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An Assessment of the Reliability and Validity of Scores Obtained by Six Popular Learning Styles Instruments

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AN ASSESSMENT OF THE RELIABILITY AND VALIDITY OF SCORES OBTAINED BY SIX POPULAR LEARNING STYLES INSTRUMENTS

by

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ABSTRACT

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Learning style refers to the cognitive, physiological, emotional, environmental, sociological, and perceptual manner in which people learn. In order to provide students with an optimal learning environment, it is necessary to match instruction with students' learning style. To do this, student learning style must be assessed by a learning style instrument.

Of the learning style instruments that are currently available, most do not have much evidence of reliability and validity. Additionally, evidence that does exist is weak. Therefore, more psychometric data are needed regarding these instruments. This study provided psychometric evidence for six popular learning styles instruments, including the Learning Style Inventory, the Productivity Environmental Preferences Survey, the Learning Styles Profile, the Grasha-

Riechmann's Student Learning Style Scale, the Edmonds Learning Style Identification Exercise, and the Group Embedded Figures Test.

Test-retest reliability was found to be good for the Group Embedded Figures Test and moderate for all other instruments. Internal structure validity of the instruments was good, indicating that the instruments do measure unique learning style constructs. However, convergent and discriminant validity evidence indicates that the instruments either do not measure the same constructs, or measure the learning style constructs in different ways.

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CHAPTER I

INTRODUCTION

The past two decades have seen the emergence of a growing number of educators and psychologists whose primary goal is to improve the quality of education. They have discovered that for the educational process to be effective, students must be provided the optimal learning environment to satisfy their particular needs. One way to meet each student's needs is to match instruction to that student's individual learning style (Baruth & Manning, 1992; Cornett, 1983; Dunn, 1982, 1990; Dunn, Beaudry, & Klavas, 1989; Dunn & Dunn, 1979; Dunn & Griggs, 1988; Messick, 1984). Keefe (1982) defined <u>learning styles</u> as ". . . cognitive, affective, and physiological traits that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment" (p. 44).

Assessment of learning styles is one way to facilitate better instruction. If a student's learning style is identified, instructional methods can be designed to meet these needs and student learning can be enhanced (Cauley, Linder, & McMillan, 1992, 1994; Cornett, 1983; Dunn, 1982, 1990; Keefe, 1982; Messick, 1984). Therefore, emphasis should be placed on recognizing students' individual learning styles and incorporating them into classroom planning and instruction.

Currently there are several instruments used to measure learning styles. Some widely used scales are the Learning

Style Profile (LSP; National Association of Secondary School Principals, 1986), the Learning Style Inventory (LSI; Dunn, Dunn, & Price, 1982a), the Productivity Environmental Preference Survey (PEP; Dunn, Dunn, & Price, 1982b), the Grasha-Riechmann's Student Learning Style Scales (GRSLSS; Grasha & Reichmann, 1975), the Edmonds Learning Style Identification Exercise (ELSIE; Reinert, 1976) and the Group Embedded Figures Test (GEFT; Witkin, Oltman, Raskin, & Karp, 1971). Although these comprehensive scales are used extensively by educators and researchers to measure learning styles, there are limited data regarding the technical quality of these instruments. For example, the reliability of the LSP is low (Blixt & Jones, 1995; Keefe & Monk, 1986; Nagy, 1995). Likewise, there is a lack of evidence regarding the test-retest reliability of the LSI; and the validity of scores obtained with the PEP has not been researched.

Currently, these learning style scales are broadly used in education and research and will undoubtedly be used even more extensively in the future. This is evidenced by the fact that many educational psychology textbooks encourage teachers to consider learning styles scales when teaching (Eggen & Kauchat, 1992; Good & Brophy, 1995; Reed & Bergemann, 1992; Slavin, 1988). This could be detrimental to students if the instruments are not technically sound. Because of the substantial lack of existing psychometric data for these scales, it is imperative that more current and thorough technical information be made available for these scales. Consequently, reliability tests and validation measures must be conducted to provide the much needed psychometric data for these widely used learning style measures.

The LSP, the LSI, and the PEP are global measures, each assessing multiple dimensions of learning styles. The GRSLSS, the ELSIE, and the GEFT, however, are more narrowly focused and each instrument measures only one dimension of learning style. Unfortunately, teachers and investigators who are interested in only a specific learning style domain are currently forced to select either a global or specific instrument without the benefit of knowing which, if either, is a more reliable and valid measure of the domain that they are assessing. Therefore, it is necessary to provide this information for both the global and more focused instruments so investigators can choose the more appropriate scale for their use.

The wide range of learning style scales available was developed for intended use with various ages. The LSI can be used with young children through high school age, whereas the LSP and GEFT can be used with any age. The ELSIE is intended for middle-school and high-school students only, and the PEP is used with adults. Although these scales cover a range of age groups, few psychometric data are provided that are specifically related to age. Therefore, it would be beneficial to determine which instruments produce reliable and valid scores for use with the various age levels.

CHAPTER II

REVIEW OF LITERATURE

Educators are constantly trying to improve the educational process by changing their teaching methods, the classroom environment, and instructional resources to provide students with an optimal learning situation. Researchers have found that one way to do this is to tailor instruction to match students' learning styles (Baruth & Manning, 1992; Cornett, 1983; Dunn, 1982, 1990; Dunn et al., 1989; Dunn & Dunn, 1979; Dunn & Griggs, 1988; Messick, 1984; Sims & Sims, 1995). According to Gregoric (1979), "Learning style consists of distinctive behaviors which serve as indicators of how a person learns from and adapts to his environment. It also gives clues as to how a person's mind operates" (p. 234).

Learning Styles: What Are They?

The concept of learning style can be broken down into several elements, including aspects such as cognitive, environmental, emotional, sociological, perceptual modality, and physiological (Cornett, 1983; Curry, 1987; Dunn et al., 1989; Dunn & Dunn, 1978, 1979; Gregoric, 1979; Keefe, 1982; Swanson, 1995). Each of these facets of learning styles can be separately measured through the use of many available instruments. Through these measures, research has shown that these areas can individually affect the manner in which students learn (Dunn & Dunn, 1978, 1979).

Cognitive

A great deal of research on learning style has examined the cognitive dimension of learning style, which affects how people process information (Messick, 1972; Schmeck, 1988). An individual's cognitive learning style determines the manner in which he/she decodes, encodes, processes, stores, and retrieves information.

One element of cognitive style is "field independence-field dependence," which refers to the way in which people experience the environment. Keefe (1982) distinguished between independents and dependents in that the former are influenced by the overall organization of the environment and are analytic and systematic. The latter see separate parts of the environment as fused and tend to be holistic learners. Another cognitive learning style distinction is cognitive complexity versus cognitive simplicity, which refers to the way in which people construe the world, ranging from a multidimensional to a unidimensional perspective. Other dimensions of cognitive styles include reflectiveness versus impulsivity, leveling versus sharping, and breadth of categorization (Keefe, 1982). For a detailed description of each of these areas, the reader is referred to Messick (1984).

Environmental

Studies have shown that students are differentially affected by factors such as sound, light, temperature, and design (Dunn et al., 1989). For example, some people work better with noise, while others need complete silence. Likewise, some individuals prefer to work in subdued lighting, while others choose brightly lit environments. Both the temperature of the learning environment and the design of the room can also affect a person's concentration. Whereas some individuals opt for an informal design, such as an easy chair, others require a formal design with a hard chair to stay awake while working. The particular environmental factors that a person requires for optimal concentration and learning represent his/her environmental learning style.

Emotional

There are several emotional elements of learning style, including motivation, persistence, responsibility, and structure. Dunn and Dunn (1978, 1979) have suggested that motivated, persistent, responsible students typically require less structure, are creative, and can make more choices while learning. However, unmotivated, less persistent, less responsible students require additional teacher assistance and environmental resources. These students work better with short assignments, frequent relaxation periods, programmed instruction, multisensory instructional packages, and teamed peer group studies. These students require more structure, including guidelines and procedures for each assignment. Reviewed in Shumsky (1972), other emotional learning style characteristics include distractibility and anxiety. Students with these characteristics may need more support during the initial stages of learning new material.

A student's orientation to studying is another motivational factor of learning style, which was proposed by Martin (cited in Entwistle, 1988). A student who has a deep approach is intrinsically interested in the material and ". . .challenges the ideas, evidence, and arguments presented by the author, tries to see interrelationships among the ideas presented, and seeks links with personal experience and the outside world" (p. 24). Conversely, students who have a surface approach to learning are concerned with verbatim recall of the text and are concerned more with finishing the assignment than gaining personal knowledge.

Individuals vary in their approach to learning in several ways, including tempo, attentiveness, and their reaction to new situations (Shumsky, 1972). Some individuals take longer to learn certain material than others. However, because they take a longer amount of time does not mean that they are less capable than faster students. In fact, some students who quickly complete a lesson may fall victim to inaccuracies.

Sociological

The sociological aspect of learning style refers to the sociological pattern in which individuals learn best. Some people prefer to work in groups with their peers, whereas others are embarrassed to show lack of knowledge. The various types of sociological patterns of learning include working alone, with peers, with an adult, or some combination. Some learners are self-directed and are better able to work independently, whereas others need adult direction and assistance (Dunn et al., 1989; Shumsky, 1972).

Perceptual Modality

Perceptual strength refers to whether a student learns better by seeing information, hearing information, or a combination of both (Dunn et al., 1989). Additionally, some people learn tactually or kinesthetically. For instance, a person who is an auditory learner would learn to read best through a "phonetics" approach, whereas a better method for a visual learner is a "word-recognition" approach.

Physical

Physical elements of learning style include intake, time, and mobility. For example, learners vary in the amount of intake they prefer while learning. Some students need to eat, drink, or chew gum while learning in order to replace energy and release tension. Additionally, the time of day affects learning in that some people learn better in the morning, while others are more able to concentrate at night. Finally, some students are not able to concentrate if they remain in one position for an extended period of time, whereas others are able to sit in one place for a while (Dunn et al., 1989).

Assessment of Learning Styles

Of course, in order for teachers to adapt their teaching methods to match their students' learning styles, these styles must first be assessed. There are a number of instruments currently available that purport to measure the various aspects of learning styles. Many authors have critiqued these instruments in an attempt to alert researchers of the relative strengths and weaknesses of using the various scales (Blakemore, 1984; Bonham, 1988; Curry, 1987; DeBello, 1989; Ferrell, 1983; James & Blank, 1993; Learning Styles, 1986; Rule & Grippin, 1988). Some of the published measures of learning styles are listed in Table 1. Information is provided in the table regarding several factors about these instruments, including the domains of learning styles that each assesses, the appropriate age, and existing technical data. To summarize,

Table 1

Some Currently Available Learning Styles Instruments

Instrument	Authors	Age	Area targeted	Val.	Rel.
Approaches to Studying Inventory	Entwistle (1988) & Ramsden (1983)	-	Instructional preference and information processing: meaning orientation, reproducing orientation, achieving orientation, and holistic orientation	fair	good
Barbe-Milone Modality Checklist	Barbe & Milone (1980)	Adults	Perceptual modality	-	-
C.I.T.E. Learning Styles Instrument	Babich, Burdine, Albright, & Randol (1980)	Students	Info processing: auditory, visual, language, numerical, kinesthetically; working conds: alone, with others	fair	-
Cognitive Preference Test	Kempa & Dube (1973)	-	Information processing: recall versus application and critical questioning versus fundamental	good	fair
Cognitive Style Delineators	Letteri (1980)	-	Field dependence/independence, scanning/ focusing, breadth of categorization, cognitive complexity, reflective/impulsive, leveling/sharpening, tolerant/intolerant	-	-
Cognitive Style Inventory	Hill (1976)	-	Processing of theoretical and qualitative symbols, modalities of inference	-	-
Edmonds Learning Style Exercise Identification	Reinert (1976)	7-12 grade	Perceptual modality: visualization, listening, activity	good	-
Grasha-Riechmann Student Learning Style Scales	Grasha & Riechmann (1975)	HS & College	How students interact with teacher, other students and learning. Includes: participant, avoidant, independent, collaberative, dependent, competitive	good	fair
Gregoric Style Delineator	Gregoric (1979)	Adults	Cognititve-concrete versus abstract; random	-	-
Group Embedded Figures Test	Witkin, Oltman, Raskin, & Karp (1971)	Ages 10 +	Cognitive/information-processing; Field-dependence/ Field-independence	good	good
Inventory of Learning Processes	Schmeck, Riblich, & Ramanaiah (1977)	College	Information Processing: synthesis-analysis, study methods, fact retention and elaborative processing	good	fair

(table continues)

Instrument	Authors	Age	Area targeted	Val.	Rel.
Instructional Preference Questionnaire	Friedman & Stritter (1976)	-	Student preferences for pacing, influence over learning, media, active role in learning and feedback in learning	fair	good
Learning Interaction Inventory	Jacobs & Fuhrmann (1980)	HS & College	Learning interaction styles: independent, dependent, in collaboration with teacher	fair	poor
Learning Modalities Inventory	Papalia (1978)	-	Cognitive styles, sensory modes, interactive learning modes, work habits, personality characteristics, intellectual dependence and independence, originality	-	-
Learning Preference Inventory	Rezler & Rezmovic (1981)	-	Abstract versus concrete, individual/interpersonal, student structure versus teacher structure	fair	poor
Learning Style Inventory	Canfield (1980)	Gr 6 - adults	Preferences for instruction in 4 areas: conditions, content mode and expectation of learning	poor	poor
Learning Style Inventory	Dunn, Dunn, & Price (1982a)	Gr 3 - 12	Preferences: environmental, emotional, sociological, physiological, psychological	good	good
Learning Style Inventory	Hanson & Silver (1980)	Adults	Cognitive-sensing versus intuition	-	-
Learning Style Inventory	Kolb (1976)	Young Adult	Concrete experience versus reflective observation, abstract conceptualization/active experimentation	fair	fair
Learning Styles Inventory	Renzulli & Smith (1978)	Gr 4 - 12	Instructional format	fair	poor
Learning Style Profile	Keefe & Monk (1986)	Gr 6 - 12	Physiological/environmental, cognitive, affective, info-processing	good	poor
Learning Styles and Strategies	Silver & Hanson (1978)	Teachers	Assesses learning style preferences	-	-
Learning Styles Questionnaire	Honey & Mumford (1989)	-	Personality factors	-	-
Myers-Briggs Type Indicator	Myers (1962)	Grade 9 +	Extroversion/introversion; sensing/intuition; thinking/feeling; judgment/perception	good	good
Modality Index	Barbe & Swassing (1988)	-	Perceptual modality	-	-
Multi Modal Paired Associates Learning Test-Rev.	Cherry (1981)	-	Perceptual modality	-	-

(table continues)

Instrument	Authors	Age	Area targeted	Val.	Rel.
Paragraph Completion Method	Hunt (1977)	HS or College	Conceptual complexity, need for structure Cognitive complexity versus simplicity	poor	poor
Oregon Instructional Preference Survey	Goldberg (1963)	-	-	poor	poor
Productivity Environmental Preferences Survey	Dunn, Dunn, & Price (1982b)	Adults	Preferences: environmental, emotional, sociological, physiological and psychological	good	good
Reading Style Inventory	Carbo (1987)	Gr 1-12	Assesses learning style preferences	-	-
Self-Directed Learning Readiness Scale	Guglielmino, Guglielmino, & Long (1987)	15 & under; 15 & over	Assesses learning preferences and attitudes toward learning	-	-
Your Style of Learning and Thinking	Torrance, Reynolds, Ball, & Riegel (1978)	HS & Adults	"Right-brained": visual-spatial, nonsequential, divergent "Left-brained": logical, analytic, verbal	good	good

Note. Dashes indicate that the authors did not provide this information. Criteria for reliability and validity: *r* = .36 (poor), *r* = .54 (moderate), *r* = .71 (good). Based on conventional magnitudes of *r* from Cohen (1988).

the instruments target a variety of learning style areas, including cognitive, perceptual, emotional, environmental, and physiological domains. Most of the scales measure specific aspects of these domains, such as field independence/dependence, attitudes, and information processing. The instruments span many ages, ranging from grade one to adult. The reliability and validity evidence for many of the tests is either nonexistent or weak, and those instruments that do have some adequate reliability tend to have low validity.

Close inspection of all of these learning style instruments would be beneficial to researchers and educators, to aid them in choosing the most appropriate scale for their investigations or classrooms. However, if one wants to study the psychometric properties of these scales in depth, it is not feasible to examine them all. This is because careful scrutiny of the instruments requires detailed technical analyses, which necessitate large samples of data and lengthy time investments. Therefore, the most comprehensive and psychometrically sound scales should be investigated first in future research.

