rotation ability that have used response time as a dependent measure have sometimes measured response time for each individual presentation of stimuli, whereas in the current study response time was measured as time taken to complete the entire assessment. In future studies, the response time for each individual presentation of stimuli in addition to the time taken to complete the entire assessment may provide greater detail into performance differences among oral contraceptive users and the phases of the menstrual cycle.

Continued research with respect to hormonal influences, oral contraceptive influence, and their relationship to sex and cognitive performance is needed. In addition, a more standardized version of the Shepard and Metzler mental rotation task should be developed in an effort to control for variability among mental rotation tasks and research into sex differences in mental rotation ability.

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Appendix A

Oral Contraceptive/Menstrual Cycle Questionnaire

ID NUMBER:

How old are you? ________________________________

What is the average length of your menstrual cycle (menses to menses, average is 28 days)? ____

How long does menses usually last (I.E. 3-4 days)?

____

What date did your last menses (menstruation) start? ___________________________

Are your monthly cycles regular (same length between menses) every time?

- ☐ Yes
- ☐ No
- ☐ Not Currently

Do you use any types of oral hormonal contraceptives (i.e. forms of birth control like the pill)

- ☐ Yes
- ☐ No

If yes, how long have you been on this type of contraceptive?

- ☐ Less than 1 month
- ☐ Longer than 1 month

If not currently on hormonal contraceptives, have you taken any oral contraceptives within the last month?

- ☐ Yes
- ☐ No

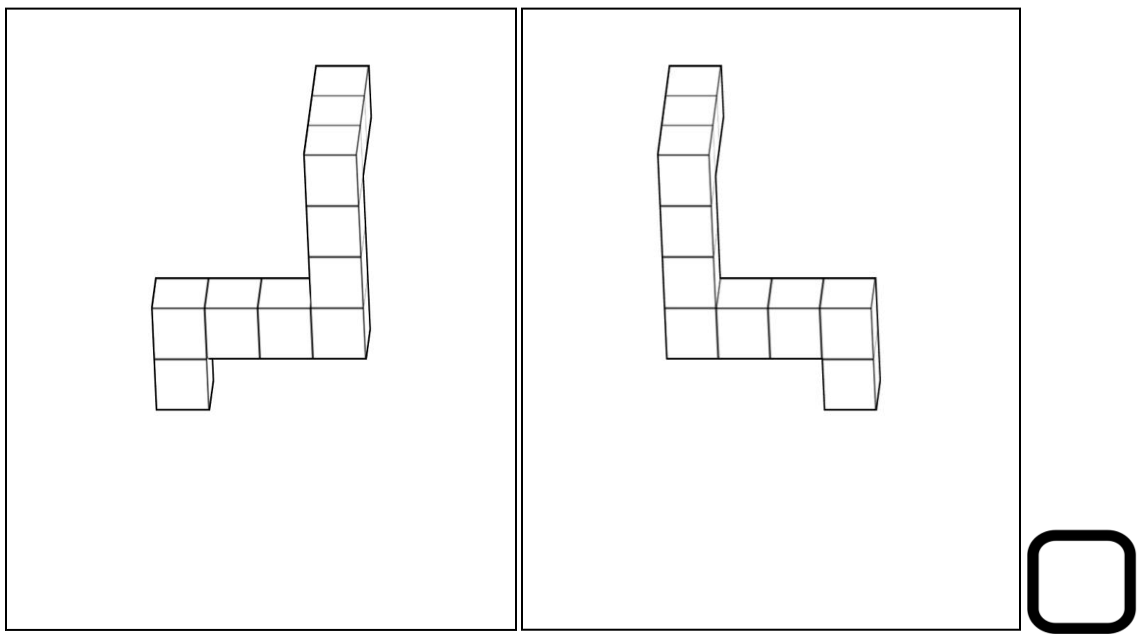
Appendix B

Shepard and Metzler Mental Rotation Task

MENTAL ROTATIONS TEST

This test is composed of the figures by Shepard and Metzler (1978) provided by Peters and Battista (2008).

Please look at these two figures:

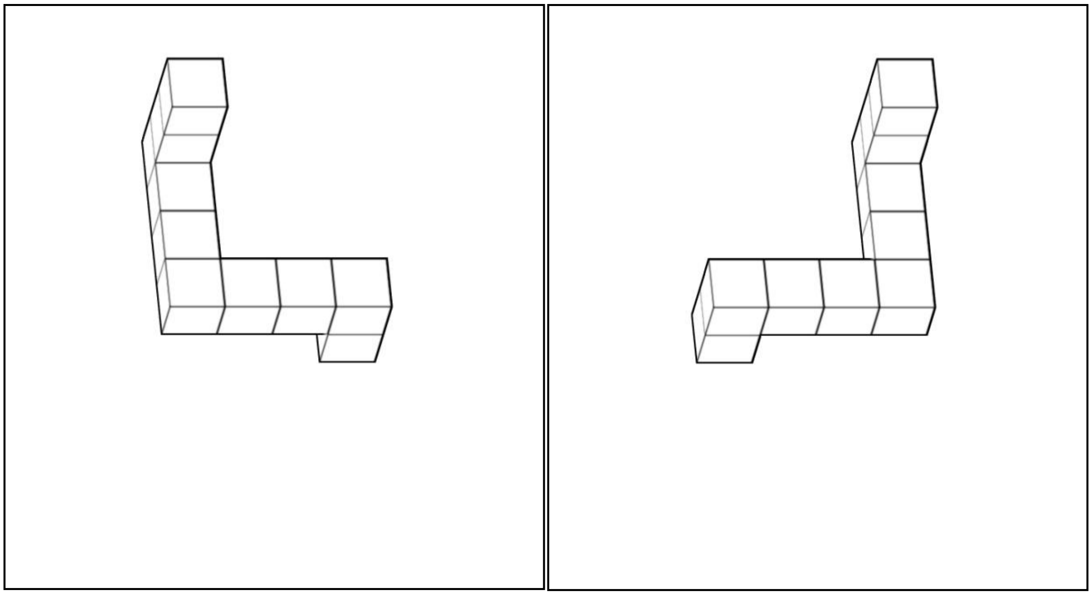


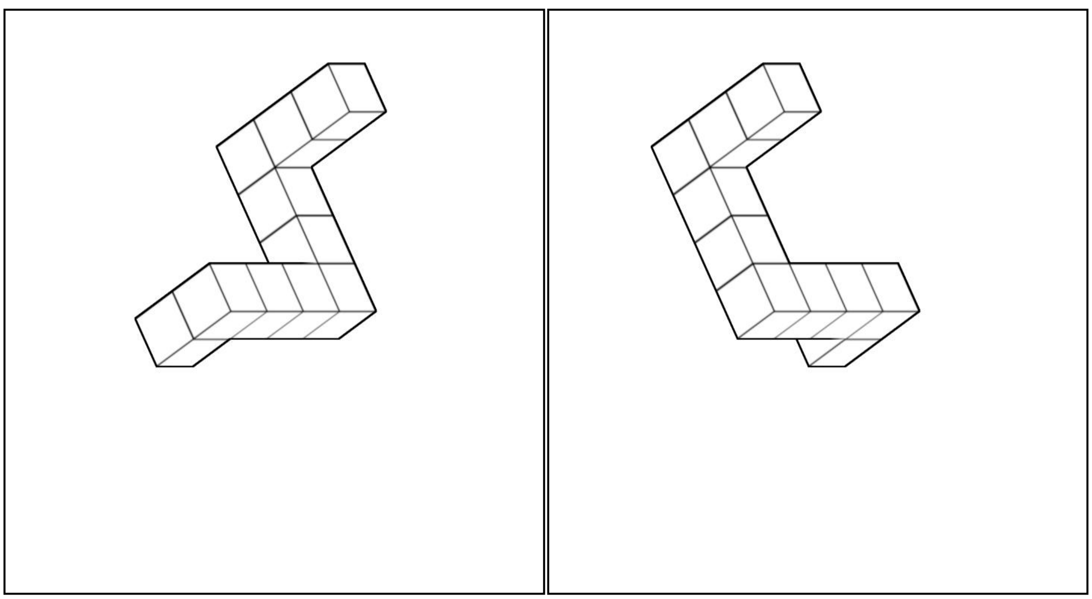
Are these images identical except for their rotation? If so, they are called mirror images. Try to imagine moving the object (or yourself with respect to the object), as you look from one drawing to the next. Indicate whether or not these are mirror images with a checkmark or an “X” in the box beside the images.

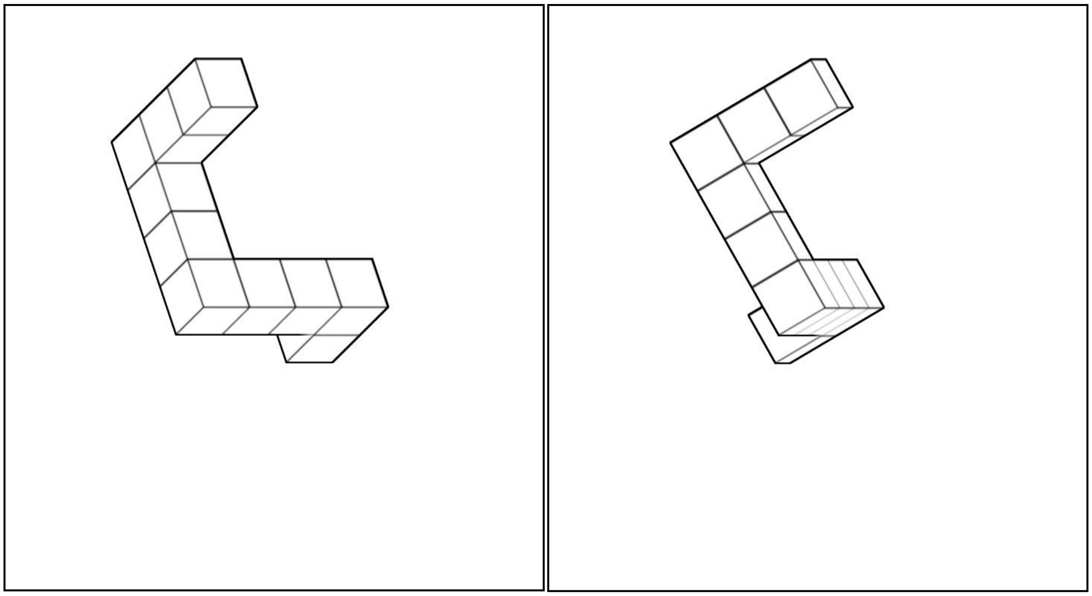
If you said they aren’t identical you are correct. These images are not mirror images.

