The Addition of Coordinate Axes to the Purdue Spatial Visualization Test-Visualization of Rotations: A Study at Two Universities

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Abstract
During the 1998 fall semester, a study was conducted at North Carolina State University and Purdue University to determine the effectiveness of adding coordinate axes to a mental rotations task. This study was a follow-up to a study conducted in the 1997 fall semester at North Carolina State University (Branoff, 1998). Undergraduate students enrolled in introductory graphic communications and technical graphics courses completed a computer version of the Purdue Spatial Visualization Test - Visualization of Rotations (PSVT). The instrument was used to record student responses and response times as well as information on gender, current major, number of previous graphics courses completed, and method used to solve the test items. Coordinate axes were added to portions of the PSVT for three of the four treatment groups to determine if the axes provided contextual cues necessary to improve scores and response times. The researchers hypothesized that coordinate axes would provide verbal cues that could be coded along with nonverbal information to improve mental rotation efficiency. A Solomon Four Group Design was used to assess the effect of the coordinate axes, determine the effect of pretest sensitization, and assess interaction between the pretest and posttest conditions.

I. Introduction

The study described in this paper is a follow-up on a study conducted during the 1997 fall semester at North Carolina State University (Branoff, 1998). The sample from the initial study included 81 students enrolled in introductory graphic communications courses. The intent of the study was to examine the effects of coordinate axes on a mental rotations task. Coordinate axes were added to items on the Purdue Spatial Visualization Test – Visualization of Rotations (Guay, 1980) for the experimental group to examine how the axes influenced scores and response times. A pretest-posttest, control group design was used in the first study where both the control and experimental groups completed the 30 items on the PSVT. After a short break period, both groups completed an equivalent form of the PSVT with coordinate axes added to the 30 items for the experimental group. The following conclusions were drawn from the initial study:

1. When examining differences between the experimental and control groups, the coordinate axes had only a small influence on scores. The mean score for the experimental group was greater than the mean score for the control group, but the difference was not significant.
2. The coordinate axes had a significant affect on response times. Analyses of response times indicated that more time was required to process the additional information present with the coordinate axes.
3. The addition of the axes eliminated gender differences on the PSVT.

4. There was a learning factor that appeared during the first study. Scores increased for both the control and experimental groups between Part 1 and Part 2. Response times decreased for both groups.

The follow-up study was designed to verify some of the conclusions from the first study and to eliminate some of the problems that resulted from the research design. The rest of this paper describes the methodology, conclusions and recommendations of the study that was conducted during the 1998 fall semester at North Carolina State University and Purdue University.

II. Methodology

Purpose of the Study
The purpose of the study was to determine whether the presence of coordinate axes in a test of spatial visualization ability affects scores and response times on a mental rotations task for students enrolled in introductory engineering and technical graphics classes. Coordinate axes were added to the PSVT to determine whether the presence of the axes was a sufficient contextual cue for improving scores and response times.

Sample
Students enrolled in introductory engineering graphics courses at North Carolina State University during the 1998 fall semester were required to participate in the study as part of the requirements for their course. Of the 361 students enrolled in GC101, GC120, GC210, and GC211, 249 students completed the study. At Purdue University, students enrolled in TG106 were given the option to participate in the study. Of the 98 students enrolled in the course, 81 completed the instrument. For the final data analysis, 12 of the 81 subjects were not included since more than 3 of their selections required less than 4 seconds to complete.

Research Design
The study was conducted using a Solomon Four-Group Design (Gall, Borg, & Gall, 1996). The purpose of selecting this design was to assess the effect of the coordinate axes, determine the effect of pretest sensitization, and assess interaction between the pretest and posttest conditions (see Table 1).

Table 1. Research Design

	Pretest	Posttest
Group 1	No Axes Present	No Axes Present
Group 2	No Axes Present	Coord. Axes Present
Group 3	Coord. Axes Present	Coord. Axes Present
Group 4	Coord. Axes Present	No Axes Present

Instrumentation
Since the main construct of interest for the study was spatial visualization ability, the Purdue Spatial Visualization Test - Visualization of Rotations (PSVT) was used to assess this construct. The PSVT consists of 30 items of increasing level of difficulty. It is a 20 minute timed test appropriate for individuals 13 and older. Initial items require a rotation of 90° on one axis followed by items requiring 180° rotation about one axis, rotation of 90° about two axes, and concluding with items requiring rotation of 90° about one axis and 180° about another axis.