Additionally, because many instruments measure different aspects of learning style, a direct comparison is not always possible (Curry, 1987). For example, those scales that assess cognitive learning style cannot be directly compared with instruments assessing environmental learning styles in terms of their relative utility because they are measuring different underlying constructs. However, as long as one takes into consideration the differences in the underlying learning style model of each scale, the reliability and validity of several instruments can be assessed to determine which instrument, or instruments, offers the most psychometrically sound information. Therefore, it is possible and necessary to compare instruments that assess slightly different aspects of learning style. However, when doing so, the learning style construct underlying each scale should be defined in detail to enable the reader to reach appropriate conclusions regarding the relative utility and application.

In determining which learning style scales in Table 1 would be most useful to investigate, one must consider two factors. First, the data available regarding the reliability and validity of these instruments should be analyzed and the psychometric properties judged for adequacy. Several reviews are currently available of learning style instruments which provide some of this information (Bonham, 1988; Curry, 1987; Ferrell, 1983; Learning Styles, 1986; Rule & Grippin, 1988). Based on these reviews, only 12 instruments listed in Table 1[1]

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[1]The other instruments listed have either been shown to have low reliability and validity or there has been no research to determine their psychometric quality. More research is necessary to determine the psychometric quality of these instruments before they can be considered useful.

demonstrate reasonable psychometric qualities. These include: the Approaches to Studying Inventory, the Cognitive Preference Test, the ELSIE, the GRSLSS, the GEFT, the Inventory of Learning Processes, the Instructional Preference Questionnaire, the LSI, the LSP, the Myers-Briggs Type Indicator, the PEP, and Your Style of Learning and Thinking. However, the information provided in the published reviews is inadequate, thereby necessitating further research to obtain more psychometric information. A later section will address how to gather this information.

A second consideration in determining the instruments that would be the most beneficial to use concerns which learning style areas are targeted. One would want to assess instruments measuring both multidimensional and unidimensional learning style domains. Of those scales that are psychometrically sound, two widely used instruments that measure multidimensions of learning styles are the LSP (NASSP, 1986) and the LSI (Dunn et al., 1982a). Additionally, Dunn et al. (1982b) published an adult version of their scale called the PEP.

An example of a unidimensional learning style instrument is the ELSIE (Reinert, 1976), which measures only perceptual modality. This can be compared to the LSP, which is designed to assess not only perceptual modality, but many other learning style domains as well. Although the LSP has more items, it focuses on several areas. The question to be asked is whether the broader or more narrowly focused instrument is a better indicator of each individual learning style dimension, or if both are equally good instruments. One way to determine if either is a valuable instrument is to assess their reliability and validity in predicting students' true learning style.

Therefore, before teachers can select a learning style instrument for use, it is essential that they know what type of instrument is best for measuring specific areas. As of yet, no research has been found that compares broad versus narrow learning style instruments.

Techniques for Analyzing Psychometric Properties of Instruments

The psychometric quality of an instrument is typically assessed in terms of reliability and validity (Anastasi, 1988; Carmines & Zeller, 1979; Worthen, Borg, & White, 1993). Reliability concerns the degree of consistency in measurement outcomes. This refers to the consistency of test scores obtained by the same person when tested on several occasions or with different sets of items. Validity refers to whether or not a test measures the trait it is supposed to measure (Anastasi, 1988).

Reliability

If a test were completely reliable, a person's measured score would equal his/her true ability. In this case the test would be perfectly consistent, always producing the same score. However, this never occurs because there is always some random error that occurs in the measurement process. This error can be due to several sources, including differences in the testing occasions, the test forms, or the test items. Each type of error can be analyzed to determine how much it contributes to a person's score on a given test. There are several ways to assess reliability, including the parallel-forms approach, the test-retest approach, and the internal consistency approach. Each of these approaches estimates measurement error from different sources (Anastasi, 1988; Carmines & Zeller, 1979; Worthen et al., 1993).

Test-Retest Reliability

Test/retest reliability assesses the stability of an instrument across time. Also called the *coefficient of stability*, this analysis involves two administrations of the same test to the same subjects with some time interval between the testing sessions. A correlation coefficient is computed between scores from the two test administrations. The higher the correlation, the less error there is due to the effects of time.

Parallel Forms Reliability

Tests of parallel forms reliability involve administering two alternate forms of the same test to the same subjects. This coefficient of equivalency is the correlation between the scores on the two parallel forms of the test. Any differences in scores between the two tests are due to content error and the lower reliability.

Another method for estimating reliability that is commonly used does not require more than one testing session. This procedure is called the split-half method and entails splitting a test into two halves and correlating the scores obtained from the halves. One disadvantage of this method is that the resulting loss of length due to splitting the test will automatically reduce the reliability of the test. Therefore, the Spearman-Brown formula can be applied to adjust for the change in the test's length.

Internal Consistency Reliability

A second problem with the split-half method is that the reliability of the test will depend in part on the manner in which the test is split. That is, different subdivisions of the same test may result in different reliability coefficients. Therefore, another procedure for assessing reliability is available that does not require the test to be split in half. This method is called internal consistency reliability and addresses the question of how homogeneous the test items are in measuring a given construct. Internal consistency measures have the advantage over test-retest reliability and parallel forms reliability in that the test only has to be administered once. The measurement error that is measured by internal consistency reliability is a combination of content sampling and heterogeneity of the behavior domain being sampled.

A common method for assessing internal consistency reliability is the Kuder-Richardson formula 20. This formula is theoretically the mean of all possible split-half combinations. Although widely used, the limitation with this formula is that it can only be used with dichotomously scored test items. Therefore, another formula, Cronbach's coefficient alpha, was developed, which is a generalized formula that can be used with both dichotomous and weighted test item scoring.

Validity

Content-Related Validity

Content-related validity refers to whether a test covers a representative sample of the behavior domain to be measured (Anastasi, 1988). To assess content-related validity, test specifications can be used to determine if the number of items that should have been included from each topic were covered. Additionally, a panel of subject matter experts can be used to assess whether a test appears to have good content-related validity.

Concurrent Criterion-Related Validity

Concurrent criterion-related validity (Anastasi, 1988) refers to the degree to which performance on a test is related to some external criterion that occurs at approximately the same time as the test. The criterion is an independent measure of the behavior that the test is assessing. For example, the concurrent criterion-related validity of a depression test can be assessed by comparing a person's score on the test to a diagnosis given by a clinician.

Construct Validity

Construct validity refers to the degree to which a test measures the theoretical construct or trait that it was intended to measure. There are several aspects of construct validity including internal structure of instruments, convergent validity of constructs, and discriminant validity of constructs (Anastasi, 1988; Cronbach & Meehl, 1955). Internal structure can be established by conducting separate exploratory factor analyses for each scale. Factor analysis is a technique that reduces a large number of intercorrelations among variables into a smaller number of factors, or constructs, that can better describe the data (Comry & Lee, 1992; Tabachnick & Fidell, 1996). To assess internal structure of an instrument, factor analysis is used to determine if subscales that are believed to measure the same trait load on the same factors.

Convergent validity of constructs can be assessed by cross instrument validation in two ways. First, exploratory factor analyses can be conducted to include all instrument subscales. If similar subscales from different instruments load onto the same factors, evidence is provided of construct validity. A second method that can be used to assess the construct validity of instruments is to examine Pearson product-moment correlations between similar subscales from different instruments to see if they correlate highly. Finally, construct validity can be further assessed by multitrait-multimethod matrices that assess convergent validity, as well as discriminant construct validity.

Internal structure assessment of construct validity. To assess if there is internal structure of an instrument, an exploratory factor analysis can be computed to see if subscales load onto hypothesized constructs. The rationale behind this method is that if a test is valid, there would be high internal structure, indicating a homogeneous test measuring only a few hypothesized constructs. However, one caveat is that high internal structure does not always indicate high validity. Cronbach and Meehl (1955) cautioned that high internal structure only supports construct validity if the underlying theory of the trait being measured calls for high item intercorrelations. For example, low internal structure might be expected if the instrument contains lie-scale items, irrelevant items, or items that may be influenced by a response set.

Cross instrument validation of convergent construct validity. One way to assess convergent construct validity is to compute exploratory factor analyses with all subscales from each instrument. This is done to determine if there is an underlying construct being measured by them all. For example, a factor analysis might be performed on scales such as the Group Embedded Figures Test, the Transaction Ability Profile, the Gregoric Style Delineator and the Cognitive Style Profile to determine if the underlying construct among them all is in fact cognitive learning style, as the authors of these scales have asserted.

Another method for assessing convergent validity of instruments is to correlate the subscales of all of the instruments with each other to see if they measure the same behavior. The rationale for this is that if the instruments correlate highly with each other, one can infer that they are measuring the same constructs.

Convergent and discriminant construct validity. Another method for assessing construct validity is the use of convergent and discriminant validation. The rationale behind this strategy is to show that a test correlates highly with other instruments with which it should theoretically correlate (convergent validation) and correlates low with instruments that it should theoretically differ (discriminant validation).

A widely used approach to determining convergent and discriminant validation is called a multitrait-multimethod matrix, which was originally proposed by Campbell and Fiske (1959). The multitrait-multimethod matrix approach allows for several traits and several methods to be validated at the same time. The matrix provides correlations between all of the methods and traits, producing three types of validation correlations; (a) heterotrait-monomethod correlations between several traits on one method, (b) heterotrait-heteromethod correlations between several traits and several methods, and (c) monotrait-heteromethod correlations between one trait and several methods. Additionally, monotrait-monomethod correlations are provided, which serve as reliability coefficients for each method.

In their 1959 article, Campbell and Fiske provided a synthetic multitrait-multimethod matrix (p. 82), which is presented in Table 2. This example includes three traits (A, B, C), each measured by three methods. The correlation coefficients contained in the solid line triangles represent different traits measured by the same method. The correlations in the dashed triangles are between different traits measured by different methods. The correlations along the diagonals in boldface represent validity

Table 2

Synthetic Multitrait-Multimethod Matrix

		Method 1			Method 2			Method 3		
	Traits	A_1	B_1	C_1	A_2	B_2	C_2	A_3	B_3	C_3
	A_1	(.89)								
Method 1	B_1	.51	(.89)							
	C_1	.38	.37	(.76)						
	A_2	**.57**	.22	.09	(.93)					
Method 2	B_2	.22	**.57**	.10	.68	(.94)				
	C_2	.11	.11	**.46**	.59	.58	(.84)			
	A_3	**.56**	.22	.11	**.67**	.42	.33	(.94)		
Method 3	B_3	.23	**.58**	.12	.43	**.66**	.34	.67	(.92)	
	C_3	.11	.11	**.45**	.34	.32	**.58**	.58	.60	(.85)

Note. Validity coefficients are the three diagonal sets of boldface numbers. Reliability coefficients are the numbers in parentheses. Heterotrait-monomethod correlations are enclosed by solid line triangles. Broken line triangles enclose heterotrait-heteromethod correlations. Adapted from "Convergent and Discriminant Validation by the Multitrait-Multimethod Matrix," by D. T. Campbell and D. W. Fiske, 1959, Psychological Bulletin, 56(2), p. 82.

coefficients in which the same trait is correlated using different methods. Finally, the correlations in parentheses along the main diagonal represent reliability coefficients.

Campbell and Fiske (1959) applied four criteria for evaluating construct validity using the multitrait-multimethod matrix. First, the monotriat-heteromethod correlations (such as .57 for methods 1 and 2, trait A) should be significantly different from zero. These correlations indicate convergent validity, in that two methods which are expected to measure the same trait should converge and have a high correlation. For example, two instruments that are expected to measure emotional learning styles should have a high correlation for this trait.

A second criterion supporting construct validity is that the validity coefficients along the boldface diagonals should be higher than the correlations in the triangles. That is, the validity coefficients indicating convergence (different methods, same trait) should be higher than the correlations between different traits measured by different methods. For example, for methods 1 and 2 the validity coefficient along the diagonal for trait A (.57) is higher than the correlations measuring traits B and C (.22, .09, .10, .22, .11, .11). Likewise, the converging validity coefficients should be higher than the correlations between different traits measured by the same method (.51, .38, .37).

A third criterion regarding construct validity postulated by Campbell and Fiske (1959) concerns discriminant validity and states that the correlations between two different methods measuring different traits (in the dashed line triangles) should be low. For example, for learning style instruments one would expect a scale measuring environmental learning style to have a low correlation with a different instrument that measures emotional learning style. The final criterion is that the same pattern of correlations should exist in all of the heterotrait triangles.

The multitrait-multimethod matrix also provides evidence of reliability. This is accomplished by the correlations along the main diagonal, which are between two measures of the same trait obtained through maximally similar methods, such as two testing sessions of the same instrument. Because the multitrait-multimethod matrix provides evidence for both reliability and convergent and discriminant construct validity, it is a useful procedure for investigating the psychometric quality of instruments.

Several procedures have been proposed to analyze the extent to which data in a multitrait-multimethod matrix meet the Campbell and Fiske (1959) criteria. Many researchers compute Pearson product-moment correlations for each of the convergent and discriminant validity coefficients and compare them according to the criteria. However, there are problems with this approach. For instance, because people merely count the number of correlations that support or contradict convergent and discriminant validity, they arbitrarily determine what constitutes a satisfactory proportion. Also, the correlations that constitute the matrix are based on observations, whereas the conclusions drawn are about underlying traits and method factors.

Finally, as the number of traits and methods increases, this procedure becomes difficult (Kenny & Kashy, 1992; Schmitt, Coyle, & Saari, 1977; Widaman, 1985).

Other analyses of the multitrait-multimethod matrix include ANOVA models, partial correlations, covariance component analysis, restricted factor analysis, exploratory factor analysis, confirmatory factor analysis, and path analysis. The preferred and most popular method is the use of confirmatory factor analysis (Brannick & Spector, 1990; Kenny & Kashy, 1992; Marsh, 1989; Marsh & Hocevar, 1983; Schmitt et al., 1977; Widaman, 1985).

Confirmatory factor analysis (CFA) involves sophisticated mathematical techniques and is used when the researcher has formulated a theory or hypothesis regarding the relationship between the variables. The variables used in CFA are then carefully chosen to test this theory. Confirmatory factor analysis has become more popular as computer programs such as EQS and LISREL have emerged (Comry & Lee, 1992; Tabachnick & Fidell, 1996).

Summary

Learning style refers to the manner in which students learn, including the cognitive, physiological, affective, and environmental factors that affect their learning. The LSI, the PEP, and the LSP appear to be widely used measures to assess multiple domains of learning style. Some popular scales that measure more narrowly focused dimensions of learning style include the GRSLSS, the ELSIE, and the GEFT. However, it is uncertain which of these measures is more psychometrically sound, more effective at targeting particular areas, or more useful with certain age groups.

Because the existing psychometric data for these scales are weak and inconclusive, it is imperative that more empirical evidence be provided to support the use of these scales. Also, some of these scales have conflicting psychometric evidence, which indicates the need for further research.

The psychometric properties of learning style scales can be assessed in terms of reliability and validity. There are several types of reliability, including test-retest, parallel forms, and internal consistency. Likewise, two types of validity are content-related and construct validity. Construct validity can be assessed in terms of internal structure, convergent validity of constructs, and discriminant validity of constructs.

CHAPTER III

THE STUDY

Purpose of the Study

This study provides test-retest reliability and construct validity data for the six instruments shown to be the most promising in measuring learning style: the LSI, the PEP, the LSP, the GRSLSS, the ELSIE, and the GEFT. Analyses of subscales were conducted both within and across the instruments to determine if they demonstrated the current learning styles theory. Although item analyses would have provided information regarding the breakdown within factors, subscale scores were used because comparison across instruments must be done at the higher domain/factor level. Additionally, the respective reliability and validity of the scores obtained with the narrowly focused scales were compared to the multidimensional scales. Finally, this study provided evidence as to whether the instruments intended for both children and adult populations are equally reliable and valid for use with both age levels.

Design

Test-retest reliability coefficients were computed to assess the reliability of the instruments in measuring learning styles. Additionally, several methods were used to establish the construct validity of the scores obtained on the scales. These methods assessed the internal structure of the scales, the convergent validity of the constructs, and the discriminant validity of constructs. Internal structure was established for each instrument by conducting separate exploratory factor analyses for each scale to determine if subscales that were believed to measure the same trait loaded on the same factors.

