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Class: 36 209 Brain and Behaviour

Title of Coursework: Mental Rotation Practical: Do we deal with mental imagery in the same way that we deal with real objects?

Deadline: Wednesday 21st April.

I affirm that this report is my own work, and does not include any unacknowledged material taken from another source.

Signed:

Date:

Abstract.

Participants' reaction times were measured when identifying pairs of congruent or incongruent shapes, one of which had been rotated through either 90° or 180°. Reaction times were longer for 180° than 90°, supporting Shepard and Metzler's (1971) mental rotation theory. The difference in reaction times was slightly larger than anticipated in light of Shepard and Metzler's benchmark of 60° rotation per second, but this could be attributed to either a more complicated visual stimulus (Cooper, 1975) or to the different mechanisms for recording the reaction times. Further study could establish whether image complexity is the culprit.

When examining the spine of a book on a shelf in the library, it is not necessary to turn your head sideways in order to read the title. Neither is it necessary to turn the book sideways in order to check the author: the information is somehow transposed from a vertical orientation to a readable horizontal one. This ability has been called mental rotation.

Shepard and Metzler (1971) studied the mental rotation of objects using congruent or incongruent pairs of two-dimensional line drawings. The objects in the drawings displayed a strong visual perspective – the objects were composed of ten uniform cubes arranged into an ‘arm’ shape – and Shepard and Metzler found that the further round an object was rotated, the longer it took to mentally rotate the object.

Shepard and Metzler’s study was in two parts, however. Their objects were presented on a circular background, so in order to rotate one of them through one plane they merely had to move the image around its centre by the requisite amount. But they also manipulated the images so that they appeared to have been tipped either forwards or backwards in relation to the original. They called these translations ‘picture plane’ and ‘depth’ rotations.

Shepard and Metzler found that there was a linear relationship between the amount of rotation of one of the pictures and the reaction time to name it as either congruent or incongruent. Although there was a difference between the reaction times for the same amount of picture plane rotation and depth rotation, both displayed a similar, linear relationship.

Shepard and Metzler examined this linear relationship further and found that, leaving aside the reaction time required to decide whether two congruent objects are the same without any rotation, the mental rotation process worked at a speed of approximately 60° per second. This does tend to imply that we rotate a mental object rather than just transpose it immediately from one position to another.

This theory of constant rotational speed excited psychologists in many fields because it provided empirical evidence for the mental manipulation of imagery.

Cooper and Shepard (1973) studied the rotation of letters of the alphabet, where the participants had to identify whether the letters were correct or mirror-images. They found a similar relationship between rotation and reaction time as Shepard and Metzler (1971), except that the relationship was not quite so linear: as the amount of rotation increased, the reaction time increased disproportionately. This may tend to imply that, since normal reading is an automatic process (Cattell, 1886), identifying a mentally-rotated letter is not as automatic a process, because the reaction time is significantly longer.

Allan Paivio (1986) proposed a dual-coding system of dealing with sensory information, in which verbal and non-verbal information are processed in parallel but interconnected systems. Mental rotation may indicate some kind of working memory platform for non-verbal imagery, where rather than just hold a mental image, it can be manipulated or worked on.

Stephen Kosslyn (1980), in his 'computational model of imagery', proposed that long-term memory recall of images relies on a mixture of imagery and propositional information. The recall of someone's face might involve the propositions that they had a striking profile and two blue eyes. The recalled image of them, however, would not include their profile and both their eyes at the same time. In order to 'see' their profile, you would construct an image with only one eye. In order to 'see' both their eyes, you would mentally rotate their face until you could no longer see their profile.

Kosslyn seems to agree with Paivio to the extent that he sees the medium for mental imagery as limited in storage capacity and also in the length of time it can retain an image – a striking similarity to working memory (Eysenck, 2000, p.267).

Mental rotation has also been implicated in spatial awareness and the control of saccade eye movements. de Sperati (1999) timed saccades where participants looked away from a visual stimulus rather than towards it. The latency of the eye-movement was found to be proportional to the distance of the saccade. While this in itself may appear unremarkable, it is worth remembering that the eye

effectively sees nothing during a saccade movement, which is a very quick movement, and the observer has to re-establish where their eye is pointing when the movement is finished. Mental rotation of the environment - the angles of the corners of the room, angles of furniture, even shadows and angles of the light would help to build a spatial awareness, from eye-movement to eye-movement, of the surrounding environment.