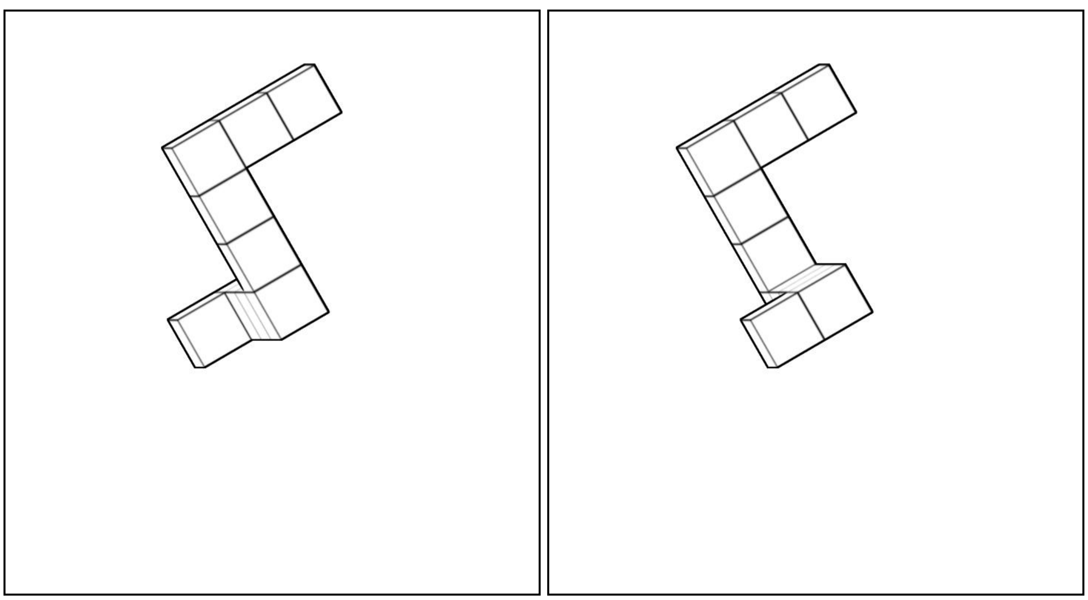
For the following 20 sets of images please indicate whether or not they are identical images with a checkmark for identical images or and “X” for non-identical images in the box beside the images.

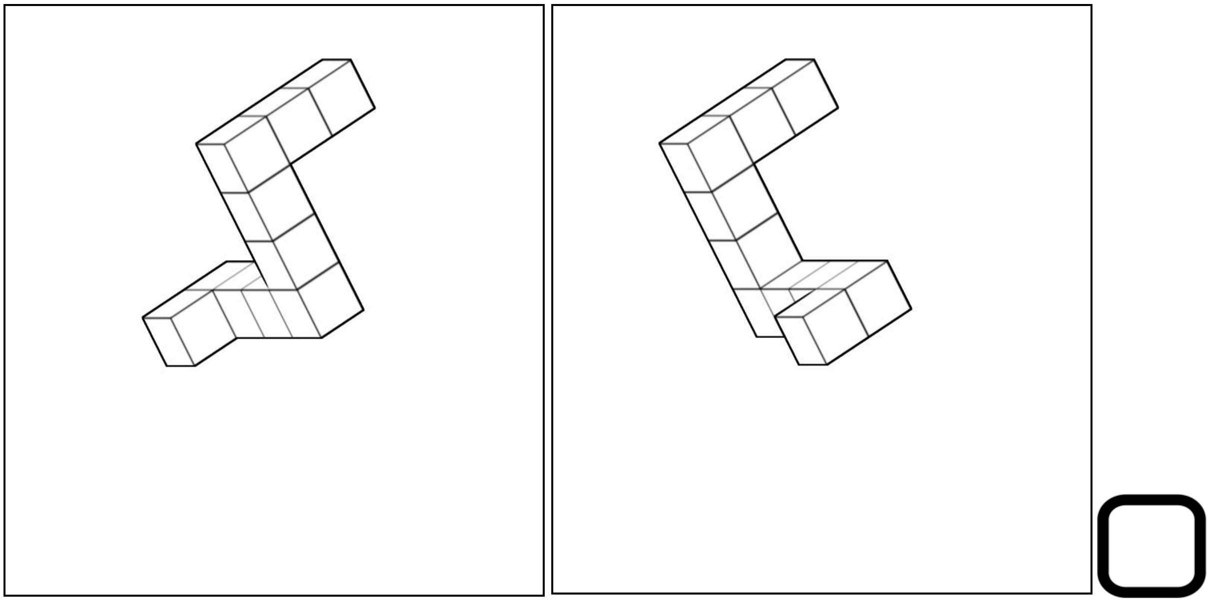
You will have 7 minutes to complete this test.

