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ABSTRACT

The relationship between students' relative ability in visual-spatial tasks as well as their verbal and numerical skills to their performance in an introductory college chemistry course was investigated. For 700 subjects, verbal and mathematics Scholastic Aptitude Test scores (SAT-V) and (SAT-M) and the following four perceptual tests were assessed: a shortened version of the Purdue Visualization of Rotations Test (ROT), the Find-A-Shape-Puzzle (FASP), an embedded figures test (EMBF) that is part of a motion picture test, and a successive figures test (SUCF) that is also part of a motion picture test. In addition, chemistry achievement subscores were calculated from regularly administered chemistry course examinations. Results indicated a fair amount of colinearity among math scores and the tests of visualization. Males did significantly better than females on the SAT-M, the ROT test, the FASP test, three chemistry achievement subscores, and the total chemistry score. A comparison of students with low and high visualization scores revealed significant differences among females on all chemistry achievement measures and on the SAT scores. The findings suggest that visualization skills play a role in chemistry achievement and that visualization skills may be more important in this context for women than for men. (SW)

VERBAL, NUMERICAL AND PERCEPTUAL SKILLS RELATED TO CHEMISTRY ACHIEVEMENT

by

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Rationale

There has been considerable work on the role of visualization skills and spatial abilities in cognitive and learning processes (Paivio, 1971; Linn and Kyllonen, 1981; Treagust, 1980; and Piburn, 1980). Although it is tempting to view students as either visual or verbal, we believe that many if not most students are best described as synthetic; they use a combination of these cognitive styles. Paivio (1971) suggests a duel system of processing with one system (sometimes the visual, sometimes the verbal) augmenting rather than substituting for the other.

In order to see whether visual-spatial skills do indeed augment achievement in situations where they might be reasonably expected to do so, we have examined the relationship between students' relative ability in visual-spatial tasks as well as verbal and numerical skills with their performance in various phases of an introductory college-level chemistry course.

Subjects

The subjects were approximately 1300 students enrolled in a college-level introductory chemistry course taken primarily by students in science, engineering and pre-professional curricula at Purdue University. Students were administered perceptual tests during their lecture or laboratory sessions at the beginning of the fall semester course. The data used for this study came from approximately 700 students for whom reasonably complete data sets had been obtained after all testing was completed, and for whom chemistry performance scores were available.

Instruments

Both the verbal (SAT-V) and mathematics (SAT-M) scores of the Scholastic Aptitude Tests were obtained from the students' records and included in the battery of scores.

Four perceptual tests were used: ROT, FASP, EMBF and SUCF.

ROT is a 20-item paper and pencil test which is a shortened version of the Purdue Visualization of Rotations test (Guay, 1976). This test requires subjects to observe how a three-dimensional block diagram has been rotated, and then predict the orientation of a second block if it was rotated similarly. A correlation of 0.61 was obtained between this test and the Sheppard-Metzler on 101 college students (Guay and McDaniel, 1978).

FASP (or Find-A-Shape-Puzzle) is a 20-item variation of the Gottschaldt Hidden Figure Test (Linn and Kyllonen, 1981). In this version, subjects are asked to find a simple figure in a more complex design. Responses may require a change in orientation of the stimulus figure.

EMBF and SUCF were components of a 16-mm motion picture test developed by McDaniel (1974). EMBF is an embedded figures test in which a figure appears on the screen for 5 seconds. This figure is then replaced by a response array consisting of 4 figures, one of which contains the original figure. Students are asked to indicate which figure (A, B, C or D) contains the original. SUCF is a successive figures test in which three or four straight lines appear on the screen, one at a time. Students are asked to mentally assemble the successive lines to form a figure and then identify this figure from four alternatives (A, B, C or D) shown on the screen.

Several chemistry achievement sub-scores were calculated from regularly administered chemistry course examinations. In this paper we will focus on three of these scores:

Sub-score 1: 9 multiple-choice questions that focused on the students' ability to solve stoichiometry problems.

