Impact of Spatial Training on "Non-rotators"

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Abstract

Rotational ability has been found to be a predictor of success in an engineering curriculum, and two main standardized tests are commonly used to measure rotational ability, the Purdue Spatial Visualization Test: Rotations, and the Vandenberg and Kuse Mental Rotations Test (MRT). A study of the MRT found certain problems on the test can be solved without the use of mental rotation, and test-takers that are successful on those problems on the test but not the ones requiring mental rotation were classified as non-rotators. This paper analyzes students participating in a spatial training course at Michigan Technological University to determine if some of the students can be considered non-rotators and if the spatial training course is successful in improving these students' rotational ability.

Background

Spatial visualization skills are important in many careers and mental rotation skills have been found to be particularly important to engineers. Several studies have found that skills of students with initially weak spatial skills can be developed through spatial training. Since 1993, a spatial training course has been offered for engineering freshmen at Michigan Technological University who score 60% or below on the Purdue Spatial Visualization Test: Rotations (PSVT:R). The one-credit fourteen-week course covers topics such as isometric and orthographic projections, reflections, cutting planes and cross sections, and object rotations. Instructors of this course have found a tremendous improvement in the spatial skills of the majority of the students taking the training. However, there are always a couple students each year who, although they do make significant gains in their spatial abilities, seem to struggle overall with the course material.

A common test to assess mental rotation skills is the Vandenburg and Kuse Mental Rotations Test (MRT) (1978). Geiser, Lehmann, and Eid (2006) found that not all items on the MRT-A (a 24 question version of the MRT redrawn by Peters, Laeng, et.al (1995)) need be solved by mental rotation, but can be solved by analytical strategies. Of the 24 questions on the MRT-A, the distractors (incorrect choices) for eight of the problems are different in shape than the target figure and can be solved correctly by comparing the shapes of the figures rather than using mental rotation.

Through a multi-group latent class analysis of 1,695 German students taking the MRT-A, Geiser, Lehmann, and Eid found a class of participants who had high solution probabilities for these eight problems but low solution probabilities for the problems requiring mental rotation. They classified this group of participants as "non-rotators." Of the 1,695 participants in the study, 13.2% of the participants fell in the non-rotator class for the first twelve items on the MRT-A, and 17.3% of the participants were classified as non-rotators on the second twelve items on the test. No studies have been performed to see if spatial training can improve the performance of the non-rotators on the MRT-A questions that require mental rotation.

Purpose of Study

In order to determine if those students who improve, but still struggle in the spatial training course, are non-rotators, and to investigate if spatial training can improve the performance of non-rotators on the questions on the MRT-A that do require rotation, students in the Michigan Tech spatial training course have been given the MRT-A on the first and last day of the course since 2009. If the students who struggled in the spatial training course were indeed non-rotators, then it may be possible these students require a specialized spatial training approach.

Method

On the first day of the spatial training class, the MRT-A was administered to all students in the class. Each item on the test shows an object, then students must choose which *two* of four possibilities are rotations of the original object. Example problems provided in the instructions for the test are shown in Figures 1 and 2 below. Note that in Figure 1 the distractors are mirror images of the target object, but in Figure 2, the distractors are different in shape than the target object. Those questions on the test where the distractors are different in shape than the target figure can be solved correctly by noticing this difference rather than using mental rotation.

