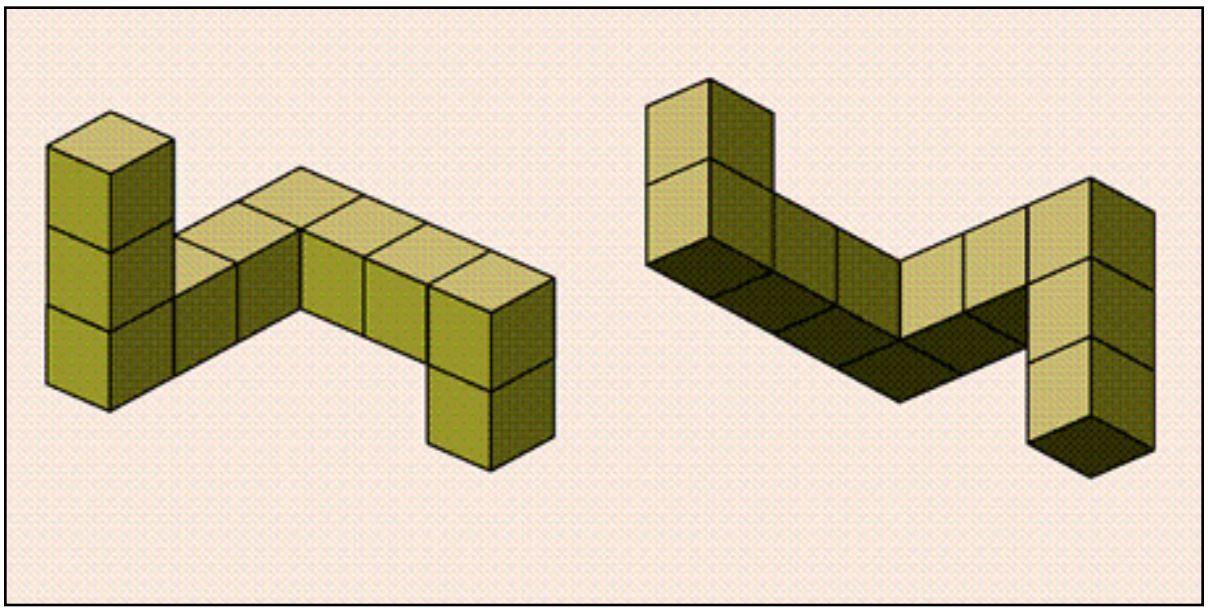
Mental Rotation Lab



How is abstract information represented by the mind? Across our previous labs, this question has been continuously lurking in the shadows. In our final lab, we will take a look directly at this issue through the lens of "mental rotation" tasks.

Imagine a dog walking down your favorite New York street. Now imagine the dog has only three legs instead of four. Now imagine putting back the fourth leg, but making the dog wear a sweater. These mental "simulations" are infinitely creative, but also can feel as vivid as our actual visual experience. When you mentally construct a picture or image in your mind it is known as *mental imagery*. Mental imagery is a classic research topic in cognitive psychology because - unlike perception or sensation research - it involves mental representations and processing of information which are not immediately perceptible (e.g., with your eyes). Psychologist know a lot about how the visual system helps us perceive our surroundings, but much less about how these perceptual representations support later abstract thinking.

The idea of mental images seem so familiar and common-place, yet it seems very difficult to get a handle on what form these representations actually take. Indeed, one of the most contentious debates in cognitive psychology in the late 1960s was about the nature of mental imagery. Are mental images real? Are they even images? At first glance these questions may seem silly because the vividness of our imagination seems so obvious to us (we called this the *argument from introspection* in lecture). However, the central question in early work on mental imagery was if the mind actually represents information in the form of images (just like a JPEG or PDF figure you put in your paper) or if all abstract thought is mediated by propositional, symbolic, language-like processes.

The two sides of this debate (discussed in lecture) were the analog camp (represented by Kosslyn) and the propositional camp (represented by Pylyshyn). The analog camp argued that mental images are image-like representations that shared much in common with the lower level perceptual properties of our experience. Indeed, proponents of these theory likened mental images to the "surface displays generated on a cathode ray tube by a computer" (Kosslyn and Pomerantz, 1977). In contrast, the propositional camp argued that mental images were represented in a more abstract, language-like representation (see lecture notes for more on this).

So, what does mental rotation have to do with any of this?

Familiar objects rotated in various ways along the axis extending outward from the page.

Mental Rotation

The original mental rotation experiments were done by Roger Shepard and Jean Metzler in 1971. In these experiments, participants viewed pairs of objects like the ones at the top of the page and were asked to judge if they were the same the object (just from a different view) or were different (in the sense of being a mirror image of the each other). The key manipulation was that the objects were rotated in various ways. For example, imagine you are holding a warm cup of coffee in your hand. Now rotate the cup 15 degrees to clockwise. Good. Now go a bit further, 30 degrees. Watch out! The liquid might fall out!