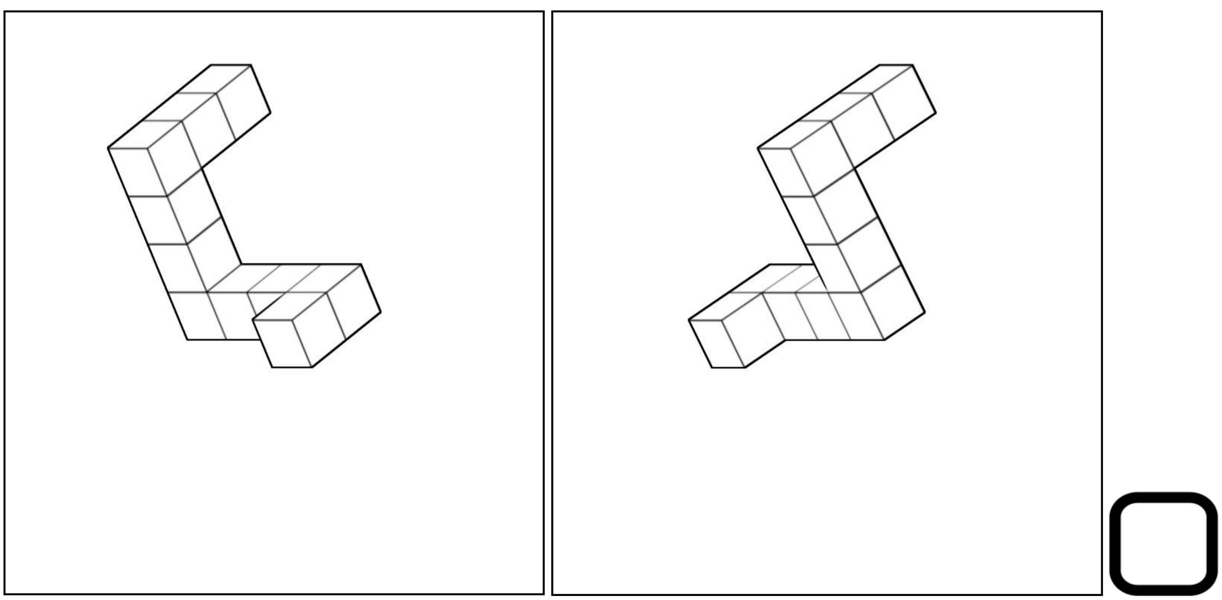


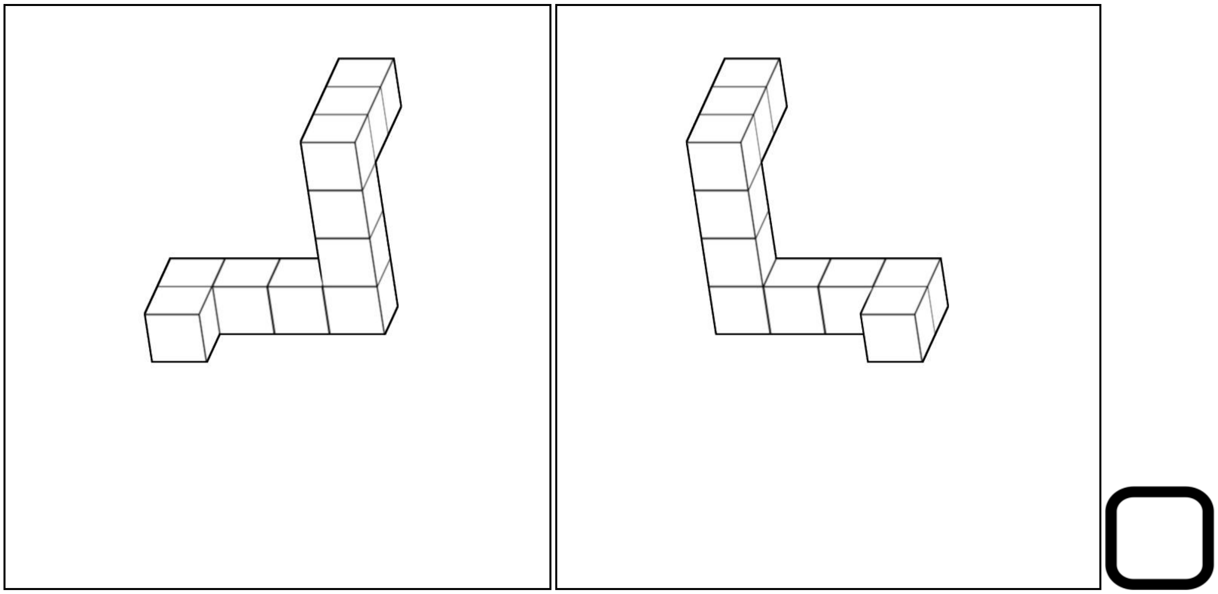


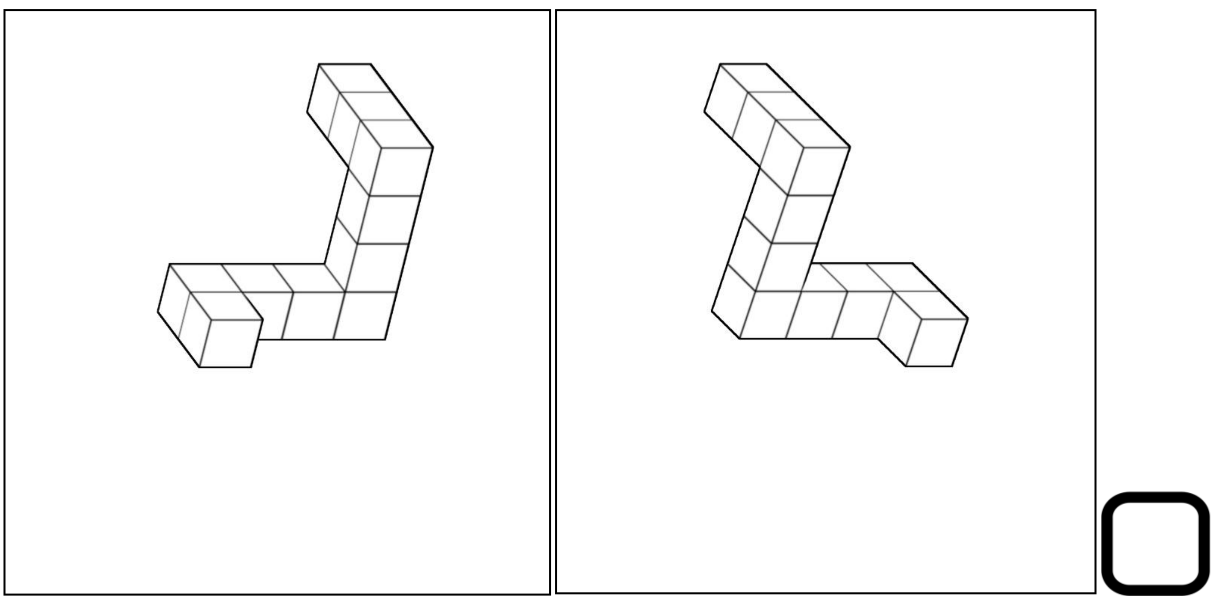


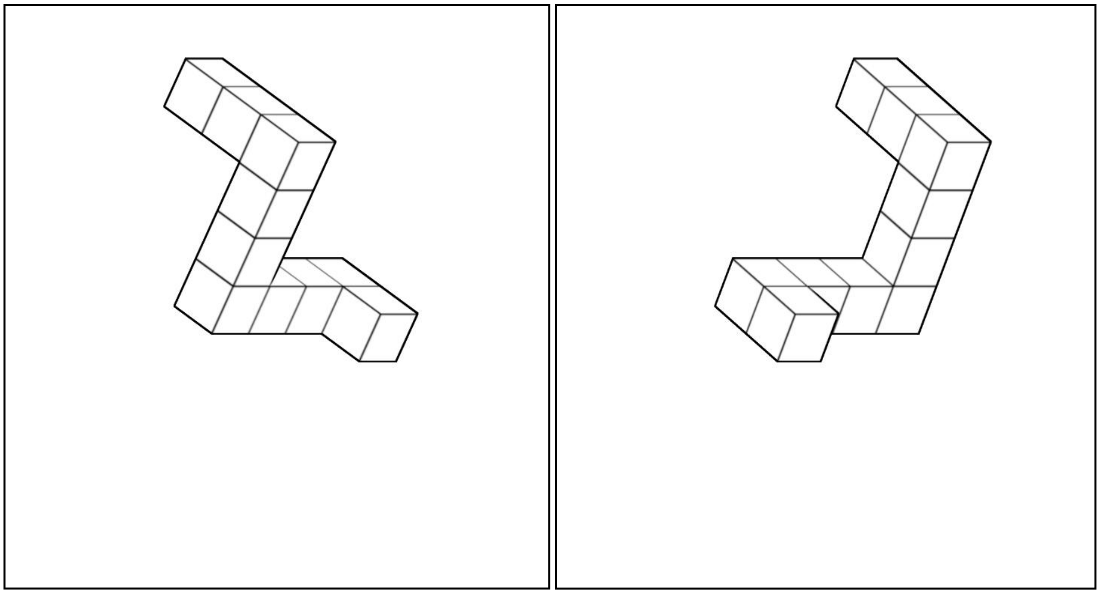


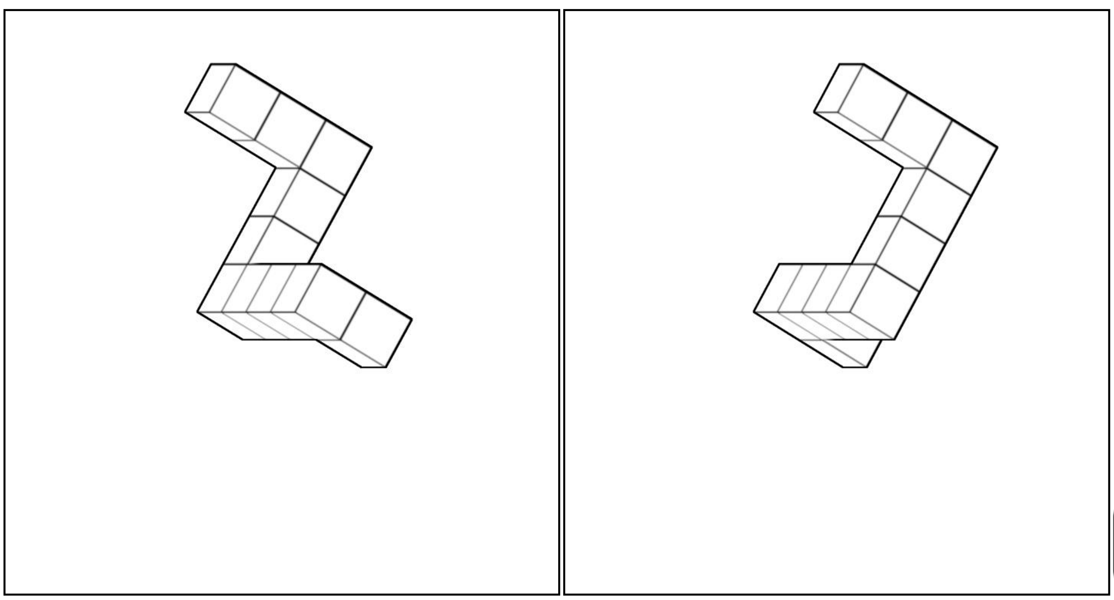


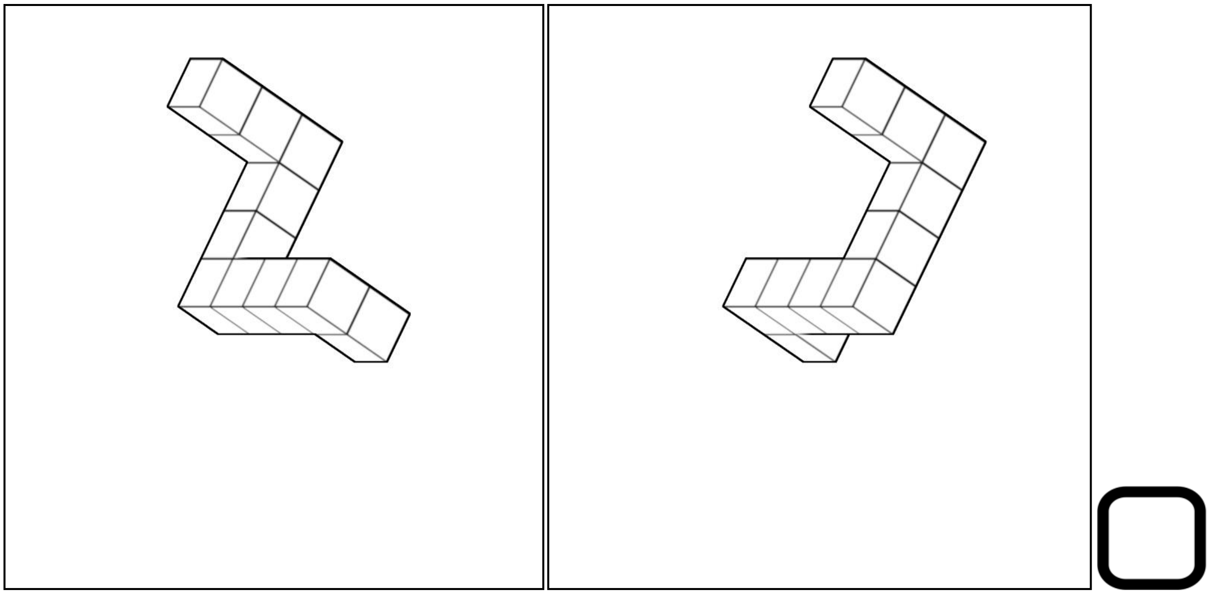


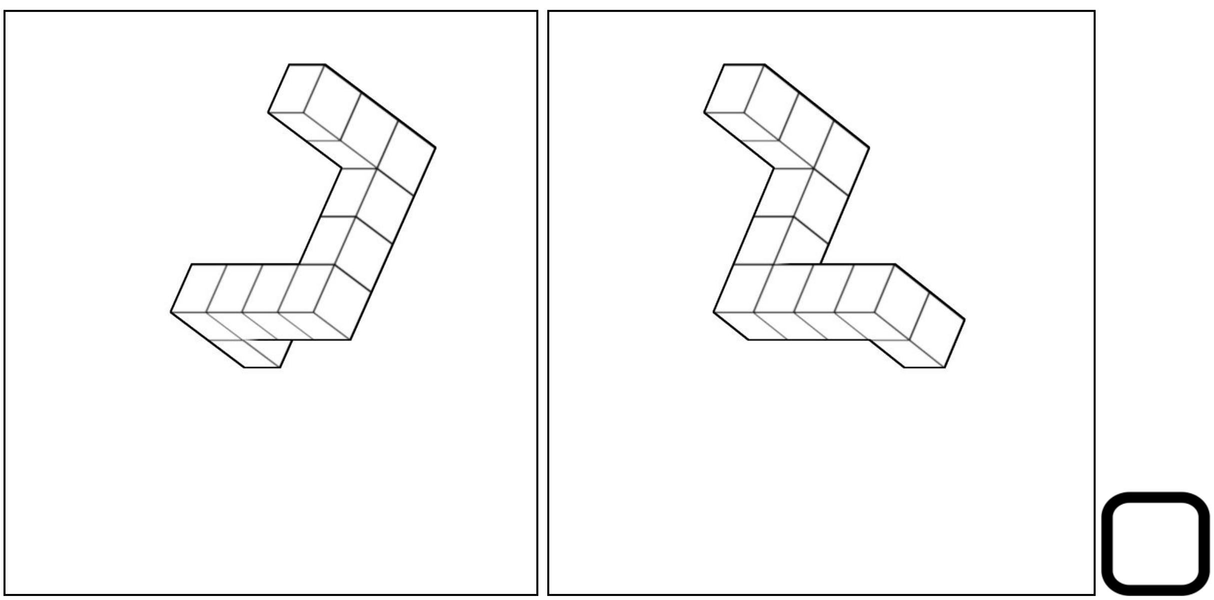


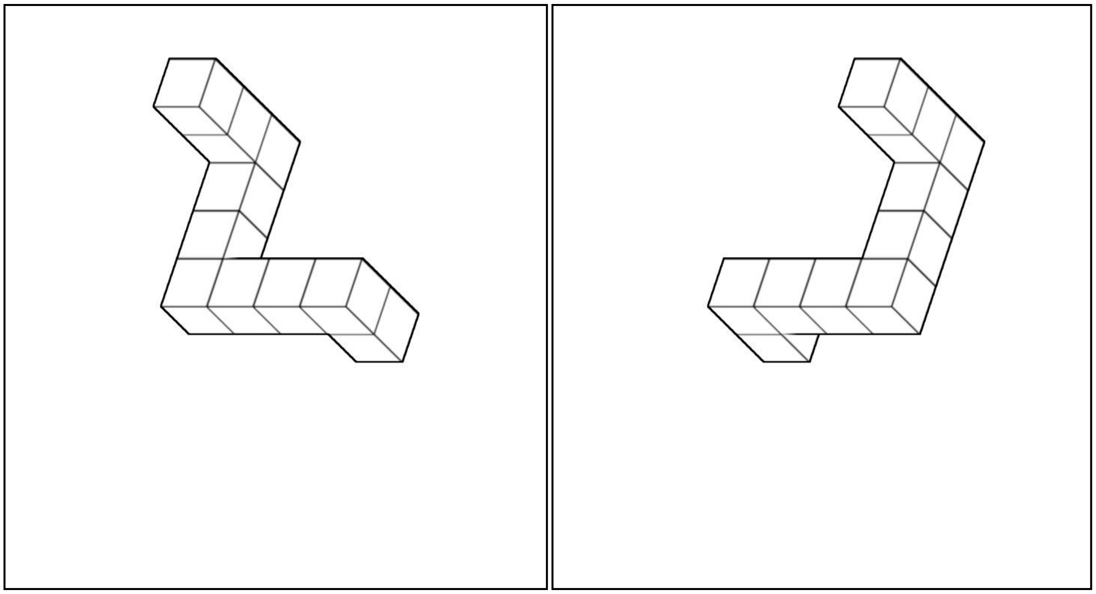


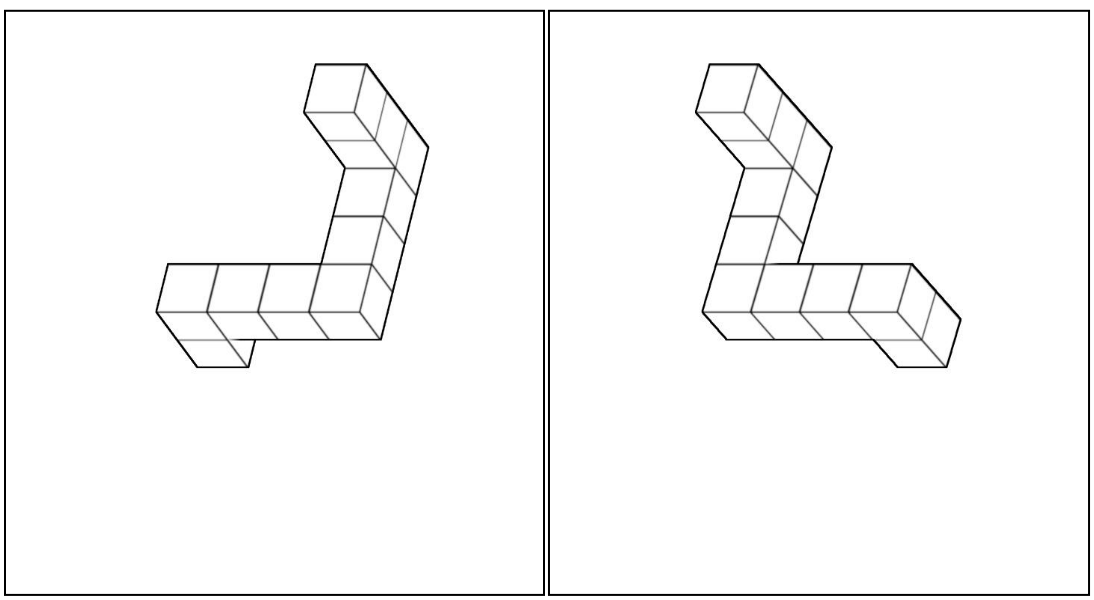


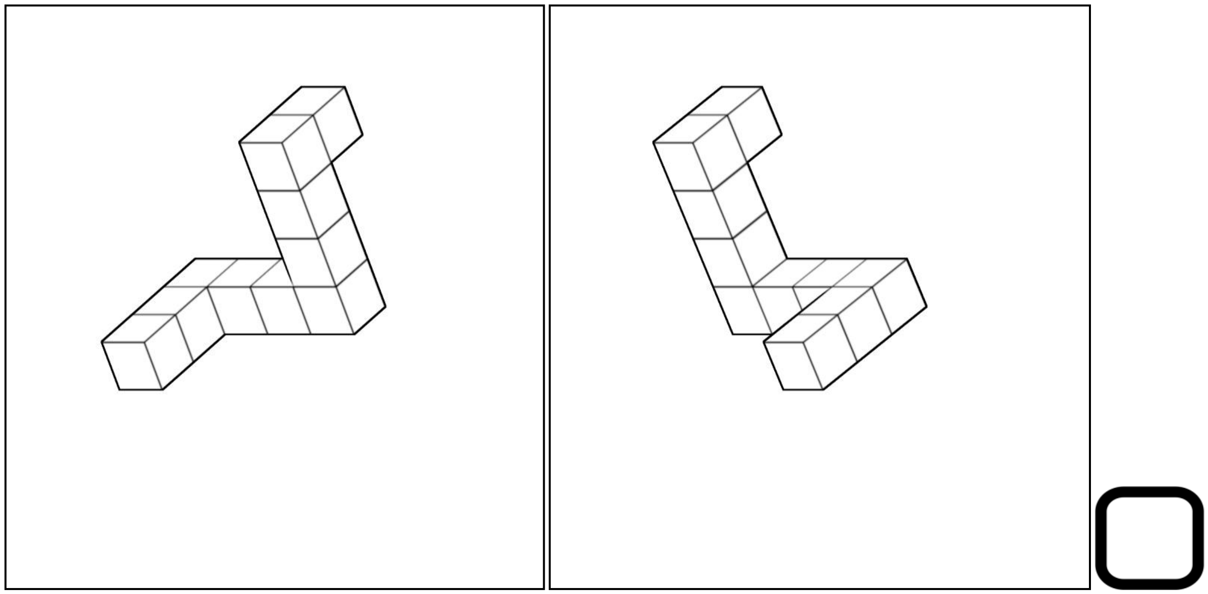


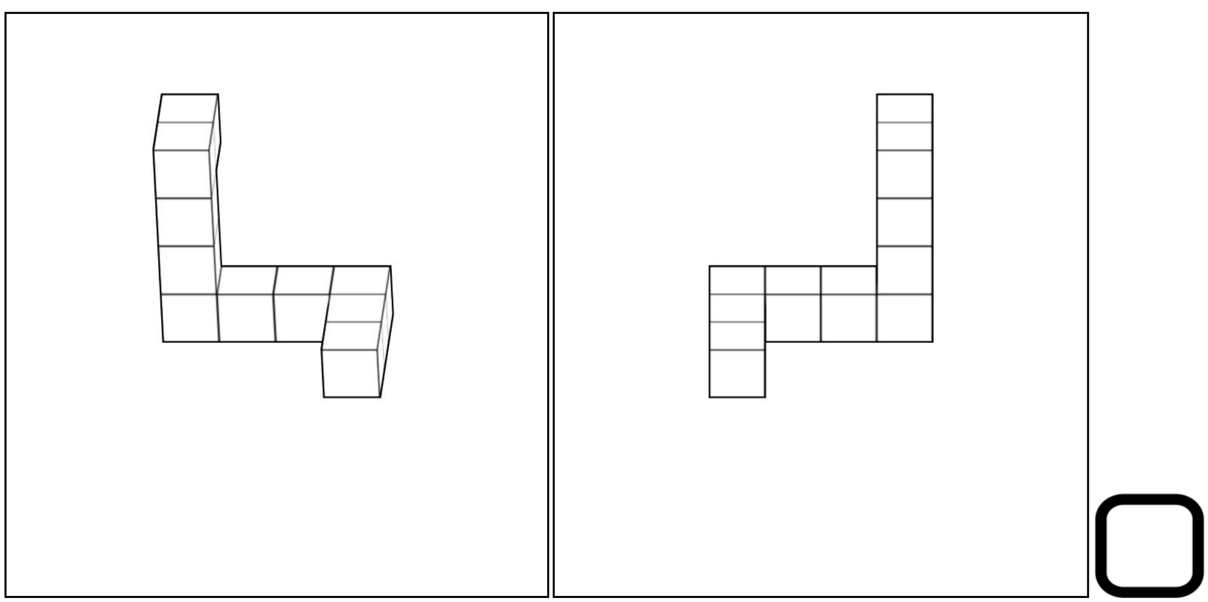


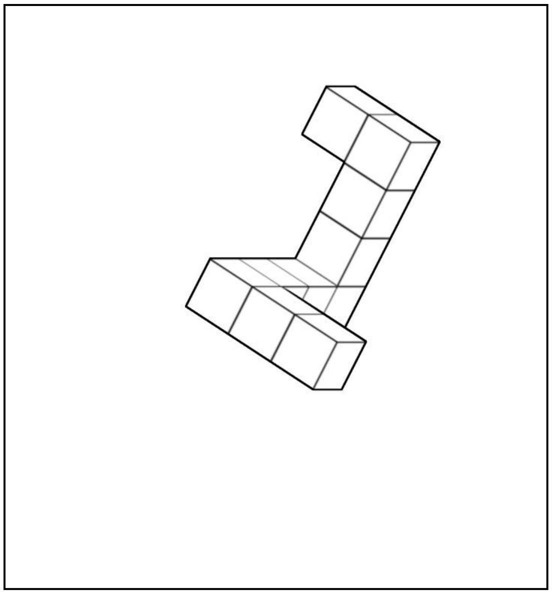


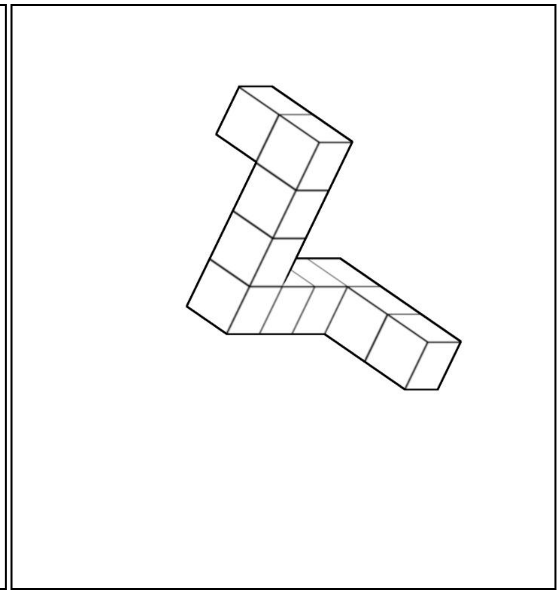


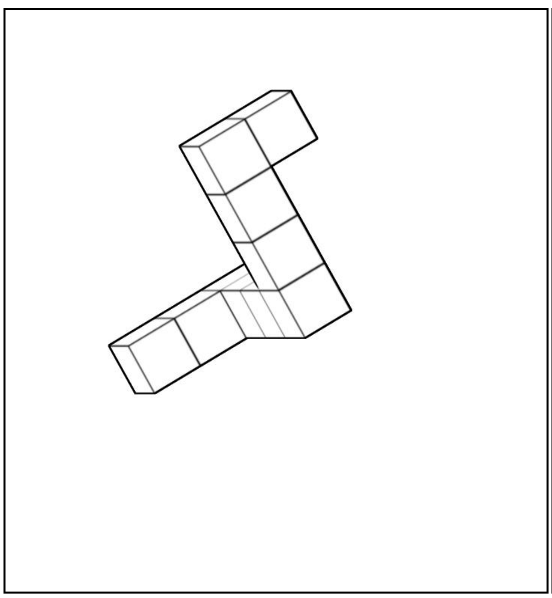


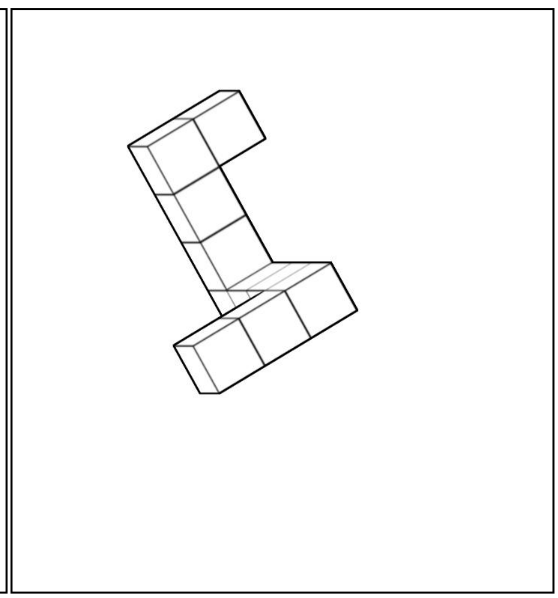


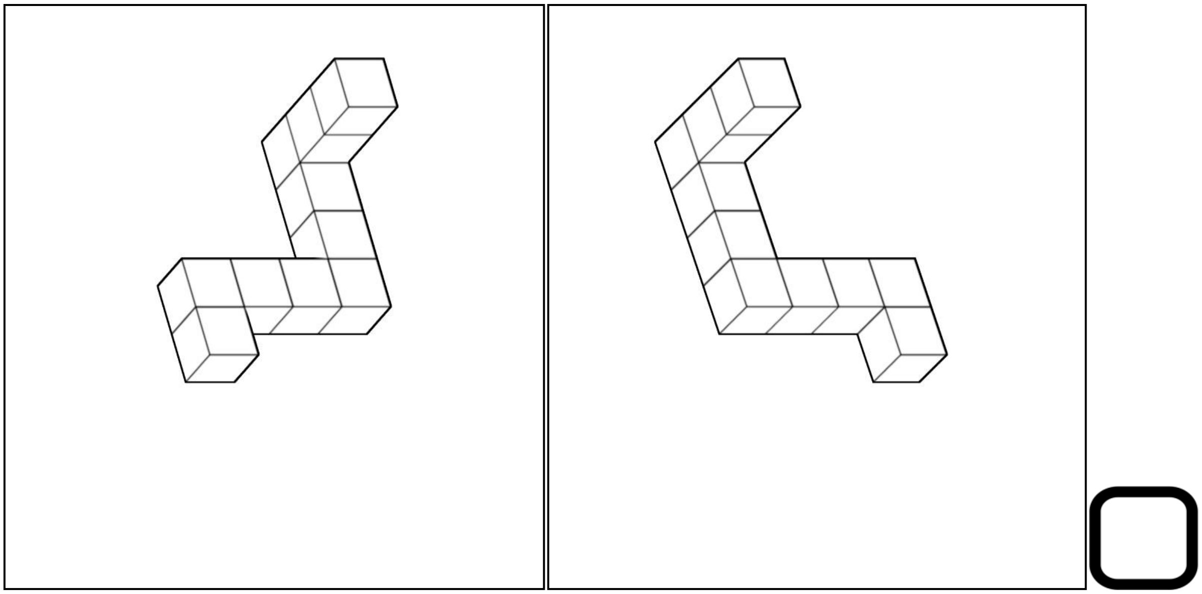


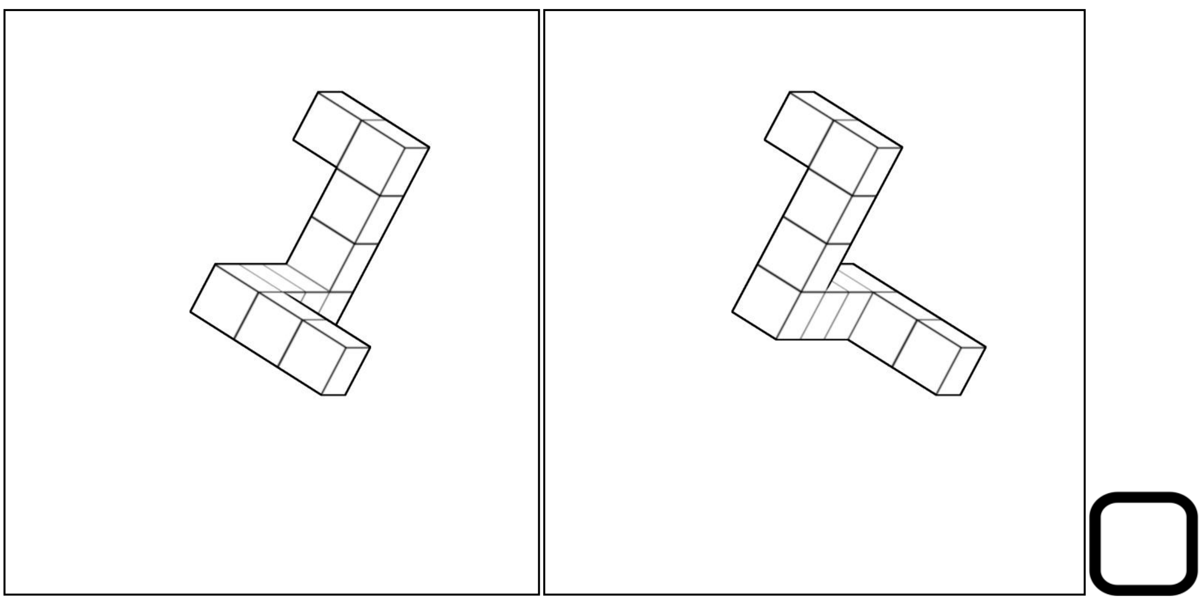












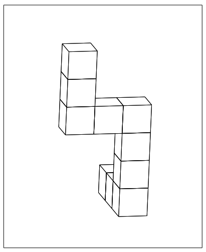
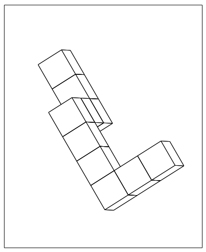
