Spatial Test Correlation in an Introductory Graphic Communications Course

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Abstract

With many spatial ability tests available for research, there is no consensus on which test(s) are preferred. A literature review produced a list of 24 tests that was used in a survey of EDGD members. The top three identified tests were the Mental Cutting Test (MCT), Mental Rotations Test (MRT), and Purdue Spatial Visualization Test: Visualization Rotations (PSVT: VR). Three sections of an introductory graphics course (N.C. State) provided spatial test scores from these tests for this research. This study examined correlations between the three identified tests and the recommendations for further research.

Introduction

Published articles on spatial abilities are found in the fields of psychology (Hetland, 2000), graphics education, and STEM areas (Connolly, Harris, & Sadowski, 2009). Wai, Lubinski, and Benbow (2009) studied efforts to identify and develop "personal attributes of scientists and engineers" and to foster their potential (p. 817). They identified spatial ability as a major contributor to success in STEM education and occupations. Spatial tests are used to measure this ability. Spatial literature in these areas was written from the researchers' viewpoint regarding spatial ability definitions, spatial tests used, and conclusions drawn (Gorska & Sorby, 2008; Linn & Peterson, 1985).

Spatial Ability Research Background

In the *Engineering Design Graphics Journal for 1936-1978* (EDGJ), there were six articles about visualization (spatial abilities). As published graphics research increased, EDGJ (1975-1996) listed many articles under visualization [spatial ability] and other associated headings (Sadowski, 1997). Miller (1996) discussed engineering graphics education history and visualization research (1920's - 1990's) and stated that the first published research article on visualization appeared in 1937. Hartman and Bertoline (2005) stated that "graphics and all that it encompasses is a unique body of knowledge that should be studied, practiced, and scientifically verified" (para. 20). Strong and Smith (2002) stated that "in industrial technology we utilize visualization in applications such as simulations, multi-media, modeling, and distance education" (p. 2). They added that "each person has their own unique visualization skills" (p. 2).

Students' spatial skills are based on their ability to mentally understand, visualize, and manipulate two-dimensional and three-dimensional physical objects or their pictorial representation (Adanez & Velasco, 2002; Miller & Bertoline, 1991). McArthur and Wellner (1996) discussed spatial ability test scores and suggested that tests are possibly incorrectly used to identify whether subjects have spatial abilities. Currently, with a large number of tests available for use in graphics education/spatial ability research, there is no consensus on which test(s) are preferred (Eliot & Smith, 1983). Therefore, a need existed to determine which spatial tests are used and preferred by graphics education researchers and if there is any statistical relationship between these tests.

Research Question

Research articles in engineering design graphics encompass a variety of interests with many researchers using varied spatial ability tests in their analyses. Some areas were prior experience on spatial tests (Baenninger & Newcombe, 1989; Deno, 1995), spatial test modification (Branoff, 2000), student assessment (Connolly, Harris, & Sadowski, 2009; Sorby & Baartmans, 2000), and spatial ability development (Connolly, 2009; Gorska, 2005).

In order to determine preferred spatial ability tests, an Engineering Design Graphics Division (EDGD) member survey was conducted which identified three preferred spatial ability tests, (the MCT, the MRT, and the PSVT: VR). Given the discussion of the varied spatial ability tests available to graphic education researchers (Eliot & Smith, 1983; Eliot, 2000) and the different tests that have been used in the graphics education research, the research question investigated was:

Are there any statistical correlations that exist between the three preferred spatial ability tests, MCT, MRT, and PSVT: VR?

This research studied student spatial ability in an introductory graphic communications course in engineering design graphics using the selected spatial ability tests. The research subjects were students in three spring semester (2012) GC 120 sections at North Carolina State University (N.C. State). Literature was located that utilized spatial ability tests that dealt with this research question.

