1.3 Rotation of Mental Images

Abstract

Psychology had an early concern for mental imagery, but problems with that research led to the virtual abandonment of the study of imagery. More recently, researchers have found ways to measure certain aspects of imagery. One successful technique uses "rotation" of mental images. A person is shown two shapes and must decide whether or not they are the same (regardless of rotation). One shape is sometimes rotated with respect to the other, and people report that they make the judgment by rotating their image of one shape to determine whether it matches the other. If peoples' reports are accurate, it should take longer to rotate the image when the stimulus is rotated farther from vertical. Shepard and his colleagues (e.g., Cooper & Shepard, 1973) have done a number of experiments of this type, and have found that images do seem to be rotated, and at a steady, measurable speed. The exercise accompanying this chapter has students perform one of two versions of this task to measure the speed of rotation of mental images.

How many windows are in your family home? Take a moment to answer this question before you continue. In order to answer the question, you probably constructed an image of each room in your house or of the outside of your house viewed from various directions and then counted the number of windows you "saw." That's an example of a mental image. Other examples might include imagining a friend's face or picturing to yourself which buildings you have to walk past to go to the library.

The study of mental imagery illustrates an interesting challenge for the science of psychology-namely, how to study internal mental processes that are not open to direct observation. Note that I cannot directly observe your mental images, nor can you observe mine. But through careful experimentation, it is possible not only to make legitimate inferences about images, but also to actually measure some aspects of them.

Because of the difficulty of studying mental images, such study fell from favor during much of the 20th century. But new techniques emerged that brought it back in a very prominent way. The modern study of images comes from two general lines of research. Paivio (1963; see Paivio, 1995, for a review) showed that concrete nouns (names of actual objects, such as "boat" or "pencil") are recalled better than abstract nouns (such as "beauty" or "justice") in a wide variety of contexts. He interpreted this concreteness effect in terms of a dual-code theory of memory: We can store concrete nouns, both in terms of the word itself and in terms of an image of the object, whereas it is hard to form images of abstract nouns. Because concrete nouns have two representations, we are more likely to retain a good retrieval cue.

The second line of research that brought imagery back to the mainstream of psychology was the work of Shepard and his colleagues (Shepard & Metzler, 1971; Shepard & Feng, 1972; Cooper & Shepard, 1973) on transformations of mental images. The discovery of quantitative relationships regarding how reaction

times change as a stimulus is altered has proved to be a very powerful tool in understanding the underlying mechanisms for many cognitive operations. The experiments accompanying this chapter illustrate this approach to studying internal processes in psychology.

Methods for Studying Mental Imagery

If mental images are in some ways analogous to direct perceptions of objects, then it follows that mental images should follow some of the same rules that govern perception of physical objects. For example, if I showed you a picture of someone and asked you who it was, but I handed you the picture upside-down, you probably would have to turn the picture right-side-up in order to recognize the face. The operation of rotating the picture would require some measurable amount of time. Does manipulation of mental images operate in a similar fashion?

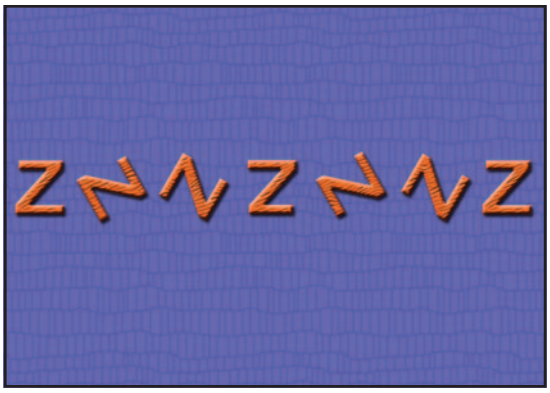

FIGURE 1.3.1

Behavioral Analysis

A series of studies suggests that they do. Cooper and Shepard (1973) briefly presented subjects with pictures of letters that were rotated left or right in varying degrees between right-side-up and up-side-down (see Figure 1.3.1). The letters also varied in that some were mirror images of actual letters. The subject's task was to report whether the letter was normal or mirror-image. The main question was whether subjects would take longer to make that judgment when the letters were rotated further from vertical. The results showed that the farther the letter was rotated, the longer it took for a subject to make the judgment about whether the letter was normal or mirror-image.