Convergent validity of the constructs was assessed by cross instrument validation in two ways. First, exploratory factor analysis was conducted for each sample with all of the subscales. This was done to see if the similar subscales from the different instruments would load onto similar factors, providing evidence of construct validity. A second method to assess the construct validity of the constructs was to examine Pearson product-moment correlations between similar subscales from different instruments to see if they correlated highly, measuring the same constructs.

Finally, construct validity of the constructs was further evaluated by six multitrait-multimethod matrices that assessed convergent validity, as well as discriminant construct validity. The data in these matrices were analyzed both by confirmatory factor analysis and according to the four criteria suggested by Campbell and Fiske (1959).

Method

Subjects

Target populations included middle-school students in Cache Valley, Utah, and college students at Utah State University who were studying to become teachers. The middle-school sample consisted of 104 seventh-grade students of which 54% were male and 46% were female. The college sample consisted of 102 subjects of which 21% were male and 79% were female. All students selected in the middle-school to participate did so as part of a class activity. For the college sample, 87% of an educational psychology class agreed to participate in the study for class extra credit points.

Instruments

The broader learning scales chosen for this study included the LSP (NASSP, 1986), the LSI (Dunn et al., 1982a), and the PEP (Dunn et al., 1982b). These were selected because they are known to have reasonably good psychometric properties and they are currently very widely used both in research and practice (Curry, 1987; DeBello, 1989; Learning Styles, 1986; Rule & Grippin, 1988). Moreover, both the LSI and the PEP were chosen because this allows for an assessment of instruments for both child and adult ages.

The more narrowly focused instruments that were selected for this study included the GRSLSS (Grasha & Reichmann, 1975), the ELSIE (Reinert, 1976), and the GEFT (Witkin et al., 1971). Each of these instruments assesses different learning style areas with different age populations, which can be seen in Table 3. Although these scales may have some psychometric weaknesses, the majority of the existing evidence suggests that they are all fair to good measures of learning style, which is one reason why they were chosen for inclusion in this study. Additionally, they were selected because they each measure a single learning style dimension that is also assessed by one or all of the multidimensional scales that were used in this inquiry.

The remainder of the learning styles instruments in Table 1 were not selected for use in this study for one or more of the following reasons: (a) no evidence was found indicating that the instrument is used extensively by researchers and educators, (b) there is no existing psychometric information available to indicate whether the instrument has any value, (c) the psychometric information that is available indicates that the reliability and validity of the scale is low, and (d) the specific learning style area targeted by the instrument is dissimilar from the subscales of the multidimensional instruments being used, thereby making comparisons between the unidimensional and

Table 3

Instruments Used in the Study

Instrument	Age	P	E	V	C	S	M
LSP	Gr 6 +	X	X	X	X	X	X
LSI	Gr 3-12	X	X	X		X	X
PEP	adults	X	X	X		X	X
GRSLSS	college					X	
ELSIE	HS						X
GEFT	Age 10 +				X		

Note. P = Physiological, E = Emotional, V = Environmental, C = Cognitive/information processing, S = Sociological, M = Perceptual modality.

multidimensional scales infeasible.

Learning Style Inventory

The LSI by Dunn et al. (1982a) consists of 104 statements in which subjects respond on a Likert scale ranging from strongly disagree to strongly agree. This scale assesses the environmental, emotional, sociological, and physical elements of a child's learning style.

Productivity Environmental Preference Survey

The PEP by Dunn et al. (1982b) was designed to diagnose adults' productivity and learning styles. This scale is essentially an adult version of their LSI, which is intended to also have applications in the workplace.

Learning Style Profile

The purpose of the LSP (NASSP, 1986) is to provide educators with an instrument for diagnosing the cognitive styles, perceptual response tendencies, and study/instructional preferences of students (Keefe, 1982). The LSP contains several subscales to assess each of these three dimensions. Cognitive skills are measured by the following subscales: analytic skill, spatial skill, discrimination skill, categorization skill, sequential processing skill, simultaneous processing skill, memory skill, and verbal-spatial preference. Perceptual responses are measures of visual perceptual response, auditory perceptual response, and emotive perceptual response. The subscales of study and instructional preferences include persistence orientation, verbal risk orientation, and manipulative preference. Finally, study time preferences are also assessed by the LSP. Although the LSP was originally intended for use with children, this scale has been used with adults (Frey & Simonson, 1990). Therefore, the LSP was used with both middle-school and college-age samples for this study.

Grasha-Reichmann's Student Learning
Style Scales

The GRSLSS (Grasha & Riechmann, 1975) is a 90-item Likert scale in which college students indicate the degree to which the statements apply to themselves. The GRSLSS measures how students interact with the teacher, other students, and the learning task. This instrument assesses the sociological element of learning style and includes six scales including: independent, dependent, avoidant, collaborative, participant, and competitive. Independent students like to work on their own and take more initiative, whereas dependent students rely on authority figures to define the learning task and learn only what is required. Avoidant learners do not prefer the traditional class format and are uninterested or overwhelmed by what goes on in the class, whereas participant learners like to interact with others while they learn. Finally, competitive learners learn material in order to perform better than other students, and corroborative learners enjoy sharing ideas through cooperative methods of learning.

<u>Edmonds Learning Style Identification Exercise</u>

The ELSIE (Reinert, 1976) measures the perceptual modality dimension of learning style. This scale is composed of 50 one-word items that are read aloud to students, who are asked to react to the words and record the manner in which the words occur to them the most spontaneously. Answers are recorded according to a forced choice including: visualization (creation of a mental picture), written (the word spelled out), listening (sound), and activity (an emotional or physical feeling about the word).

Group Embedded Figures Test

The GEFT (Witkin et al., 1971) assesses the cognitive aspect of learning style. The instrument is intended for both children and adults and consists of 25 pictorial items in which subjects are required to identify simple geographic target figures that are embedded in larger complex geographic shapes. This scale measures whether subjects are field-dependent or field-independent. The ability to locate the embedded figure is characteristic of field-independence. Field-independent individuals are more analytically oriented and function more autonomously. People who are field-dependent use their surroundings to process information, view patterns more globally, and tend to be more socially oriented.

Several authors have evaluated the reliability and validity of these six instruments. These psychometric data can be seen in Table 4.

Procedure

College students who volunteered to participate in the study met in two sessions, each lasting approximately 1 hour. For one session individuals were first given the GEFT, which lasted 20 minutes, followed by the PEP, which took approximately 30 minutes to complete. This was

Table 4

Psychometric Properties of the Instruments Used in This Study

Instrument	Reliability	Validity
Learning Style Inventory	Poor technical information is provided by the authors of the instrument (Hughes, 1992). Internal consistency reliability is low and no evidence is provided regarding test-retest reliability.	Little information is available regarding the factor analysis procedures used to assess construct validity. Also, factor analysis may not have been conducted properly.
Productivity Environmental Preference Scale	Reliability is low and appears to be computed from an earlier version of the scale using a true/false format. No test-retest reliability reported in manual. A study by Murray-Harvey (1994) shows long term test-retest reliability is poor ranging from .20 to .64.	Little information is provided by the authors other than some correlations of the test scores with GPA. A factor analysis computed by Murray-Harvey (1994) failed to provide evidence for construct validity.
Grasha-Riechmann's Student Learning Style Scale	Test-retest ranges from .76 to .83 (Blakemore, 1984).	Curry (1987) cites some validity evidence indicating moderate concurrent and predictive validity.
Edmonds Learning Style Identification Exercise	Poor evidence of reliability (Curry, 1987; DeBello, 1989). Test-retest from .95 to .99 (n = 763) (Curry, 1987).	No evidence of validity (Curry, 1987; DeBello, 1989).
Learning Style Profile	Cronbach's alpha ranges from .47 to .76 for the various subscales (Keefe & Monk, 1986). Test-retest using a 10-day interval ranges from .36 to .82 for the Subscales (Keefe & Monk, 1986). Consistency and stability reliability for the LSP are low (Blixt & Jones, 1995; Nagy, 1995).	Concurrent validity with the *GEFT*, the *ELSIE*, and the *LSI* ranges from .15 to .71. Correlated with other scales which themselves have low reliability and validity. Content validity assessed by a task force formed by the test developers. A lack of evidence relating the subscales to learning or instruction.
Group Embedded Figures Test	Parallel forms, corrected by Spearman-Brown prophecy formula = .82 (Witkin et al., 1971) Test-retest ranges from .78 to .92 (Curry, 1987)	A valid measure of field-dependence/field-independence with fourth-, fifth-, and sixth-grade students (Thompson, Pitts, & Gipe, 1983). Good criterion and construct validity (Curry, 1987; Rule & Grippin, 1988).

followed by the GRSLSS, which took between 15 and 45 minutes to complete. At the second session subjects were given the LSP, which took approximately 50 minutes to complete.

Middle-school students also met in two sessions. For one session, individuals were first given the ELSIE, which took 10 minutes to complete, followed by the GEFT, which lasted 20 minutes. Next, the LSI was administered, which lasted approximately 30 minutes. For the other session subjects completed the LSP, which took about 50 minutes. Two testing sessions were used to eliminate any effects of fatigue.

All of the middle-school subjects were retested one month later with the same instruments. College subjects were also retested one month later. The percentage of college subjects that retested varied, depending on volunteer availability. Forty percent of the subjects returned for retest of the GEFT and the PEP. Forty-two percent returned for the GRSLSS and 10% retook the LSP. The same procedure as the original testing sessions were followed for the retest sessions.

The LSI and PEP were sent to the publisher for computer scoring. The scores provided by these instruments were a total number of items answered in the keyed direction for each scale, which were then converted to standard scores to determine learning style preferences. The remaining four scales were scored by the researcher. The LSP yielded raw scores for each subscale which were then converted to T-scores to determine learning style preference. The GRSLSS is a Likert scale, and the score was the total number of ratings assigned to items comprising each scale. The GEFT yielded a score of the total number of correctly identified figures, and the ELSIE yielded a score of the total number of responses in each category. After scoring, feedback, including scores on the scales and interpretation of scores, was given to the students.

CHAPTER IV

RESULTS

Reliability

As mentioned previously, test-retest reliability assesses the stability of an instrument across time. This analysis involves two administrations of the same test to the same subjects with some time interval between the testing sessions. Test-retest reliability was evaluated using Pearson product-moment correlation coefficients. These correlations were computed between scores from the first and second testing sessions to establish test-retest reliability for each of the instruments included in this study.

Test-retest correlation coefficients were computed for scores from both the middle-school and college samples. The middle-school reliability coefficients are shown in Table 5, and the college sample reliability coefficients are listed in Table 6. Caution should be used when interpreting the statistical significance of these coefficients due to small sample sizes.

For the middle-school sample, the reliability of all subscales is statistically significant except for the LSP evening subscale. The reliability could not be calculated for the LSP memory subscale because of zero variance of scores from the first testing occasion. The average

Table 5

Test-Retest Reliability Coefficients for the Middle-School Sample

Instrument subscale	Reliability (r)		n
Learning Style Profile			
Analytic	.61	***	81
Spatial	.64	***	81
Discrimination	.34	**	81
Categorization	.41	***	81
Sequential-processing	.52	***	81
Simultaneous processing	.53	***	81
Memory	.38	***	81
Visual	.47	***	81
Auditory	.35	***	81
Emotive	.40	***	81
Persistence	.65	***	81
Verbal-risk	.46	***	81
Verbal-spatial	.46	***	81
Manipulative	.39	***	81
Early morning	.41	***	81
Late morning	.30	***	81
Afternoon	.61	***	81
Evening	-.08		81
Grouping	.22	*	81
Posture	.53	***	81
Mobility	.45	***	81
Sound	.50	***	81
Lighting	.70	***	81
Temperature	.52	***	81
Edmonds Learning Style Identification Exercise			
Visualization	.65	***	92
Written word	.56	***	92
Auditory	.67	***	92
Emotive	.54	***	92
Learning Style Inventory			
Sound	.68	***	88
Light	.61	***	88
Temperature	.52	***	88
Design	.24	*	88
Motivation	.73	***	88
Persistence	.33	**	88
Responsibility	.58	***	88
Structure	.67	***	88
Alone/peer oriented	.62	***	88
Authority-oriented	.62	***	88
Several ways	.64	***	88
Auditory	.41	***	88
Visual	.38	***	88
Tactile	.54	***	88
Kinesthetic	.64	***	88
Intake	.62	***	88
Evening/morning	.53	***	88
Late morning	.41	***	88
Afternoon	.48	***	88
Mobility	.60	***	88
Group Embedded Figures Test	.80	***	93

* $p < .05$
** $p < .01$
*** $p < .001$

Table 6

Test-Retest Reliability Coefficients for the College Sample

Instrument subscale	Reliability (r)		n
Learning Style Profile			
Analytic	.55		9
Spatial	.48		9
Discrimination	.82	**	9
Categorization	.80	**	9
Sequential-processing	.76	*	9
Simultaneous processing	.82	**	9
Memory	N/A		9
Visual	.89	***	9
Auditory	.77	*	9
Emotive	.47		9
Persistence	.19		9
Verbal-risk	.90	***	9
Verbal-spatial	.92	***	9
Manipulative	.76	*	9
Early morning	.82	**	9
Late morning	.22		9
Afternoon	.83	**	9
Evening	.78	*	9
Grouping	.84	**	9
Posture	.81	**	9
Mobility	.82	**	9
Sound	.94	***	9
Lighting	.45		9
Temperature	.87	**	9
Grasha-Riechmann Student Learning Style Questionnaire			
Avoidance	.77	***	41
Collaberative	.79	***	41
Competitive	.89	***	41
Dependence	.71	***	41
Independence	.64	***	41
Participant	.73	***	41
Productivitty Environmental Preference Survey			
Sound	.58	***	39
Light	.75	***	39
Temperature	.76	***	39
Design	.71	***	39
Motivation	.69	***	39
Persistence	.65	***	39
Responsibility	.82	***	39
Structure	.77	***	39
Alone/peer oriented	.74	***	39
Authority-oriented	.68	***	39
Several ways	.58	***	39
Auditory	.34	*	39
Visual	.71	***	39
Tactile	.56	***	39
Kinesthetic	.42	**	39
Intake	.85	***	39
Evening/morning	.80	***	39
Late morning	.38	*	39
Afternoon	.72	***	39
Mobility	.79	***	39
Group Embedded Figures Test	.84	***	39

* $p < .05$
** $p < .01$
*** $p < .001$

subscale reliability for the LSP is .45 (N = 81). The average subscale reliability for the ELSIE is .61 (N = 92). Finally, the average subscale reliability for the LSI is .54 (N = 88).

For the college sample, the average subscale reliability for the LSP is .72 (N = 9). The average subscale reliability for the GRSLSS is .76 (N = 41), and the average subscale reliability for the PEP is .67 (N = 39).

Validity

Several types of construct validity were assessed for all six scales. Types of construct validity evaluated included internal structure of the instruments, convergent validity of constructs, and discriminant validity of constructs. Internal structure was established for each instrument by conducting separate exploratory factor analyses for each scale to determine if subscales, which were believed to measure the same trait, loaded on the same factors.

Convergent validity of the learning style constructs was assessed by cross instrument validation in two ways. First, exploratory factor analyses were conducted for each sample that included all of the instrument subscales. This was done to see if similar subscales from the different instruments would load onto the same factors, providing evidence of construct validity. A second method used to assess the construct validity of the instruments was to examine Pearson-product moment correlations between similar subscales from different instruments to see if they correlated highly.

Finally, construct validity was further assessed by six multitrait-multimethod matrices. These matrices provided further evidence in addition to the exploratory factor analyses and subscale correlations regarding the convergent validity of the constructs, as well as providing data regarding the discriminant validity of the instruments.

The data in the multitrait-multimethod matrices were analyzed in two ways. First, the data were analyzed by confirmatory factor analysis. However, as the results will indicate, the CFA analyses did not produce results for many of the matrices. Additionally, for those CFA results that were produced, the findings were tenuous due to problems inherent in the analyses. Therefore, the patterns of correlations in the multitrait-multimethod matrices were also inspected to determine if they met the four criteria suggested by Campbell and Fiske (1959). These criteria were discussed earlier and are summarized again in Table 7.

