

Science Education Collection

# Mental Rotation

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## Overview

Source: Laboratory of Jonathan Flombaum—Johns Hopkins University

Visual mental imagery refers to the ability to conjure images in one's mind's eye. This allows people to process visual material above and beyond the constraints of a current point-of-view; for example, a person could imagine, using their mind's eye, how something might look in a different color, or what it would look like if it were made from a different material or rotated and seen from a different perspective. Mental imagery seems to support important human behaviors in many contexts. For example, people report visualizing routes and maps when planning a route or giving directions. They report visualizing movements, such as swinging a bat, to prepare for an actual action. They also report the mental rotation of objects in order to consider how an object might fit into a receptacle or clear a barrier.

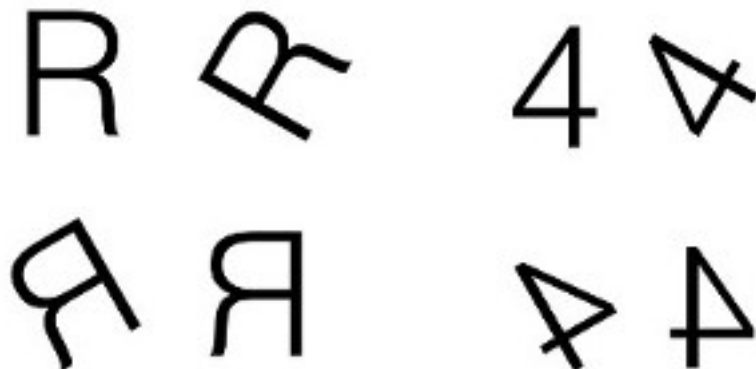
This video demonstrates how to use the mental rotation procedure in order to investigate visual mental imagery.

## Procedure

### 1. Stimulus design.

1. Present the stimuli for this experiment—letters and numbers, along with their mirror images (**Figure 1**)—in various rotations.

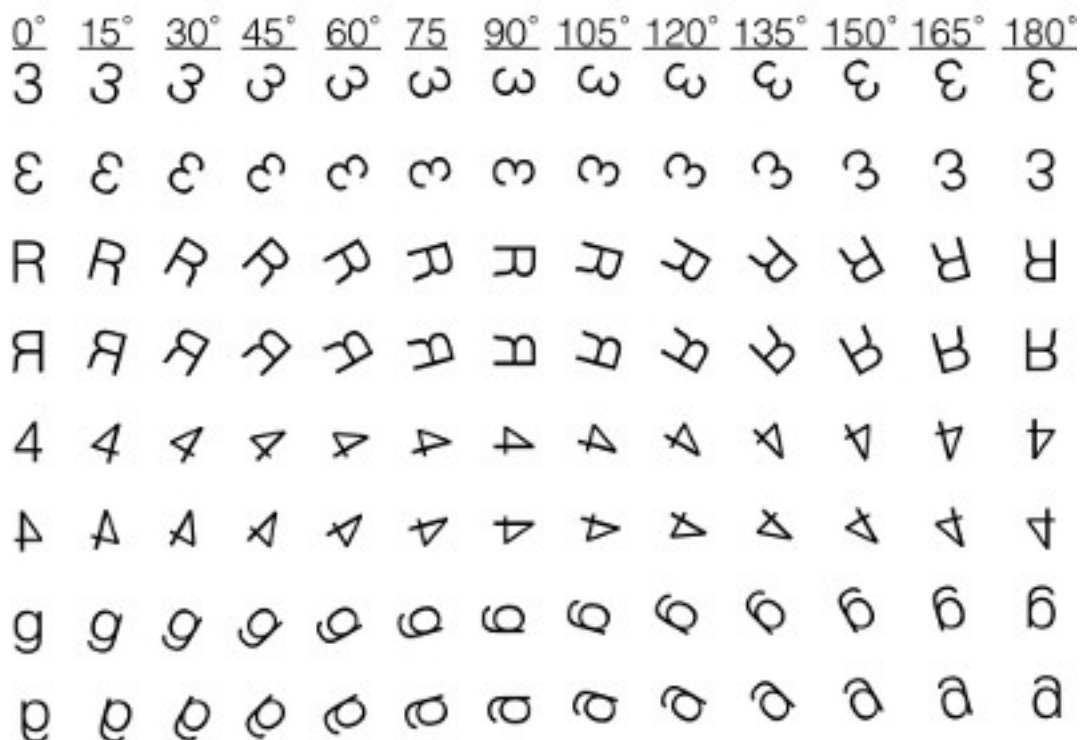
#### Sample Stimuli for Mental Rotation Task



