5-1996

A Validation Study of the Trio Measure of Visual Processing Ability

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A VALIDATION STUDY OF THE TRIO MEASURE OF VISUAL PROCESSING ABILITY

by

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Psychology

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1996

ABSTRACT

A Validation Study of the Trio Measure

of Visual Processing Ability

by

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Utah State University, 1996

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Trio is a newly developed group-administered instrument designed to measure visual ability for application in cognitive styles research. This study investigated the validity of Trio as seen in its convergence or divergence with two established tests, one conceptually related and one conceptually unrelated. The correlation of Trio scores with scores on these other two tests was examined using a sample of undergraduate students.

The analysis of the relationship between scores on Trio and on the conceptually related Learning Figures Test failed to provide evidence that these two tests are measuring the same construct. At the same time, Trio's correlation with the unrelated ACT English section was shown to be fairly low. This second finding supports the conclusion that Trio scores are not severely confounded by verbal ability level.

(46 pages)

DEDICATION

This thesis is dedicated to my wife, Julie. I will always treasure her support and patience throughout this experience and in so many others.

ACKNOWLEDGMENTS

I wish to thank my major professor, Dr. Lani Van Dusen, and my committee members, Dr. Deborah Hobbs and Dr. Xitao Fan, for their assistance and cooperation in carrying out this study.

Jonathan David Spach

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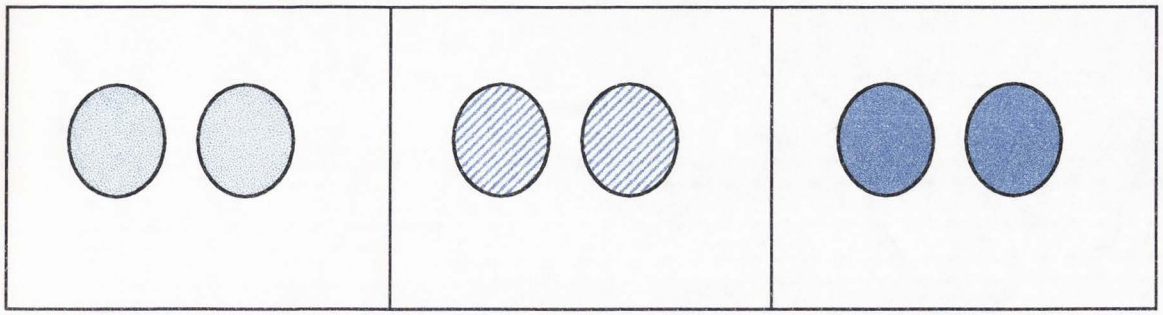

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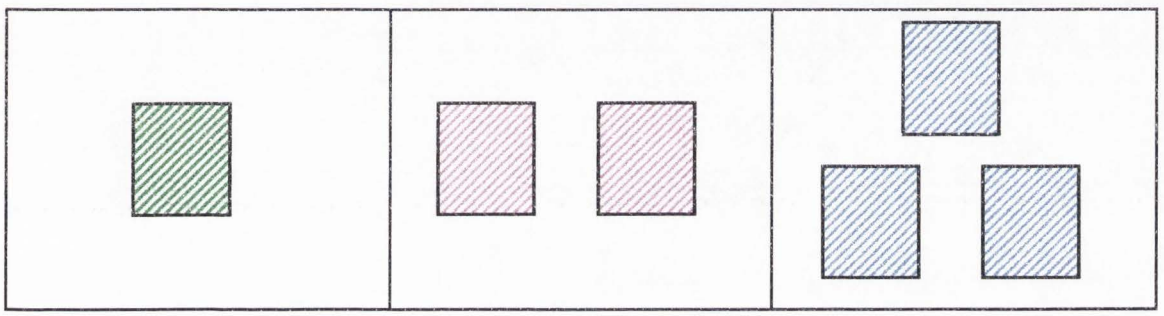

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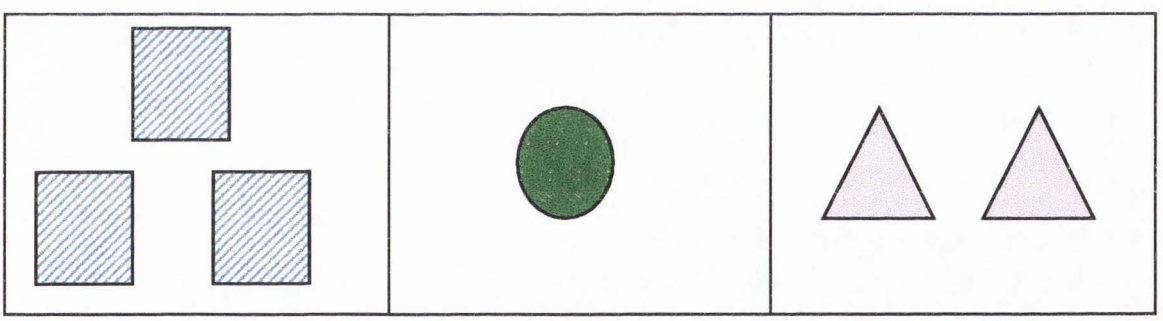

