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ABSTRACT

The objective of this study was to provide data related to learning styles and to learning environments, to identify appropriate experiences for the non-major biology student. Investigated was whether congruence existed between a measured amount of cognitive process or analytical skill and the resultant answer on a test question which required that skill. Performance on one cognitive process, analytic skill on the Learning Style Profile (LSP) test, was evaluated for 96 students. Included in the evaluation were: (1) a determination of the amount of analytic skill required for six test questions in the computer test bank; (2) the students' score on the LSP analytic subscale; and (3) whether the students answered the analytical skills questions correctly or incorrectly. Results suggested that there was a relationship between a measured amount of analytic skill and a student's ability to perform on questions perceived to require analytical skill. Recommendations for course design are included. (KR)

# Cognitive Process Analysis of Test Questions in a Computer-Managed College Biology Course Based on a Learning Style Assessment With Emphasis on Analytic-Spatial Skill

by

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## INTRODUCTION

Douglass (1979) has shown that students' achievement in three units (genetics, evolution, and mitosis) within a high school biology course was significantly higher when instruction was presented in each student's preferred learning style. Reviews by Claxton & Murrell (1987) and Dunn (1980 and 1984) on pre-college learning style are replete with examples indicating that when instruction is matched to learners' preferred learning modes, motivation and achievement increase. Claxton & Murrell (1987) write that, in higher education, an important question to be asked of any instructional strategy is whether that effort is consistent with the learning styles of the students concerned. Although there was a large amount of literature available on pre-college education regarding learning style, it was not until 1987 that support of this approach in higher education was evident through the work of Claxton & Murrell. Claxton & Murrell cite the Curry (1983) model used in this study (Figure 1) as a learning style framework.

For many years, science educators have desired the development of a scientifically literate populace (Fensham, 1987; Flannery, 1987; Gabel, 1976, Hurd, 1986; Walberg, 1983; Yager, 1986). Miller reported at the 1989 meeting of the American Association for the Advancement of Science (AAAS) that only 6% of U.S. adults possess the level of understanding of science and technology needed to function minimally as citizens and consumers. He reported that only one in 18 adults has enough vocabulary and understanding of scientific concepts to make informed decisions on issues such as nuclear power and genetic engineering. Miller continued with the "major source of adult scientific literacy is exposure to college level science courses." (p. 21).

Bloch (1987) and Gardner (1985) both call on college teachers to take the lead in improving science education at the pre-college level, but neither of them say how that can be done. Teachers at the pre-college level are dependent on college science teachers for their understanding of science. Elementary school teachers take classes in the non-major sections in science during their undergraduate years. Therefore, improvements in the courses for non-majors would directly affect this population, who will in turn educate future scientists. Bloch suggests that current reward systems are at fault: there are no rewards in academic science for spending time improving undergraduate non-major courses.

Improvement is needed in courses for the non-majors; as previously stated, these are the primary science courses which are taught to the pre-college teacher at the elementary education level. In addition, many middle and junior high teachers can be found in courses for the non-major in science. Anything that scientists do to improve instruction for the non-major in science would be a great step towards improving science education. Improvement in the courses for the non-major could improve literacy for large numbers of citizens.

Westheimer (1987) writes that though scientists do not really want to teach the "unwashed" (meaning the non-major), that special courses in science for them probably are needed. He writes about the invention and reinvention of many of these courses for non-majors in biology across the country; such courses are difficult to design and frequently fail in their purpose. Westheimer speaks eloquently of the need of the individuals who populate these courses to learn some substantive science - the legislators, the educators, the lawyers and judges, and the business executives of the future in America.

Yet there is evidence that courses in science for the non-science major may not be meeting the needs of the students in these courses. The evidence is fragmented; however, indicators of segments of possible problems are stated by Robb ("G E's Walter Robb," 1989). Robb says that improvement in undergraduate courses for all students is needed, including the major, because even at the level of sophomore, students continue to drop out of science as a major, even though they've gotten that far and still have an interest in chemistry or another scientific discipline.

## STATEMENT OF PURPOSE

The intent of this study was to obtain descriptive quantitative information on the cognitive processes of non-major undergraduate students in a general biology class. No data currently exists in the learning style literature on cognitive processes required of students in undergraduate biology courses. Another purpose of the study was to determine if a measured amount of a cognitive processing skill (analytic) is related to a student's ability to answer a question which is perceived to require that skill.