**Figure 1. Sample stimuli for a mental rotation task.** The top rows show two characters (R and 4) and a copy of each rotated. The bottom row shows a mirror image of each (on the right side of each pair) and a rotated version of each, as well. The mental rotation task involves identifying rotated versions of familiar characters and distinguishing them from rotated versions of their mirror images.

2. Use PowerPoint, Keynote, or a similar program to generate the stimuli.
3. For this experiment, use the uppercase letter 'R' and the lowercase letter 'g,' along with the numbers '4' and '7.'
4. In PowerPoint, make one copy of each of the four characters. Use the Helvetica Light font for this experiment.
5. Make a second copy of each character and flip them to produce a mirror image of each.
6. Make 12 copies of each of the four characters and their mirror images.
7. Rotate each of the 12 copies by an increasing increment of 15°. The original copy of each is 0°, the next is 15°, then 30°, and so on, until 180°. Reference **Figure 2** to see the full set of stimuli used for this experiment.

## Stimuli for Mental Rotation Task



**Figure 2. A complete set of stimuli for the mental rotation task.** Four characters (3, R, 4, and g), each paired with their mirror images and rotated in 15° increments between 0 and 180.

8. From the 13 rotated copies of each stimulus and its mirror image, generate the stimuli for each individual trial. A trial consists of one of the four non-mirror images printed at the top of a page. The bottom of the page includes that letter or number and its mirror image at one of the 12 rotations (**Figures 3 and 4**).
9. Make a page for each trial of the experiment. Each of the four numbers/letters have 13 trial pages, so make sure there are 52 pages total and print them out.
10. Number the backs of the pages 1-52. The number on each page is the number tag. The number a page is labelled with does not matter. However, when numbering the pages, also make a key, a table that reports the nature of the trial on each page and the correct answer (left or right), so responses can be associated with individual trials later. Create the key to look something like an Excel spreadsheet labelled "Mental Rotation Key" (**Table 1**).

Number Tag	Character	Angle	Correct Answer
1	3	60	RIGHT
2	g	75	RIGHT
3	g	30	RIGHT
4	g	60	LEFT
5	g	165	RIGHT
6	4	105	LEFT
7	3	15	LEFT
8	3	165	LEFT
9	4	180	LEFT
10	R	15	RIGHT
11	g	180	RIGHT
12	g	45	RIGHT
13	g	105	RIGHT
14	3	45	RIGHT
15	4	15	LEFT
16	R	60	LEFT

17	R	45	LEFT
18	R	150	LEFT
19	g	0	RIGHT
20	R	30	LEFT
21	3	120	LEFT
22	4	90	LEFT
23	R	75	LEFT
24	4	135	RIGHT
25	3	180	LEFT
26	4	45	LEFT
27	R	90	RIGHT
28	4	0	LEFT
29	4	120	LEFT
30	3	135	RIGHT
31	R	135	LEFT
32	3	30	LEFT
33	4	75	LEFT
34	3	105	LEFT
35	3	150	LEFT
36	R	105	RIGHT
37	4	60	RIGHT
38	4	30	LEFT
39	R	120	RIGHT
40	R	180	RIGHT
41	g	135	RIGHT
42	3	0	LEFT
43	3	90	LEFT
44	4	150	RIGHT
45	4	165	LEFT
46	3	75	RIGHT
47	R	165	LEFT
48	g	90	RIGHT
49	g	150	RIGHT
50	g	15	LEFT
51	R	0	RIGHT
52	g	120	RIGHT

**Table 1. An example of a key that reports the nature of the trial on each page and the correct answer (left or right).**

### Sample Test Page

Which of the two  
characters below is the: R

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**Figure 3. A sample test page for one trial of the mental rotation experiment.** The participant must report whether the character on the left or the right (below the line) is the rotated 'R' (as opposed to its mirror image rotation).