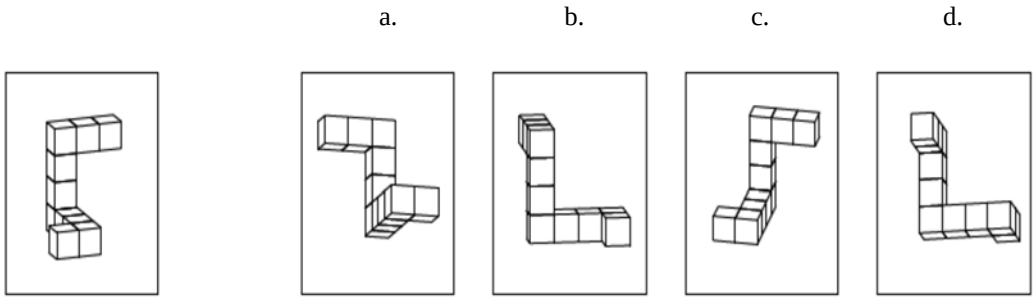

Figure 1: Example problem on MRT-A instructions that may require rotation

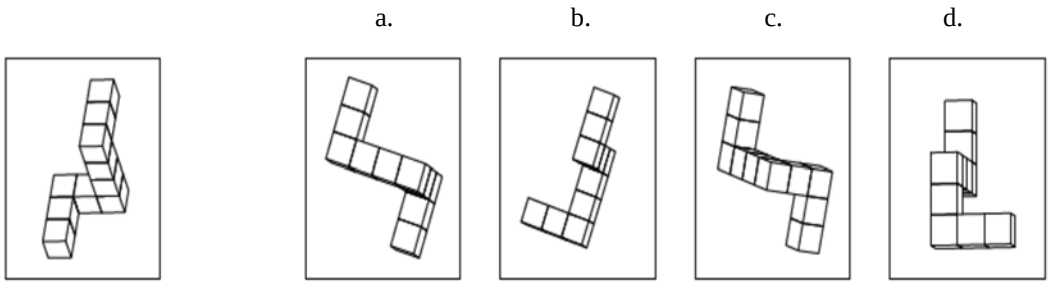

Figure 2: Example problem on MRT-A instructions that may not require rotation

The 24-question test was administered in two parts. Students were given four minutes to complete the first twelve questions of the MRT-A, the twelve question test booklets were collected, and the next twelve questions were distributed. Students then had another four minutes to complete the second set of twelve questions on the test. Standard testing procedures call for answers to be indicated by putting an "X" across the two figures which are rotated versions of the target figure. However, the instructors asked students to indicate their results on an optical scanning form, rather than on the test booklet itself. The test is scored such that both correct figures must be correctly identified to score a point, for a maximum of 24 points possible. This same testing procedure was used on the last day of the 14-week class.

In order to determine if students could be classified as non-rotators at the beginning of the spatial training course, the success rate on attempted MRT-A questions not requiring rotation was compared to the success rate on those attempted that required rotation on the MRT-A pre-test. Success on attempted problems rather than all possible problems was compared as few students complete the twelve questions in the four minute time period and the non-rotation questions are not equally distributed among the twelve questions. Students were classified as non-rotators if they scored 25 percent or below on attempted questions requiring rotation (slightly better than chance), but had a higher success rate on attempted problems not requiring rotation. To determine if the spatial training course was effective at increasing students' rotational abilities, pre- and post-test analyses were performed using both the MRT-A and the PSVT:R.

Results

Table 1 below compares the success rate on attempted questions on the MRT-A pre-test for students classified as "rotators" and "non-rotators." Although a success rate of 25% or below on attempted problems requiring rotation was the target criteria, one student who scored 27% on problems requiring rotation and 80% on problems not requiring rotation was also classified as a non-rotator due to the large difference in success rate between the two types of problems. Of the 459 students who took the MRT-A at the beginning of the spatial training course, 28 (6.1%) were determined to be non-rotators. The percentage of students classified in our study as non-rotators is

about half those classified as non-rotators in the Geiser, Lehmann, and Eid (2006) study. This is surprising as all students in this study scored 60% or below on the PSVT:R, while Geiser, Lehmann, and Eid sampled a general population of students; however, it could be that engineering attracts a large proportion of people with high spatial ability, so this could perhaps be a reason we observed fewer non-rotators. When the course instructors reviewed the names of the students classified as non-rotators through this analysis, some of the students appearing on the list were unexpected as they seemed to perform quite well in the spatial training course. Some, but not all, of the students that really struggled in the course were identified as non-rotators.