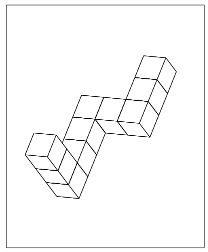
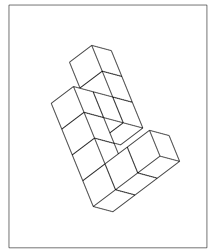
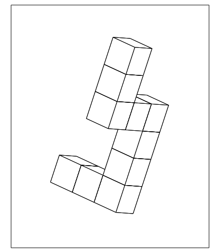
Appendix C

Vandenberg and Kuse Mental Rotation Task

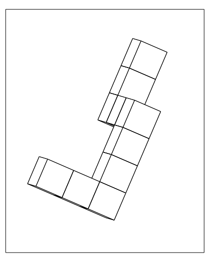
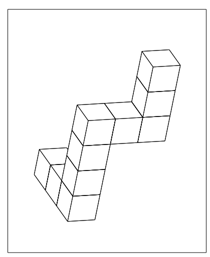
MENTAL ROTATIONS TEST (MRT-A)

This test is composed of the figures provided by Shepard and Metzler (1978), and is, essentially, an Autocad-redrawn version of the Vandenberg & Kuse MRT test.

Please look at these five figures

Note that these are all pictures of the same object which is shown from different angles. Try to imagine moving the object (or yourself with respect to the object), as you look from one drawing to the next.

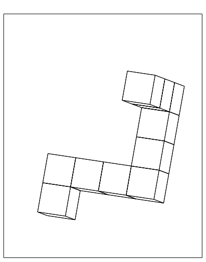
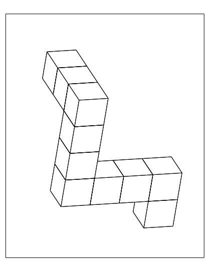