### Sample Test Page

Which of the two  
characters below is the: 4

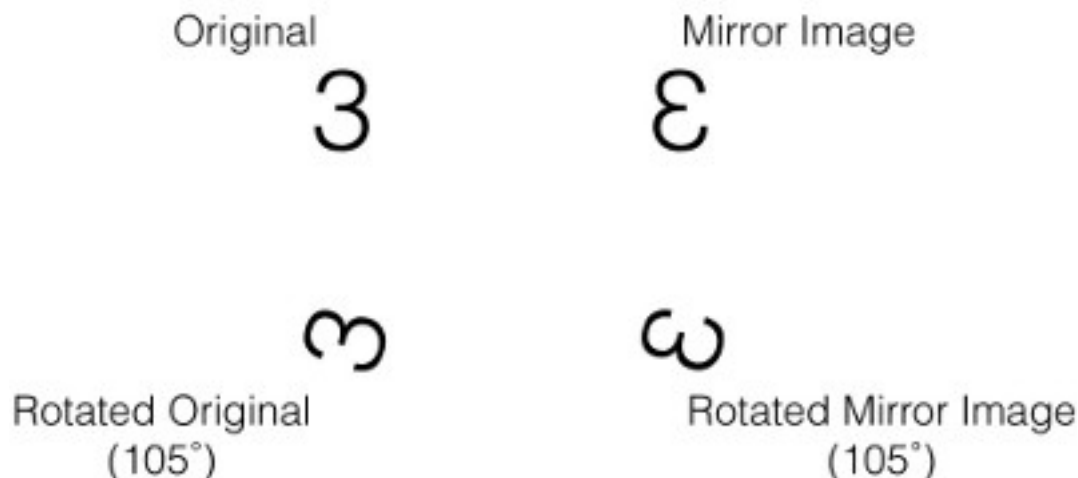
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**Figure 4. A sample test page for one trial of the mental rotation experiment.** The participant must report whether the character on the left or the right (below the line) is the rotated '4' (as opposed to its mirror image rotation).

11. In order to associate results with the content of each trial, a place to record the results is needed, so make another spreadsheet with a column for the trial number, a column for the number tag of that trial, a column for the response given (right or left), and a column for the time it takes the participant to produce a response. Print out this response sheet.
12. In addition, make a demo page to use in order to explain the instructions. Have it show an example of one of the characters, its mirror image, and some examples of the character at one of the rotations. Label it clearly (**Figure 5**).

### Instructions Sheet



**Figure 5. An instruction sheet.** This sheet presents one of the characters, its mirror image, and a rotation of each in order to facilitate explanation of the procedure to the participant.

13. In addition to printed versions of the trial and demo pages, acquire a stopwatch for the experiment, and it is also useful to have an assistant to help with timing and recording responses.

## 2. Procedure.

1. Use the demo page to explain the instructions to the participant: "This experiment will investigate your ability to rotate objects using visual imagery. On each trial, you will be asked to decide which one of two images is a rotated version of a familiar number or letter. The alternative will be a mirror image rotation of the same number or letter. Here is one example: the number 3. And here is its mirror image. In a trial, you will see the original 3, along with something like the two examples on the bottom of the page, the rotated 3 and a rotation of its mirror image. You will say "left" or "right" to indicate which one you think is the original. You should respond as quickly as possible without sacrificing accuracy. In other words, respond as soon as you are sure of the answer, but not sooner."
2. Shuffle the 52 test pages to randomize the order. After shuffling, enter the number tags of the trials in the order they will be presented in on the response sheet.
3. Start the experiment. Place the stack of pages face-down between the experimenter and the participant, the number tags facing up.
4. Have the assistant hold the stopwatch.
5. On each trial, have the assistant say, "Go," when they start the timer. At this signal, flip over the page for that trial. Have the participant study the page and say "right" or "left" to indicate which character is the answer for that trial.
6. When the participant reports a response, have the assistant stop the timer. Then, record the response time and the answer given on the response sheet.
7. Repeat this procedure for all 52 trials.