Table 1: MRT-A Pre-test Analysis

	Score for Attempted Problems not Requiring Rotation	Score for Attempted Problems Requiring Rotation	Overall Score out of 24 Possible Problems	Number of Students
Rotators	84.1%	67.2%	12.5	431
Non-rotators	67.4%	16.8%	5.2	28

Table 2 compares the MRT-A pre- and post-test results for the students identified as non-rotators on the pre-test. Students are listed on the table primarily in order from least improvement to most improvement on percentage correct of attempted rotator questions. From Table 2, it can be noted that:

- Students 9 through 27 all had gains of greater than 19% in their success rate.
- Students 9 through 27 with the exception of student 12 had success rates greater than 40% on attempted rotator problems.
- Student 8 had a success rate greater than 25% on attempted problems, but a smaller percentage gain on the post-test compared to the pre-test. A closer analysis of student 8 showed this student was correct on 3 out of 12 attempted rotator problems on the pre-test, but was correct on 6 out of 16 attempted problems on the post-test.
- Students 1 through 7 on Table 2 generally did not show the improvement students 8 through 27 did, and their score for the attempted rotator problems on the post-test was still below 25%.
- While students 8 through 28 showed significant improvement in their overall score and success rate on attempted rotator problems, they were still below the averages for all other students in the spatial training.

By comparing the pre- and post-test MRT-A results, it appears students 8 through 27 did shift from being non-rotators to becoming rotators, while students 1 through 7 did not. One of the students

identified as a non-rotator on the pre-test only attended the spatial training course sporadically and did not complete the post MRT-A and PSVT:R, so this student was removed from further analyses.

Table 2: Comparison of Pre- and Post-Test Success on MRT-A

Student	Pre-test Score out of 24	Post-test Score out of 24	Pre-test Score for Attempted Problems not Requiring Rotation	Post-test Score for Attempted Problems not Requiring Rotation	Pre-test Score for Attempted Problems Requiring Rotation	Post-test Score for Attempted Problems Requiring Rotation	Percent Improvement on Post-Test Attempted Problems Requiring Rotation
1	4	6	37.5%	62.5%	8.3%	8.3%	0.0%
2	4	7	28.6%	62.5%	16.7%	14.3%	-2.4%
3	6	7	37.5%	50.0%	18.8%	18.8%	0.0%
4	5	8	75.0%	83.3%	25.0%	25.0%	0.0%
5	5	10	75.0%	62.5%	25.0%	31.3%	6.3%
6	3	7	75.0%	50.0%	0.0%	18.8%	18.8%
7	3	7	75.0%	57.1%	0.0%	23.1%	23.1%
8	10	12	87.5%	75.0%	25.0%	37.5%	12.5%
9	4	12	66.7%	87.5%	22.2%	41.7%	19.4%
10	7	10	80.0%	25.0%	27.3%	50.0%	22.7%
11	9	12	85.7%	71.4%	23.1%	46.7%	23.6%
12	3	7	25.0%	25.0%	6.7%	31.3%	24.6%
13	5	9	60.0%	83.3%	25.0%	50.0%	25.0%
14	4	12	50.0%	50.0%	22.2%	50.0%	27.8%
15	4	9	50.0%	75.0%	25.0%	60.0%	35.0%
16	5	10	75.0%	100.0%	22.2%	60.0%	37.8%
17	6	14	62.5%	87.5%	8.3%	46.7%	38.3%
18	9	16	75.0%	100.0%	18.8%	60.0%	41.3%
19	5	8	100.0%	75.0%	12.5%	55.6%	43.1%
20	2	12	40.0%	50.0%	0.0%	50.0%	50.0%
21	5	9	100.0%	75.0%	25.0%	75.0%	50.0%
22	6	19	100.0%	75.0%	22.2%	81.3%	59.0%
23	4	18	37.5%	87.5%	6.7%	68.8%	62.1%
24	6	14	100.0%	100.0%	22.2%	88.9%	66.7%
25	10	18	100.0%	100.0%	23.1%	92.3%	69.2%
26	2	17	50.0%	62.5%	0.0%	75.0%	75.0%
27	6	16	100.0%	100.0%	18.2%	100.0%	81.8%
Student 1 – 7 Average	4.3	7.4	57.7%	61.1%	13.4%	19.9%	6.5%
Student 8 – 27 Average	5.6	12.7	72.2%	75.2%	17.8%	61.0%	43.2%
All other students in the spatial training	12.5 (n = 431)	16.5 (n= 416)	84.1%	86.4%	67.2%	72.9%	