Methodology

First, an EDGD preferred spatial ability test survey was developed. The survey was given to the 2011 EDGD membership via a listserv. In order to develop a listing of spatial tests, a review of articles from 1996 to the present in the graphics education field was conducted. This review shows that articles are predominantly published in journals from ASEE, the EDGD, and the *Journal for Geometry and Graphics* as well as conference proceedings from ASEE and EDGD

(Chin, 2004; Sadowski, 1997; Wladaver, 1978). These sources identified ten spatial ability tests from several principal (first writer) researchers that specifically utilized spatial ability tests and included their test research results. A review of the spatial ability tests available through the *Educational Testing Service* provided an additional listing of tests that graphics education researchers may use. A compilation of tests from these sources provided a final list of 24 spatial ability tests available for researchers. Through an online survey, EDGD members were asked to select their preferred tests from the list of 24. From the survey results, the top three preferred spatial ability tests were the Mental Cutting Test (MCT, Figure 1, developed by the College Entrance Examination Board in 1939), Mental Rotation Test by Vandenburg and Kuse (MRT, Figure 2, Vandenberg & Kuse 1978), and the Purdue Spatial Visualization Test: Visualization of Rotations (PSVT: VR, Figure 3, Guay, 1977).

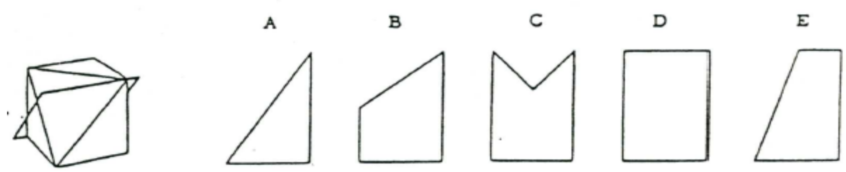

Figure 1. Problem MCT Example

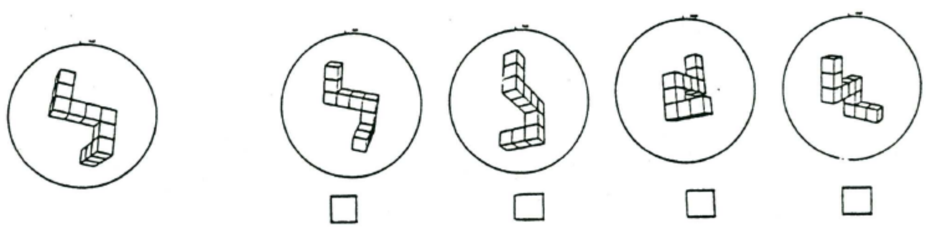

Figure 2. Problem MRT Example

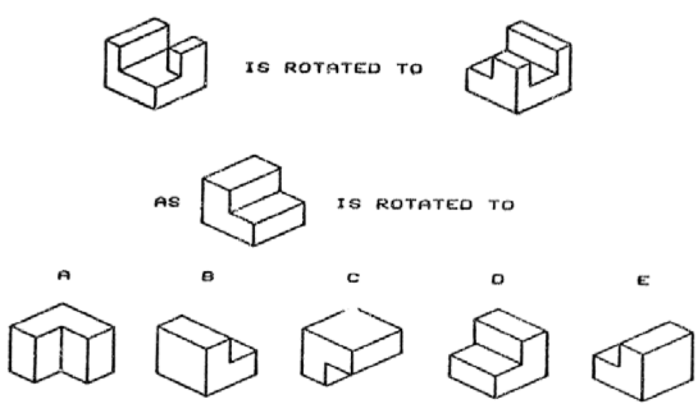

Figure 3. Problem PSVT: VR Example

Three GC 120 sections were used in this study. Students in these sections signed an IRB consent form. Table 1 shows the design of a spatial ability testing sequence for each GC 120 section. Using this sequence, student pretest sensitization between the three tests was minimized preventing test data contamination.

Finally, test subjects were fully instructed on each test's requirements before the start of each test. Moodle™ course management software was used for test administration to all sections.