The first stimulus object used to specify the type of rotation is the same for all 30 items. The second stimulus object is different for each item. All objects are isometric pictorials of one of the following types of three-dimensional solids: truncated hexahedrons, right circular cylinders, right rectangular prisms, or right triangular prisms. Scoring the PSVT is simply a matter of adding the number of correctly answered items. Guay (1980) reports internal consistency coefficient results (KR-20) of .87, .89, and .92 from studies conducted on 217 university students, 51 skilled machinists, and 101 university students respectively. Sorby and Baartmans (1996) conducted a study involving 492 freshmen engineering students. They reported a KR-20 coefficient of .82. Battista, Wheatley and Talsma (1982) administered the PSVT to 82 preservice elementary teachers enrolled in an undergraduate geometry course. A KR-20 internal consistency coefficient of .80 was reported. For the study conducted at North Carolina State University during the 1997 fall semester, internal consistency coefficients of .82 and .80 were calculated for Parts 1 and 2 of the computer-based PSVT respectively (Branoff, 1998). For this study, coordinate axes were added to the first and second stimulus objects as part of the treatment condition (see Figure 1).

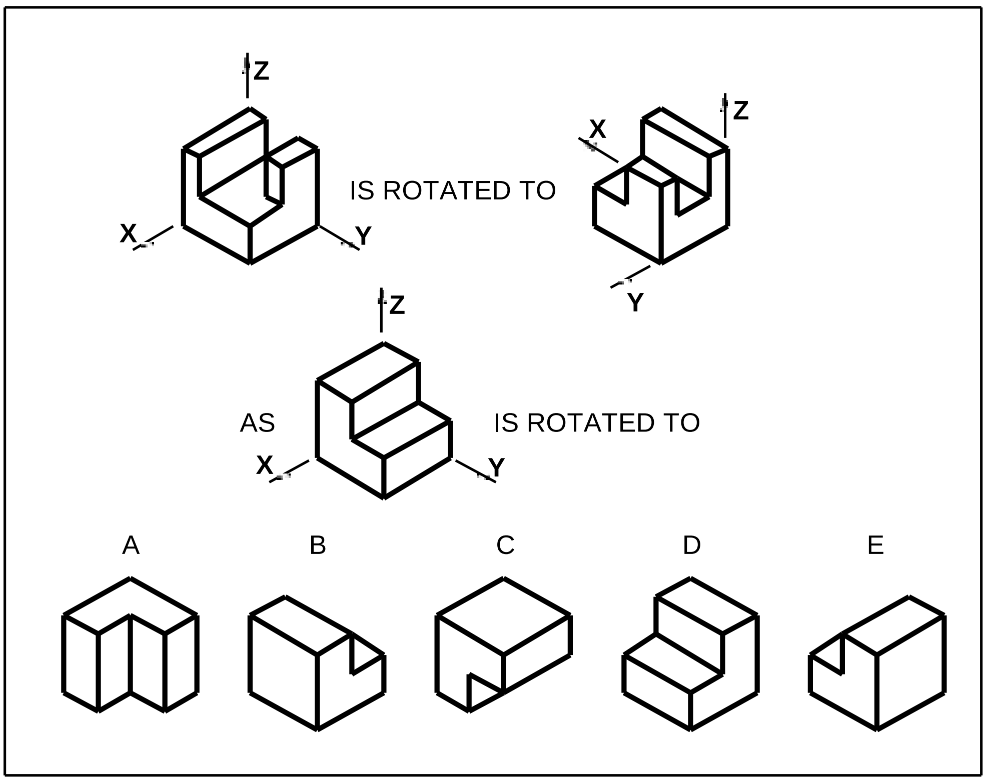


Figure 1. Visualization of Rotations Test with coordinate axes added.

Procedures

During the summer of 1998, the principal researcher developed four computer versions of the PSVT. All four versions of the instrument consisted of 60 items. The first 30 items were identical to the 30 items on the paper pencil version of the PSVT. The second 30 items were an equivalent form of the PSVT. Coordinate axes were added to the following sections: the first 30 items for Groups 3 and 4; the second 30 items for Groups 2 and 3.

The purpose of developing the computer versions of the PSVT was to provide accurate data on scores and response times. The tests were designed such that data was gathered in a spreadsheet format. The tests were also used to collect data on gender, age, current major, number of previous graphics courses taken, and questions on the approach taken to solve the problems (holistic or analytic). Students at North Carolina State University completed the computer-based PSVT during the first 6 weeks of classes. Students at Purdue University completed the instrument during the ninth week of classes.