Sub-score 3: 9 multiple-choice questions on the structures of crystals which were chosen because they dealt with what was felt to be a highly visual-spatial chemistry task.

Sub-score 6: A fill-in-the-blank quiz on crystal structure concepts.

Analysis

A correlation matrix was generated among all variables. The differences between means for males and females for all variables were evaluated by T-tests. T-tests were also used to evaluate differences between high visual ability groups (more than 0.5 SD above the mean) and low visual ability groups (more than 0.5 SD below the mean) for both males and females.

Results

The correlation matrix is presented in Table 1.

The results of the comparison of means for male and female students on all variables are summarized in Table 2. Males did significantly better than females on chemistry sub-score 1, sub-score 3, sub-score 6, SAT-M, ROT and FASP.

The results of the T-test comparing high visual ability females with low visual ability females presented in Table 3 indicates that high visual ability females outperform low visual ability females on all chemistry sub-scores as well as both SAT-M and SAT-V.

For males, differences between high and low visual ability groups were only found for SAT-M and sub-score 1. Furthermore, these differences, where observed, were not as large as the differences observed for females.

Conclusions

In summary, the zero-order correlations indicated a fair amount of colinearity among math scores and the tests of visualization.

The T-tests indicated that males did significantly better than females on the SAT-M test, the ROT test, the FASP test, sub-scores 1, 3 and 6, and the total chemistry score. These differences suggested a separate analysis of the data for each sex.

This subsequent analysis comparing students with low and high visualization scores revealed significant differences among females on all chemistry achievement measures and on the SAT scores as well. Fewer significant differences and differences of smaller magnitude were found in the similar comparisons for the males. These findings suggest that visualization skills play a role in chemistry achievement, and more interestingly, that visualization skills may be more important in this context for women than for men.

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MEAN CHEMISTRY SCORES FOR THE HI/LO SPATIAL GROUP (MALES)

		SUBSCR 1	SUBSCR 3	QUIZ
EMBF	HI	27.67	25.74*	16.79[3]
	LO	27.17	23.35	14.79
SUCF	HI	29.62[1]	26.19	17.47[3]
	LO	24.59	25.71	14.71
ROT	HI	28.09[3]	25.93	16.58[3]
	LO	25.71	23.96	14.33
FASP	HI	28.79[3]	26.86[3]	17.17[3]
	LO	26.53	24.24	15.08
COMB SCR	HI	29.30[1]	27.10*	18.09[2]
	LO	25.67	24.75	15.11

MEAN CHEMISTRY SCORES FOR THE HI/LO SPATIAL GROUP (FEMALES)

		SUBSCR 1	SUBSCR 3	QUIZ
EMBF	HI	26.43[3]	24.40	16.13[3]
	LO	23.98	22.06	13.33
SUCF	HI	27.46[2]	23.62	16.87[2]
	LO	22.45	22.50	12.49
ROT	HI	28.36[2]	26.98[1]	18.36[1]
	LO	24.64	21.41	13.54
FASP	HI	27.69[3]	26.89[2]	17.46[1]
	LO	24.74	22.15	13.41
COMB SCR	HI	29.66[1]	27.50[2]	19.34[1]
	LO	24.13	22.05	13.49

MEAN CHEMISTRY SCORES FOR HI/LO SPATIAL GROUPS

		SUBSCR 1	SUBSCR 3	QUIZ
EMBF	HI	27.30[3]	25.15[2]	16.66[2]
	LO	25.70	22.76	14.23
SUCF	HI	28.79[1]	25.18	17.15[2]
	LO	23.70	24.31	13.94
ROT	HI	28.13[1]	26.09[1]	17.04[1]
	LO	25.09	22.36	13.90
FASP	HI	28.59[1]	26.94[1]	17.24[1]
	LO	25.75	23.15	14.42
COMB. SCR.	HI	29.29[1]	26.99[1]	18.35[1]
	LO	24.83	23.35	14.40