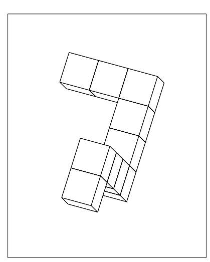
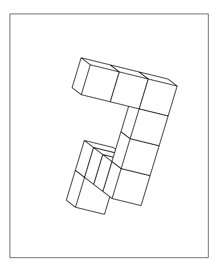
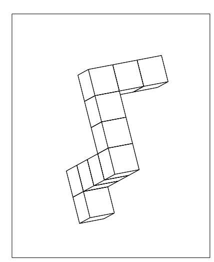



Here are two drawings of a new figure that is different from the one shown in the first 5 drawings. Satisfy yourself that these two drawings show an object that is different and cannot be "rotated" to be identical with the object shown in the first five drawings.

Now look at this object:

Two of these four drawings show the same object. Can you find those two? Put a big X across them.

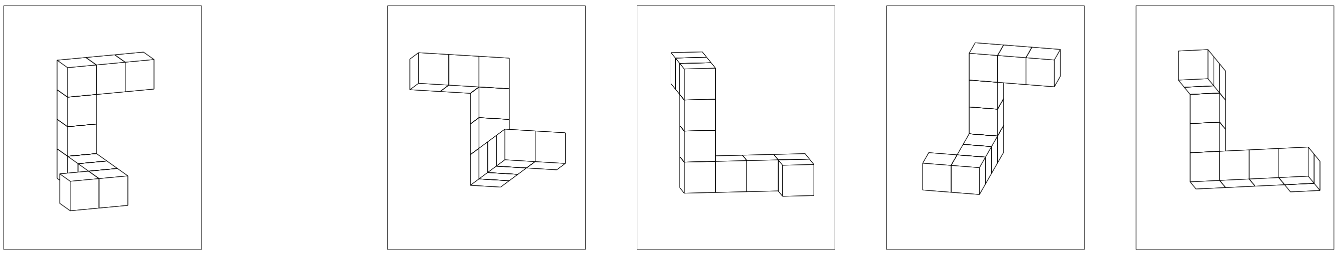
1.

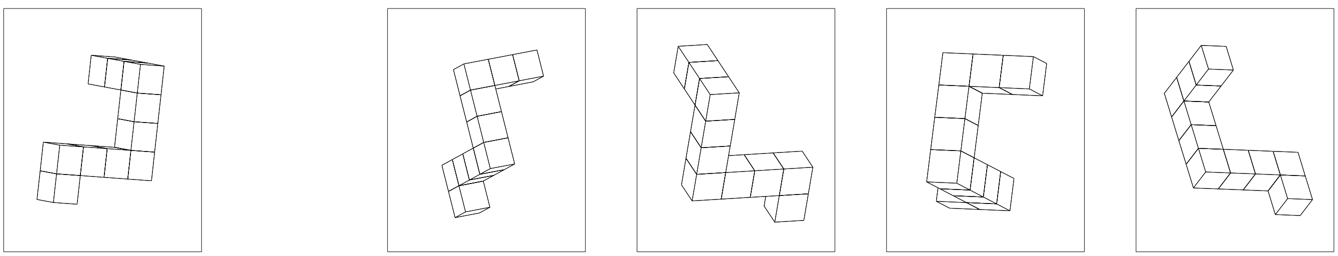
If you marked the first and third drawings, you made the correct choice.

Here are three more problems. Again, the target object is shown twice in each set of four alternatives from which you choose the correct ones.