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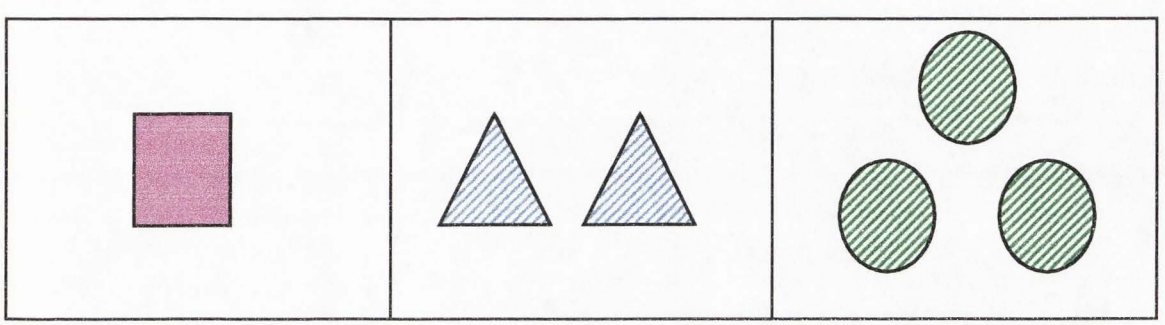

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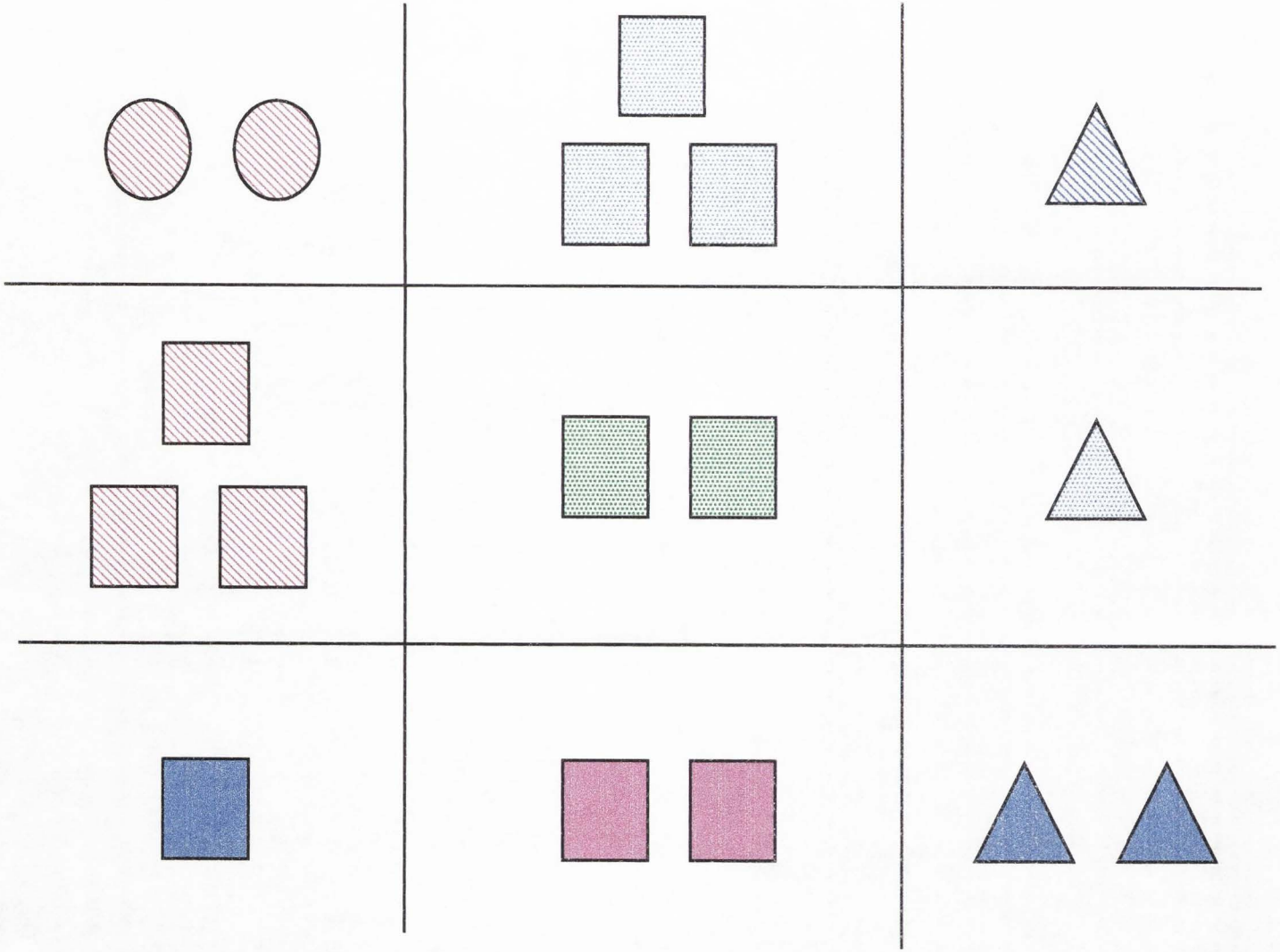