III. Hypotheses and Results

Based on the review of literature and the conclusions from the 1997 study, 16 research hypotheses were developed. The hypotheses and results are presented below in Table 2.

Table 2. Hypotheses and Results for Both Universities.

Hypotheses	NC State Data	Do results support hypothesis?	Purdue Data	Do results support hypothesis?
Hypothesis 1 - There will be no significant difference in Part 1 mean scores between Groups 1 & 2.	F=3.56 df=125 p=0.0615	Yes	F=0.11 df=36 p=0.7388	Yes
Hypothesis 2 - There will be no difference in Part 1 mean response times between Groups 1 & 2.	F=0.73 df=125 p=0.3956	Yes	F=4.00 df=36 p=0.0533	Yes
Hypothesis 3 - There will be no difference in Part 1 mean scores between Groups 3 & 4.	F=0.27 df=122 p=0.6062	Yes	F=6.03 df=31 p=0.0200*	No
Hypothesis 4 - There will be no difference in Part 1 mean response times between Groups 3 & 4.	F=3.58 df=122 p=0.0610	Yes	F=2.30 df=31 p=0.1400	Yes
Hypothesis 5 - There will be a significant difference in mean scores on Part 1 between Groups 1 & 2 (no coordinate axes present) and Groups 3 & 4 (coordinate axes present)-combined Group 3 & 4 will have a higher mean.	F=2.92 df=248 p=0.0886	No	F=4.82 df=68 p=0.0315	No Difference was contrary to research hypothesis
Hypothesis 6 - There will be a significant difference in mean response times on Part 1 between Groups 1 & 2 and Groups 3 & 4- Group 3 & 4 will have higher mean.	F=0.71 df=248 p=0.4004	No	F=1.74 df=68 p=0.1919	No
Hypothesis 7 - Mean scores for males will be higher than mean scores for females on Part 1 for Groups 1 & 2.	F=8.68 df=125 p=0.0038*	Yes	F=4.37 df=36 p=0.0440*	Yes

Hypothesis 8 - There will be no significant difference in mean scores between males and females on Part 1 for Groups 3 & 4.	F=0.71 df=122 p=0.4002	Yes	F=2.83 df=31 p=0.1028	Yes
Hypothesis 9 - There will be no significant difference between the mean score on Part 1 and the mean score on Part 2 for Groups 1 and 3-same treatment for both parts of test.	**Group 1** t=1.668 p=0.1003 **Group 3** t=2.210 p=0.0308*	Yes No	**Group 1** t=-1.725 p=0.1026 **Group 3** t=1.1165 p=0.2844	Yes Yes
Hypothesis 10 – The score on Part 2 of the PSVT will be significantly higher than score on Part 1 for Group 2.	t=4.012 p=0.0002*	Yes	t=-0.8178 p=0.4242	No
Hypothesis 11 - There will be no significant difference between the mean score on Part 1 and the mean score on Part 2 for Group 4.	t=-1.114 p=0.2697	Yes	t=-3.5979 p=0.0022*	No
Hypothesis 12 - There will be a significant difference between the mean response time on Part 1 and the mean response time on Part 2 for all Groups.	t=-13.247 p=0.0001*	Yes	t=-9.4254 p=0.0001*	Yes
Hypothesis 13 - Mean response times for Groups 2 & 3 will be higher than mean response times for Groups 1 & 4 on Part 2-axes will require more processing time.	F=0.82 df=248 p=0.3653	No	F=0.56 df=68 p=0.4588	No
Hypothesis 14 - There will be a significant difference in mean scores on Part 2 between Groups 1 & 4 (no coordinate axes present) and Groups 2 & 3 (coordinate axes present)-combined Group 2 & 3 will have a higher mean.	F=7.11 df=248 p=0.0082*	Yes	F=0.47 df=68 p=0.4963	No
Hypothesis 15 - Mean scores for males will be higher than mean scores for females on Part 2 for Groups 1 & 4 (no coordinate axes present).	F=6.86 df=123 p=0.0100*	Yes	F=1.72 df=35 p=0.1982	No
Hypothesis 16 - There will be no difference in mean scores between males and females on Part 2 for Groups 2 & 3 (coordinate axes present).	F=1.92 df=124 p=0.1687	Yes	F=14.41 df=32 p=0.0006*	No

* significant at α=0.05.