Table 1. Testing Sequence

GC 120 Sections	MCT	MRT	PSVT: VR
00A	administered 1st	administered 2nd	administered 3rd
00B	administered 3rd	administered 1st	administered 2nd
00C	administered 2nd	administered 3rd	administered 1st

Data Results

The data was collected from three night sections (N = 100 participants) of GC 120. The specific data collected and analyzed was student test scores on each spatial ability test. Since each GC 120 section was a small convenience sample, non-parametric tests were used for all spatial ability test score analyses (Scales & Petlick, 2004). The level of significance used for all hypotheses testing was $p \leq .05$. Table 2 shows the statistical data for all three spatial ability tests.

Table 2. Spatial Ability Test Statistics

Test	N	Tests Not Taken	Mean	Median	Min	Max	SD
MCT	99	1	11.93	12.00	3.00	25	5.051
MRT	99	1	27.97	30.00	2.00	40	9.357
PSVT:VR	98	2	21.43	22.00	0.00	30	6.236

Internal Test Consistency

According to Gall, Gall, and Borg (2003), "internal consistency is an approach to estimating test score reliability [coefficient results] in which the individual items of the test are examined" (p. 197). Kuder-Richardson formulas K-R 20 can be used for this evaluation where test items are scored dichotomously (Richardson & Kuder, 1939). All spatial ability tests used in this study were scored dichotomously; therefore, the K-R 20 formula was used in calculating internal consistency. The calculated K-R 20 coefficients are: MCT (.815), MRT (.868), and the PSVT: VR (.888).

Spatial Test Correlation Conclusions

Sheskin (2004) presents the Spearman's rank-order correlation coefficient non-parametric test that uses rank ordered data for the correlation analysis between two sets of data. As discussed by Greene and D'Oliveira (1999), Spearman's non-parametric test is used for the correlation between a test subject's score on two different tests.

The null hypotheses, H_0: $r_s = 0$, (no correlation between each spatial ability test pair) for all combinations of spatial tests were rejected. The alternate hypotheses, $H_1 : r_s \neq 0$, (there was positive correlation in this study) were accepted. The positive correlation results were $H_{1\ MCT/MRT}$: $r_s = .351$, $H_{1\ MCT/PSVT:\ VR}$: $r_s = .599$, and $H_{1\ MRT/PSVT:\ VR}$: $r_s = .647$.

Suzuki, Shiina, Makino, Saito, and Jingu (1992) reported correlations between the MCT and the MRT of 0.43, 0.42, and 0.58 for studies at three universities which is similar to the correlation result found in this study (.351). Sorby (2000) reported a correlation from a 1999 study between the PSVT: VR and the MCT of 0.528 which is similar to the correlation result found in this study (.599). There were no research articles located reporting correlation between the MRT and PSVT: VR that could provide support for the correlation result found in this study.

These correlation results, although positive but varied in correlation strength (strength of linear association) relate to other reported correlation findings (Agresti & Finlay, 1997).

Future Research Recommendations

The discussion on recommendations for further research is divided into two areas to provide additional investigation into these results: First, the EDGD online survey was a listing of 24 spatial tests included some tests that were only mentioned but not actually used in the reviewed graphic research literature. The listing of 24 tests could be reviewed and shortened to tests actually used in graphics education research for an EDGD membership re-evaluation of top preferences.

Given the discussion on Suzuki, Shiina, Makino, Saito, and Jingu's (1992) interpretation that the MCT evaluates some form of spatial ability, but they were unsure what characteristic the MCT was evaluating and this evaluation by extension may also apply to the MRT and the PSVT: VR. The literature review on spatial factors found evidence that the true spatial tests measurements may not be accurately known among graphics education researchers. An extensive review of the literature on spatial ability factors (such as visualization) should be undertaken to ensure that the factors evaluated by each spatial test is accurately known and not possibly surmised.

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