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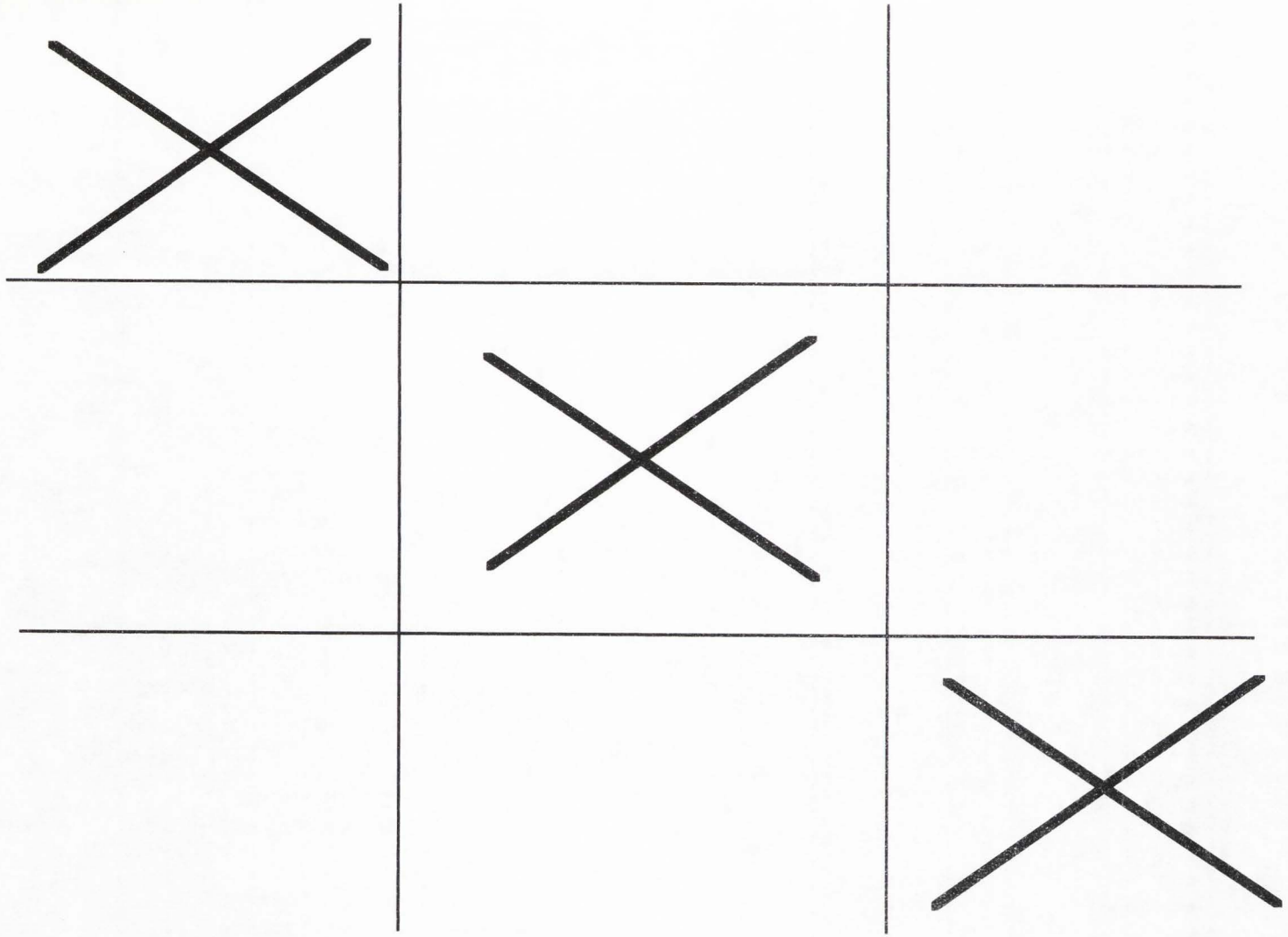

Figure 6. Correctly marked Trio answer grid.

Based on the above description of Trio, it can be seen that this measurement ought to be classified as a measure of spatial perception rather than of spatial visualization. This is due to the distinct emphasis on the recognition and mastery of the characteristics of visual stimuli and to the lack of emphasis on the mental manipulation of these images to envision what they would look like in different positions.