IV. Conclusions and Discussion

Effects of Coordinate Axes on Scores – The addition of coordinate axes to the PSVT clearly influenced scores for the North Carolina State University subjects. On Part 1 of the PSVT, the mean score for groups with the axes present had a higher mean score (23.34) than groups where the axes were not present (22.22). As mentioned earlier, this was not a significant difference. On Part 2 of the PSVT for students at North Carolina State, the mean score for groups with the axes present had a significantly higher mean score (24.26) than the groups without axes (22.46). Previous results concerning gender differences were verified during the current study. Males scored significantly higher than females when the axes were not present. When the axes were present, no mean score differences existed between males and females.

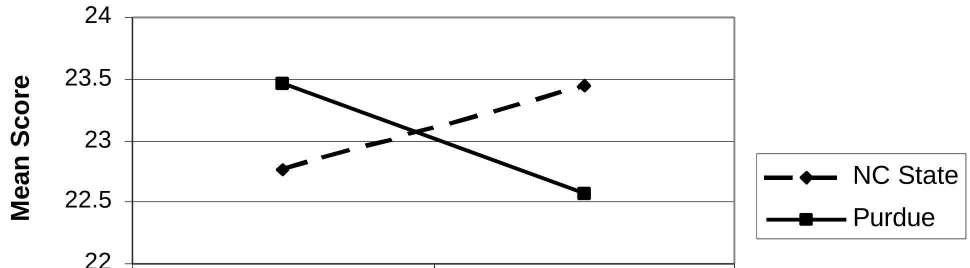
The Purdue University results were different than the results at North Carolina State University concerning scores on the PSVT. On Part 1 of the PSVT, the mean score for groups with the axes present had a significantly lower mean score (22.25) than groups where the axes were not present (24.51). On Part 2 of the PSVT, the same was true. Groups with the axes present had a lower mean score (22.82) than the groups where the axes were not present (24.06). On Part 1 of the PSVT, results concerning gender differences were consistent with previous results. The mean score for males was significantly higher than the mean score for females. The coordinate axes did not eliminate gender differences on the PSVT. Significant mean score differences still existed between males and females when the axes were present.

Effects of Coordinate Axes on Response Times – The addition of coordinate axes to the PSVT had some influence on response times. For the North Carolina State University subjects, the only significant difference was found between Group 1 (no axes present) and Group 4 (axes present) on Part 1 of the PSVT. For the Purdue University subjects, a significant difference was found between Group 2 (no axes present) and Group 4 (axes present) on Part 1 of the PSVT. On Part 2, significant differences were found between Group 1 (no axes present) and Group 3 (axes present) and Group 1 (no axes present) and Group 4 (no axes present). The differences on Part 2, however, did not seem to be related to the presence of coordinate axes.

Tables 3, 4 and 5 display mean score and mean response time data from both universities. The tables reveal two noticeable differences between the two universities. Mean scores for North Carolina State students increased while mean scores for Purdue students decreased. Mean response times for Purdue students were significantly lower than mean response times for North Carolina State students.

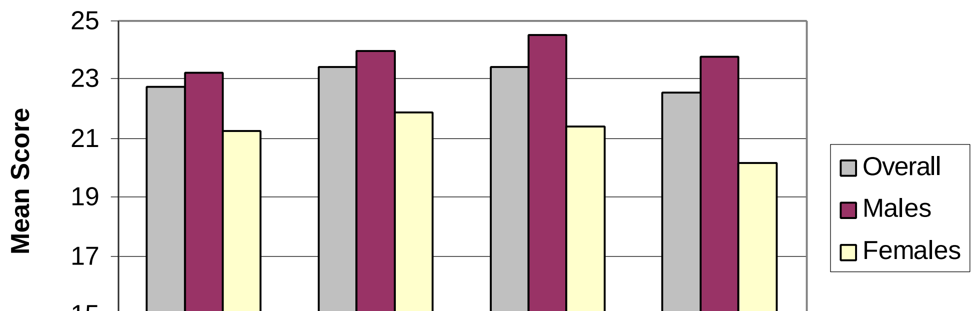
One possible explanation for the inconsistencies in results between North Carolina State University and Purdue University is the conditions under which data was collected. North Carolina State University students completed the PSVT as part of the requirements for their course. Students signed up to complete the instrument outside of class time. Students at Purdue University were given the option for completing the instrument at the end of a laboratory session. Although most students elected to complete the PSVT, formal and informal analyses of response times indicated that many students might not have given their best effort.