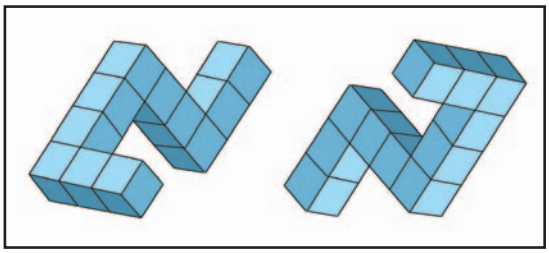

FIGURE 1.3.2 – *Example 2D figures similar to those used by Shepard and Metzler*

Shepard and Metzler (1971) did a similar experiment, except that they presented two figures at once, and subjects had to decide whether or not the two figures were the same (see Figure 1.3.2).

The figures varied in that one was rotated with respect to the other. Again, the greater the rotation, the longer it took subjects to identify two figures as the same or different. The

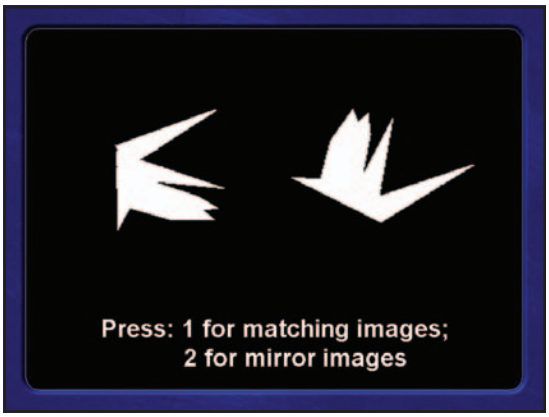

FIGURE 1.3.3 – *Example trial from the Rotation of Mental Images experiment*

experiment in which you will participate is similar to the Shepard and Metzler (1971) experiment, except that two-dimensional (2D) geometric forms are used (see Figure 1.3.3).

Psychophysiological Analysis

An issue of considerable interest to both cognitive scientists and neuroscientists is whether the production of mental images uses any of the brain mechanisms used during actual perception. That is, are some of the same parts of the brain that are used when we actually see an object also used when imagining that same object? Some evidence suggests that this is true. Using PET scans, Kosslyn et al. (1993) showed similar patterns of activation of the cerebral cortex during both perceptual and imagery versions of the same task.

A similar result was reported by Le Bihan, Turner, Zeffiro, Cuenod, Jezzard, and Bonnerot (1993) using functional Magnetic Resonance Imaging (fMRI). They showed an increase in activation of the visual cortex, but not of the non-visual cortex, during both perception and imagery (though the activation was slightly less with imagery). Kosslyn and Sussman (1995) reviewed other evidence for the intimate role of imagery in everyday perception.

Georgopulous, Lurito, Petrides, Schwartz, and Massey (1989) studied activation of single neurons in the motor cortex of a monkey trained to perform a version of a mental rotation task. As the monkey prepared to move its arm in a certain way, there were changes in activation of neurons along a trajectory, as would be expected if there was an anticipation of moving the arm through a series of locations.

Additional Findings

Sex differences in the mental rotation task are another fascinating development. Studies consistently find rather large differences in reaction time for mental rotation tasks, favoring males. For the version of the task used in the experiment accompanying this chapter, the difference is usually about 200 ms. This difference in mental rotation is one of the largest sex differences found in cognitive tasks (Hyde & McKinley, 1997). The cause of the sex difference in mental rotation is not known, though there has been a lot of speculation about both biological and psychological causes (Caplan, Crawford, Hyde, & Richardson, 1996; Halpern, 2000). Research on an analogous task suggests that the difference may be reduced or eliminated by practice (Kass, Ahlers, & Dugger, 1998).