Investigating the Validity of Trio

In 1995, research was conducted to measure the test-retest reliability of Trio (Van Dusen & Spach, 1995). The results of this research are encouraging and are reported in Chapter III under "Instruments." Still, there remains a need to thoroughly establish the validity of Trio.

For the purpose of investigating the validity of Trio, the most appropriate measures for comparison are those taken from the matching or recognition category, as this is most closely associated with spatial perception. A closer look at the characteristics of instruments available in this category results in a rapid narrowing of scope in identifying a test that suggests itself for comparison with Trio.

Within the area of matching or recognition abilities, several tasks should be excluded from consideration in the validation of Trio, mainly due to their failure to adequately isolate specifically visual processing. These categories, which were identified earlier, include maze/copying tasks, embedded-figures tasks, and figural combination tasks. As should be clear from the earlier

discussion of verbal mediation, such instruments would not provide useful information regarding the validity of Trio as a measure of nonanalytic visual processing ability.

Because they require imagining the rotation of depicted figures, figural rotation tasks are at least very closely related to the rotation tasks (such as the Mental Rotations Test) that Eliot and Stumpf (1992) placed in the manipulation category. For this reason, figural rotation tasks are not the best choice for a validation of the matching task, Trio. Since figural combination tasks demand that items be imaginatively rearranged, such tasks also lean toward a visualization classification.

The drawbacks of the tasks in the above subcategories lead to the isolation of what Eliot (1980) calls figural memory tasks as the best candidate for finding an appropriate correlate for Trio. Figural memory tests require that subjects draw or identify from memory a figure or characteristics of a figure that is shown briefly (Eliot, 1980, p. 849). Because drawing involves physical skills that may be as much a matter of kinesthetic proclivity as they are a matter of visual processing ability, an identification task is more appropriate for the present purpose than is a task requiring drawing.

The Learning Figures Test from Germany's Test of Medical Skills (Eliot, 1980) is a current and useful example of a figural memory test that does not require drawing. This test, which has been incorporated by Stumpf (Eliot & Stumpf, 1992) at the Center for Talented Youth at Johns Hopkins University into a spatial test battery, was selected for use in this study. It should be noted,

however, that while being the best choice available for this purpose, the validity of the Learning Figures Test for this purpose has not been thoroughly demonstrated. The test's characteristics are more fully discussed in Chapter III.

Summary

This discussion of the current array of visual tests shows that many of the categories are made up primarily of instruments that do not lend themselves well to cognitive style research. This is chiefly due to the failure of these tests to effectively isolate visual processing, but also generally to the expense and inconvenience of single-subject administration. Within the category of tasks that focus upon spatial perception or visual recognition, only one subcategory of existing instruments is well-suited for measuring specifically visual processing--the category of figural memory tasks.

Still, a closer look has revealed that even figural memory tasks display a limitation of scope--the exclusive focus on shape--that Trio overcomes. For this reason, it can be argued that Trio provides a deeper investigation into spatial perception than do figural memory tasks.

What is needed, however, is to investigate the convergent validity of Trio by investigating its relationship to an established figural memory task. As recommended by Campbell and Fiske (1959), this examination ought to be carried out in light of a concurrent observation of the relationship between Trio and a measure of a separate construct--that of verbal ability.

CHAPTER III

THE STUDY

Purpose of the Study

The foregoing review of literature indicates that there is a need to investigate the construct validity of the newly developed Trio as a measure of visual processing ability. The purpose of this study is to address this issue through examining the correlation of Trio scores with scores from other relevant mental tests.

Specifically, the study seeks to answer the following two research questions:

1. What is the degree and significance of the relationships between Trio scores and scores on another established test of visual-spatial ability, the Learning Figures Test?

2. What is the degree and significance of the relationship between Trio scores and an established test of verbal ability, the English section of the ACT?

Anastasi (1988) cited correlation with other tests as one accepted method of establishing construct-related validity, or the extent to which a test measures a trait or construct such as visual or verbal ability. If a test purports to measure a construct for which there already exists an established and accepted instrument of measure, the construct validity of the new test can be examined by looking at the correlation between scores on the two tests. Scores on a valid instrument are expected to converge with scores on other tests measuring the same construct

and to diverge from scores on unrelated tests. The answer to the first research question will address Trio's convergent validity, or the degree to which Trio scores correlate positively with an established test purporting to measure the same or a similar construct.

By the same principle, if there is an established measure that is recognized as a reliable indicator of some *other* construct distinct and different from the construct in question, a valid new test is not expected to correlate too highly with such a measure (Campbell & Fiske, 1959). An extremely high correlation coefficient would suggest that the tests are essentially interchangeable, a moderate to high correlation that the two are closely related, and a low correlation that there is little relationship between what the tests measure. The answer to the second research question will address Trio's divergent validity, or the degree to which Trio successfully avoids measuring skill in verbal processing. If Trio measures a distinctly visual construct, one would expect the results of a verbal test to show a low correlation with Trio.