The instructional design model of business and industry has been followed (Coldeway and Coldeway, 1987; Dodge, 1987; Kearsley, 1984; Mager, 1984; McCombs, 1985). These models utilize learner characteristics to design modular instruction for training.

## IDENTIFICATION OF STUDENT LEARNING STYLE

The subjects were enrolled at a large mid-Western University in a non-majors biology course Winter Quarter, 1988. The course is taught by the audiotutorial method and is computer-managed. Students were administered the Learning Style

Profile (LSP) produced by the National Association of Secondary School Principals (NASSP) (Keefe, Monk, Letteri, Languis & Dunn, 1986) during the first class period.

The LSP contains 126 items divided into 23 subscales of research-based learning style elements which are classified into cognitive, affective, and physiological/environmental domains. Internal consistency reliability estimates of the LSP for each sub-scale measures from 0.47 to 0.76 with an average of 0.61 (Keefe, et al, 1986). Analytic subscale reliability is 0.64. Table 1 displays standard mean scores and standard deviations on all 23 subscales for all of the students who took the Learning Style Profile (n=922).

## HYPOTHESES

General: Cognitive processing skills (analytic, spatial, discrimination, categorization, sequential processing and memory), as measured by the Learning Style Profile, will predict student ability to answer questions which demand those skills.

Specific: Analytic skill will predict student ability to answer questions which are perceived to demand analytic skill.

Null: There is no relationship between a student's score in analytic processing skill, as measured by the Learning Style Profile, and the student's score on questions which are perceived to demand that skill.

## PROCEDURE

There are over 20,000 test items in the computer-managed test bank for the non-major biology course. The questions are keyed to the unit objectives and consist of three types, called low, high, and image. "Low" type questions are meant to be recall. "High" type questions are meant to require a higher level of difficulty than recall, possibly analysis or application. "Image" type questions are, in effect, either laboratory practical type questions or diagram identification. Questions were drawn systematically from two units in order to optimize the chance to obtain questions from each type of question classification. Since the number of questions per objective varies (range 2-29), some questions in the test bank are presented to each student and some probably are presented to only a few. Therefore, questions were selected from each classification type (low, high and image) and from objectives with few questions and with many questions. Fifty-eight questions were thus selected to be rated according to cognitive processes.

Since interrater reliability was low and multiple processes were required of each question, only six questions for which there was unanimous agreement as to the cognitive process required (analytic skill) were then selected for a preliminary test. Students who were presented those questions and who answered correctly or incorrectly were identified. The goal was to determine if there is congruence between a student's skill level in analytic skill, as measured by the LSP, and the student's ability to answer questions which require that skill. Eight different students per cell, for a total of 96 students, were randomly identified from the computer-managed testing records for each of the six questions. An analysis of variance was performed to evaluate cognitive process requirements of questions in the computer-managed test bank and the relationship of cognitive process requirements and cognitive process scores of students, as measured by the LSP.

## RESULTS

The data from these comparisons are presented in Tables 2 and 3. Two questions each were from each of types low, high and image Two rating levels,high (value of 12 which consisted of a unanimous score of 4 from each of 3 raters), and low (value of 0, which consisted of a unanimous score of 0 from each of 3 raters) were evaluated. The record of performance (right or wrong) for each student on each question was analyzed and is presented in Table 2. Two groups of students who had been asked these questions were formed; those who answered correctly and those who answered incorrectly.

No significant differences were found (see Table 3) of those students' analytical scores from the analytic subscale of the Learing Style Profile based on any one of the three major variables (question level of difficulty, amount of analytic ability required as determined by ratings of three different persons, or right/wrong answer). Therefore, the hypothesis could not be rejected for the five item analytic scale proposed by the NASSP. However, an additional analysis of variance was performed on the same group of 96 students, as explained following the results of factor analysis presented next.

Since the LSP had never been administered to a college population and no normative data existed prior to this study, factor analysis was chosen to attempt to add validity to the use to the instrument for older adolescents and adults. Several factor analyses were attempted, including one exactly like that described in the Technical Manual for the LSP, a 19 factor solution.

Table 4 presents the results from a nine factor solution, varimax rotation, which yielded a six item factor loading on the LSP variable, analytic skill subscale. Table 5 presents the factor standard regression coefficients of all items which loaded with the analytic factor. Two items from the spatial subscale loaded with the analytic items. Item 26 was not included because the factor loading was below .30. The reliability of this six item analytic scale was .645.