## 3. Analysis.

1. When the experiment is done, analyze the data.
2. Enter the handwritten number tags, responses, and response times into a digital copy of the response sheet, and save it with a new name, for example, "Participant 1 MR responses" (Table 2).

Trial #	Number Tag	Response Given	Response Time	Number Tag2	Character	Angle	Correct Answer	Answer Correct?
4	1	RIGHT	4876	1	3	60	RIGHT	1
38	2	RIGHT	6758	2	g	75	RIGHT	1
40	3	RIGHT	3579	3	g	30	RIGHT	1
26	4	LEFT	8752	4	g	60	LEFT	1
10	5	RIGHT	6494	5	g	165	RIGHT	1
49	6	LEFT	6587	6	4	105	LEFT	1
16	7	LEFT	3434	7	3	15	LEFT	1
45	8	LEFT	9172	8	3	165	LEFT	1
35	9	LEFT	1856	9	4	180	LEFT	1
17	10	RIGHT	6818	10	R	15	RIGHT	1
12	11	RIGHT	4797	11	g	180	RIGHT	1
5	12	RIGHT	5378	12	g	45	RIGHT	1
21	13	RIGHT	3301	13	g	105	RIGHT	1
25	14	RIGHT	1393	14	3	45	RIGHT	1
33	15	LEFT	3937	15	4	15	LEFT	1
42	16	LEFT	5827	16	R	60	LEFT	1
31	17	LEFT	6004	17	R	45	LEFT	1
9	18	LEFT	6174	18	R	150	LEFT	1
46	19	RIGHT	6619	19	g	0	RIGHT	1
3	20	LEFT	2276	20	R	30	LEFT	1
18	21	LEFT	4176	21	3	120	LEFT	1
28	22	LEFT	7819	22	4	90	LEFT	1
24	23	LEFT	7368	23	R	75	LEFT	1
6	24	RIGHT	4984	24	4	135	RIGHT	1
47	25	LEFT	4495	25	3	180	LEFT	1

7	26	LEFT	5476	26	4	45	LEFT	1
50	27	RIGHT	7919	27	R	90	RIGHT	1
27	28	LEFT	7182	28	4	0	LEFT	1
48	29	LEFT	5793	29	4	120	LEFT	1
13	30	RIGHT	8986	30	3	135	RIGHT	1
36	31	LEFT	9457	31	R	135	LEFT	1
11	32	LEFT	7903	32	3	30	LEFT	1
29	33	LEFT	9703	33	4	75	LEFT	1
51	34	LEFT	9565	34	3	105	LEFT	1
1	35	LEFT	9341	35	3	150	LEFT	1
8	36	RIGHT	2849	36	R	105	RIGHT	1
52	37	RIGHT	2355	37	4	60	RIGHT	1
2	38	LEFT	2094	38	4	30	LEFT	1
32	39	RIGHT	7338	39	R	120	RIGHT	1
43	40	RIGHT	5431	40	R	180	RIGHT	1
37	41	RIGHT	2734	41	g	135	RIGHT	1
19	42	LEFT	5978	42	3	0	LEFT	1
14	43	LEFT	3305	43	3	90	LEFT	1
22	44	RIGHT	5273	44	4	150	RIGHT	1
41	45	LEFT	4472	45	4	165	LEFT	1
23	46	RIGHT	2353	46	3	75	RIGHT	1
34	47	LEFT	8211	47	R	165	LEFT	1
20	48	RIGHT	2049	48	g	90	RIGHT	1
44	49	RIGHT	9719	49	g	150	RIGHT	1
39	50	LEFT	9562	50	g	15	LEFT	1
15	51	RIGHT	1282	51	R	0	RIGHT	1
30	52	RIGHT	3548	52	g	120	RIGHT	1