Method

Design

This study followed a correlational design in which subjects were selected and tested, and the results then analyzed in terms of the bivariate linear correlations among the various scores yielded. The two variables in the first correlation calculated were Trio scores and scores on the Learning Figures Test;

while the second correlation was for Trio scores and scores on the English section of the ACT.

Subjects

The sample consisted of 65 student volunteers from four undergraduate classes in the College of Education at Utah State University. Sixty-one of the 65 students in the sample were female. The students were primarily Caucasian.

Thirty-seven of the students received extra credit for participating. Students did not know before the study that it involved specifically visual activities, but only that it had to do with cognitive abilities in general.

Instruments

The instruments administered as part of this study were Trio and the Learning Figures Test. Scores from the English section of the ACT (taken previously as a college entrance requirement) were also used as part of this study. Descriptions of these three instruments follow:

Trio.[6] Trio requires the subject to quickly identify differences and similarities in visual attributes (shape, number, color, and shading) of symbols in a matrix, and to then select a group of three blocks of symbols that bear a certain relationship to one another--a trio. A raw score reflects the number of matrices presented for which the subject correctly identified a trio.

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[6] For more on Trio, see the discussion in Chapter II of this thesis, pp. 12-17.

An overhead projector was used to present the nine matrices (including the sample matrix, which was not used in scoring) to each group of subjects. Subjects marked their responses on answer sheets consisting of blank matrices.

Standard Trio scores for university undergraduates range from 0 to 8 with a mean of 3 and a standard deviation of 1.5. Reliability of 0.78 has been established using the test-retest method at an interval of 3 weeks (Van Dusen & Spach, 1995).

Learning Figures Test. The Learning Figures Test (LFT) is a subset of the CTY Spatial Test Battery (Eliot & Stumpf, 1992) and was originally taken from the Test for Medical Studies (TMS), a nationwide medical school aptitude examination used in Germany. The test consists of 20 figures, each of which has a darkly shaded section covering roughly one fifth of its area. Shaded objects similar to those in the LFT appear in Figure 7. The task is to memorize the figures during a 5-minute period. Then, during a separate 5-minute reproduction period, subjects are presented with the figures again, only this time without shading and in a different order, and are asked to identify which section of each figure should be shaded. The number of correctly identified shaded sections is the subject's raw score.

The reproduction period does not directly follow the memorization period, but rather takes place after an interim time period during which other mental tasks are performed. In the present study, during the interim period subjects performed a verbal task requiring the generation of rhyming pairs of

conceptually related words. In the cognitive equivalent of cleansing the palate between dinner courses, a verbal task was used to interrupt any rehearsal-based analytical techniques subjects might be employing to verbally mediate the visual information presented during the memorization period. Subjects were forced to turn their verbal processing attention to another task. This interim activity took 7-10 minutes, including instructions.

The internal consistency of the LFT has been previously established and is indicated by an adequate alpha coefficient of 0.71 (Stumpf, 1995). In a factor-analytic study, the test was shown to load heavily on a perceptual speed factor (Stumpf & Jackson, 1994), which is consistent with an effective control of analytic reasoning, or verbal mediation.