Internal Structure Assessment of Construct Validity

Separate exploratory factor analyses were conducted for each instrument to assess internal structure construct

Table 7

Campbell and Fiske (1959) Criteria for Assessing Convergent and Discriminant Validity

Criteria	Description
Criterion #1	The values in the validity diagonal should be significantly different from zero and sufficiently large to encourage further examination of validity.
Criterion #2	A validity diagonal value should be higher than the correlations between that variable and any other variable having neither trait nor method in common.
Criterion #3	A variable should correlate higher with a different method measuring the same trait than with the same measure measuring a different trait.
Criterion #4	The same pattern of interrelationships should exist in all of the heterotrait triangles.

validity by examining to see if the subscales loaded onto factors measuring the underlying constructs hypothesized by the test developers. Separate factor analyses were conducted for each sample for instruments that were used with both samples. This analysis could not be conducted for the GEFT because it only has one subscale and therefore, one construct. Principal factors extraction with varimax rotation was performed for each instrument using SPSS version 6.1 (SPSS, Inc., 1993). One common determination of the number of factors to include in a factor analysis is to extract factors whose eigenvalues are greater than 1.0

(Comry & Lee, 1992; Tabachnik & Fidell, 1996). Therefore, factors with eigenvalues greater than 1.0 were extracted for these analyses. Additionally, scree plots supported this decision. Caution should be used when interpreting the results of the exploratory factor analyses due to small sample sizes.

<u>Edmonds Learning Style Identification Exercise</u>

Three factors were extracted for the ELSIE. Percentages of variance explained by each factor and factor loadings are shown in Table 8. Because the visual and word subscales are both "visual" measures, one would expect three distinct perceptual modality factors: visual, auditory, and emotive. The loadings do provide evidence of three factors, although the two visual subscales (visual and word) do not distinguish the factors well because these subscales loaded high on different factors.

The first factor is auditory in nature, the second factor can be considered emotive, and the third factor is visual. Yet, the visual subscale loaded on all three factors. Additionally, the visual and auditory subscales loaded high on the same factor. However, the visual and word subscales loaded in opposite directions for factors one and three, which would be expected. Overall, the results of this analysis support the three distinct underlying constructs for the ELSIE that were hypothesized (verbal,

Table 8

Rotated Factor Matrix of ELSIE Subscales

Subscale	Factor 1	Factor 2	Factor 3
ELSIE emotive	-.09	.99	-.10
ELSIE visual	-.71	-.58	-.40
ELSIE auditory	.93	-.19	-.29
ELSIE word	-.12	-.07	.99
Percent variance	38.5	34.5	26.7

auditory, and emotive).

Grasha-Reichmann's Student Learning Styles Scales

One would have expected three sociological factors to emerge, because this instrument has three sets of subscales, each with two opposing subscales measuring a single construct. For example, one would expect the avoidant and participant subscales to load on the same factor, because they measure the same trait (willingness to participate), only in opposite directions. Likewise, the collaborative and collective subscales should load together, as well as the dependent and independent subscales.

The percentages of variance for the extracted factors and factor loadings are shown in Table 9. As expected, almost three distinct factors emerged, as can be seen by these factor loadings. The only ambiguity is the collaborative subscale, which loaded on both factors 1 and 3. Otherwise, there are clear factors for willingness to take part in activities (factor 1), amount of reliance on others (factor 2), and amount of cooperation (factor 3). Additionally, for each pair of subscales loading on factors 1 and 2, one subscale loads positive and one loads negative. This indicates that they represent opposing qualities, as would be expected. This analysis generally supports the construct validity of the GRSLSS because the three underlying traits that would be expected emerged in the factor analysis.

Productivity Environmental Preference Survey

Because the PEP is a multidimensional instrument, this scale was expected to have five learning style constructs: emotional, environmental, physiological, sociological, and perceptual modality (see Table 3). However, this analysis yielded seven factors with eigenvalues greater than 1.0. Percentages of variance for the extracted factors and factor loadings are displayed in Table 10. The highest loading subscales for each factor are blocked together. Also, all loadings of .30 or larger are highlighted in boldface in the table, indicating moderate loadings. One can see in Table 10 that the factors loaded almost as expected. Based on the factor loadings, the first factor represents an emotional dimension of learning style, consisting of motivation,

Table 9

Rotated Factor Matrix of GRSLSS Subscales

Subscale	Factor 1	Factor 2	Factor 3
GRSLSS avoidant	**-.89**	.11	.21
GRSLSS participant	**.90**	.07	.17
GRSLSS competitive	-.09	.03	**.92**
GRSLSS collaborative	**.48**	.04	**.48**
GRSLSS independent	.17	**-.88**	.18
GRSLSS dependent	.19	**.79**	.35
Percent variance	33.0	25.7	18.5

persistence, and responsibility.

The second factor represents the physiological domain of learning style, including the various times people learn best. Subtests that load high on the third factor include tactile, kinesthetic, intake, and mobility. Although one might expect these variables to correlate together onto one factor, this factor does not represent one type of learning style in particular.

The fourth factor includes the subscales of alone/peers and several ways, which represent the sociological manner in which people prefer to learn. The fifth factor is environmental, including lighting, temperature, and design. The sixth factor includes structure and authority, which do

Table 10

Rotated Factor Loadings of the PEP

Instrument subscale	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
PEP Motivation	**.85**	.02	.12	.24	.16	.11	-.05
PEP Persistence	**.81**	-.05	.07	.08	.02	-.06	.06
PEP Responsibility	**.66**	.01	**-.49**	.03	-.02	-.24	-.04
PEP Evening/morning	.07	**.64**	.05	.21	**.44**	.09	.23
PEP Late morning	-.09	**.90**	.03	-.10	-.07	-.06	-.08
PEP Afternoon	-.01	**-.93**	.06	-.04	-.17	-.01	.03
PEP Tactile	.24	.20	**.66**	-.05	.07	.00	-.11
PEP Kinesthetic	.06	.09	**.59**	-.09	-.17	**.46**	-.09
PEP Intake	.11	-.24	**.40**	-.08	-.28	-.18	.02
PEP Mobility	-.29	-.20	**.60**	-.07	.01	.04	.21
PEP Alone/peers	-.12	-.04	.20	**-.81**	.03	.13	.13
PEP Several Ways	.15	.01	.01	**.87**	.05	.08	.04
PEP Light	.21	.07	-.18	-.03	**.62**	.28	.36
PEP Temperature	.05	.04	-.16	.13	**-.72**	.12	.22
PEP Design	.08	**.31**	-.22	.15	**.64**	.00	-.01
PEP Structure	-.16	-.07	.06	.04	-.05	**.78**	-.02
PEP Authority	.29	.07	.11	**-.39**	.22	**.58**	.15
PEP Auditory	.15	-.06	.16	.01	-.03	-.16	**.82**
PEP Visual	**.32**	-.06	.20	.17	.02	-.25	**-.65**
PEP Sound	**.37**	-.06	**.30**	-.17	-.21	**-.37**	.03
Percent of variance	15.9	13.3	10.8	8.6	7.1	6.1	5.1

not represent a specific learning style.

The seventh factor can be interpreted as perceptual modality because it includes auditory and visual perceptual modality subscales. Finally, the sound subscale is a poor indicator of the environmental learning style domain because it loads moderately on several factors.

The results of the exploratory factor analysis on the PEP are in strong support of the construct validity of this instrument. With the exception of the sound subscale, which loaded on three factors, the subscales all loaded onto factors that represent the hypothesized underlying constructs of the PEP.

Learning Style Inventory

The same five learning style constructs that were expected for the PEP were anticipated for the LSI, because this is also a multidimensional instrument (emotional, environmental, physiological, sociological, and perceptual modality). Yet, this analysis also yielded seven factors, with the percents of variance explained for each of the extracted factors and factor loadings, shown in Table 11. The results of this analysis are not as good as those from the PEP. The first LSI factor may represent an emotional factor because it includes the subscales of motivation, persistence, and responsibility. However, other subscales also loaded high on this factor, including structure, authority, and afternoon.

Table 11

Rotated Factor Loadings of the LSI

Instrument subscale	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
LSI Motivation	**.81**	-.07	.04	.09	.06	.13	.15
LSI Persistence	**.75**	-.12	-.03	-.02	.04	.11	-.10
LSI Responsibility	**.70**	-.14	.05	-.13	-.04	-.14	.20
LSI Structure	**.61**	-.04	**.34**	-.01	.06	-.17	.25
LSI Authority	**.58**	.24	.19	.08	.22	.17	.10
LSI Afternoon	**.61**	.08	.00	-.01	.15	**-.51**	.16
LSI Intake	-.26	**.55**	.23	.00	-.09	**-.32**	-.05
LSI Alone/peers	-.11	**.81**	.14	-.20	-.01	-.07	-.08
LSI Several ways	.20	**.77**	.18	-.19	.17	.06	-.10
LSI Tactile	.18	.19	**.82**	.05	-.01	.01	-.08
LSI Kinesthetic	.29	.17	**.75**	-.01	.05	-.04	.00
LSI Auditory	.09	.14	.10	**-.88**	-.03	-.04	.00
LSI Visual	.07	-.24	.19	**.75**	.27	.13	.07
LSI Temperature	.10	.12	-.10	.15	**.74**	-.16	-.16
LSI Late morning	.12	-.02	.11	.06	**.79**	.20	.15
LSI Evening/morning	.19	-.12	-.05	.12	.11	**.74**	.26
LSI Design	.12	-.09	.12	.17	-.19	**.33**	**.70**
LSI Mobility	-.06	**.31**	-.12	**.38**	-.26	.02	**-.61**
LSI Sound	**-.42**	**.38**	-.19	-.18	.10	**-.38**	.05
LSI Light	.12	**.43**	**-.40**	.17	.08	-.10	**.48**
Percent of variance	22.9	13.9	7.9	7.1	5.5	5.0	4.8

The second factor depicts a sociological factor because it includes the alone/peers and several ways subscales. Yet, intake also loaded high on this factor. The subscales on the third factor do not represent a specific learning style domain.[2] The fourth factor represents perceptual modality because the auditory and visual subscales loaded high on this factor. The fifth factor cannot be named based on current theory, because it includes an environmental subscale (temperature) and a physiological subscale (late morning).

The sixth factor represents the physiological dimension, because the evening/morning subscale loaded high on it. Additionally, although the afternoon subscale loaded higher on the first factor (.61), it also has a high loading on this factor (-.51). Yet, the late morning subscale has only a low loading on this factor (.20). Similar to the fifth factor, the seventh factor cannot be named because it includes an environmental subscale (design) and a physiological subscale (mobility). Finally, the sound and light subscales are poor indicators of environmental learning style because each of these subscales loaded moderately on several factors.

Although the exploratory factor analysis of the LSI did

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[2]This factor does not support the perceptual modality learning style domains proposed by Dunn et al. (1982a). However, this factor may represent merely a *tactile* domain, rather than a more general *perceptual modality* domain.

not produce results as good as the PEP analysis, there is still good evidence of construct validity for this scale. Four strong learning style factors emerged, including the emotional, sociological, and perceptual modality domains. Additionally, the physiological factor is adequate, including high loadings of two out of three of the physiological subscales.

Learning Style Profile

Two separate exploratory factor analyses were conducted for this instrument, one for each sample. This is also a multidimensional instrument, and thus six constructs were hypothesized to emerge. The same constructs as the PEP and LSI were anticipated (emotional, environmental, physiological, sociological, and perceptual modality), as well as an additional cognitive construct predicted by the cognitive subscales of the LSP. Nine factors were extracted for the middle-school sample.

Middle-school sample. Factor loadings for the middle-school sample and percentages of variance for each factor are shown in Table 12. None of the factors represent a single distinct learning style domain based on current theory. However, for some factors the majority of the high-loading subscales are from a particular domain, allowing for an interpretation to be made. The first factor includes a perceptual modality subscale (manipulative), two environmental subscales (posture and sound), and a

Table 12

Rotated Factor Loadings of the LSP for the Middle-School Sample

Instrument subscale	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9
LSP Manipulative	**-.54**	.19	.00	**-.36**	-.09	-.12	**-.35**	**.33**	.10
LSP Posture	**-.51**	-.15	-.25	.04	-.19	.19	.27	.28	-.05
LSP Mobility	**.76**	.06	-.13	.12	-.15	.01	-.11	-.05	-.19
LSP Sound	**.82**	.00	.01	-.13	.03	.07	-.05	.18	.06
LSP Analytic	.01	**.70**	.12	.10	.05	-.03	.11	-.08	.09
LSP Spatial	-.07	**.64**	.05	**.35**	.04	.00	.20	-.10	.15
LSP Catagorization	.03	**.73**	.13	-.06	-.05	.19	-.23	.09	-.09
LSP Grouping	**-.37**	**-.58**	.09	-.05	-.24	.04	-.26	.05	.01
LSP Visual	-.01	.04	**.83**	-.07	.00	**-.46**	-.01	-.08	.10
LSP Auditory	-.07	-.08	**-.84**	.08	-.08	-.29	.02	.11	-.14
LSP Persistence	-.20	.25	**.55**	.18	.19	.14	.19	.22	-.16
LSP Discrimination	.11	.08	-.22	**.63**	.02	-.16	-.28	.25	.22
LSP Sequential	.04	.25	.01	**.75**	-.02	-.01	.21	-.06	-.11
LSP Late morning	-.22	.03	.15	**.54**	-.22	**.45**	.00	.09	-.02
LSP Verbal-spatial	.01	.05	.22	.05	**.59**	.06	**-.33**	.03	-.14
LSP Afternoon	.20	.06	.03	.00	**.64**	.19	.14	-.11	.13
LSP Light	.22	.00	.01	.05	**-.73**	.11	.07	-.01	.05
LSP Emotive	.08	.08	.02	-.04	.11	**.88**	.04	-.03	.09
LSP Temperature	-.10	.15	.07	.06	-.06	.03	**.85**	-.06	.00
LSP Evening	.03	-.11	-.06	.04	.01	.02	-.10	**.84**	-.04
LSP Simultaneous	-.04	.04	.10	-.10	-.04	.19	-.03	-.10	**.75**
LSP Early morning	-.09	.04	.05	.15	-.03	-.20	.09	**.43**	**.57**
LSP Memory	-.06	**.43**	-.15	**.36**	.12	-.04	-.09	**-.31**	**.46**
LSP Verbal-risk	**.41**	.21	.04	-.14	**.47**	-.01	.22	.19	-.01
Percent of variance	13.5	10.4	9.2	6.9	6.2	5.8	5.4	4.7	4.5

physiological subscale (mobility). This factor might be interpreted as an environmental factor due to the two environmental subscales and the loading of light (.22).

Three cognitive subscales loaded high on the second factor (analytic, spatial, and categorization). However, this cannot be interpreted as strictly a cognitive factor because a sociological subscale (grouping) loaded high on it, and several other cognitive subscales (discrimination, verbal-spatial, and simultaneous-processing) have very low loadings on this factor. Yet, the sequential-processing and memory cognitive subscales load slightly on this factor (.25 and .43, respectively), providing some support in favor of this being a cognitive factor.

The third factor includes two perceptual modality subscales (visual and auditory) and one emotional subscale (persistence). The presence of the emotional subscale, as well as the absence of the manipulative and emotive perceptual modality subscales (loadings are .00 and .02, respectively), casts doubt as to whether this factor can be interpreted as a perceptual modality factor.

Both the fourth and fifth factors include cognitive and physiological subscales. Additionally, the fifth factor has a high loading for an environmental subscale (light). The fourth factor may be of a cognitive nature due to the two cognitive subscales (discrimination and sequential-processing), as well as moderate loadings of two other cognitive subscales, memory (.36) and spatial (.35). The fifth factor most likely cannot be named because of the various learning style domain subscales that loaded high on it.

Only one subscale loaded high on each of the sixth, seventh, and eighth factors. The sixth factor consists of an emotive subscale (perceptual modality). Other perceptual modality subscales (visual and auditory) had moderate loadings on this factor (-.46 and -.29, respectively), yet the manipulative subscale loaded low (-.12). However, these loadings are high enough to interpret the sixth factor as being perceptual modality.

The high loading subscale on the seventh factor is temperature, an environmental subscale. The other environmental subscales did not load high on this factor (sound = -.05, posture = .27, and light = .07); therefore, this is probably not an environmental factor.

The highest loading subscale on the eighth factor is evening (physiological). Another physiological subscale (early morning) has a moderate loading on this factor (.43), yet the remaining physiological subscales have low loadings on this factor (mobility = -.05, late morning = .09, and afternoon = -.11). Therefore, this should not be interpreted as a physiological factor.

The ninth factor consists of a cognitive subscale (simultaneous-processing) and a physiological subscale (early morning). Additionally, two other cognitive subscales have slightly moderate loadings (memory = .46 and discrimination = .22). However, the remaining cognitive subscales do not load onto this factor (analytic = .09, spatial = .15, categorization = -.09, sequential-processing = -.11, and verbal-spatial = -.14). Because five of the eight cognitive subscales do not load onto this factor, it most likely is not a cognitive factor.