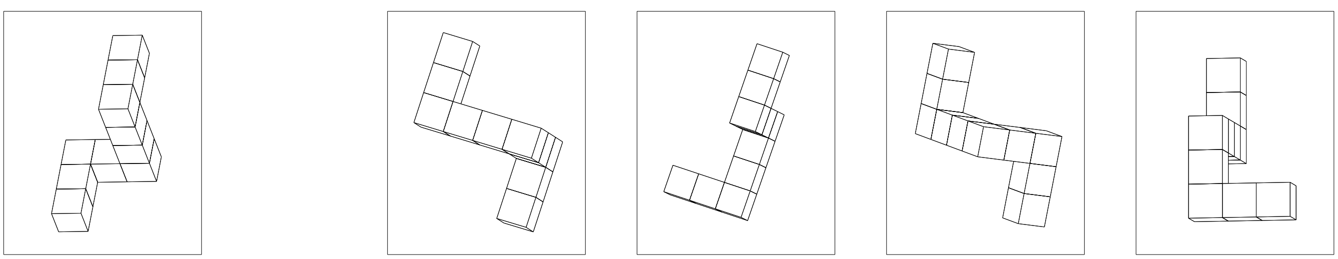
2.a



3.a



4.a

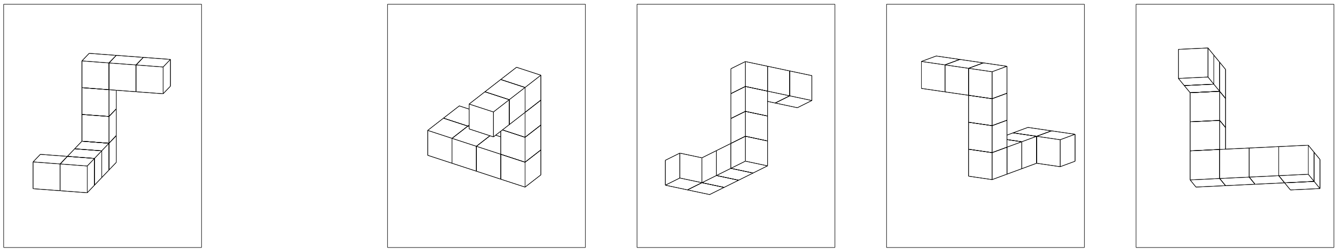


Correct Choice: 2: second and third
3: first and fourth
4: first and third

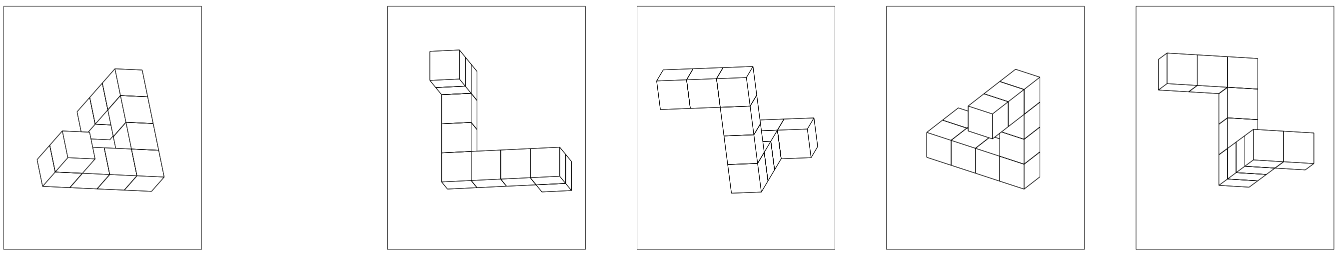
When you do the test, please remember that for each problem set there are two and only two figures that match the target figure.

You will only be given a point if you mark off both correct matching figures, marking off only one of these will result in no marks.