Following the six item loading of the analytic scale, an additional analysis of variance test was performed on the same 96 students presented in Tables 2 and 3. A reanalysis of student answers based on an analytic scale composed of the six items which loaded together in the 9-factor solution was performed and are presented in Table 6 and 7.

Because no standard scores were available for this newly created subscale on the LSP, raw scores were used and the data were transformed using a square root transformation. In this analysis, presented in Tables 6 and 7, a significant three factor interaction was found on the transformed date. There is a significant interaction between question type, amount analysis required and whether or not the student answered the question right or wrong ($p < .04$).

The three factor interaction is difficult to interpret but a sense of the interactions can be obtained from an examination of the means shown in Table 6. Generally, with A and B held constant and looking at mean scores of correct vs incorrect, the incorrect is generally lower except for low level questions and low amount of analysis. Students who missed high analytic questions from the low cognitive level set had lower LSP analytic scores than those answering correctly. Students who missed the low analytic questions from the low cognitive level set had higher LSP analytic scores than those answering correctly. All cells A x B x C are basically the same except for 1) low question type X high analytic X incorrect (low LSP score of 1.45), 2) low question type X low analytic X correct (low LSP score of 1.75).

It is not unexpected that those with low LSP analytic scores should be less successful on high analytic questions. It is less obvious why those with low LSP analytic scores should be more successful on low analytic questions. Perhaps the use of analytic skills on low level - recall items results in confusion or misinterpretation. Students may read more into the question than is expected or may refuse to memorize material.

Since a three-way interaction between question type, high vs low analytic requirement, and correct vs incorrect response was found, the hypothesis is rejected for analytic ability. The hypothesis could not be rejected for the other five cognitive processes.

## CONCLUSIONS

The six item analytic subscale (Table 6 and 7) shows a three factor interaction, which suggests that there is a relationship between a measured amount of analytic skill (if a different and improved analytic subscale is used) and a student's ability to perform on questions which are perceived to require analytic skill. Novak wrote (1970) that

> In general, we have found that students who spend more time working in the learning center also achieve higher scores on tests of botanical knowledge. However, when the students in one botany class were grouped according to analytic ability, as determined by a test requiring application of information to the solution of problems in biology, marked differences between students ranked as having high analytic ability and those with low analytic ability were found. Students with high analytic ability gained more knowledge in nine hours of study in the learning center than students with low analytic ability acquired in twenty hours, over a five-hour week block of materials (1970, p.73).

Linn (1980) showed that components of the field dependence-independence (FDI) construct included items similar to the ones which factored together in this study. Linn's factor analysis of 12 different tests of FDI showed two dimensions associated with items in this study: analytic and spatial. One of Linn's dimensions measured cognitive restructuring of unfamiliar geometric shapes, similar to items 25, 26, 28, 29 and 40 in the Learning Style Profile.

The other dimension identified by Linn was generation of novel representations of material such as paper folding, similar to item 37 on the Learning Style Profile.

The literature isn't clear as to what kinds of items measure analytic and spatial ability. This study supports that confusion as to just what kind of items measure analytic and what kind of items measure spatial ability.

Spatial ability was identified by this researcher as a predictor for success in this course and no gender differences were found. Those data will be presented in another paper. Literature on spatial ability is abundant. The results of this study demonstrate, however, that some components of spatial ability may overlap with some components of analytic ability. Analytic ability has been used frequently by science educators to design test questions and to measure student progress (Novak, 1970).

Scientific literacy as a goal of science educators may be more tenable to achieve if mismatches between cognitive demands and cognitive abilities are avoided. Attention should be given to cognitive process requirements of both instruction and test questions. Biologists who design courses for the non-major should examine learning style literature and select those elements of learning style which they find necessary for achievement and literacy in their courses. It may be that some elements, once identified as necessary for achievement, may require remediation. A first step toward that end, remediation, may be to train question writers in what constitutes a cognitive process such as analytic and spatial skill.

RECOMMENDATIONS FROM THE LSP FOR COURSE DESIGN

Capitalize on students' above average categorization and sequential processing skills as well as visual perceptual responses by providing more learning opportunites which require those skills (Table 1). Recommendations regarding the other 17 subscales on the LSP will be reported in another paper.

## IMPLICATIONS FOR RESEARCH REGARDING COGNITIVE DEMAND REQUIREMENTS

1. Since the data on the entire population (N=922) are available, further research should include a larger sample (larger than 96 students) and involve the analysis of more than six questions.