Finally, the memory (cognitive) and verbal-risk (sociological) subscales have moderate loadings on several factors. Because of this, these subscales are poor indicators of their respective learning style domain. Overall, the factor analysis of the LSP for the middle-school sample provides little support for the construct validity of this instrument. Nine factors were extracted from the analysis, with only four being somewhat interpretable based on current theory. Two of these factors (two and four) may be interpreted as cognitive learning style factors. Additionally, the first factor can be interpreted as environmental and the sixth as perceptual modality. No clear factors emerged for the sociological, emotional, and physiological dimensions of learning style.

<u>College sample.</u> A separate factor analysis was conducted for the LSP using the college sample. This analysis extracted eight factors, with percentages of variance explained by each factor and factor loadings

displayed in Table 13.

The first factor has high loadings for four different modality subscales (emotional, perceptual modality, environmental, and physiological), and therefore cannot be named. The second factor appears to be a cognitive factor due to high loadings of three cognitive subscales (discrimination, sequential-processing, and verbal-spatial). Additionally, another cognitive subscale loads slightly on this factor (memory = .20). Yet, the remaining cognitive subscales have low loadings on factor 2 (analytic = .04, simultaneous-processing = .14, spatial = .16, and categorization = .12).

Two perceptual modality subscales loaded high on the third factor (visual and emotive). However, the other two perceptual modality subscales, manipulative and auditory, have low loadings on this factor (-.05 and .02, respectively). This makes a perceptual modality interpretation of this factor questionable.

The fourth factor does not represent a specific learning style domain because the high loadings are for one cognitive subscale and one environmental subscale. Moreover, no other cognitive or environmental subscales have high loadings on this factor.

The fifth factor consists of one sociological (verbal-risk) and one physiological (afternoon) subscale. Other physiological subscales (mobility = -.30, evening = .28, and

Table 13

Rotated Factor Loadings of the LSP for the College Sample

Instrument subscale	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8
LSP Persistence	**.65**	-.01	.22	.26	-.04	.11	-.21	-.22
LSP Manipulative	**.55**	**.36**	-.05	-.01	**-.39**	-.08	.22	.06
LSP Posture	**.80**	-.08	-.07	-.13	-.22	-.05	.05	.01
LSP Mobility	**-.67**	-.06	-.01	-.01	**-.30**	-.20	-.07	-.13
LSP Discrimination	-.04	**.75**	.02	-.15	.13	.11	-.01	-.12
LSP Sequential-process	-.12	**.60**	.14	.16	-.21	-.02	.03	.16
LSP Verbal-spatial	.25	**.64**	.00	.26	.02	-.29	-.06	.19
LSP Grouping	**.32**	**.57**	-.10	.21	-.12	**.32**	.15	.13
LSP Visual	.03	-.15	**-.89**	.06	-.04	-.03	-.25	-.03
LSP Emotive	.00	.02	**.88**	-.13	.10	.12	-.28	-.03
LSP Analytic	.17	.04	-.03	**.78**	-.05	.08	-.14	.22
LSP Sound	-.15	.09	-.10	**.76**	.10	-.02	.16	-.02
LSP Verbal-risk	.01	-.04	.28	-.04	**.64**	-.20	-.05	-.05
LSP Afternoon	-.27	-.04	-.15	.23	**.69**	.19	-.25	.09
LSP Memory	.27	.20	.01	-.17	.05	**.77**	-.08	-.02
LSP Late morning	-.05	-.25	.05	.28	.04	**.61**	.05	-.01
LSP Auditory	-.05	.18	.02	.10	-.08	-.10	**.82**	.11
LSP Light	.21	**-.39**	.09	-.01	-.04	.13	**.58**	-.27
LSP Simultaneous-process	-.01	.14	-.15	.28	.00	-.14	.17	**.70**
LSP Spatial	.02	.16	.02	.11	-.01	**.40**	-.07	**.70**
LSP Evening	.03	-.10	.18	-.22	.28	**-.35**	-.10	**.55**
LSP Categorization	-.15	.12	**-.47**	.01	.06	**.35**	-.27	.04
LSP Temperature	.00	-.08	.04	-.09	**.57**	.12	**.47**	**.35**
LSP Early morning	-.08	-.19	.27	**-.47**	**-.48**	-.18	-.15	-.01
Percent of variance	13.5	10.4	9.2	6.9	6.2	5.8	5.4	4.7

early morning = -.48) loaded moderately on this factor. However, one physiological subscale (late morning = .04) did not. Yet, due to the several high physiological loadings, factor five appears to represent the physiological learning style domain.

The sixth factor consists of a cognitive (memory) subscale and a physiological (late morning) subscale. Three other cognitive subscales (spatial = .40, verbal-spatial = -.29, and categorization = .35) loaded moderately on this factor, yet the remaining four did not. Although this may lead to a cognitive interpretation of this factor, all of the physiological subscales also loaded slightly onto this factor (mobility = -.20, afternoon = .19, evening = -.35, and early morning = -.18). Therefore, this factor can be interpreted as a cognitive factor, but an even better interpretation may be that it represents the physiological domain of learning style.

The seventh factor may be interpreted as a perceptual modality factor because of the high loading of auditory (.82), and the slightly moderate loadings of visual (-.25), emotive (-.25), and manipulative (.22). Although there is a high loading of the environmental subscale light (.58), all of the remaining environmental subscales, except temperature (.47), have low loadings on this factor.

Finally, the eighth factor is comprised of two cognitive subscales (simultaneous-processing and spatial) and one physiological subscale (evening). The other subscales from these domains have low loadings on this factor, therefore making an interpretation in favor of either domain unlikely. The categorization, temperature, and early morning subscales of the LSP load moderately high on several factors; therefore, they are not good indicators of any specific learning style domain.

Overall, the analysis on the college sample for the LSP provides some support for the construct validity of this instrument. Of the eight factors that were extracted, only four were somewhat interpretable given current theory. Two of these factors (5 and 6) may be interpreted as physiological learning style factors. Additionally, the second factor can be interpreted as cognitive and the seventh as perceptual modality. No clear factors emerged for the sociological, emotional, and environmental dimensions of learning style.

Summary

Generally, results of the separate exploratory factor analyses indicate that most of the instruments have good internal structure. This provides some evidence of good construct validity for the instruments, in that many are measuring the particular learning style constructs that they purport to assess. However, these analyses do not indicate whether the instruments are all measuring these constructs in the same manner. Therefore, exploratory factor analyses were conducted including all instruments to determine the construct validity of the constructs.

Cross-Instrument Validation of Convergent Construct Validity

Exploratory Factor Analyses

The first method of assessing the convergent construct validity of the constructs required conducting separate exploratory factor analyses on each sample including subscales from all of the instruments. These analyses were done to determine if the subscales loaded onto different factors representing the various learning style dimensions. Principal factor extraction method with varimax rotation was used in this exploratory factor analysis using SPSS version 6.1 (SPSS, Inc., 1993).

Using the traditional cutoff criterion of extracting factors with eigenvalues greater than 1.0 resulted in extraction of 17 factors, which would have been difficult to interpret clearly. Additionally, theory suggests that there should only be about six factors of learning style (physiological, environmental, emotional, cognitive, sociological, and perceptual modality). Therefore, a cutoff criterion of eigenvalues greater than 2.0 was used for this analysis, which resulted in extraction of less factors. Caution should be used when interpreting the results of the exploratory factor analyses due to small sample sizes.

Middle-school sample. The middle-school factor analysis extracted seven factors with eigenvalues greater than 2.0. Percentages of variance explained by the factors and factor loadings are shown in Table 14, with all loadings greater than .30 shown in boldface, indicating moderate loadings. Additionally, subscales are grouped into blocked factors according to their highest factor loading.

Factor 1 suggests evidence of convergent validity for the subscales of late morning and persistence because the same subscales from two instruments loaded on this factor. This factor appears to represent the emotional learning style domain because all of the emotional subscales (motivation, persistence, and responsibility) loaded high on this factor.

Some evidence of convergent validity between the LSP and LSI can be seen in factor two for the posture, sound, and mobility subscales because the same subscales from both instruments load on the same factor. However, at the same time, many other subscales also loaded on this factor, making interpretation difficult.

There are four environmental subscales that loaded high on factor 2 (LSP posture, LSI design, LSP sound, and LSI sound). Additionally, four physiological subscales loaded high on this factor (LSP mobility, LSI mobility, LSI evening/morning, and LSI intake). These subscales all indicate a certain degree of convergent validity because the

Table 14

Rotated Factor Loadings of All Instruments for the Middle-School Sample

Instrument subscale	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
LSI Authority	**.67**	-.10	.02	.05	-.06	.13	.00
LSI Structure	**.64**	-.17	.09	.10	-.05	.00	.11
LSI Motivation	**.77**	-.15	-.01	.03	.06	-.18	-.14
LSI Responsibility	**.61**	-.16	.17	-.18	.19	-.08	.06
LSI Persistence	**.66**	-.10	.08	**-.36**	-.01	-.03	-.06
LSP Persistence	**.56**	-.07	.25	-.20	-.14	**-.32**	.05
LSI Late morning	**.39**	-.04	-.04	-.18	.14	.09	-.25
LSP Late morning	**.43**	-.07	.21	.14	.19	.06	.05
LSI Afternoon	**.54**	.04	.05	-.08	.26	.21	.14
LSP Posture	.13	**-.49**	-.14	**.32**	.11	.11	.05
LSI Design	.04	**-.50**	-.05	.03	.26	.14	-.03
LSP Sound	-.11	**.67**	-.09	-.12	.08	-.03	-.08
LSI Sound	**-.31**	**.47**	-.13	.00	**.35**	-.11	**.34**
LSP Mobility	-.04	**.66**	.05	.00	.10	.15	-.27
LSI Mobility	-.10	**.37**	.09	.22	-.08	.02	**-.31**
LSI Evening/morning	.22	**-.46**	-.05	.03	-.05	.05	-.23
LSP Verbal-risk	.17	**.42**	.12	.09	**-.30**	-.24	.09
LSI Alone/peers	.03	**.53**	-.13	**.37**	-.09	.14	**.44**
LSP Manipulative	.09	**-.49**	-.23	-.17	-.13	.09	.06
LSI Intake	-.11	**.67**	-.12	.04	.01	.09	.23
GEFT	.04	-.07	**.57**	-.19	-.15	.02	**.30**
LSP Analytic	.08	.04	**.67**	-.22	-.11	-.05	-.10
LSP Spatial	.10	-.06	**.76**	.05	.02	-.05	.09
LSP Catagorization	.05	.11	**.43**	-.13	-.06	-.07	.12
LSP Sequential	.22	-.03	**.65**	.08	.13	.15	-.01
LSP Memory	-.04	-.02	**.63**	.19	-.09	.06	.03
LSP Grouping	.13	**-.33**	**-.56**	-.10	.07	.09	.09

(table continues)

Instrument subscale	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
ELSIE Emotive	-.05	.18	-.17	**.57**	.08	**-.42**	.09
ELSIE Visual	.02	.08	-.14	**-.83**	.01	-.06	.00
LSP Visual	.05	-.02	.05	**-.78**	-.14	-.16	.05
LSI Light	.09	.10	-.10	.07	**.65**	.19	.08
LSP Light	.05	.14	-.08	-.01	**.72**	.01	.00
LSI Tactile	**.38**	.23	-.14	.00	**-.56**	.29	.10
LSP Verbal-spatial	.00	.10	.06	-.18	**-.65**	.01	.09
ELSIE Auditory	-.06	-.05	.23	**.31**	.08	**.70**	-.17
LSP Auditory	-.09	-.11	-.10	**.46**	.08	**.63**	-.10
LSP Emotive	.01	.12	.10	**.33**	.07	**-.58**	.05
LSP Evening	.06	-.09	-.23	-.03	.02	**.31**	.12
LSP Discrimination	.03	.02	.29	.11	.05	**.52**	.16
LSI Auditory	.16	.07	.10	.02	-.11	-.07	**.76**
LSI Visual	.19	-.08	-.12	-.06	-.03	.00	**-.74**
LSP Early morning	.15	-.13	.08	-.09	.18	.17	**.36**
LSI Several ways	**.35**	**.46**	-.01	.14	-.07	.27	**.36**
LSI Kinesthetic	**.49**	.17	-.09	.07	**-.37**	.27	.08
LSI Temperature	**.31**	.15	-.09	.06	.20	.12	-.29
LSP Temperature	.29	-.07	**.33**	.08	.26	-.20	**-.37**
ELSIE Word	.10	-.26	.05	.05	-.18	-.28	.12
LSP Afternoon	-.18	.27	.20	.02	-.28	-.24	-.01
LSP Simultaneous	-.03	-.12	.12	-.01	.02	-.19	-.09
Percent of variance	12.0	8.1	6.9	6.2	5.1	4.5	4.4

same subscales of two instruments loaded onto the same factor. However, other subscales also loaded onto this factor, making interpretation difficult. For example, this factor also includes two sociological subscales (LSP verbal-risk and LSI alone/peers) and one perceptual modality subscale (LSP manipulative). No other environmental subscales loaded even moderately on this factor. However, one sociological subscale (LSP grouping = -.33), two perceptual modality subscales (LSI tactile = .23 and ELSIE word = -.26), and one physiological subscale (LSP afternoon = .27) loaded slightly on this factor. Therefore, this factor is difficult to interpret because of the many different learning style domain subscales that loaded on it.

Factor 3 is a cognitive factor because it has six high-loading cognitive subscales. Additionally, another cognitive subscale (LSP discrimination = .29) loaded moderately on this factor. Moreover, although there is one sociological subscale (LSP grouping), no other subscales of this domain loaded even moderately onto this factor.

Only perceptual modality subscales loaded high on factor 4. Likewise, two more perceptual modality subscales (ELSIE auditory = .31 and LSP auditory = .46) loaded moderately on this factor, giving this factor a perceptual modality interpretation. Additionally, convergent validity of the visual subscales is indicated by high loadings of both the ELSIE and LSP visual subscales.

Factor 5 is comprised of environmental, perceptual modality, and cognitive subscales. Slightly moderate loadings of these domains include the perceptual modality subscale of LSI kinesthetic (-.37), the environmental subscales of LSI temperature (.20), and LSP temperature (.26). Some convergent validity can be seen by these temperature subscales, as well as the light subscales for the LSI and the LSP because the same subscales from two instruments load on the same factor. However, because of the variety of learning style domains that loaded high on this factor, no clear interpretation is possible.

The high loadings of the ELSIE and LSP auditory subscales provide evidence of convergent validity for auditory subscales for factor 6. This factor includes three subscales of perceptual modality and one physiological and cognitive subscale. Several other perceptual modality subscales have slightly moderate loadings on this factor (ELSIE emotive = -.42, LSI tactile = .29, LSI kinesthetic = .27, and ELSIE word = -.28). Therefore, this factor would best be interpreted as one of perceptual modality.

The seventh factor consists of two perceptual modality subscales and one physiological subscale. No other perceptual modality subscales loaded even moderately on this factor. Yet, several other physiological subscales (LSI late morning = -.25, LSP mobility = -.27, LSI mobility = -.31, LSI evening/morning = -.23, and LSI intake = .23) have slightly moderate loadings on factor 7. Therefore, this factor can be interpreted as physiological.

The overall factor analysis for the middle-school sample extracted seven factors, five of which were interpretable. Factor 1 is emotional, factor 3 is cognitive, factors 4 and 6 are perceptual modality, and factor 7 represents the physiological domain of learning style. Because so many distinct learning style factors emerged, this analysis provides support for the construct validity of these scales.

<u>College sample.</u> The college sample factor analysis of all instruments extracted seven factors with eigenvalues greater than 2.0. Percents of variance explained by the factors and factor loadings are shown in Table 15.

Factor 1 suggests some evidence of convergent validity for the posture subscales due to the high loadings of these subscales from both the PEP and the LSP. Additionally, convergent validity is found for the afternoon subscales. This factor appears to be physiological due to four high-loading subscales, as well as four slightly moderate-loading physiological subscales (LSP mobility = -.26, LSP late morning = -.34, PEP intake = -.28, and PEP mobility = -.31).