Note: [1] indicates that the difference between the means is significant at or below the .001 level

[2] indicates significance at or below the .01 level

[3] indicates significance at or below the .05 level

* indicates significance between .05 and .10

SUMMARY OF T-TEST ANALYSIS COMPARING MALES AND FEMALES

VARIABLE	MEAN SCORE FEMALE	MALE	T-VALUE	T-SIGNIF.
Chemistry 115 Group				
Subscr 1	25.36	27.50	-2.48	.014*
Subscr 3	23.56	25.03	-1.82	.069*
SAT-V	493.32	485.29	1.20	.232
SAT-M	562.62	596.16	-5.21	.000*
Quiz	15.35	16.08	-1.14	.255
EMBF(t-score)	49.62	50.21	-0.77	.444
SUCF(t-score)	49.42	50.60	-1.67	.096*
ROT(t-score)	46.05	52.87	-9.57	.000*
FASP(t-score)	48.72	51.17	-2.86	.004*
Comb.Scr.	197.35	205.90	-3.92	.000*

TABLE V.18: PEARSON CORRELATION COEFFICIENTS FOR MALES AND FEMALES

	EMBF		SUCF		ROT		FASP		COMB. SCR.	
	(M)	(F)	(M)	(F)	(M)	(F)	(M)	(F)	(M)	(F)
EMBF			.29[1]	.21[1]	.26[1]	.27[1]	.21[1]	.19[1]	.68[1]	.62[1]
SUCF					.31[1]	.31[1]	.23[1]	.20[1]	.65[1]	.52[1]
ROT							.38[1]	.46[1]	.67[1]	.75[1]
FASP									.66[1]	.72[1]
Subscr1	.06	.17[1]	.16[1]	.20[1]	.13[2]	.17[1]	.06	.11[3]	.14[2]	.21[1]
Subscr3	.10[3]	.08*	-.003	.07	.11[2]	.20[1]	.19[1]	.20[1]	.15[2]	.21[1]
Quiz	.10[3]	.18[2]	.06	.17[2]	.13[2]	.25[1]	.17[2]	.29[1]	.18[2]	.34[1]
SATV	.19[1]	.10[3]	.09[3]	.18[1]	.12[2]	.29[1]	.10[3]	.26[1]	.17[1]	.28[1]
SATM	.24[1]	.25[1]	.26[1]	.33[1]	.27[1]	.45[1]	.10[3]	.36[1]	.31[1]	.48[1]

Note: [1] indicates a significance level at or below .001

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	EMBF (M)	EMBF (F)	SUCF (M)	SUCF (F)	ROT (M)	ROT (F)	FASP (M)	FASP (F)	COMB. SCR. (M)	COMB. SCR. (F)
EMBF			.29[1]	.21[1]	.26[1]	.27[1]	.21[1]	.19[1]	.68[1]	.62[1]
SUCF					.31[1]	.31[1]	.23[1]	.20[1]	.65[1]	.52[1]
ROT							.38[1]	.46[1]	.67[1]	.75[1]
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Subscr3	.10[3]	.08*	-.003	.07	.11[2]	.20[1]	.19[1]	.20[1]	.15[2]	.21[1]
Quiz	.10[3]	.18[2]	.06	.17[2]	.13[2]	.25[1]	.17[2]	.29[1]	.18[2]	.34[1]
SATV	.19[1]	.10[3]	.09[3]	.18[1]	.12[2]	.29[1]	.10[3]	.26[1]	.17[1]	.28[1]
SATM	.24[1]	.25[1]	.26[1]	.33[1]	.27[1]	.45[1]	.10[3]	.36[1]	.31[1]	.48[1]

Note: [1] indicates a significance level at or below .001

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* indicates a significance between .05 and .10