

# MENTAL ROTATION IN ARTISTS AND NON-ARTISTS

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## Abstract

This research was conducted to compare visuospatial skills in male and female artists and non-artists. Twenty artists (10 males and 10 females) and 20 non-artists (10 males and 10 females) were tested for accuracy and reaction time in a lateralized three-dimensional mental rotation task. Males had significantly fewer errors than females, which is consistent with previous research, but this main effect for gender was not found for reaction time. Findings did not support the hypotheses that artists are more skilled in visuospatial tasks, have a smaller gender difference in mental rotation ability, and have a different pattern of lateralization for mental rotation than non-artists.

## Introduction

There is a well-documented gender difference in human performance on tasks testing certain types of visuospatial skills (e.g., Kimura, 1999; Snyder & Harris, 1993). Specifically, males tend to perform better than females on spatial orientation, or “mental rotation,” tasks, in which a subject is required to imagine how a given figure will appear when in a different spatial orientation (or as seen from a different perspective) (Kimura 1999; Masters 1998; Masters & Sanders, 1993; Peters, et al, 1995; Resnick, 1993). This gender difference has been shown consistently on a variety of mental rotation tests, whether using familiar or unfamiliar (Kail, Carter, & Pellegrino, 1979), two-dimensional or three-dimensional (Collins & Kimura, 1997; Geary, Gilger, & Elliot-Miller, 1992; Sanders, Soares, & D’Aquila, 1982) figures. This effect has also been shown across cultures (Amponsah & Krekling, 1997; Silverman, Phillips, & Silverman, 1996).

However, there is evidence to suggest that this robust sex difference may be less pronounced when comparing individuals with higher overall spatial skills. For example, Turner (1998) tested male and female engineering students on a mental rotation task and found the typical male superiority effect, but found this effect to be significantly smaller when comparing males and females within a subset of higher spatial performers. High levels of spatial ability, and specifically, higher scores on mental rotation tasks, have been shown to be associated with experience in spatially related activities and areas of study, such as math and science. Peters, et al (1995) found that college students concentrating in the physical sciences performed better on a mental rotation test than those concentrating in the social sciences and humanities.

In another study looking at spatial experience, Olsen, Eliot, and Hardy (1988) compared participants’ activities and academic courses with performance on the Spatial Dimensionality Test (SDT) (Eliot 1984; as cited in Olsen, Eliot, & Hardy), which is a battery of 6 types of spatial tasks, consisting mostly of tasks involving mental rotation. Olsen and colleagues found significant correlations between subjects’ performance on the test and participation in a variety of activities and courses thought to involve visuospatial abilities. Among their findings were strong relationships between high spatial task performance and certain artistic activities (drawing, mechanical drawing, jewelry making, and photography) and art courses (architecture, drafting, studio arts, and applied design).

Visual artists represent a group of people that actively incorporate visuospatial skills, such as spatial orientation, into their daily lives. It has been suggested that there is a strong connection between tests of visuospatial abilities and skills intrinsic to the work of artists (Kay, 1996). Thus, one might expect artists to have enhanced levels of performance on such tasks and indeed, this has been demonstrated. In a comparison of artists with non-artists, Winner and Casey (1992) found that artists tend to perform better on certain types of tasks which require the use of visual image memory and suggested that artists may use different types of strategies to code such information. They also suggested that artists’ brains may be differentially lateralized for certain types of visuospatial tasks. However, it is not clear how different types of visuospatial abilities are lateralized in the general population and whether gender or artistic ability may have an effect on such lateralizations.

A number of studies examining the lateralization of mental rotation skills have found an effect for right hemisphere dominance on such tasks (Corballis, 1997; Heidler, 1996; Nalçaci, Cicek, Kalaycioglu, &

Yavuzer, 1997). However, some studies show a relationship between lateralization and spatial ability, practice, and gender. Voyer and Bryden (1990) found that high spatial ability individuals were faster at mentally rotating two-dimensional figures projected to the right visual field (processed in the left hemisphere), while low spatial ability individuals were faster when images were viewed in the left visual field (right hemisphere). Their data also revealed a significant left hemisphere advantage in males and a marginally right hemisphere advantage in females. In a study on the effects of practice, Voyer (1995) found that with increased practice, subjects shifted from a right hemisphere advantage to a left hemisphere advantage on a mental rotation task. These studies suggest that hemisphere dominance in mental rotation may be influenced by level of spatial ability.

The purpose of the present study was to address the issues raised by such comparisons of visuospatial abilities in terms of their relationship to gender and artistic ability/experience. Specifically, this experiment aimed to determine first, whether the gender difference typically shown in tests of mental rotation abilities occurs when comparing male and female artists, and second, whether mental rotation is differentially lateralized between genders and among artists and non-artists. In order to assess these questions, male and female artists and non-artists were tested on a visual field-lateralized mental rotation task of three-dimensional figures. It was predicted that artists, as a group, would perform better than non-artists and that within the non-artist group, males would perform at a higher level than females, whereas within the artist group, no such effect of gender would be found. It was also predicted that artists would show a left hemisphere advantage and non-artists would show a right hemisphere advantage in mental rotation abilities.