In the Shepard & Metzler (1971) experiments, the time it took people to decide if an object was the same (just rotated) or different (a mirror reflection) depended on the **angle of rotation** (see Figure on the right is taken from the original paper - one of our target readings). In other words, it would take you longer to decide if the 30 degree rotated version of your cup was the same as the upright version relative to the 15 degree rotated version. The idea is that in order to make the same/mirror judgement, people ***actually mentally rotate the object***. Bigger angles require more time to "rotate" in your mind just as they would in the real world (see Figure below). As mentioned in class, Cooper (1976) performed an even more interesting followup which provided even stronger evidence that people rotate objects when doing the matching task. Thus, most people agree that people do seem to perform some kind of mental rotation.

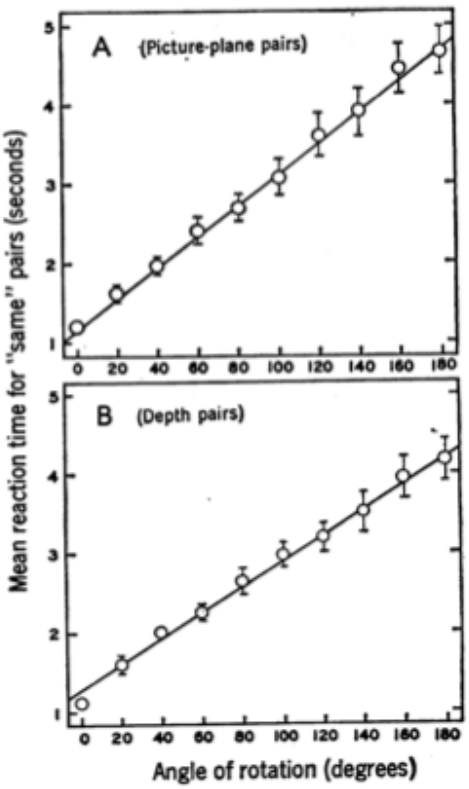


Fig. 2. Mean reaction times to two perspective line drawings portraying objects of the same three-dimensional shape. Times are plotted as a function of angular difference in portrayed orientation: (A) for pairs differing by a rotation in the picture plane only; and (B) for pairs differing by a rotation in depth. (The centers of the circles indicate the means and, when they extend far enough to show outside these circles, the vertical bars around each circle indicate a conservative estimate of the standard error of that mean based on the distribution of the eight component means contributed by the individual subjects.)

Why is this surprising?

Take a moment to think about this result: the speed of making a same/mirror judgment depends

on the angle at which the object pair is rotated. It is a trivial result, but also kind of profound. Think about all the possible ways the experiment *might* have worked out. Perhaps the representations we have to thinking about objects is more sophisticated. Instead of mentally rotating objects until they match we might be able to do a quick match based on some other property. Why rotate? Why not do some other type of transformation? Rotation implies stepping through a large number of intermediate states (1 degree, 2 degree, 3 degree, etc...), not all of which are critical to the actual same/mirror judgment.

The mental rotation experiments of the early 70s suggested that the abstract, mental processing of objects in our mind followed similar principals to those in the real world. This result was exciting to the analog theorists (like Kosslyn) who felt the mental images were like perceptual representations. On the other hand, it is not obvious how the propositional theory might explain this finding. There is nothing inherent to the propositional theory that would predict that objects would be matched based on rotations. Indeed, when you think about the propositional theory, it gives you some ideas about alternative algorithms or procedures for doing that task that are independent of angle (for example matching features and relations between different parts of the object). Of course, the propositional theory could be modified to account for this result (assuming that matching is done with a sequence of small, incremental "transformations" of some abstract representation). However, this seems like an ad-hoc add-on to the theory rather than a natural implication of the view the representations are propositional.

In the end, the field decided that, despite these intriguing results, the mental imagery debate was unlikely to resolved on the basis of behavioral data alone (Anderson, 1978). In effect, both the analog and propositional theory made a cardinal sin in theorizing about cognitive function: **they each considered only the nature of the representation and not the *process* which operates over those representations.** As we have discussed this semester extensively, specification of both the representation and the processes that operates over those representations is critical for any cognitive theory. As time as gone on, the debate about mental imagery are a little less contentious, although the question of the substrate of mental representation is still very active. The analog/imagery perspective is now most often associated with the ***embodied cognition*** movement (which argues that much of thinking is tied to the spatial properties of the world and our interactions with the environment). In addition, there have been a number of attempts to "blend" both the analog and proposition ideas (similar to the dual-code theory of Anderson, 1978). One example of this is the "perceptual symbols systems" approach from Barsalou (1999) which argues for a propositional representation that operates *over* images.