The implication of de Sperati's findings is that you have to mentally rotate the room to match what your eye sees, and that is what takes the time, not the actual eye-movement.

Cooper (1975) proposes that there are other factors dictating the speed of mental rotation: the familiarity of the object; and the complexity of the object. It should be easier and therefore quicker to rotate a familiar object than an unfamiliar one, perhaps because you have a better long-term memory reference for the familiar object. It should be more difficult and therefore slower to rotate a complex object than a simple one, because you have more points of reference to manipulate.

Eysenck (2000) suggests that these studies indicate for the most part that "visual images have all the attributes of actual objects in the world", with a few exceptions; that verbal description of the manipulation of an object may produce an inaccurate mental image, that the complexity of a real object does not affect the ability to manipulate it, and that real objects are permanent, not subject to memory decay.

This experiment will revisit Shepard and Metzler's classic 1971 study and, with the benefits of modern computer graphics and tachioscopic timing, test the relationship between object rotation and reaction time.

The hypothesis to be tested is that, when identifying whether a pair of differently-oriented objects are congruent or incongruent, the reaction time will increase when the amount of rotation between the objects is increased.

Method.

Design

This is a repeated measures experiment, with just over 100 participants performing the same computer-based test to identify whether pairs of shapes, one of which has been rotated, are congruent or incongruent. The rotated shapes were rotated randomly through the picture plane or the depth plane, and by angles in increments of 30°. All the participants performed the whole test of 48 trials.

The independent variable is the amount of rotation between the two objects presented on the screen, and the dependent variable is the reaction time to identify them as congruent or incongruent pairs of objects. This experiment is testing a one-tailed hypothesis, and the data collected is on a ratio scale.

Participants

The participants were second-year undergraduate psychology students, who took part as a requirement of their course. They were not selected by age, gender, or by any other criteria. Their ages ranged between eighteen and approximately fifty, and their gender distribution is assumed to be equal.

Materials

Participants were given a sheet of paper (see appendix A) which explained the mental rotation phenomenon, and gave instructions for accessing the experiment over the internet.

The experiment was performed using an internet-based application running on an IBM PC compatible computer with a 14-15" cathode ray tube display. Responses were recorded by clicking one of two on-screen buttons, marked 'same' or 'different' with the computer mouse. The application is downloaded from the internet, but runs on the local client computer, eliminating any network latency.

The application was written using Macromedia Authorware by Doctor Ken McGraw and Doctor Mark Tew from the Department of Psychology at the University of Mississippi.

Procedure

The experiment took place in a computer laboratory at the University over the course of six sessions, which were held in the afternoon of a normal working day.

Participants read their sheet on the mental rotation phenomenon, and then accessed the experiment as per the instructions. The application first warned that, since timing was a factor in this experiment, users should quit all other applications that could cause the computer to freeze or run slowly. It is assumed that all participants did so; the experiment was the first task they had used the computers for in these sessions.

After giving their informed consent for the experiment, they registered their name, gender and age, were given a brief explanation of how the experiment works, and shown an example of the pairs of objects (see figure 1):

'On each trial of this experiment you will be shown a pair of 3-D objects like the one below and asked whether the objects are the same or different. Ignore rotational differences when making your judgements. The experiment will measure the time it takes to choose same or different. Accuracy is more important than speed.'