## Method

### Participants

A total of 40 people (20 male and 20 female) participated and were included in the study. Participants for the artist group were 10 males (3 right handed (RH), right eye dominant (RED); 3 RH, left eye dominant (LED); 2 non-right handed (NRH), RED; 2 NRH, LED) and 10 females (5 RH, RED; 3 RH, LED; 1 NRH, RED; 1 NRH, LED) who were recruited from the art departments of two undergraduate universities with comparable admissions standards and academic requirements. Prior to participation, participants in the artist group (hereafter referred to as “artists”) indicated that they were either art majors or art professors and considered themselves artists. Nine of the artists (five males and four females) were fine arts majors within the art college of one university, nine (five males and four females) were studio art majors at the other university (a liberal arts university), and the remaining two females were studio art professors at that same university. Participants for the non-artist group were 10 male (6 RH, RED; 2 NRH, RED; 2 NRH, LED) and 10 female (3 RH, RED; 3 RH, LED; 1 NRH, RED; 3 NRH, LED) undergraduates. Prior to participation, participants in the non-artist group (hereafter referred to as “non-artists”) indicated that they were not art majors and did not consider themselves artists. Four of the non-artists (three males and one female) were enrolled in an introductory psychology class and received course credit for their participation. The remaining 16 non-artists were volunteers. Individuals who did not meet the criteria for either group were allowed to participate, but were not included in the results of the study. One individual was excluded on this basis because he indicated that he was not an art major, but liked to draw.

### Materials

**Apparatus.** The mental rotation task, which consisted of eight practice trials and 80 test trials, was administered on one of two Macintosh laptop computers that were positioned with the screen two feet from the view of the subject. On one computer (computer 1), the “z” key on the keyboard was labeled “same” and the “/” key was labeled “diff”. On the other computer (computer 2), the “z” key on the keyboard was labeled “diff” and the “/” key was labeled “same”. For the experiment, a chin rest was positioned centrally in front of the computer being used (at a distance of .61 m from the screen). Grayscale shaded images of three-dimensional shapes were created and rendered in different three-dimensional rotations about X, Y, and/or Z axes using Render Boy software on a Macintosh desktop computer.

**Stimuli.** Each trial consisted of the successive presentation of two grayscale shaded images of three-dimensional shapes. For each trial the first image was presented in the center of the screen and covered an area no larger than an average of 645.16 mm<sup>2</sup>. The second image was presented laterally to the

left or right visual field between 1 and 1.5 degrees visual angle from center and covered an area no larger than an average of 322.58 mm<sup>2</sup>, thus subtending an area no larger than 1.5 degrees visual angle. For the practice trials, four simple three-dimensional shapes (cube, cylinder, triangle, cone) were each rendered in two different rotations/spatial orientations, (creating a view 1 and view 2 for each shape) yielding a total of eight different images. For the test trials, 20 different complex three-dimensional shapes (each composed of at least two simpler three-dimensional shapes) were created so that each shape could be paired with one of the other shapes based on similar features. Each shape was rendered in two different orientations (view 1 and view 2 for each shape) yielding a total of 40 different images.

Design and Procedure. Before beginning the mental rotation task, subjects were asked to read and sign a statement of informed consent. Subjects were also tested for eye dominance and asked to fill out a form on which they responded to items on the Annett Handedness Inventory and indicated name, age, date of birth, sex, and eye dominance. Each subject was then instructed to sit in a seat in front of a computer and place his or her chin in a chin rest, which was positioned so that the subject was .61 m from the computer screen. The experimenter first briefly explained the task, then subjects were given detailed instructions on the screen at the start of the task. In the instructions, subjects were told to keep their gaze on the center of the screen throughout all trials. After reading the instructions subjects were given an opportunity to ask the experimenter any questions and to press a key to begin the practice trials. Upon completing the practice trials, subjects were given another opportunity to ask questions and to press a key to begin the test trials. After 40 test trials, subjects were given a short break.

The format for the task was as follows: for each trial, a cross appeared in the center of the screen, indicating the focus point, and immediately began shrinking in size until it disappeared over the course of 1000 ms. This was immediately followed by the presentation of the first image in the center of the screen for 500 ms. As soon as the first image disappeared, the second image was presented to either the left visual field (LVF) or right visual field (RVF) for 180 ms. Subjects were instructed (at the beginning of the task) to make a judgment after presentation of the two images by responding with “same” to indicate that the first and second image represented two views of the same three-dimensional shape and responding with “different” to indicate the first and second image represented two different three-dimensional shapes. Subjects were told to press a button on the keyboard marked “same” with a designated hand for “same” responses and to press a button on the keyboard marked “diff” with the other hand for “different” responses. Immediately after a subject responded, the next trial began with the cross/focus point in the center of the screen. Accuracy of response and reaction time for correct responses were recorded.