2. Raters of questions should be trained in evaluation of cognitive demands of instruction and of evaluation measures. They should be familiar with the kinds of cognitive processes students use when answering questions. Interrater reliability should be high.

3. Questions should be carefully examined for concept density. Concept density as a problem may be indicated by questions which require many cognitive processes within the same question. This problem was identified because no question of the 58 initially examined contained only one cognitive process (as measured by the LSP cognitive skill subscale of analytic, spatial, discrimination, categorization, sequential processing and memory). Every question required two or more processes, according to the three raters.

4. Reconstruct the LSP analytic scale to include item numbers 37 and 40. Omit item 26 from the analytic scale.

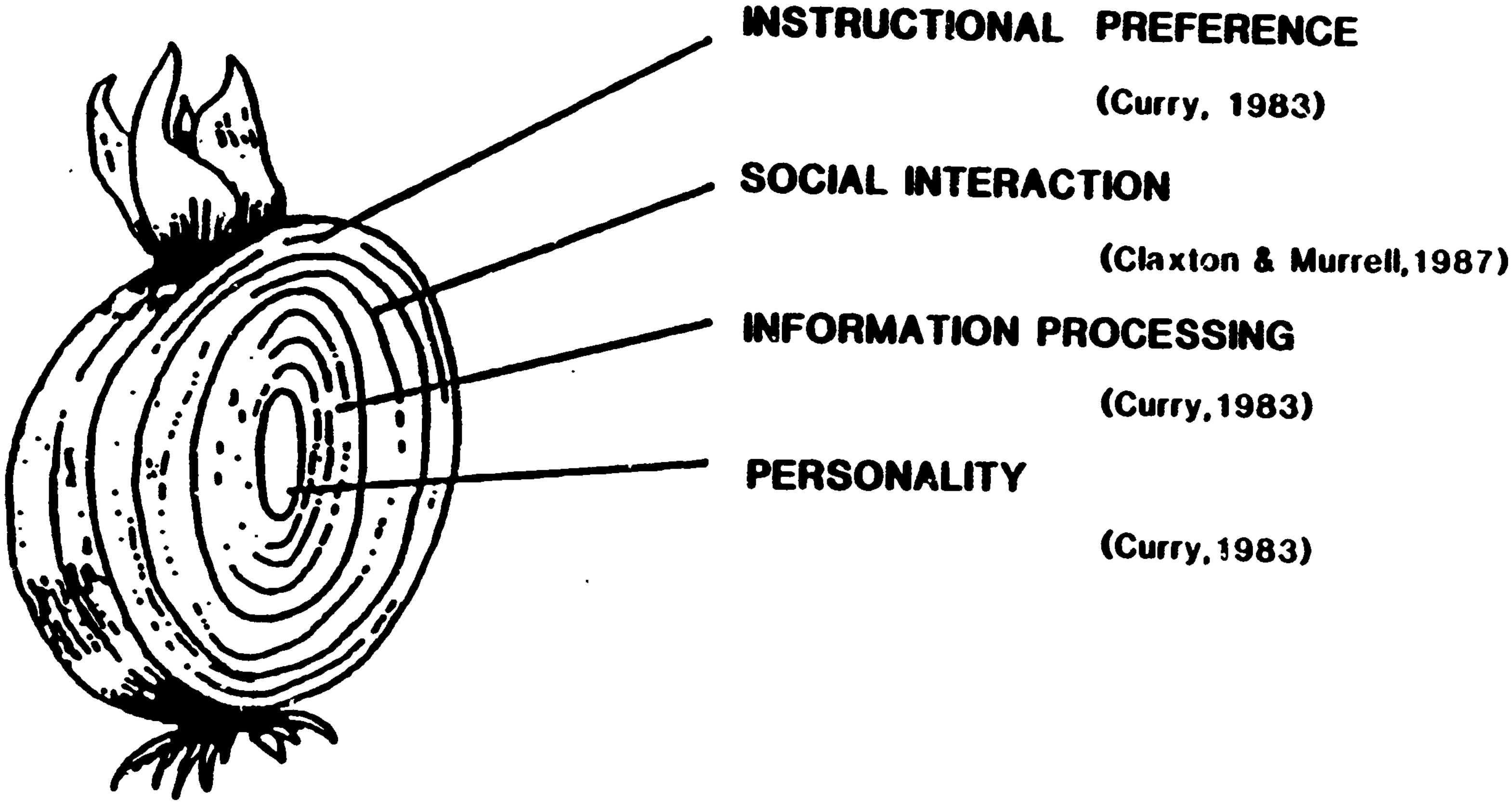


Figure : Learning Style Framework

TABLE 1

LEARNING STYLE PROFILE SUMMARY DATA

This profile is for: Non-science major undergraduates N=922

<u>Birthdate</u>: <u>Sex</u>: <u>Grade</u>: <u>Race</u>:
<u>Date</u>: Winter 1988 <u>School</u>: The Ohio State University <u>Class</u>: Biology 110

Skills--General approach to processing information

| | Score | S.D. | Weak | Average | | Strong |
|---|---|---|---|---|---|---|
| Analytic | 50.32 | 8.12 | | XX | XX | |
| Spatial | 53.98 | 12.24 | | | XXXX | |
| Discrimination | 46.56 | 10.77 | | XXXX | | |
| Categorization | 56.96 | 7.90 | | | XXXX | |
| Sequential | 54.30 | 5.47 | | | XXXX | |
| Memory | 46.64 | 11.18 | | XXXX | | |

Perceptual responses--initial response to verbal information

| | Score | S.D | Weak | Average | | Strong |
|---|---|---|---|---|---|---|
| Visual | 53.87 | 10.66 | | | XXXX | |
| Auditory | 44.73 | 9.39 | | XXXX | | |
| Emotive | 49.84 | 10.31 | | XX | XX | |

Orientations and preferences--
Preferred response to study or instructional environment