Table 2 also compares pre- and post-test success on attempted non-rotator questions. Some students were less successful on the non-rotator problems on the post-test than they were on the pre-test. This may be because these students attempted to use a different strategy (possibly a rotation strategy) on the post-test than they did on the pre-test. In comparing these groups of students it can be seen that:

- Students 8 – 27 had a 14.5% higher pre-test average and a 14.1% higher post-test average on the non-rotator questions than students 1 – 7.
- On the rotator questions, students 8 – 27 had a 4.4% higher pre-test average and a 41.1% higher post-test average than students 1 – 7. This may suggest that students 8 – 27 had initially better developed spatial skills (but not rotational skills) than students 1 – 7.

Pre- and post-test results on the PSVT:R are compared in Table 3 on the next page. Scores for student 1 are shown, but were not averaged with the remaining students as this student put forth little effort in the spatial training class and it appeared the post-test score for this student was skewing the results. Pre- and post-test scores were not found for student 7. Students 2 - 6 had the same average pre-test score on the PSVT:R as students 8 – 27. Unlike the MRT-A results, it appears that the spatial training helped students 2 - 6 almost as much as students 8 - 27 (students 8 - 27 had a PSVT:R post-test average only 1.7% higher than students 2 - 6). This may be due to the fact that the rotation content of the spatial training course is more similar to the rotation tasks performed on the PSVT:R than the MRT-A. In the training, students are asked to identify how an object is rotated or to perform a rotation of an object about one or more axes of a 3-D Cartesian coordinate system. Problems on the PSVT:R are rotated in this fashion also, while problems on the MRT-A are rotated in a more random fashion. Student familiarity with rotations about axes of a 3-D Cartesian coordinate system may have helped all non-rotators equally on the PSVT:R. It should be noted that both pre- and post-test averages of students 1 – 27 were below the averages for all other students in the spatial training course, indicating that the students initially identified as non-rotators did have more difficulty with rotations than the other students participating in the training.

Table 3: Comparison of Pre- and Post-Test Success on PSVT:R

Student	PSVT:R pre-test score out of 30	PSVT:R post-test score out of 30
1	17	5
2	12	16
3	12	20
4	18	22
5	13	17
6	16	23
7		
8	3	16
9	12	23
10	17	26
11	12	20
12	14	19
13	17	14
14	14	14
15	13	23
16	18	13
17	17	21
18	16	24
19	16	27
20	14	22
21	18	22
22		24
23	15	22
24	13	18
25	13	19
26	11	16
27	16	19
Student 2 – 6 average	14.2	19.6
Student 8 – 27 average	14.2	20.1
All other students in the spatial training	15.6 (n=436)	22.8 (n= 419)

Conclusion

Students were classified as non-rotators if they scored 25% or below on attempted MRT-A questions requiring rotational strategies. Of the students in the spatial training, only 6.1% were classified as non-rotators. Additionally, the instructors were surprised that some of the students were identified as non-rotators as well as some of the students that were not labeled as such.

Spatial training appears to have helped a significant number of these non-rotators become rotators. On the MRT-A post-test, approximately 75% of the students initially classified as non-rotators improved their ability to rotate enough to no longer be considered non-rotators (their success rate on questions requiring rotational strategies improved to more than 25%). This indicates that there is a smaller group of students (25% of non-rotators, 1.5% of students trained) that did not significantly improve their rotational skills. However, it does appear that the spatial

training does help this small percent of students improve on rotation tasks tested on the PSVT:R nearly as well as the other non-rotators. While the spatial training improved most non-rotator's rotational skills, their skills are still below average for the students participating in the spatial training.

References

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