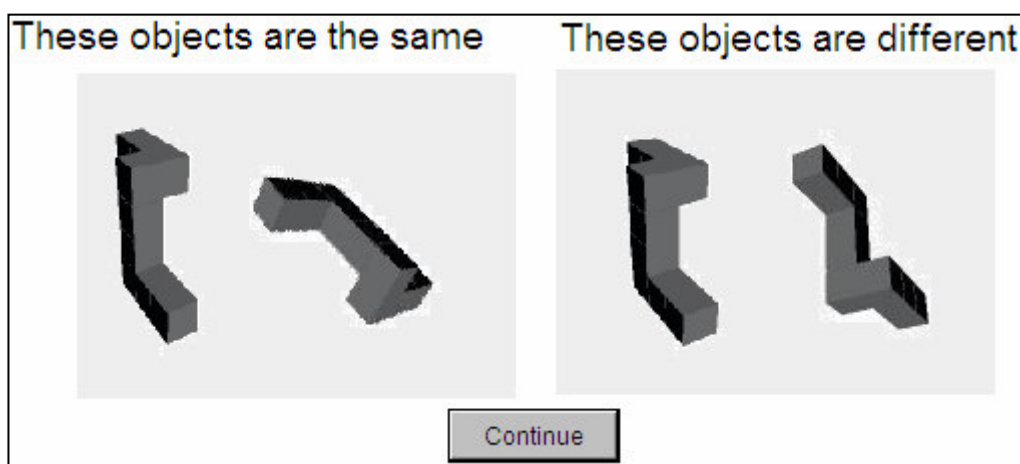


Figure 1: Two pairs of objects from the introduction page of the experiment.

The experiment started with an animated clock counting down to the start of each of forty-eight trials, and a reminder of how many trials remained. When the countdown finished, two images were presented on the screen, accompanied by a computer-produced sound. Participants had to use the mouse to click one of two on-screen buttons, one marked 'same' and one marked 'different'.

In between each trial, participants were shown their current scores. They were required to click an on-screen button to start the countdown to the next trial.

At the end of the experiment, the participants' results were transmitted to the web servers at the University of Mississippi, from where they were downloaded by the experimenters and a sample taken for testing.

Results.

The results are for reaction times to pairs of images, one of which has been rotated through either 90° or 180°. The results are from a random sample of thirty participants (see appendix B).

The mean reaction time for 90° rotation was 4.55 seconds, standard deviation 0.5782. The mean reaction time for 180° rotation was higher at 6.337 seconds, standard deviation 0.6088. The data were normally distributed, and on a ratio scale. The mean reaction times are shown in figure 2.

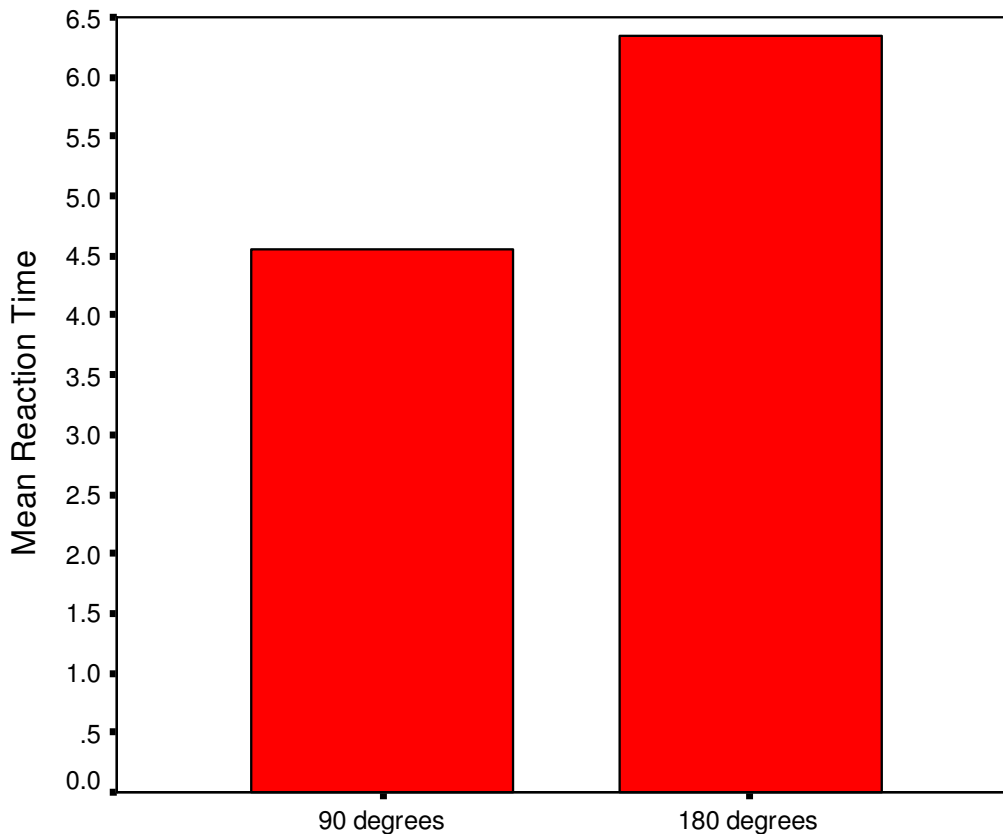


Figure 2: Mean Reaction Time for 90° and 180° rotation.