| | Score | S.D | Weak | Average | | Strong |
|---|---|---|---|---|---|---|
| Persistence | 48.89 | 9.86 | | XXXX | | |
| Verbal Risk | 48.75 | 9.32 | | XXXX | | |
| Manipulative | 48.44 | 10.34 | | XXXX | | |
| Study Time: | | | | | | |
| Early Morning | 50.59 | 10.74 | | | XXXX | |
| Late Morning | 49.57 | 9.47 | | XX | XX | |
| Afternoon | 50.69 | 9.31 | | | XXXX | |
| Evening | 52.75 | 9.05 | | | XXXX | |

| | | | | High | Neutral | | High | |
|---|---|---|---|---|---|---|---|---|
| Verbal-Spatial | 48.09 | 6.93 | Spatial | | XX | | | Verbal |
| Grouping | 41.50 | 7.07 | Small | | XX | | | Large |
| Posture | 54.81 | 10.35 | Informal | | | XX | | Formal |
| Mobility | 48.07 | 9.77 | Stillness | | XX | | | Movement |
| Sound | 44.13 | 9.36 | Quiet | | XX | | | Sound |
| Lighting | 52.14 | 10.04 | Dim | | | XX | | Bright |
| Temperature | 53.29 | 10.37 | Cool | | | XX | | Warm |

Consistency score: Normative sample: 1986 -- National
NASSP--National Association of Secondary School Principals, Reston, VA

## Scale Indicators

| Weak, Low or High | Average or Neutral | Strong or High |
|---|---|---|

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| < 30 | 30-35 | 36-40 | 41-43 | 44-47 | 48- | 52 | 53-56 | 67-59 | 60-64 | 65-70 | > 70 |

Standard Score Range

TABLE 2

LEARNING STYLE PROFILE FIVE ITEM ANALYTIC SCORE
QUESTION ANALYSIS N=96
Analytic Subscale = five items (25, 26, 27, 28, 29)
[B]

| Question Type | High Analytic | | | | Low Analytic | | | |
|---|---|---|---|---|---|---|---|---|
| | Correct | | Incorrect | | Correct | | Incorrect | |
| Low | Mean | 51.63 | Mean | 46.75 | Mean | 44.13 | Mean | 49.13 |
| | S.D. | 6.80 | S.D. | 8.29 | S.D. | 9.48 | S.D. | 6.96 |
| [A] ' .gh | Mean | 50.63 | Mean | 50.75 | Mean | 49.13 | Mean | 48.13 |
| | S.D. | 11.35 | S.D | 5.97 | S.D. | 6.96 | S.D. | 9.23 |
| Image | Mean | 50.63 | Mean | 49.25 | Mean | 53.25 | Mean | 49.13 |
| | S.D. | 9.43 | S.D. | 7.85 | S.D. | 7.08 | S.D. | 9.40 |