The Imagery Debate

Although many researchers accept that mental images exist and that they are depictive, rather than descriptive, others have challenged that point of view. Kosslyn (1994) argued that the issue of whether there are depictions (images) or descriptions that represent our knowledge of spatial/visual objects had been settled in favor of the existence of images. Essentially, the claim is that mental images involve the same brain mechanisms that are used in actual perception. Pylyshyn has raised doubts about this interpretation. Though the debate is too wide-ranging to be covered here, the principle arguments and counter-arguments were summarized by Pylyshyn (2002, 2003). Pylyshyn's (2002) Mental imagery: In search of a theory was published in Behavioral and Brain Sciences, which is a journal with which the student of psychology should be acquainted. The journal publishes lead articles on various areas of research, with invited commentaries by other researchers in the field, and the lead author's reply to them. Kosslyn, Thompson, and Gaddis (2002) are among those who replied to Pylyshyn's lead article. (The lead article and all of the commentaries and replies are available in PDF format on Zenon Pylyshyn's web site at *www.uccs.rutgers.edu/faculty/pylyshyn.html*.)

Methodological Considerations

There have been two general types of presentations used in studies of mental rotation. Cooper and Shepard (1973) presented single pictures, with subjects comparing them to a stored representation of an upright object, such as a letter. Shepard and Metzler (1971) presented two stimuli at a time, with one rotated relative to the other, as in the experiment accompanying this chapter. Note that this permits the use of arbitrary, abstract stimuli for which there is no defined "right-side-up." This has the advantage of not relying on subjects' memories; however, it also presents a disadvantage in that it is harder to determine which figure is being rotated-perhaps the subject rotates both at once.

Expected Running Time = 18 minutes

Questions

1. What are the dependent and independent variables in this experiment? What are some important controls?

2. Can we rotate images in more than the two dimensions used in this experiment? Shepard and Metzler (1971) performed such an experiment, and you should refer to their article.

3. What is the speed of rotation of the shapes? Calculate this in degrees per second. Was the speed constant? Compare your results to Shepard and Metzler's (1971) findings with "picture-plane" pairs. If there is a difference, how might it have been influenced by the nature of the shapes used? Cooper (1975) also compared a number of different images. This experiment used two of her shapes.

4. How clear are your mental images? Discuss this with your classmates. You may find that some people claim that they "see" their images almost as clearly as if they were actually looking at the objects. Others will report that they have only rather vague images. These reports are like the introspection used by early psychologists. What sorts of problems are there in interpreting these reports?

Extension Experiments

Because this experiment involves the presentation of bitmapped image files, it is possible for you to make many modifications to the stimulus materials using the existing program. In order to do this, you will need to have your stimuli stored as .bmp files. If you use a graphics program to make the stimulus files, simply save them as .bmp files. If you choose to draw your stimuli freehand or to copy them from another source, use a scanner to import them into a graphics program where you can adjust the size and save the result as a .bmp file. Note that you will need to make copies of the stimuli in all necessary rotations. Most graphics programs enable you to rotate an image easily by a specified amount.

Advanced Questions

1. Is the speed of rotation dependent on the specific shapes used? (Note that, in this experiment, the data were averaged across shapes, but the data as to what shape was used on each trial was stored by the computer and could be subject to analysis.) Cooper (1975) compared a number of different shapes. The two used in this experiment were her Forms B and D.

2. What are the results for non-visual presentation? Specifically, what happens if the shapes are presented haptically (i.e., by touch)? See Carpenter and Eisenberg (1978).

3. Another task that has been used to study the manipulation of mental images is mental paper-folding, in which a subject is shown a diagram of a box that has been unfolded into a flat surface. Two edges are marked, and the subject must decide whether those edges would meet if the object were folded into a box again. For this task, it seems that people must make a series of discrete manipulations of the mental image, rather than a continuous change such as rotation. Shepard and Feng (1972) did an experiment using this task, finding that there was an increase in reaction time as the number of "folds" required was increased. Stimuli such as they used can be drawn easily on paper. Because of the time required to do this task, a stopwatch can be used to record the reaction times with sufficient accuracy.

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