A related samples t-test returned a value of -12.657 with 29 degrees of freedom, which is significant at the one percent level ($t(29)=-12.657$, $p<0.01$). The calculations were performed using SPSS for Windows v.11.5 (see appendix C).

Discussion.

The results support the hypothesis that when identifying whether a pair of differently-oriented objects are congruent or incongruent, the reaction time will increase when the amount of rotation between the objects is increased.

This supports the findings of Shepard and Metzler (1971) in so far as the amount of rotation affects the reaction times. The difference between the mean reaction times for 90° and 180° is approximately 1.79 seconds. According to Shepard and Metzler's study, the extra 90° between 90° and 180° rotation should add, at 1 second per 60° , 1.5 seconds to the reaction time.

Although the difference in reaction time is slightly longer than predicted by Shepard and Metzler, Cooper's (1975) ideas that object complexity and familiarity could affect reaction times may offer an explanation. The objects used in this study are slightly more complex than those used in the Shepard and Metzler study: they are shaded in different colours and do not have the simplicity of a line drawing. It could therefore be reasonable to attribute the extra 0.3 seconds to that differing level of complexity.

If the reaction times for 180° and 90° are projected backwards to find a reaction time for 0° of rotation in this study, the projected reaction time is 2.75 seconds. In the Shepard and Metzler study, the projected reaction time for 0° of rotation is between 1 and 1.25 seconds. This may also tend to support the proposition that the objects in this study are more difficult to identify than Shepard and Metzler's, although caution is advisable when projecting a result from only two pieces of data.

Another possible explanation for this disparity in reaction times is that Shepard and Metzler used a tachioscope with two levers, one for each hand, to register a 'same' or 'different' response. This study used on-screen buttons to be activated by the computer mouse. A participant with a hand on each lever is likely to register a faster response than a participant trying to coordinate eye, hand and cursor to hit a relatively small on-screen button.

Further research could clarify the object complexity issue. If the experiment was repeated using two sets of analogous objects: the existing shaded objects; and a matching set of the simpler line drawing objects as used by Shepard and Metzler, it could be established whether image complexity was really that influential in reaction times.

The results of other studies into mental rotation and the manipulation of imagery owe a lot to Shepard and Metzler, but it would be a mistake to claim that this study supported each of those other findings: it is only safe to say that this study supports the basis upon which they were built.

This study has examined the mental rotation phenomenon using congruent and incongruent pairs of objects rotated through various axes and by varying amounts. The results support Shepard and Metzler's 1971 experiments. Although not exactly matching up with their rotational speed of 60° per second, the slight variation may be attributable to either the difference in the method of recording an answer – a computer mouse instead of a lever – or a difference in the complexity of the experimental objects.

Subsequent studies based on Shepard and Metzler's findings have provided a fairly firm basis to conclude that we do deal with mental imagery in the same way that we deal with real objects. Although this study does not in itself reach any conclusions on that subject, it does support the premise upon which these further studies were based.

References.

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Appendix B: Reaction Time Data

Reaction times in seconds at 90° and 180° of rotation from a random sample of 30 participants.

Participant	90°	180°
1	4.2	5.9
2	3.6	6.5
3	4.5	5.3
4	5.1	6.9
5	4.8	7.3
6	5.6	6.4
7	4.7	6.0
8	3.9	5.6
9	5.0	5.8
10	4.2	6.7
11	5.7	5.9
12	4.4	6.8
13	3.4	5.5
14	4.1	6.5
15	4.7	5.9
16	4.6	6.6
17	5.1	7.2
18	5.2	6.2
19	5.5	6.2
20	4.8	7.4
21	4.3	6.8
22	4.5	6.4
23	3.6	5.8
24	4.6	5.6
25	4.0	7.4
26	4.8	7.0
27	3.9	5.6
28	4.5	6.8
29	4.8	5.5
30	4.4	6.4