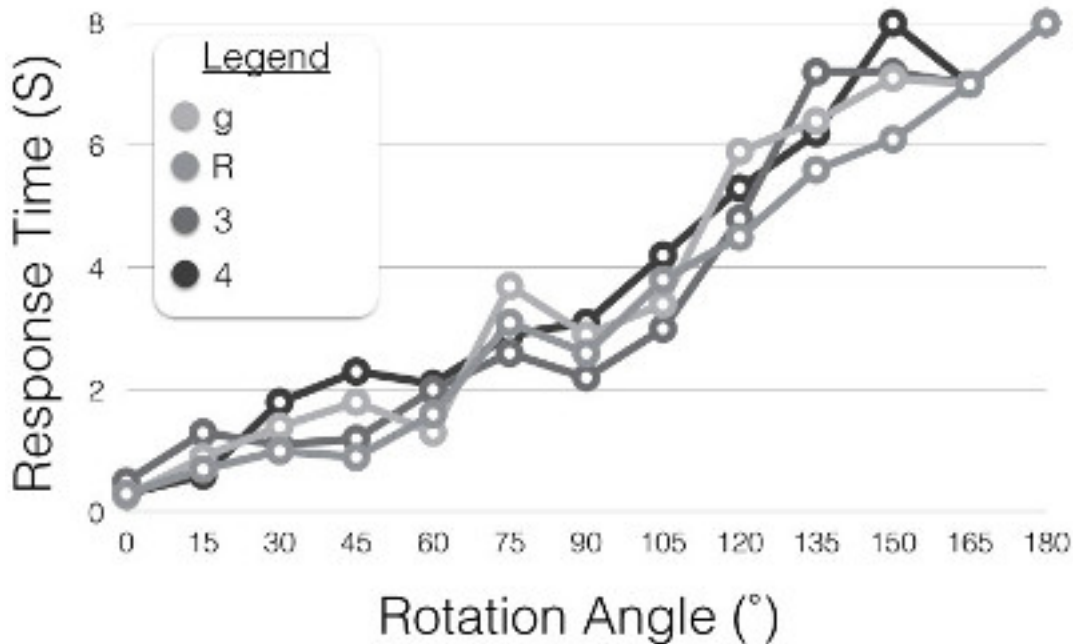
**Table 2. An example of a completed response sheet.**

3. Open the response key and sort by number tag. Cut and paste the contents of the response key into the sheet with the participant responses, so now there are columns reporting both the responses and response times of the participant, and the details of each trial.
4. Add one more column to the end of the sheet, labelled "Response Correct?" Compare the response given with the correct response in each row, and enter a 1 in the response correct row if the answer given was correct or a 0 if it was not.
5. Summarize the results. Average the "Response Correct?" column to see the overall proportion of trials with correct responses. This should be very high or perfect for most participants. Average the response time column to get a sense of the overall response times. That column can also be averaged while filtering by the letter on the trial and/or the orientation of the letter.

## Results

A common way to graph the results is to plot the response time for each character as a function of the rotation of the character (and its mirror image; **Figure 6**).

## Response Times as a Function of Rotation



**Figure 6. Results from the mental rotation task.** Response times are plotted for each of the characters as a function of the amount of rotation in a given trial. Generally, response times are longer the more a character is rotated from its canonical orientation, suggesting that brain mechanisms simulate physical transformations.

One of the most interesting common results associated with mental rotation tasks is that the amount of time it takes to produce a response is proportional to the degree of rotation distinguishing the target character and its rotated pair. In other words, the time it takes to rotate an object mentally seems proportional to the time it would take to actually rotate physical objects in order to place them at the same orientation. This suggests that mental rotation relies on mechanisms that really try to simulate physical space in the brain, even though no pieces of the brain rotate.

### Applications and Summary

One of the main practical applications for mental rotation tasks is to identify people who are especially good at visual thinking about physical spaces. Think about the skills it takes to be a good architect, mechanical engineer, an expert carpenter, or welder. Some people are really good at using mental imagery to guide their actions, and some people are not very good at all, reporting that they don't even really see pictures in their mind's eye the way most people do. The mental rotation test is a good way to identify exceptionally good and exceptionally bad visualizers in order to help people find the best uses of their abilities.

Mental rotation has also been an important part of neuroscience research aimed at understanding the parts of the occipital and parietal lobes involved in human vision. One of the most surprising findings is that when people mentally rotate objects without looking at them, there is an enormous amount of brain activity in visual cortex and brain areas generally thought to be involved in seeing. In other words, the brain systems used to actually see visual stimuli are also used to imagine visual stimuli.