Table 3. Overall Mean Scores for Both Universities.



	Score on Part 1	Score on Part 2
NC State	22.77	23.45
Purdue	23.46	22.57

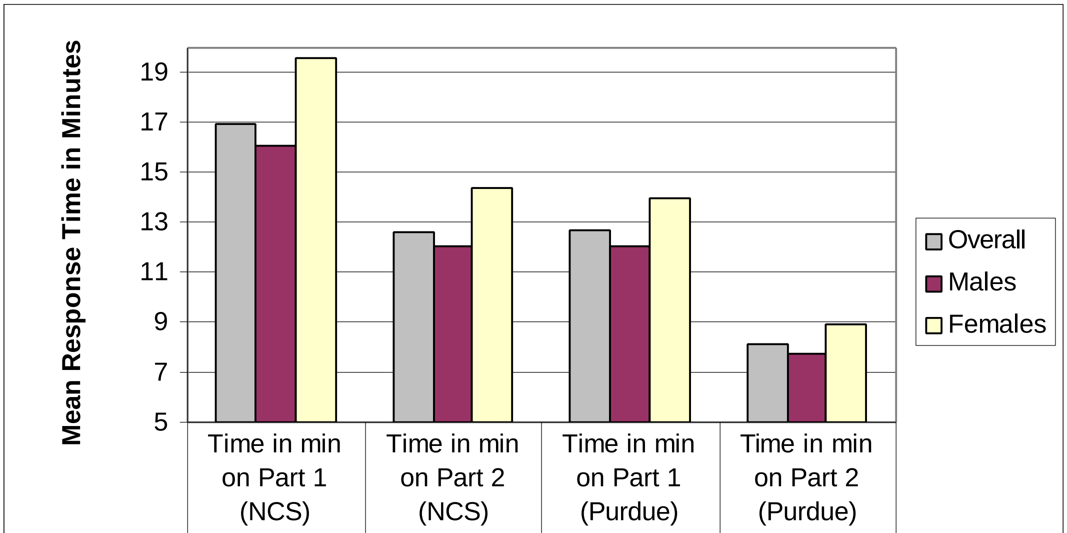
Table 4. Mean Scores By Gender.



	Score on Part 1 (NCS)	Score on Part 2 (NCS)	Score on Part 1 (Purdue)	Score on Part 2 (Purdue)
Overall	22.77	23.45	23.46	22.57
Males	23.26	23.96	24.5	23.78
Females	21.28	21.9	21.39	20.17

Implications for Teaching Methods in Graphics Education
Although the addition of coordinate axes to the PSVT did produce statistically significant differences in mean scores, educators need to examine the practical significance of adding coordinate axes to instructional materials in the classroom. Adding coordinate axes to some instructional materials as well as sketches made on the board may help some students. The addition of the coordinate axes seemed to eliminate gender differences for scores on the PSVT in some environments.

Table 5. Mean Response Times By Gender.



	Time in min on Part 1 (NCS)	Time in min on Part 2 (NCS)	Time in min on Part 1 (Purdue)	Time in min on Part 2 (Purdue)
Overall	16.96	12.6	12.69	8.13
Males	16.1	12.09	12.02	7.71
Females	19.6	14.35	14.02	8.97

Recommendations for Further Research

This study examined the effects of the addition of coordinate axes to a test measuring spatial visualization ability. The conclusions reached by the researchers suggest several areas of further research.

1. The study needs to be replicated at other universities with similar populations to verify the generalizations made with regards to the influences of the coordinate axes.
2. The study needs to be replicated with a different target population to verify the effects of the coordinate axes. The coordinate axes may influence scores and response times differently for high schools students or undergraduate, non-engineering students.

V. References

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VI. Biographical Information

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Ted is an assistant professor of Graphic Communications at North Carolina State University and has been an ASEE member since 1986. He has taught courses in introductory engineering graphics, computer-aided design, descriptive geometry, and vocational education. Ted has a bachelor of science in Technical Education, a master of science in Occupational Education, and a Ph.D. in Curriculum and Instruction. His current academic interests include spatial visualization ability, information processing theory, geometric dimensioning and tolerancing, and descriptive geometry.

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