LSP analytic subscale standard score for eight SS/cell, all different

TABLE 3

ANALYSIS OF VARIANCE OF QUESTION TYPE, AMOUNT OF ANALYSIS
(FIVE ITEMS), AND CORRECT VS INCORRECT RESPONSE
TO MULTIPLE CHOICE TEST QUESTIONS
Analytic Subscale = five items (25, 26, 27, 28, 29)

| Source | Sum of Squares | Degrees of Freedom | F | P Value |
|---|---|---|---|---|
| Question Type (A) | 116.69 | 2 | 0.83 | 0.44 |
| High versus Low (B) analysis required | 30.38 | 1 | 0.43 | 0.51 |
| Correct vs (C) incorrect response | 26.04 | 1 | 0.37 | 0.55 |
| AB | 68.69 | 2 | 0.49 | 0.62 |
| AC | 36.02 | 2 | 0.25 | 0.78 |
| BC | 24.00 | 1 | 0.34 | 0.56 |
| ABC | 188.69 | 2 | 1.34 | 0.27 |
| Error | 5884.00 | 84 | | |
| Total | 6426.50 | 95 | | |

TABLE 4

FACTOR ANALYSIS OF LEARNING STYLE PROFILE
N=558 (no missing values)

| Factor Name | Eigen Value | Percent Variance | Cumulative Percent Variance |
|---|---|---|---|
| 1. Persistence | 4.19 | .11 | .11 |
| 2. Sound | 3.61 | .09 | .20 |
| 3. Study Time--Evening | 3.01 | .08 | .28 |
| 4. Lighting | 2.71 | .07 | .35 |
| 5. Grouping | 2.50 | .06 | .41 |
| 6. Temperature | 2.44 | .06 | .48 |
| 7. Manipulative | 2.24 | .06 | .53 |
| 8. Analytic | 1.96 | .05 | .59 |
| 9. | 1.72 | .04 | .63 |

TABLE 5

ANALYTIC FACTOR COMPONENTS

| Item Number | Standard Regression Coefficient |
|---|---|
| 25 | .50 |
| 27 | .44 |
| 28 | .63 |
| 29 | .53 |
| 37 | .36 |
| 40 | .35 |

TABLE 6

LEARNING STYLE PROFILE SIX ITEM ANALYTIC SCORE
QUESTION ANALYSIS (square root transformation)
Analytic Subscale = six items (25, 27, 28, 29, 37, 40)
[B] N=96

| | Question Type | High Analytic | | | | Low Analytic | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Correct | | Incorrect | | Correct | | Incorrect | |
| | Low | Mean | 2.11 | Mean | 1.45 | Mean | 1.75 | Mean | 2.01 |
| | | S.D. | .25 | S.D. | .93 | S.D. | .58 | S.D. | .30 |
| [A] | High | Mean | 2.02 | Mean | 1.94 | Mean | 2.01 | Mean | 1.90 |
| | | S.D. | .45 | S.D | .35 | S.D. | .33 | S.D. | .55 |
| | Image | Mean | 2.06 | Mean | 2.01 | Mean | 2.24 | Mean | 1.98 |
| | | S.D. | .36 | S.D. | .27 | S.D. | .35 | S.D. | .48 |

LSP analytic subscale raw score for eight SS/cell, all different

TABLE 7

ANALYSIS OF VARIANCE OF QUESTION TYPE, AMOUNT ANALYSIS,
(SIX ITEMS), AND CORRECT VS INCORRECT RESPONSE
TO MULTIPLE CHOICE TEST QUESTIONS
(square root transformation)
Analytic Subscale = six items (25, 27, 28, 29, 37, 40)

| Source | Sum of Squares | Degrees of Freedom | F | P Value |
|---|---|---|---|---|
| Question Type (A) | 0.95 | 2 | 2.15 | 0.12 |
| High versus Low (B) analysis required | 0.06 | 1 | 0.26 | 0.61 |
| Correct vs (C) incorrect response | 0.53 | 1 | 2.41 | 0.12 |
| AB | 0.07 | 2 | 0.16 | 0.85 |
| AC | 0.05 | 2 | 0.11 | 0.90 |
| BC | 0.30 | 1 | 1.36 | 0.25 |
| ABC | 1.45 | 2 | 3.28 | 0.04 |
| Error | 18.57 | 84 | | |
| Total | 21.98 | 95 | | |

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