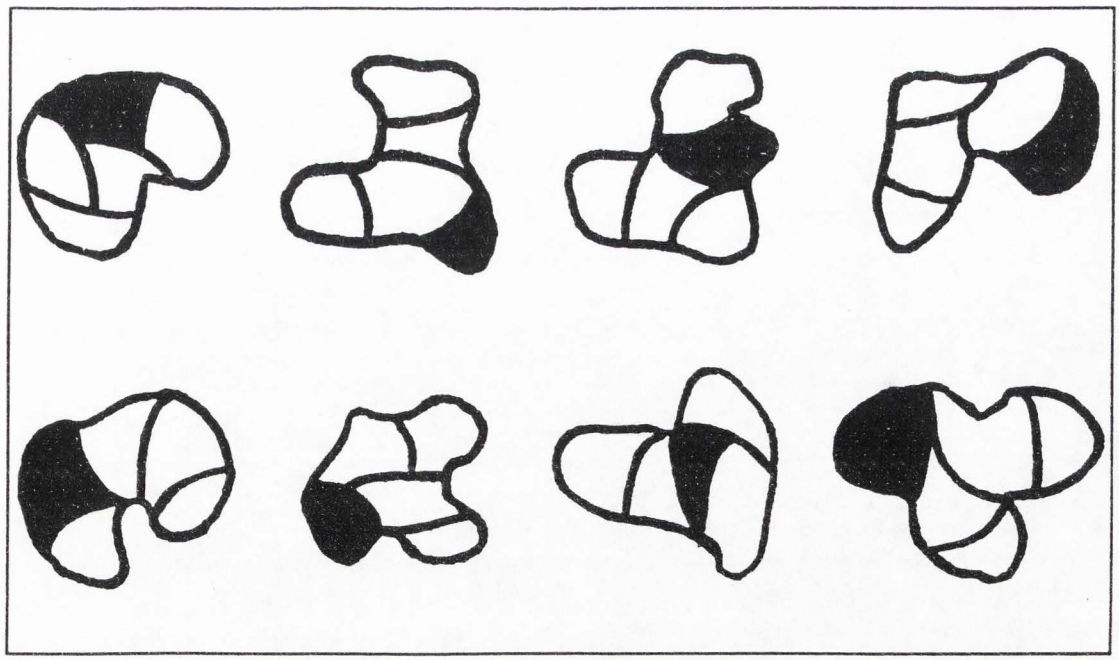

Figure 7. Shaded objects similar to those in the Learning Figures Test.

English Section of the ACT. The English section of the ACT is well-established as a measure of ability in English language usage, mechanics, and rhetorical skills and is commonly used in the selection and admission process for 4-year colleges and universities in the United States. At the student's request, ACT scores are reported directly to college or university admission offices. ACT English scores were obtained, with the permission of the students, from their Utah State University records. Three students, whose scores were not to be found in University records, provided a copy of their ACT score reports.

Procedure

Students were notified in class of the opportunity to participate in the study and that the study had something to do with cognitive abilities. Both Trio and the LFT were administered to subjects in a single session, taking about 45 minutes. Four sessions were offered to allow more participants to fit a session into their individual schedules. At the conclusion of each session, participants were debriefed as to the general purpose of the study and were told to expect the results before the end of the academic term.

A correlation analysis was conducted using the scores from each pair of instruments. Bivariate correlation coefficients were calculated expressing the degree of linear relationship between the following pairs of scores:

1. Trio scores and LFT scores.
2. Trio scores and ACT English scores.

Scores and their interpretation were provided to students several weeks after the tests were administered.

CHAPTER IV

RESULTS AND DISCUSSION

Results

Correlation: Trio and LFT

A correlation coefficient was calculated, and a nondirectional (two-tailed) *t* test was applied using the conventional $p < .05$ level as the cutoff for statistical significance. The correlation coefficient for the bivariate relationship between Trio scores and LFT scores was calculated at $r = .075$. With 65 subjects, the probability of finding a linear correlation as strong as this one when there is in fact no correlation at all in the abilities measured ($\rho = 0$) is estimated at $p = .578$, or a 58% chance. This falls far short of the $p < .05$ needed to establish statistical significance.

Correlation: Trio and ACT English

A correlation coefficient was calculated for Trio with ACT English scores, and a nondirectional (two-tailed) *t* test was applied using the conventional $p < .05$ cutoff level for statistical significance. The correlation coefficient for the bivariate relationship between Trio scores and ACT English scores was calculated at $r = .251$.

ACT scores were unavailable for 11 of the 65 students in the sample,[7] so the resulting number of students for this correlation was 54. The correlation coefficient of $r = .251$ is not statistically significant ($p = .067$). The probability of a correlation this strong emerging as a mere artifact of chance sampling bias is higher than the established cutoff. Moreover, in light of the fact that both the ACT English section and Trio are measuring performance based on mental processing, this is a very modest correlation.

Discussion

Convergent Validity

A statistically significant and moderate to high correlation was expected between Trio scores and LFT scores. Such a degree of correlation would have supported the conclusion that these tests both measure the same thing--namely, visual ability.

The low correlation between Trio scores and LFT scores represents a distinct lack of support for the validity of Trio as a measure of spatial perception. Following the categorization of tests of visual/spatial ability found in Eliot's (1980) leading index, Trio's approach to measuring visual ability is most similar to the tests in the figural memory subset of the spatial perception category. The LFT is an established measure from this subcategory. These results provide no evidence that these two tests measure the same construct.

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[7] The leading reasons for ACT English scores being unavailable were that the University did not require these scores of all transfer or re-entry students.

It is possible that the homogeneity of the study's subjects may have served to lessen the correlation between the two instruments. All but four of the subjects were females. In Sex Differences and Cognitive Abilities (1986), Halpern explains that, while a number of researchers have found women to be more variable in their scores on visual/spatial ability tests, "most major reviews of the literature have concluded that males are more variable in their . . . performance than females" (p. 49). If the scores of females on Trio and/or the LFT are indeed less variable than men's scores, then using a sample composed primarily of women would serve as a restriction of range, which could artificially moderate the correlation between the measures. However, it should be noted that the range of Trio scores in this study was consistent with the range previously observed among students in these undergraduate courses.

Another explanation for the low correlation may surround the difference in the dimensions of visual information covered by the two measures. While the LFT focuses primarily on shape and shading, Trio also requires that color and quantity be quickly processed. Trio, thus, encompasses a broader range of types of visual information. If visual processing is not a unitary construct across these various dimensions, this difference could serve to explain some moderation in the degree of linear relationship between the tests. Unfortunately, the literature does not include studies on the unity of these dimensions, and the limitation in scope of existing visual tests has been discussed in Chapter II. A factor analysis of Trio responses separating out errors revolving around the various tested

dimensions of visual information might provide insight along this line of inquiry.