Throughout the eight practice trials, each of the eight practice images appeared once centrally and once laterally, with both views of each of the four shapes appearing in the same trial once and once only. Throughout the 80 test trials, each of the 40 test images appeared twice centrally and twice laterally. For one of the two trials in which one view of a particular shape (view 1 of shape A) was the central image, the other view of that same shape (view 2 of shape A) was the lateral image and a response of “same” was correct. For the other of the two trials in which one view of a particular shape was the central image (view 1 of shape A), one of the views of the similarly-featured paired shape was the lateral image (view 1 or 2 of shape B) and a response of “different” was correct. For both practice and test, lateral images were presented to each visual field for half the trials and each type of response was correct on half the trials. Trials were counter-balanced for visual field presentations and correct response type. For each subject, trials were presented in one of four random orders on one of two computers. On one computer (computer 1) subjects used their left hand for “same” responses and their right hand for “diff” responses. On the other computer (computer 2), the opposite hands were used for each response. Trial orders and computers were counter-balanced across subjects for artistic ability (artists and non-artists) and sex.

## Results

Accuracy and reaction time (measured in milliseconds) were each subjected to a repeated measures analysis of variance having two levels of each of the following independent variables: artistic ability (artists and non-artists), sex (males and females), handedness (right and non-right), and eye dominance (right and left), with two levels of visual field (right and left) as the within subjects variable. There was no significant effect for artistic ability and there were no significant interactions between artistic ability and gender, or between artistic ability and visual field.

## Accuracy

In terms of accuracy, the only significant effect was a main effect for sex,  $F(1, 25) = 5.62, p < .05$ , such that males ( $M = 11.55, SD = 6.22$ ) made significantly fewer errors than females ( $M = 15.10, SD = 5.44$ ).

## Reaction Time

For reaction time, there was a marginally significant interaction between sex and eye dominance,  $F(1, 25) = 4.03, p < .057$ . Independent samples  $t$  tests showed that right eye dominant males ( $M = 817.70, SD = 145.18$ ) had significantly faster reaction times than left eye dominant males ( $M = 1010.17, SD = 145.18$ ),  $t(18) = 2.91, p < .01$ . In females, although the opposite trend for eye dominance was shown, this difference was not significant. There was also a marginally significant three-way interaction between artistic ability, handedness, and eye dominance,  $F(1, 25) = 3.99, p < .058$ . In non-artists, there was a significant interaction between handedness and eye dominance,  $F(1, 16) = 9.21, p < .01$  such that right handed, right eye dominant non-artists had significantly faster reaction times ( $M = 810.09, SD = 98.78$ ) than right handed, left eye dominant non-artists ( $M = 1056.93, SD = 190.71$ ),  $t = 3.02, p < .05$ . In non-right handed non-artists, although the opposite trend for eye dominance was shown, this effect was not significant. In artists, there was no significant interaction between handedness and eye dominance. No other effects were significant.

## Discussion

The results of the mental rotation task showed that males made significantly fewer errors than females. This finding replicates the results of previous studies showing male dominance in mental rotation tests (Kimura 1999; Masters 1998; Masters & Sanders, 1993; Peters, et al, 1995; Resnick, 1993) and indicates that the visuospatial task designed for this study is to some extent an adequate measure of mental rotation abilities. The interactions between sex and eye dominance and handedness and eye dominance are also consistent with the literature. For example, right eye dominant males were faster than left eye dominant males, as is consistent with the tendency for more people to be right eye dominant and right handed, thus having faster reaction times due to dominant ipsilateral connections. This idea is further shown in the interaction between handedness and eye dominance in the non-artists. That right handed, left eye dominant non-artists were slower is probably due to the need for corpus callosal transfer. In the non-right handed non-artists, the trend for eye dominance was in the expected direction (left eye dominant individuals were faster), but this effect was not significant. This could be due for the tendency for non right-handed individuals to have more multi-dominant hemispheres.

Although the present study is consistent with previous tests assessing mental rotation skills in terms of gender and accuracy, males also tend to have faster reaction times and such an effect was not found in this experiment. This may indicate that the task was relatively less demanding. In perceptual tasks that are of low levels of difficulty, females tend to have faster reaction times than males and this has been shown in lateralized two-dimensional mental rotation tasks (Voyer & Bryden, 1990).

It is thus possible that in the present study, the images were too simple to present a challenge to groups that might show lower levels of mental rotation abilities when tested on more complex shapes. This could also explain why artistic ability had no effect on performance. In addition, it could explain why there was no effect of visual field. Artists and non-artists may have different patterns of lateral dominance for mental rotation (Winner & Casey, 1992), but the images in this task may have been too simple to pose a challenge to the non-dominant hemisphere. However, the lack of significant findings in this study to support the original predictions could also indicate that 1) the effect of gender on performance on mental rotation tasks is a robust phenomenon that will not be affected by artistic ability, 2) artists as a group do not have significantly higher levels of mental rotation abilities, and 3) artists and non-artists do not have a differential hemisphere advantage for mental rotation. Further research using lateral presentations of more complex visuospatial stimuli may help to answer these questions.

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