Convergent validity can be seen in factor 2 for the persistence and afternoon subscales. However, a clear interpretation of this factor cannot be made because other

Table 15

Rotated Factor Loadings of All Instruments for the College Sample

Instrument subscale	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
PEP Design	**.63**	**.41**	-.02	-.07	-.06	-.25	-.01
LSP Posture	**.70**	.29	-.02	-.12	-.21	-.21	-.01
PEP Afternoon	**-.80**	-.20	-.14	.06	-.02	-.09	-.14
LSP Afternoon	**-.66**	.21	-.12	.24	-.11	.17	**.30**
PEP Evening/morning	**.82**	.01	.13	-.20	.14	-.12	-.10
PEP Late morning	**.59**	.14	-.12	.13	-.06	**.36**	.12
LSP Manipulative	**.65**	.03	.31	.11	.15	-.08	-.18
PEP Persistence	-.12	**.72**	.00	.19	.07	-.04	-.21
LSP Persistance	.28	**.69**	.06	-.06	-.06	.15	-.02
PEP Responsibility	.01	**.69**	.14	.06	-.28	**-.30**	.06
PEP Motivation	**.32**	**.70**	.11	.01	.11	-.17	-.05
GRSLSQ Participation	.12	**.61**	-.09	-.11	**.32**	.08	**.39**
LSP Mobility	-.26	**-.51**	-.09	-.06	.20	.06	**-.36**
LSP Late morning	**-.34**	**.39**	.10	.08	-.05	-.21	-.06
GRSLSQ Independent	.00	.03	**.51**	.01	.24	**.40**	.09
PEP Alone/peers	**-.30**	**-.36**	**-.60**	**.33**	.20	.00	.06
LSP Grouping	.27	.11	**.71**	.11	-.26	.09	.02
PEP Visual	.02	.11	**.55**	.20	-.13	.01	-.12
LSP Spatial	-.02	-.05	**.48**	.09	-.05	.05	.22
LSP Sequential	.00	.00	**.54**	.13	.07	.00	-.05
PEP Sound	-.20	.13	.02	**.68**	.08	.09	-.05
LSP Sound	-.15	.02	.13	**.67**	.00	.00	-.05
LSP Analytic	.15	.15	.08	**.63**	-.10	.18	-.01
LSP Simultaneous	.03	-.21	**.30**	**.50**	.11	.10	.27
LSP Emotive	-.16	.20	.06	**-.52**	.21	.24	.11
LSP Early morning	.18	-.29	-.18	**-.58**	-.06	-.06	-.12
PEP Intake	-.28	-.07	.23	**.49**	-.02	.04	-.44

(table continues)

Instrument subscale	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
PEP Auditory	-.09	-.04	-.09	**-.35**	**.48**	-.07	-.29
LSP Visual	.04	-.14	**-.32**	**.37**	**-.44**	.01	-.24
GRSLSQ Collaborative	-.11	-.18	**-.51**	.17	**.55**	.00	.19
GRSLSQ Competitive	.07	.08	.12	.10	**.68**	.04	-.22
PEP Structure	-.06	-.28	.00	-.08	**.45**	-.12	-.08
PSP Authoriy	.18	.06	**-.37**	**.31**	**.61**	-.10	.23
PEP Mobility	**-.31**	**-.36**	-.11	.07	**.42**	.03	-.20
LSP Catagorization	-.16	-.04	.02	.15	**-.46**	.01	-.15
PEP Light	.29	.15	-.12	.00	**.33**	**-.67**	.05
LSP Light	.11	.18	-.28	.04	.13	**-.62**	.05
PEP Tactile	**.36**	.00	.09	.28	.17	**.59**	.06
PEP Kinesthetic	-.06	.08	-.08	.15	**.40**	**.54**	-.02
GRSLSQ Dependent	.15	.08	.02	.01	.16	**-.50**	.18
LSP Evening	.11	.03	.00	-.01	-.15	.05	**.42**
LSP Temperature	-.10	-.10	.05	.08	.08	-.18	**.82**
PEP Responsibiliy	.01	**.69**	.14	.06	-.28	**-.30**	**.06**
LSP Verbal-risk	-.12	.20	-.25	-.05	**.34**	.29	**.41**
GEFT	.29	.03	**.39**	.20	.20	**.38**	.05
GRSLSQ Avoidant	-.08	**-.55**	.08	-.13	-.07	-.08	**-.56**
LSP Auditory	.20	-.09	**.40**	.22	**.37**	**-.39**	.24
PEP Several ways	.11	**.31**	**.51**	**-.47**	.00	-.04	-.18
LSP Discrimination	.03	.03	**.34**	-.07	.22	**.33**	-.11
LSP Memory	.07	**.32**	.25	-.29	.04	.13	-.07
LSP Verbal-spatial	.27	-.03	**.46**	.27	-.19	**.45**	.12
Percent of variance	13.4	9.6	8.0	7.1	5.7	5.0	4.6

subscales also loaded high onto this factor. Two other emotional subscales loaded high onto this factor, as well as one sociological subscale and two physiological subscales. Additionally, three physiological subscales (PEP afternoon = -.20, LSP afternoon = .21, and PEP mobility = -.36) loaded slightly moderately on this factor. Finally, four sociological subscales (PEP alone/peers = -.36, LSP verbal-risk = .20, GRSLSS avoidant = -.55, and PEP several ways = .31) loaded moderately on this factor.

Three sociological, one perceptual modality, and two cognitive subscales loaded high on the third factor. Additionally, three perceptual modality subscales (LSP manipulative = .31, LSP visual = -.32, and LSP auditory = .40) loaded moderately on this factor. Likewise, five cognitive subscales (LSP simultaneous-processing = .30, GEFT = .39, LSP discrimination =.34, LSP memory = .25, and LSP verbal-spatial = .46) loaded moderately on factor 3. Finally, three sociological subscales loaded moderately on this factor (GRSLSS collaborative = -.32, LSP verbal-risk = -.25, and PEP several ways = .51). Factor 3 consists of an almost equal number of loadings from different learning style domains, thereby making interpretation difficult.

Factor 4 also consists of loadings from subscales of several different learning style domains. Two environmental, two cognitive, one perceptual modality, and two physiological subscales loaded high on this factor.

Therefore, interpretation cannot be made for this factor. However, some evidence of convergence validity is provided for the auditory subscales, along with the high-loading physiological subscales of sound.

Factor 5 has high loadings from two learning style domains, making interpretation not possible. Two sociological subscales had high loadings (GRSLSS collaborative and competitive), and two sociological subscales had moderate loadings (GRSLSS participation = .32 and LSP verbal-risk = .34) on this factor. Furthermore, two perceptual modality subscales had high loadings (PEP auditory and LSP visual) and two had moderate loadings (PEP kinesthetic = .40, and LSP auditory = .37) on factor 5.

Loadings on factor 6 are split among several learning style domains. Two environmental subscales (PEP and LSP light) loaded high on this factor. Additionally, four perceptual modality subscales loaded onto factor 6 including PEP tactile, PEP kinesthetic, LSP emotive, and LSP auditory. This factor cannot be named because of the high loadings of subscales of various learning style domains. However, there is some evidence of convergent validity for the posture subscales because the same subscale from two instruments loaded onto the same factor.

Several learning style dimensions also define factor 7. Five physiological subscales loaded onto the factor, as well as one environmental, two emotional, and four sociological subscales. Because of the variety of learning style domains represented by the loadings on this factor, it cannot be interpreted.

The exploratory factor analysis of all instrument subscales for the college sample extracted seven factors with eigenvalues greater than 2.0, of which only one was clearly interpretable (factor one = physiological). Because only one out of seven factors could be interpreted, this exploratory factor analysis does not provide much convergent evidence of construct validity for the instruments.

Subscale Correlations

The second method of assessing the convergent construct validity of the constructs was to correlate related subscales of all of the instruments. Instrument subscales were correlated with the same subscales of other tests to see if they measured the same learning style construct. Correlations were computed for all similar subscales of the instruments and are listed (collapsed across the samples) in Table 16. Caution should be used when interpreting these coefficients due to small sample sizes.

As can be seen in the table, none of the scales correlated statistically significantly for the physiological learning style domain, indicating low construct validity for this area. However, correlations for the environmental and emotional domains were all moderate and statistically significant. None of the instruments correlated highly for

Table 16

Correlations of Same Subscales of Various Instruments Demonstrating Construct Validity for Both Samples Collapsed

Subscale	Subscale	r	p	n
Physiological Domain				
LSP early morning	LSI evening/morning	-.01	n.s.	92
LSP late morning	LSI late morning	.20	n.s.	92
LSP afternoon	LSI afternoon	-.11	n.s.	92
LSP evening	LSI evening/morning	.03	n.s.	92
LSP early morning	PEP evening/morning	.31	n.s.	51
LSP late morning	PEP late morning	-.21	n.s.	51
LSP afternoon	PEP afternoon	.43	n.s.	51
LSP evening	PEP evening/morning	-.08	n.s.	51
Emotional Domain				
LSP persistence	LSI Persistence	.52	.001	92
LSP persistence	PEP Persistence	.37	.001	51
Environmental Domain				
LSP sound	LSI sound	.44	.001	92
LSP light	LSI light	.59	.001	92
LSP temperature	LSI temperature	.41	.001	92
LSP posture	LSI design	.37	.001	92
LSP sound	PEP sound	.65	.001	51
LSP light	PEP light	.61	.001	51
LSP temperature	PEP temperature	.68	.001	51
LSP posture	PEP design	.75	.001	51
Sociological Domain				
LSP grouping	LSI alone/peers	-.19	n.s.	92
LSP grouping	PEP alone/peers	-.56	.001	51
LSP grouping	GRSLSQ independent	.46	.001	51
LSP grouping	GRSLSQ dependent	-.06	n.s.	51
LSP verbal risk	GRSLSQ avoidant	-.24	n.s.	51
LSP verbal risk	GRSLSQ collaberative	.40	.01	51
PEP alone/peers	GRSLSQ independent	-.14	n.s.	104
PEP alone/peers	GRSLSQ dependent	-.05	n.s.	104
Perceptual Modality Domain				
LSP manipulative	LSI tactile	.02	n.s.	92
LSP visual	LSI visual	.04	n.s.	92
LSP auditory	LSI auditory	-.09	n.s.	92
LSP manipulative	PEP tactile	.22	n.s.	51
LSP visual	PEP visual	-.01	n.s.	51
LSP auditory	PEP auditory	.04	n.s.	51
LSP visual	ELSIE visualization	.47	.001	93
LSP auditory	ELSIE listening	.50	.001	93
LSP emotive	ELSIE emotive	.33	.001	93
ELSIE visualization	LSI visual	.04	n.s.	99
ELSIE auditory	LSI auditory	-.13	n.s.	99
Cognitive Domain				
LSP analytic (college)	Group Embedded Figures Test	.47	.001	49
LSP analytic (middle school)	Group Embedded Figures Test	.51	.001	94

Note. This table is not in the format of a typical correlation table because there are too many empty cells due to the fact that all six instruments were not administered to both samples.

the sociological dimension. The only statistically significant correlations for the perceptual modality domain were between the ELSIE and the LSP, but these correlations are only moderate. Finally, the LSP analytic subscale correlated moderately and statistically significantly with the GEFT for both the middle-school and college samples.

Convergent and Discriminant Construct Validity

Another procedure used to assess the construct validity of the instruments was the assessment of six multitrait-multimethod matrices. These matrices also allowed for an assessment of discriminant construct validity. Only three learning style domains had enough methods measuring the same traits to be used in the multitrait-multimethod matrices. These domains included environmental, perceptual modality, and physiological learning styles. Separate multitrait-multimethod matrices were constructed for each of these learning style domains. The same test-retest reliability coefficients as previously presented are shown again along the diagonals of the matrices. These coefficients are discussed on page 41.

Confirmatory Factor Analyses

The data in these matrices were first analyzed by the confirmatory factor analysis method using LISREL 8.12 (Jöreskog & Sörbom, 1994). Typically, many researchers allow methods and traits to correlate when doing CFA.

However, there is no theory to suggest that learning style methods or domains should be related. Additionally, when attempted, none of the CFA analyses would converge when traits or methods were allowed to correlate among themselves and/or with each other. Also, when these correlations are fixed to zero, the variance can be decomposed into additive trait, method, and error components (Marsh, 1989). For these reasons, the method and trait correlations were fixed to zero for all of the CFA models analyzed below. Caution should be used when interpreting the results of the confirmatory factor analyses due to small sample sizes.

Environmental domain of learning style, middle-school sample. Two multitrait-multimethod matrices were used for the environmental learning style domain, one for each sample. The matrix of correlations for the middle-school sample included subscales of two methods (LSP and LSI) assessing four traits (sound, light, temperature, and posture). This matrix of correlations can be seen in Table 17.

The hypothesized confirmatory factor analysis model for the environmental domain using the middle-school sample is shown in Figure 1. The two method factors and four trait factors are shown in circles, whereas the eight measured subscale indicators are in squares. The CFA for the middle-school model would not produce a result, exhibiting that it would not converge. This indicates problems with the

Table 17

<u>Multitrait-Multimethod Matrix--Environmental Domain of Learning Style, Middle-School Sample</u>

Subscale	LSP(s)	LSP(l)	LSP(t)	LSP(p)	LSI(s)	LSI(l)	LSI(t)	LSI(p)
LSP(s)	(.94) **							
LSP(l)	.10	(.45) **						
LSP(t)	-.14	.08	(.87) **					
LSP(p)	-.33 *	.05	.16	(.81) **				
LSI(s)	**.44 ****	.31	-.06	-.10	(.68) **			
LSI(l)	.12	**.59 ****	-.05	-.03	.16	(.61) **		
LSI(t)	.06	.12	**.41 ****	-.01	.06	.10	(.52) **	
LSI(p)	-.13	.15	.06	**.37 ****	-.20	.17	-.11	(.24)

Note. Test-retest reliability coefficients are in parentheses. Methods: LSP = Learning Style Profile, LSI = Learning Style Inventory. Traits: s = sound, l = light, t = temperature, p = posture.

* $p < .01$.

** $p < .001$.

hypothesized model and/or the CFA analysis (Jöreskog & Sörbom, 1994).

<u>Environmental domain of learning style, college sample.</u> The multitrait-multimethod matrix of correlations for the college sample included subscales of two methods (LSP and PEP), which assessed the same four traits (sound, light, temperature, and posture). This matrix is shown in Table 18. The confirmatory factor analysis model for the environmental domain using the college sample is displayed in Figure 2.

The analysis of the college model did converge and produce results. There were, however, serious problems with the variances and covariances of the residuals of the indicators. Because there was an improper solution, the results should be interpreted with caution. The LISREL maximum likelihood estimated path coefficients are shown in Figure 2. These estimates indicate support for construct validity for the traits because they are high (.78 to .95). Additionally, the method estimates are lower (-.15 to -.60), which supports high construct validity for the scales because high method factors would indicate error when using a multitrait-multimethod CFA model. This is because high method coefficients indicate that the measurements depend too much on the particular instrument used to measure the learning style, rather than the trait itself. Therefore, low method coefficients are desired to support the construct

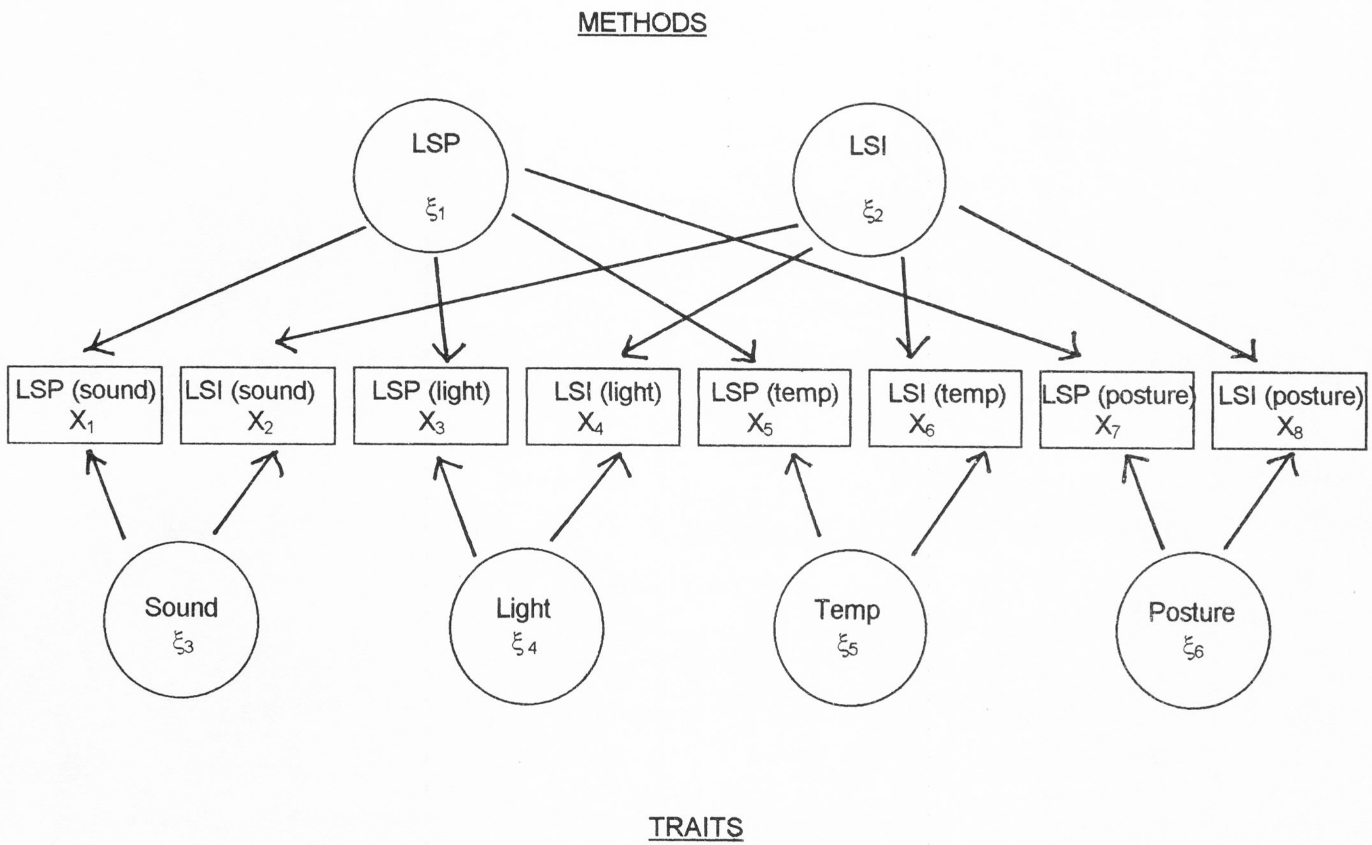


Figure 1. Hypothesized model for environmental domain of learning style, middle-school sample.