A third factor that may have served to lower the correlation between these two tests is a possible floor effect in Trio scores. The distribution of Trio scores was skewed toward the low end of the curve. This effect is illustrated in Figure 8, which shows that the number of subjects scoring 0 on Trio is equal to the combined number of those scoring 5, 6, 7, and 8. In contrast, the distribution of scores for the LFT is much closer to normal in shape, as is shown in Figure 9.

If the actual distribution of ability for this sort of task among the subjects in this study is normal,[8] then this skewness indicates that Trio may be too difficult to discriminate effectively among those with performance levels in the lower range. A brief statistical profile of results by measure is provided in Table 1.

Table 1

Results by Measure

Measure	Range	Mean	SD
Trio	0 to 7	2.6	1.5
LFT	1 to 18	9.0	4.0
ACT English	12 to 33	24.3	4.1

[8] Normality is assumed for most psychological constructs (Anastasi, 1988).

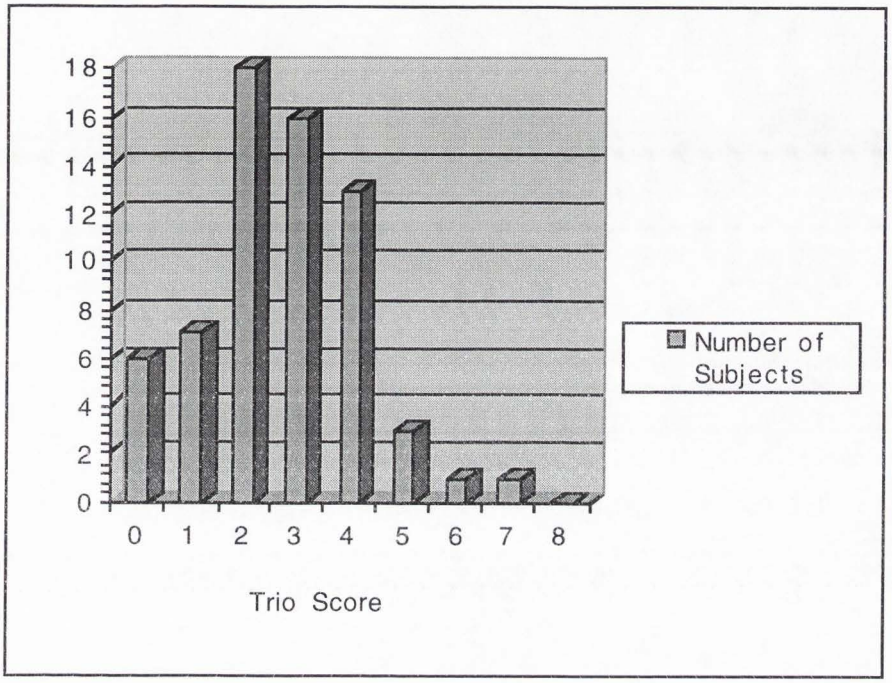

Figure 8. Distribution of Trio scores.

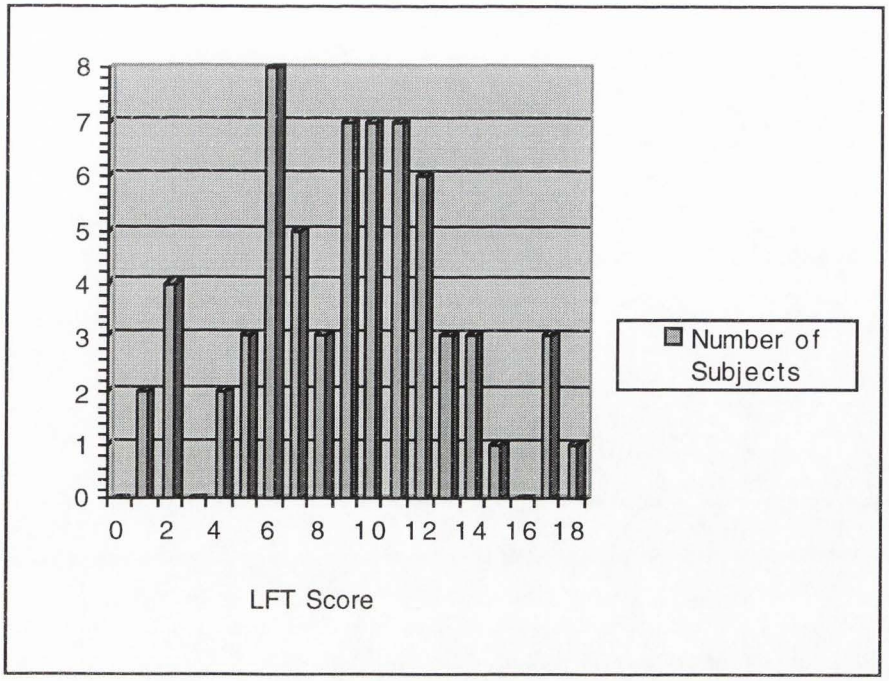

Figure 9. Distribution of Learning Figures Test scores.