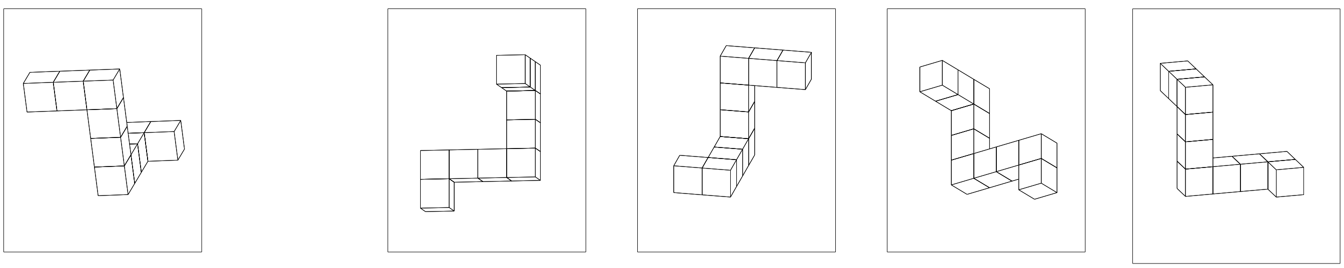
1.a



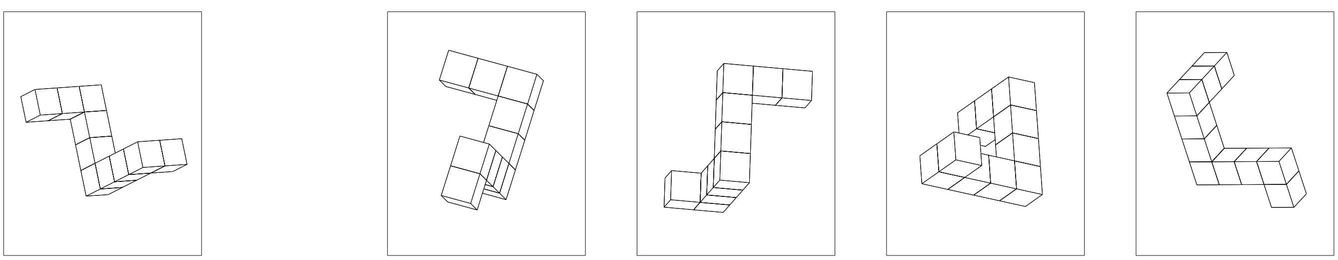
2.a



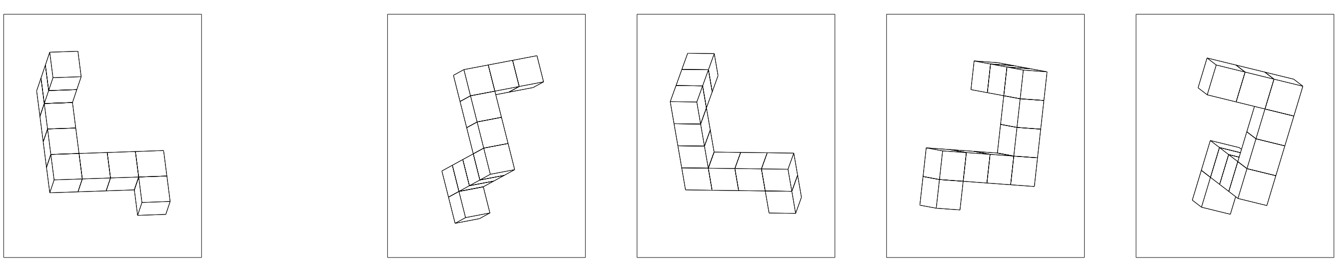
3.a



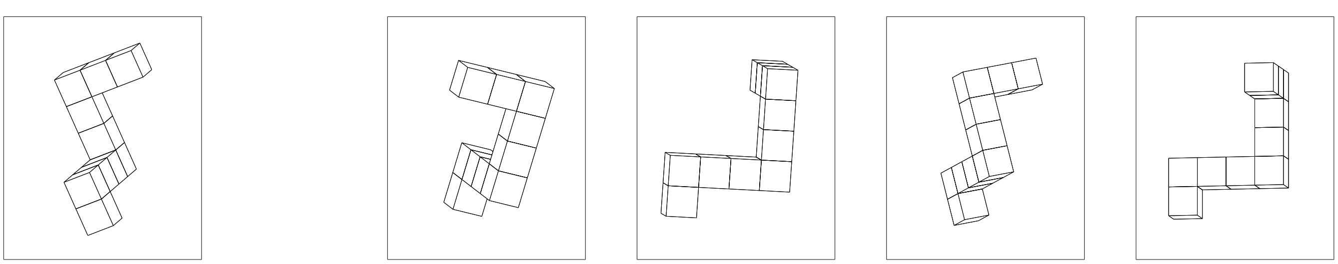
4.a



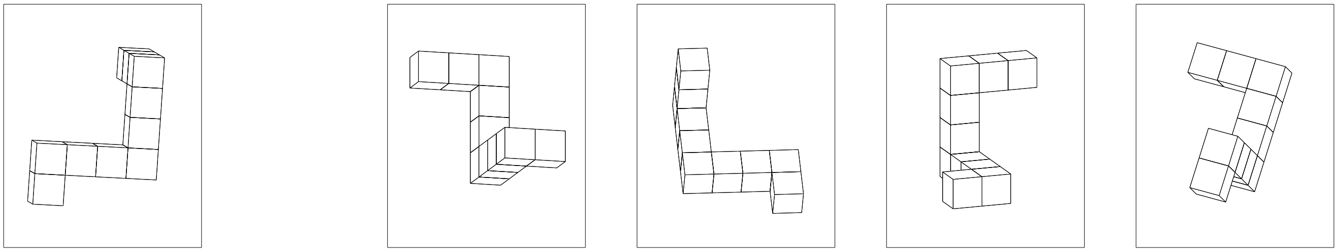
5.a



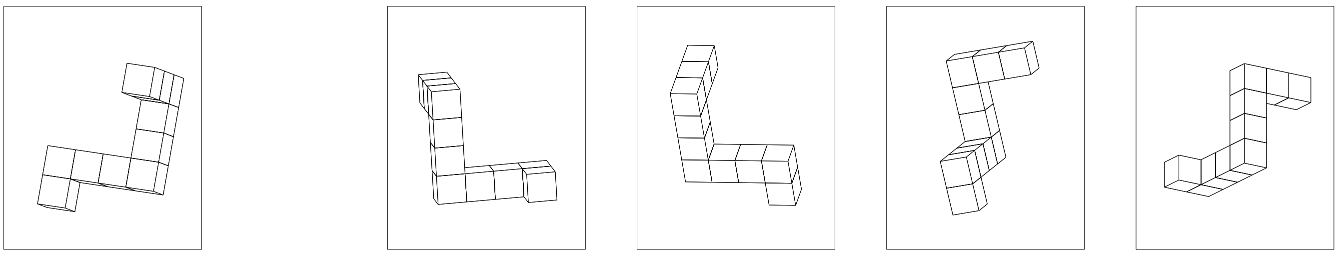
6.a



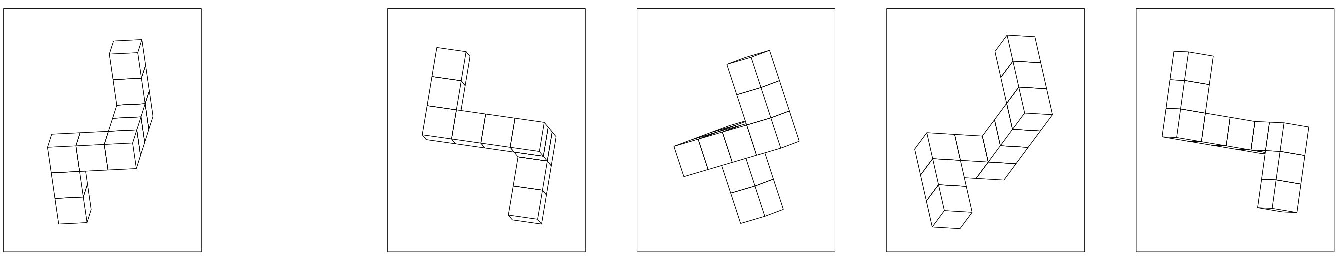
7.a



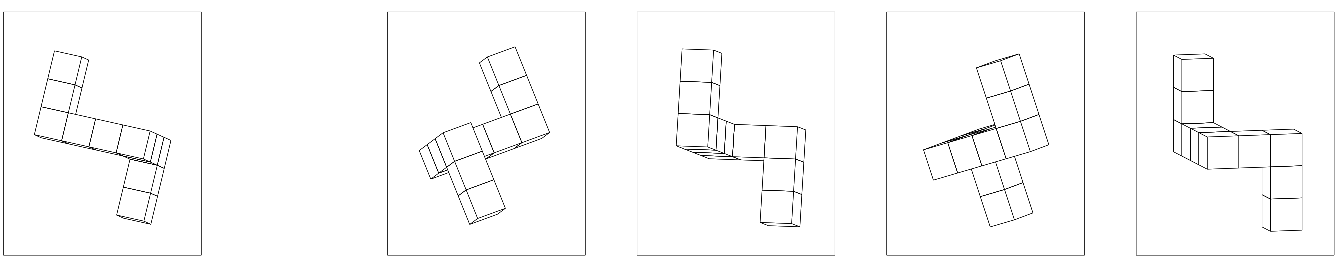
8.a



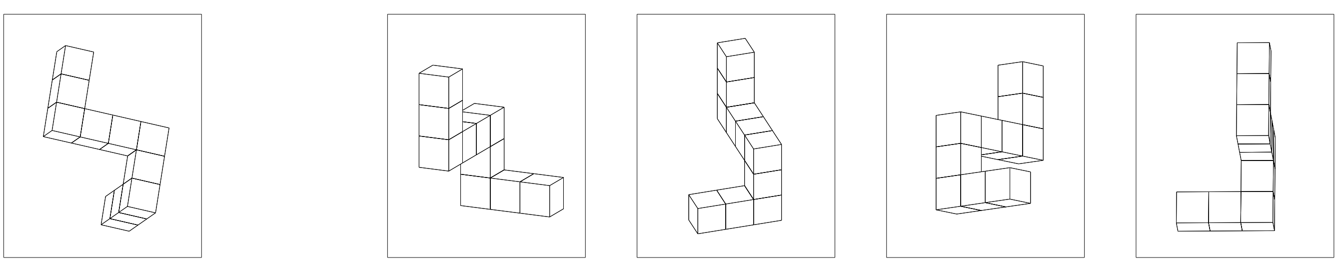
9.a



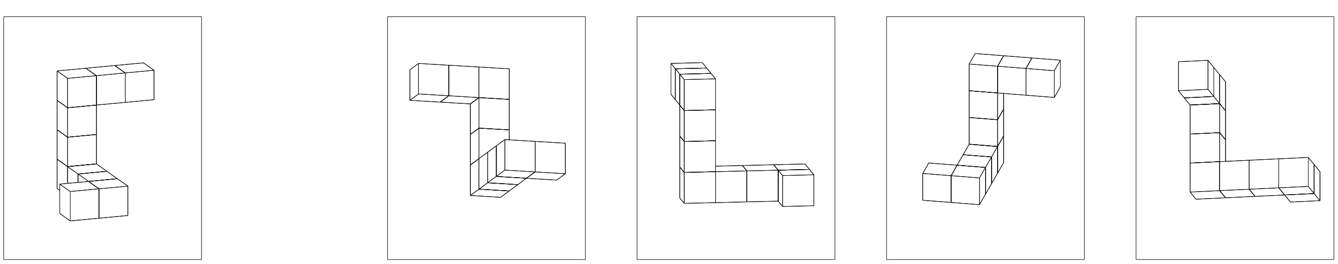
10.a



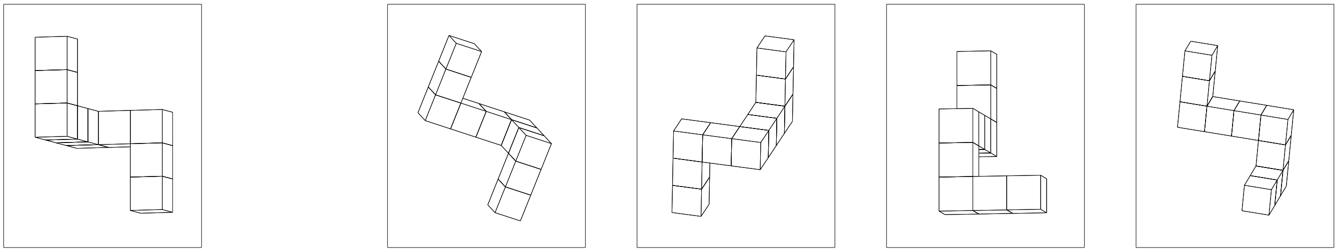
11.a



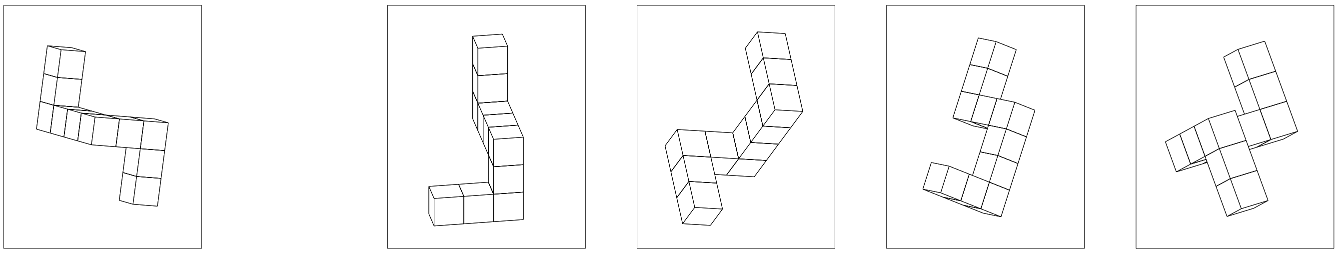
12.a



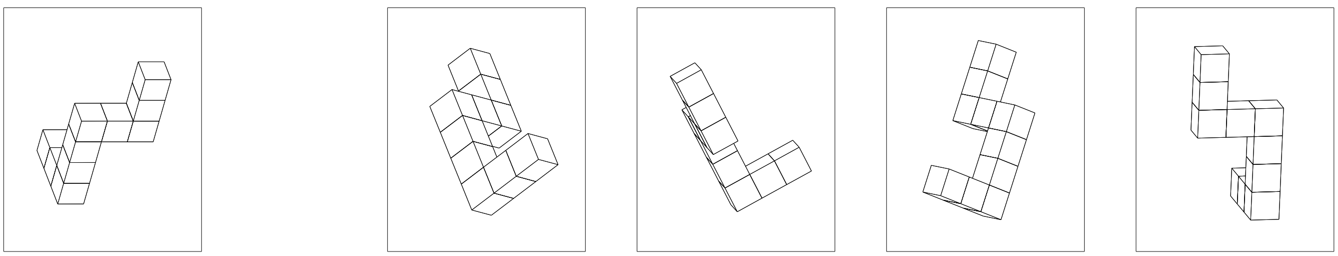
13.a



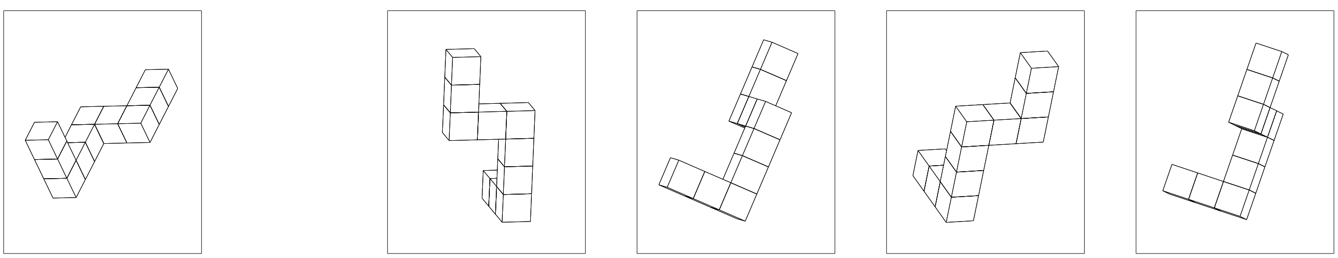
14.a



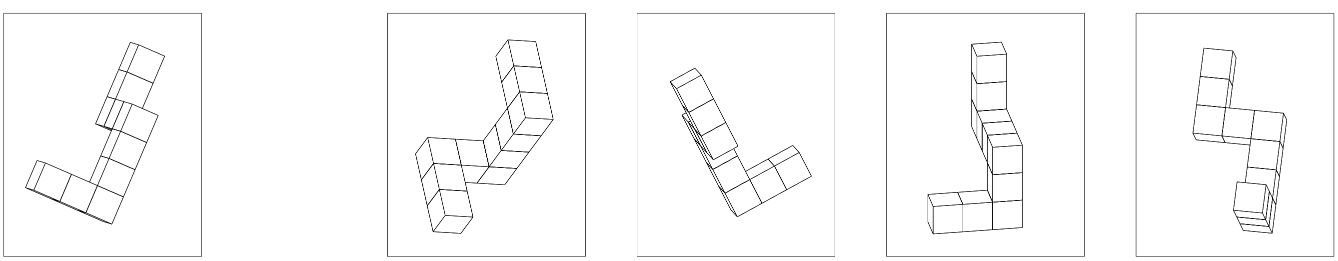
15.a



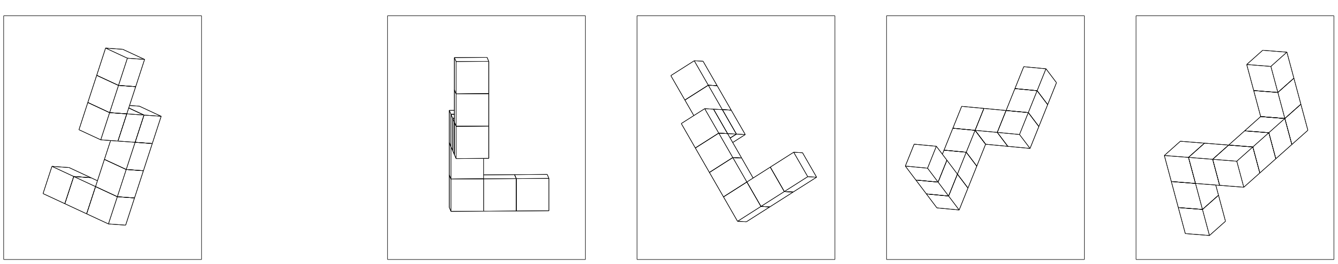
16.a



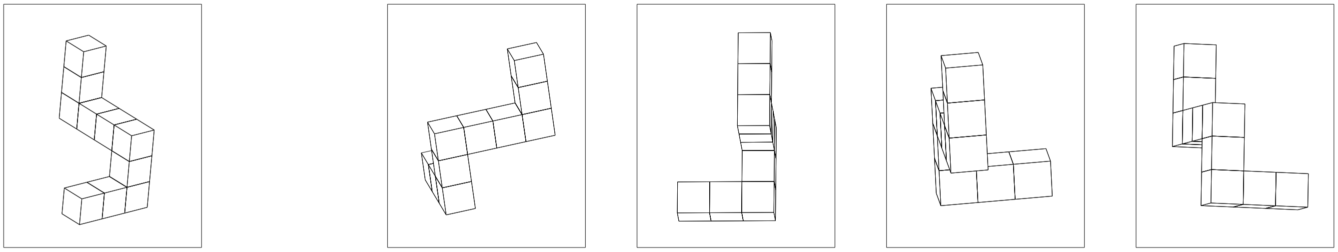
17.a



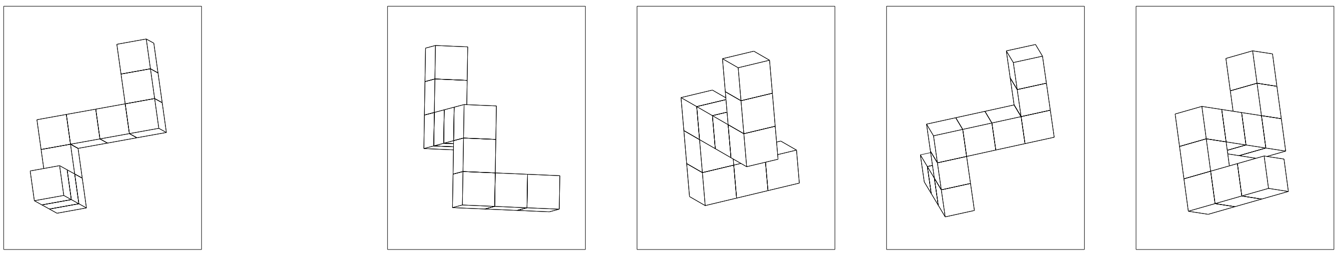
18.a



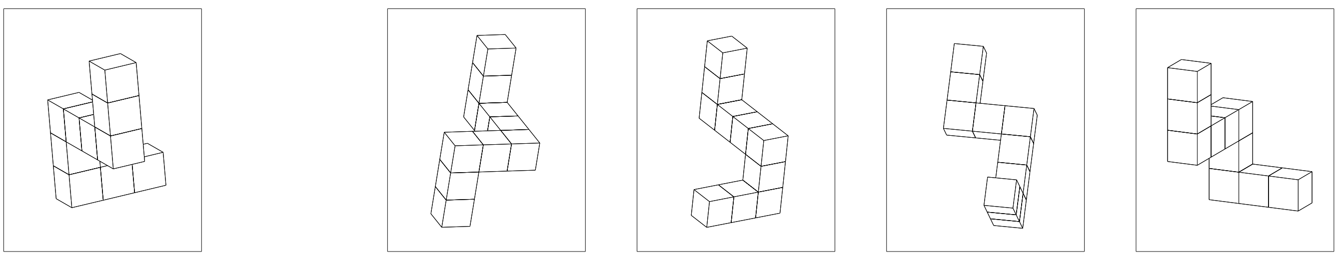
19.a



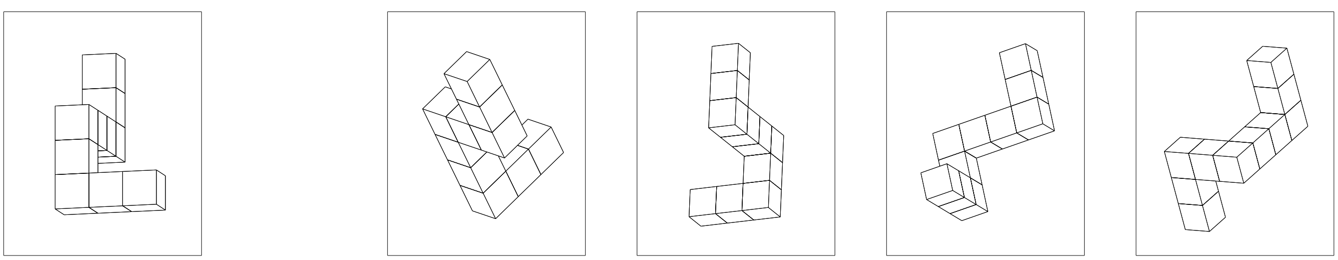
20.a



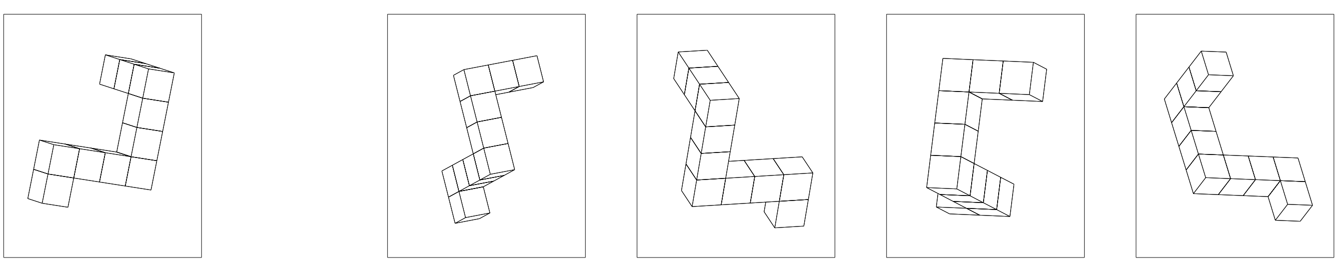
21.a



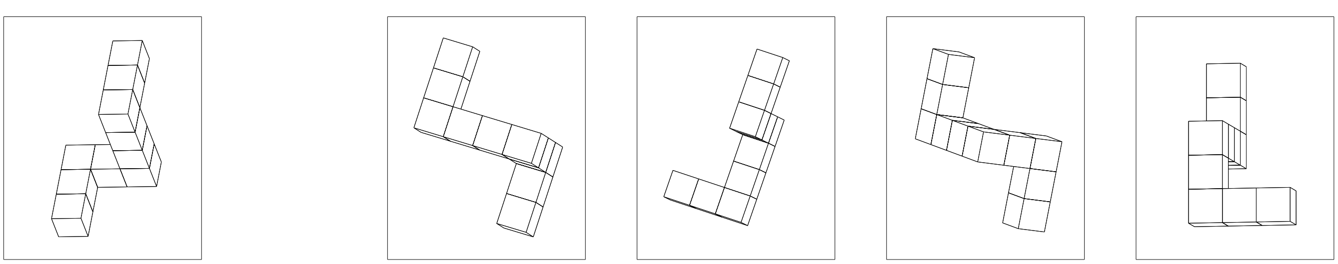
22.a



23.a



24.a



Appendix D

Participant Information Letter & Participant Consent Form

PARTICIPANT INFORMATION LETTER

Sex Differences in Cognition: A Look at the Mental Rotation Task and Possible Mediatory Effects

You have been invited to participate in a research project focusing on the relationship of female hormones to measures of spatial abilities. The purpose of this research is to better understand whether female performance of spatial abilities relates to hormonal fluctuations whether oral contraceptives affect this. In particular, we are investigating whether there are differences in spatial processing, on two different mental rotation tasks, between women who are taking oral contraceptives compared to the performance of women who are not taking these medications This research is being completed in requirement for a Honours project by the student investigator, Emma McIntosh. The research is being supervised by Dr. Cathy Ryan.

Participation in this project will take about 30 minutes of your time and will involve completing a short questionnaire, and two different versions of a Mental Rotation task. Your participation in the research project will pose no harm to you. Your participation in this research project is entirely voluntary. If you are a current Psychology 102 student you will be compensated for your participation with one bonus mark to the online component of your class. If you are not in Psychology 102 currently, you will be compensated for your participation with an entry into a lottery for a $50 cash prize. You may stop your participation in the research project at any time, without penalty or prejudice and will still receive full compensation for your participation. All information collected in the course of this project will remain confidential and anonymous, and you will not be able to be identified from any of your responses. Your name and contact information will always remain separate from your testing materials to ensure anonymity. Only the student investigator, Emma McIntosh and her supervisor (Dr. Cathy Ryan) will have access to the data resulting from this research project.

If you have any questions or concerns about this research project, you may consult with the student investigator Emma McIntosh (efmcintosh@upei.ca, 902-940-3812) or the Honours supervisor for this project Dr. Cathy Ryan (ryan@upei.ca, 902- 566-0323).