Table 18

<u>Multitrait-Multimethod Matrix--Environmental Domain of Learning Style, College Sample</u>

Subscale	LSP(s)	LSP(l)	LSP(t)	LSP(p)	PEP(s)	PEP(l)	PEP(t)	PEP(p)
LSP(s)	(.94)**							
LSP(l)	.03	(.45)**						
LSP(t)	.06	.11	(.87)**					
LSP(p)	-.21	.17	-.03	(.81)**				
PEP(s)	**.65 ****	.02	.02	-.34	(.58)**			
PEP(l)	-.12	**.61 ****	.09	.27	-.22	(.75)**		
PEP(t)	-.04	.21	**.68 ****	.09	.04	-.19	(.76)**	
PEP(p)	-.01	.23	-.14	**.75 ****	-.16	.35 **	-.20	(.71)**

Note. Test-retest reliability coefficients are in parentheses. Methods: LSP = Learning Style Profile, PEP = Productivity Environmental Preference Scale. Traits: s = sound, l = light, t = temperature, p = posture.

* $p < .01$

** $p < .001$

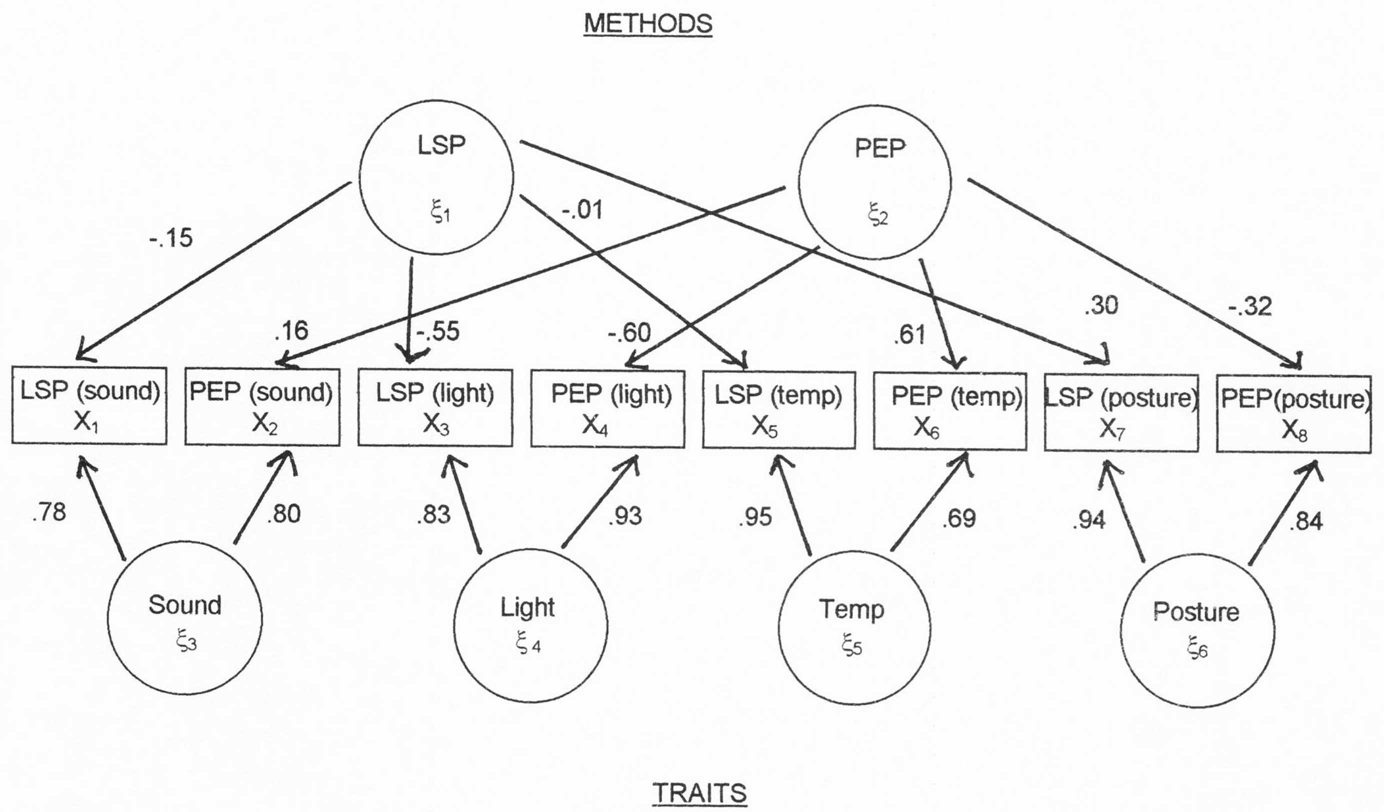


Figure 2. Hypothesized model for environmental domain of learning style, college sample.

validity of the scales. However, as mentioned, the estimates are suspect due to the improper solution of the CFA. This is indicated by the fact that the coefficients for each subscale add to greater than one.

Additionally, the total variance can be partitioned to show the variance due to method, trait, and error sources. Table 19 shows these variance components. Again, these numbers should be interpreted with caution due to the improper solution, as is evidenced by the negative error variance for light measured by the PEP. For the LSP method, trait accounts for about 77% of the variance, method accounts for about 10%, and random error explains the remaining 13% of the variance. For the PEP method, trait accounts for about 67% of the variance, method accounts for about 22%, and random error explains the remaining 11% of the variance.

Although the fit indices should also be interpreted with caution, they do not support the fit of the model. The goodness of fit of the model is very low as indicated by the statistically significant chi-square (χ^2 = 52.54, df = 12, p < .00). Although the GFI (.89) is high, when adjusted for degrees of freedom, the AGFI is relatively low (.66), indicating a poor fit of the model. Finally, residuals are high (-.34 to .34), also indicating a poor fit.

There are a few high correlations scattered throughout the matrix that may have created internal statistical

Table 19

Variance Components Partitioned for Trait, Method, and Error Sources for the College Sample, Environmental Domain

Subscale	Trait	Method	Error
LSP			
Sound	.61	.02	.37
Light	.69	.30	.01
Temperature	.90	.00	.10
Posture	.88	.09	.03
PEP			
Sound	.64	.03	.33
Light	.86	.36	-.22[a]
Temperature	.48	.37	.15
Posture	.71	.10	.19

[a]The negative error variance is due to improper solutions.

conflicts and may have resulted in an unsolvable model. For example, the correlation between LSP posture and PEP sound is -.34, and the correlation between LSP posture and PEP light is .27. Also, the correlation between LSP light and PEP temperature is high (.21). All three of these correlations should be very low because they represent discriminant validity between different methods measuring different traits. Additionally, there are some inconsistencies in the correlations. For instance, the correlation between PEP light and LSP sound is negative (-.12), whereas there is a positive correlation between the opposite, LSP light and PEP sound (.02).

Perceptual modality domain of learning style, two methods, three traits. Two multitrait-multimethod matrices were used for the perceptual modality learning style domain using the middle-school sample. Only the middle-school sample was used for this analysis because there were not enough methods measuring perceptual modality traits for the college sample to produce a multitrait-multimethod matrix. The first multitrait-multimethod matrix included two methods and three traits, whereas the second matrix consisted of three methods and two traits.

The first multitrait-multimethod matrix of correlations for the perceptual modality domain includes subscales of two methods (ELSIE and LSP) assessing three traits (verbal, auditory, and emotive). The LSI was not included in this model because it does not have an emotive subscale. This matrix can be seen in Table 20. The hypothesized confirmatory factor analysis model is shown in Figure 3. The CFA for this model did not converge, indicating problems with the model and/or the CFA analysis.

Perceptual modality domain of learning style, three methods, two traits. The second multitrait-multimethod matrix of correlations for the perceptual modality domain

Table 20

Multitrait-Multimethod Matrix--Perceptual Modality Domain of Learning Style, Middle-School Sample (2 Methods, 3 Traits)

Subscale	ELSIE(v)	ELSIE (a)	ELSIE(e)	LSP(v)	LSP(a)	LSP(e)
ELSIE(v)	(.65)**					
ELSIE(a)	-.39 **	(.67) **				
ELSIE(e)	-.16	-.23	(.54) **			
LSP(v)	**.13**	-.31 *	-.31 *	(.47)**		
LSP(a)	-.19	**.50 ***	.04	-.64 **	(.35)**	
LSP(e)	.05	-.25	**.33 ****	-.39 **	-.41 **	(.40) **

Note. Test-retest reliability coefficients are in parentheses. Methods: ELSIE = Edmonds Learning Style Inventory Exercise, LSP = Learning Style Profile. Traits: v = verbal, a = auditory, e = emotive.
 * $p < .01$.
** $p < .001$.

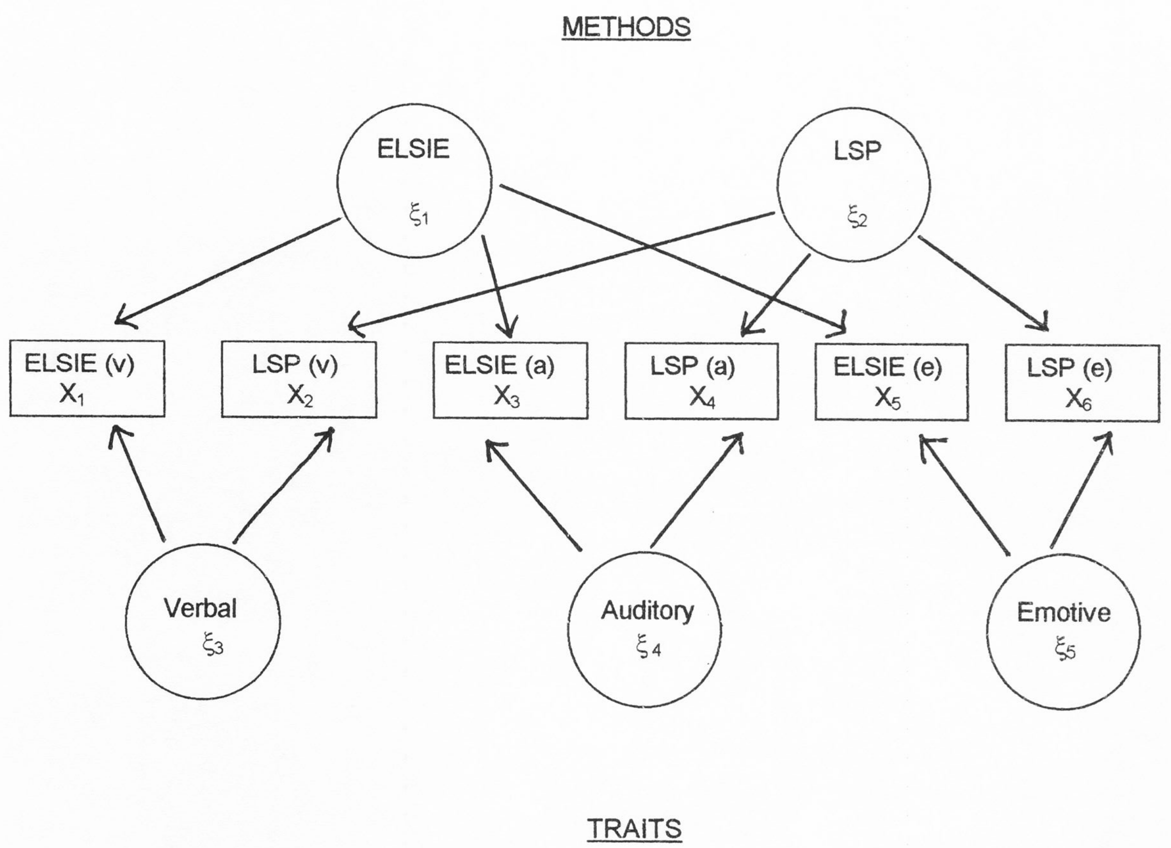


Figure 3. Hypothesized model for perceptual modality domain of learning style, middle-school sample (2 methods, 3 traits).

includes subscales of three methods (ELSIE, LSP and LSI) assessing two traits (verbal and auditory). This matrix can be seen in Table 21. The hypothesized confirmatory factor analysis model is shown in Figure 4. Although the analysis of this model did converge, there were problems with the variances and covariances of the residuals of the indicators. Like the earlier model, because there is an improper solution, the results should be interpreted with caution. The LISREL maximum likelihood estimated path coefficients are shown in Figure 4. These estimates indicate more support for the method factors than the trait factors. This is a problem for construct validity, because high method coefficients indicate error in measurement. However, as mentioned, these estimates are suspicious due to the improper solution. This is evidenced by the fact that the coefficients add to greater than one.

The total variance is partitioned to show the variance due to the method, trait, and error sources in Table 22. Again, these numbers should be interpreted with caution due to the improper solution, as is evidenced by the negative error variance for auditory measured by the LSI. For the ELSIE method, trait accounts for about 39% of the variance, method accounts for about 33%, and random error explains the remaining 28% of the variance. For the LSP method, trait accounts for about 31% of the variance, method accounts for about 51%, and random error explains the remaining 19% of

Table 21

Multitrait-Multimethod Matrix--Perceptual Modality Domain of Learning Style, Middle-School Sample (3 Methods, 2 Traits)

Subscale	ELSIE(v)	ELSIE(a)	LSP(v)	LSP(a)	LSI(v)	LSI(a)
ELSIE(v)	(.65) **					
ELSIE(a)	-.44 **	(.67) **				
LSP(v)	**.47 ****	-.31 *	(.47) **			
LSP(a)	-.33 **	**.50 ****	-.64 **	(.35) **		
LSI(v)	**.04**	.01	**.04**	.00	(.38) **	
LSI(a)	-.01	**-.13**	.06	**-.09**	-.61 **	(.41) **

Note. Test-retest reliability coefficients are in parentheses. Methods: ELSIE = Edmonds Learning Style Inventory Exercise, LSP = Learning Style Profile, LSI = Learning Style Inventory. Traits: v = verbal, a = auditory.

* $p < .01$.