Divergent Validity

It was expected that Trio scores would not correlate highly with ACT English scores. If the Trio instrument is a valid measure of visual ability, the degree of the linear relationship between these two variables ought to be much lower than that between Trio and the LFT, which also measures visual ability. Because cognitive abilities in verbal and visual processing areas do go hand-in-hand to some extent, some positive correlation was expected, perhaps even a statistically significant one. But if Trio measures something besides general mental ability (which it purports to), then the scores should have not overlapped too closely.

The moderate to low correlation between Trio and the ACT English section indicates that Trio most likely does not measure the same construct that the ACT English subtest measures. Inasmuch as the ACT English section is recognized as a measure of verbal ability, the results of this study show that Trio measures something different from verbal ability.

In order to provide a more informed perspective, a correlation coefficient was calculated expressing the observed linear relationship between ACT English scores and LFT scores. At $r = 0.287$, the coefficient indicated a higher degree of correlation than was found between Trio and the ACT English. In fact, the LFT's correlation with the ACT English was statistically significant, at $p = 0.036$ ($N = 54$). Trio's divergence from measuring verbal ability appears to be even more satisfactory than that shown by the LFT.

At the time of the writing of this thesis, Heinrich Stumpf was conducting research that may help to place more accurately the Spatial Test Battery (and perhaps the LFT itself) within the structure of spatial ability in general. A paper being written in conjunction with his work may provide further evidence of the validity of the LFT as a measure of visual ability.

CHAPTER V

CONCLUSION

Summary

An analysis of the relationship between scores on Trio and on the LFT failed to provide evidence that these two tests are measuring the same construct. The correlation coefficient between the two sets of scores was much lower than expected for two tests that measure visual processing ability with a strong degree of isolation from verbal mediation strategies. Thus, Trio does not appear to measure the same area of mental processing as does the LFT, an established test of visual/spatial ability. However, the statistical significance of the LFT's correlation with the verbal ACT English section, together with the LFT's relative limitation in scope over the dimensions of visual ability, leaves open the question of the validity of the LFT for this purpose.

The results of Trio's divergent validity test were favorable. The lack of a statistically significant correlation between Trio and the ACT English suggests that Trio measures something fundamentally different from verbal processing. Based on these results, further investigation of Trio's potential as a visual measure may be warranted.

Limitations of the Study

The chief limitation of this study revolves around the validity of the LFT as a measure of visual processing ability. The test was the best one available as

identified through an extensive search of the literature, and it corresponds well to the subcategory of visual ability which Trio is designed to assess. In addition, the test is well established as part of aptitude batteries used in the United States and in Germany. However, little direct empirical documentation of the LFT's validity as a measure of visual processing ability can be found. Despite its high face validity and its inclusion in the CTY Spatial Test Battery, the LFT itself may not be sufficiently valid to serve as an accurate concurrent measure of visual processing ability.

Another limitation of this study is the previously discussed concern about potential restriction in the ranges of scores on the two visual tests due to the homogeneity of the subjects in the sample.

Future Studies

The two lines of inquiry that offer themselves most clearly for further research coming out of this study are (a) a thorough investigation of the validity of the LFT as a measure for isolating visual processing ability, and (b) a careful look at what exactly Trio *does* measure.

It is possible that the LFT, developed as a part of a medical school aptitude battery, may be an excellent choice in assessing visual ability as cognitive styles research grows. On the other hand, it may be that performance on this older instrument does not contribute information that is uniquely useful in constructing a profile of an individual's overall cognitive patterns and tendencies.

If Trio does not measure what the LFT measures, nor does it measure what the ACT English section measures, but it is reliable and shows face validity as a visual measure, then just what is it that Trio measures? As indicated earlier in this chapter, an analysis of the patterns of correct and incorrect Trio answers might provide a useful starting point for this inquiry. In addition, an advisable step in the future development of Trio is to attempt to lower the floor of the test by including some items of lesser difficulty. This would increase Trio's capacity to accurately discriminate among persons with lower performance levels.

Finally, a similar study to the present one using a sample with greater male representation, or with a broader representation from the general adult population (minorities, non-college-bound individuals,[9] etc.) might allow for a wider generalization of the findings to the population. This benefit, in addition to decreased susceptibility to potential concerns regarding restrictions in range on visual measures, renders such a replication strongly advisable.

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[9] Using non-college-bound individuals would likely require the use of an alternative test of verbal ability, since the ACT English test is primarily administered to college-bound students.

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