Mental rotation remains one of the core phenomena that cognitive psychologists study. In our lab we are going to replicate the mental rotation experiment as an excuse to learn a bit about linear regression.

Required Readings

Shepard, R.N. and Metzler, J. (1971) "Mental rotation of three-dimensional object." *Science*, 117, 701-703.

Takano, Y. and Okubo, M. (2002) "Mental rotation." in Lynn Nadel (Ed.), *Encyclopedia of Cognitive Science*, London: Macmillan.

[these papers will be available from the class website]

Optional Readings

Anderson, J.R. (1978) "Arguments concerning representations for mental imagery" *Psychological Review*, 85(4), 249-277.

Kosslyn, S.M., Ganis, G. and Thompson, W.L. (2001) "Neural foundations of imagery" *Nature Reviews Neuroscience*, 2, 635-642.

Further Reading

Hugdahl, K., Thomsen, T. and Ersland, L. (2006) "Sex differences in visuo-spatial processing: An fMRI study of mental rotation" *Neuropsychologia,* 44(9), 1575-1583.

Flusberg, S.J. and Boroditsky, L. (2010) "Are things that are hard to physically move also hard to imagine moving?" *Psychonomic Bulletin and Review,* 18, 158-164.

[the other papers are available via Google scholar accessed from NYU's network]

Lab Steps

#1: Collect Data.....

To collect data for our experiment we are going to use a web based version of the mental rotation task. Unfortunately, since the computers in our lab are without internet, you will do this at home. The URL for the experiment is here: http://psych.hanover.edu/JavaTest/Cognition/Cognition/mentalrotation_instructions.html

When you click the link at the bottom of the page that says "Click here to start the experiment" a window will pop up that should take over your entire screen. The first page lets you configure various aspects of the experiment. We want to test the following parameters:

Stimulus Type	**Original 3D**
Number of Rotation Angles:	**7**
Should the left stimulus be allowed to rotate or be fixed?	**Rotate**
Stimulus Size:	**300 pixels**
Number of Trials per Level:	**15**
Dist. from Fixation:	**0.15**
Delay before stimuli:	**1000**
Stimulus on till response:	**YES**

When you have this entered in correctly, press "Done" to begin the experiment. A fixation cross will appear in the center of the screen. Press the space bar when you are ready to begin.
On each trial view the pairs of items. If they are the same item (ignoring rotation) press 's'. If these are mirror reflections (i.e., you can't rotate one to make it the same as the other), press 'm' (for mirror reflection).

#2: Get results and process them.....

When you get done, the experiment will display a set of results. Write down or take a screen shot of the display. Finally, at the bottom of the screen is a button that says "Show Trial Data". When you press this it will pop up your data in a format looking like this:

```
Trial : Angle : Stimulus : Response : RT(msec)
1 : 180 : Mirror : Same : 10421.0
2 : 90 : Same : Same : 469.0
3 : 90 : Mirror : Same : 272.0
4 : 0 : Same : Mirror : 376.0
```

Select all the data in the window and copy-paste it into a text file (using text edit on the mac or wordpad on the PC). Save the data to a text file on your computer (like Todd.txt).

Next, open the data in Excel. When you open the data the "Text Import Wizard" will appear. In the first option choose "Delimited". Also choose to start the import at row 2 (skipping the header). Next, excel will ask you for what delimiter you want to use. In this file, the colon is the divider, so choose "other" and enter the ":" character. You should see that excel detects the columns in the preview window. Click Finish (you can skip the next step of the import wizard).

Now that you have your data, we need to format it a bit for R. First lets add a "subject number" column. Using the subject number you received in class make a new column that just has your subject number over and over. To do this, select the first column of data (the trial number) and choose "insert column". Then in the first column type your subject number. Then select the bottom corner of that top cell and drag downwards. Here is what my data looks like now (I pretended to be subject 13):

	A	B	C	D	E	F
1	13	1	180	Mirror	Same	10421
2	13	2	90	Same	Same	469
3	13	3	90	Mirror	Same	272
4	13	4	0	Same	Mirror	376
5	13	5	90	Same	Same	112
6	13	6	0	Mirror	Mirror	79
7	13	7	0	Mirror	Same	8
8	13	8	90	Mirror	Mirror	87
9	13	9	0	Mirror	Same	87
10	13	10	180	Mirror	Mirror	80
11	13	11	90	Same	Same	47
12	13	12	90	Same	Mirror	95
13	13	13	0	Same	Same	80

Now, choose "save as" and save your data as <subject number>.txt. Make sure the format is "tab delimited text".