This research project has been approved by the Research Ethics Committee of the Department of Psychology, as a subcommittee of the UPEI Research Ethics Board. Any concerns about the ethical aspects of your involvement in this research project may be directed to Dr. Stacey MacKinnon, Chair of the Research Ethics Committee, Department of Psychology, phone (902) 566-0402; email: smackinnon@upei.ca.

PARTICIPANT CONSENT FORM

Sex Differences in Cognition: A Look at the Mental Rotation Task and Possible Mediatory Effects

You have been invited to participate in a research project focusing on the relationship of female hormones to measures of spatial abilities. The purpose of this research is to better understand whether female performance of spatial abilities relates to hormonal fluctuations due to oral contraceptives. In particular, we are investigating whether there are differences in spatial processing, on two different mental rotation tasks, between women who are taking oral contraceptives compared to the performance of women who are not taking these medications. This study will have approximately 40 female participants, who are all over the age of 18 and U.P.E.I students.

I understand that my participation involves completing a short questionnaire, and being tested on two Mental Rotation tasks by Emma McIntosh, the study's student investigator. This testing will be conducted in the Behavioural Neuroscience lab area in Memorial Hall.

I have read and understood the material about this study in the Information Letter, and understand that:

1. My participation in the study is entirely voluntary;
2. I may discontinue my participation at any time without any adverse consequence;
3. My results will be kept anonymous, and the results will be digitally coded;
4. My results will be kept confidential by being kept on a password protected computer in the locked Behavioural Neuroscience lab;
5. My participation in the research project will pose no harm to me;
6. If you are a current Psychology 102 student you will be compensated for your participation with one bonus mark for the online component of the class. If you are not in Psychology 102 you will be compensated for your participation with an entry into a lottery for a $50 cash prize.
7. You may stop your participation in the research project at any time, without penalty or prejudice and will still receive full compensation for your participation
8. Once all data have been submitted and identifiers removed, I will no longer have the opportunity to request that my data be removed from the study;
9. I have the freedom not to answer any question included in the research;
10. I may have a copy of the signed and dated consent form to keep.

This research is being conducted by Emma McIntosh for academic credit in the Honours program under the supervision of her honours supervisor, Dr. Cathy Ryan. Any questions or concerns about this study can be directed to either Emma McIntosh (efmcintosh@upei.ca, 902-940-3812) or Dr. Cathy Ryan (ryan@upei.ca, 902-566-0323) .

This research has been approved by the Research Ethics Committee of the Department of Psychology, as a sub-committee of the UPEI Research Ethics Board. Any concerns regarding your involvement in this study may be directed to Dr. Stacey MacKinnon, Chair of the Research Ethics Committee, Department of Psychology, phone (902) 566-0402; email: smackinnon@upei.ca. Other concerns regarding your involvement in this study may be directed directly to the UPEI Research Ethics Board at (902) 620-5104 or reb@upei.ca

I consent to participating in research on hormonal influences on sex differences in visuospatial abilities.

Participant name (please print): Witness name :

Participant signature: Witness signature :

Date: ___/___/___ Date: ___/___/___