** $p < .001$.

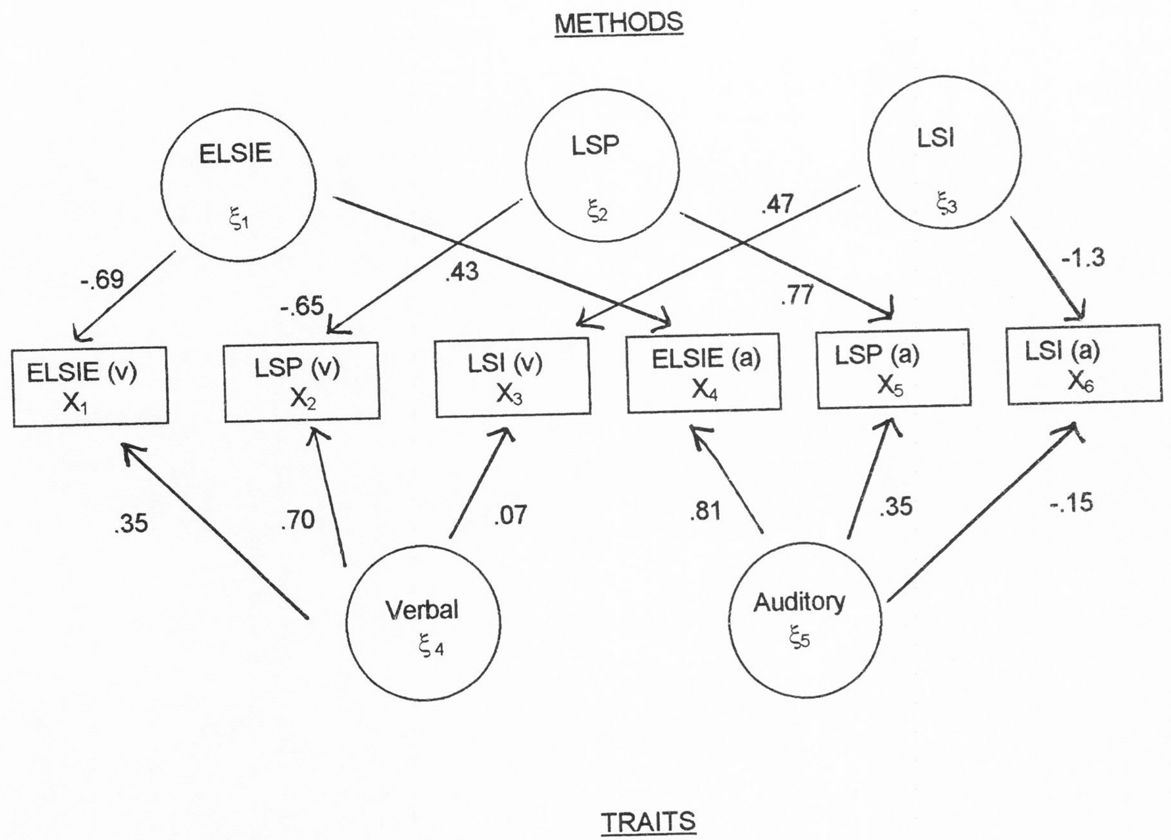


Figure 4. Hypothesized model for perceptual modality domain of learning style, middle-school sample (3 methods, 2 traits).

Table 22

Variance Components Partitioned for Trait, Method, and Error Sources for the Perceptual Modality Domain (3 Methods, 2 Traits)

Subscale	Trait	Method	Error
ELSIE			
Visual	.12	.48	.40
Auditory	.66	.18	.16
LSP			
Visual	.49	.42	.09
Auditory	.12	.59	.29
LSI			
Visual	.00	.22	.78
Auditory	.02	1.69	-.71[a]

[a]The negative error variance is due to improper solutions.

the variance. Finally, for the LSI method, trait accounts for about 1% of the variance and method accounts for about 95% of the variance. Yet, these numbers are inaccurate, because of the negative error variance for the LSI auditory caused by an improper solution.

Although they should also be interpreted with caution, the fit indices do not support the fit of the model. The goodness-of-fit chi-square is low and statistically significant (χ^2 = 18.66, df = 3, p < .00), indicating a poor fit of the model. Additionally, although the GFI (.94) is high, when adjusted for degrees of freedom, the AGFI is relatively low (.58), indicating a poor fit of the model. Finally, residuals are high (-.33 to .22), also indicating a poor fit.

There are a few high correlations scattered throughout the matrix that may have created internal statistical conflicts and may have resulted in an unsolvable model. For example, the correlation between LSP visual and LSP auditory is -.64 and the correlation between LSI visual and LSI auditory is high (-.61). Also, the correlation between ELSIE visual and ELSIE auditory is -.44 These correlations should all be very low because they each represent discriminant validity between two traits measured by the same scale. Additionally, there are some inconsistencies in the correlations. For instance, the correlation between LSI visual and ELSIE auditory is positive (.01), whereas there is a negative correlation between the opposite, LSI auditory and ELSIE visual (-.01).

Physiological domain of learning style, middle-school sample. Two multitrait-multimethod matrices were used for the physiological learning style domain, one for each sample. The matrix of correlations for the middle-school sample included subscales of two methods (LSP and LSI) assessing four traits (early morning, late morning, afternoon, and evening). This matrix of correlations can be seen in Table 23. The hypothesized confirmatory factor analysis model is shown in Figure 5. This analysis did not converge, indicating that the model does not fit the data and/or there were problems with the CFA analysis.

Physiological domain of learning style, college sample. The matrix of correlations for the college sample included subscales of two methods (LSP and PEP) assessing four traits (early morning, late morning, afternoon, and evening). This matrix of correlations can be seen in Table 24. The hypothesized confirmatory factor analysis model is shown in Figure 6. This analysis also did not converge, indicating that the model does not fit the data and/or there were problems with the CFA analysis.

Campbell and Fiske Criteria

Because there were problems inherent in the confirmatory factor analyses and results were not produced for several multitrait-multimethod matrices, the data were subsequently analyzed in terms of the Campbell and Fiske (1959) criteria. These criteria (presented in Table 7) were used to further assess the convergent and discriminant construct validity of the instruments.

Environmental domain of learning style, middle-school sample. The multitrait-multimethod matrix for the middle-school sample indicates good convergent validity by the

Table 23

<u>Multitrait-Multimethod Matrix--Physiological Domain of Learning Style, Middle-School Sample</u>

Subscale	LSP(em)	LSP(lm)	LSP(a)	LSP(e)	LSI(em)	LSI(lm)	LSI(a)	LSI(e)
LSP(em)	(.41)**							
LSP(lm)	.09	(.30)**						
LSP(a)	-.01	-.06	(.61)**					
LSP(e)	.14	.01	-.10	(-.08)				
LSI(em)	**-.01**	.07	-.27 *	.03	(.53)**			
LSI(lm)	.26	**.20**	-.08	-.09	.27 *	(.41)**		
LSI(a)	.15	.13	**-.11**	.11	-.11	.13	(.48)**	
LSI(e)	-.01	.07	-.27 *	**-.03**	1.00	.27 *	-.11	(.53)**

Note. Test-retest reliability coefficients are in parentheses. Methods: LSP = Learning Style Profile, LSI = Learning Style Inventory. Traits: em = early morning, lm = late morning, a = afternoon, e = evening.

* $p < .01$.

** $p < .001$.

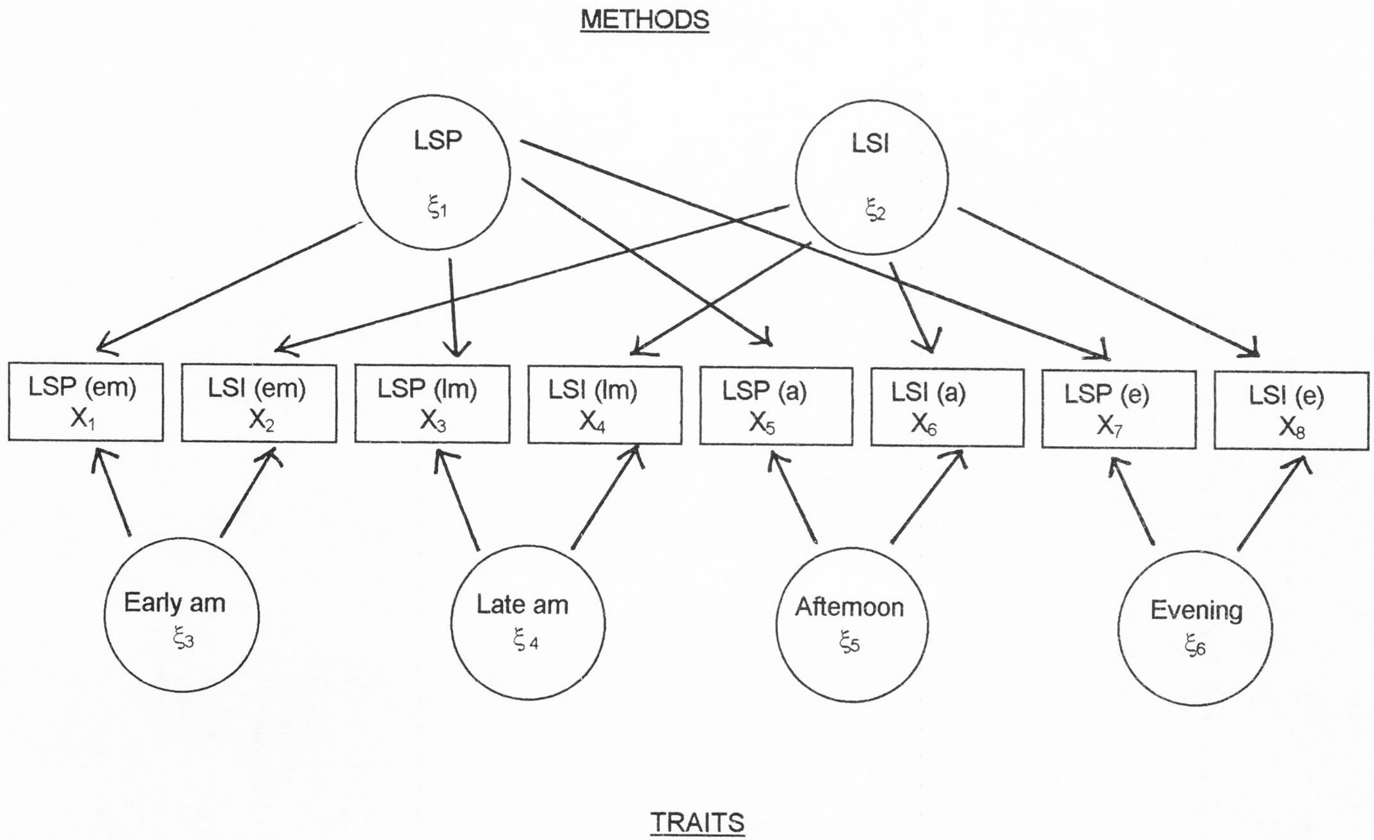


Figure 5. Hypothesized model for physiological domain of learning style, middle-school sample.

Table 24

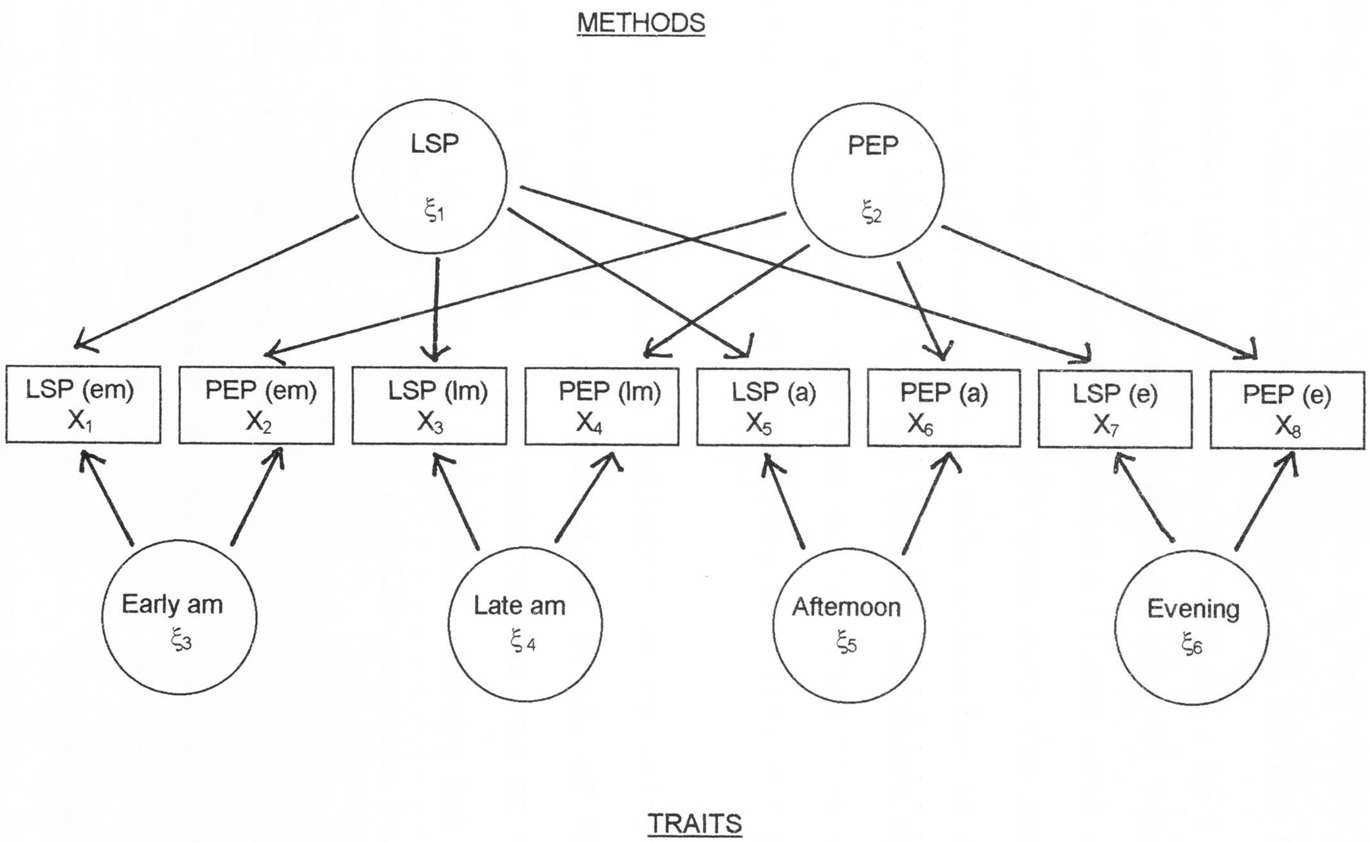
Multitrait-Multimethod Matrix--Physiological Domain of Learning Style, College Sample

Subscale	LSP(em)	LSP(lm)	LSP(a)	LSP(e)	PEP(em)	PEP(lm)	PEP(a)	PEP(e)
LSP(em)	(.82)**							
LSP(lm)	-.20	(.22)						
LSP(a)	-.45 **	.10	(.83)**					
LSP(e)	.10	-.13	.12	(.78)**				
PEP(em)	**.31**	-.15	-.78 **	-.08	(.80)**			
PEP(lm)	-.05	**-.21**	-.18	-.14	.38 *	(.38)		
PEP(a)	-.05	.21	**.43**	.00	-.65 **	-.81 **	(.72)**	
PEP(e)	.31	-.15	-.78 **	**-.08**	1.00 **	.38 **	-.65 **	(.80)**

Note. Test retest reliability coefficients are in parentheses. Methods: LSP = Learning Style Profile, PEP = Productivity Environmental Preference Scale. Traits: em = early morning, lm = late morning, a = afternoon, e = evening.

* $p < .01$.

** $p < .001$.



<u>Figure 6.</u> Hypothesized model for physiological domain of learning style, college sample.

statistically significant correlations between the different methods measuring the same traits (.44, .59, .41, .37). Additionally, there is some evidence of discriminant validity. First, the coefficients in the validity diagonals (.44, .59, .41, .37) are higher than all of the other values in the matrix.

The second requirement for discriminant validity is that each variable should correlate higher with a different method measuring the same trait than with the same method measuring a different trait. This criterion is met in this matrix. For example, the LSP measure of sound correlates higher with the LSI measure of sound (.44) than with LSP measures of light (.10), temperature (-.14) and posture (-.33).

Finally, discriminant validity can be evidenced by the same pattern of trait interrelations in all of the heterotrait triangles. This matrix consists of similar correlations in all of the triangles, except for the correlation between LSP sound and LSP posture (-.33). Yet, overall, the discriminant validity of the data is supported according to the criteria.

<u>Environmental domain of learning style, college sample.</u> The multitrait-multimethod matrix for the college sample also shows high convergent validity. This is seen by the statistically significant correlations between the different methods measuring the same traits (.65, .61, .68, .75).

According to the Campbell and Fiske (1959) criteria, there is evidence of discriminant validity. First, the coefficients in the validity diagonals (.65, .61, .68, .75) are higher than the values in their respective heterotrait, heteromethod triangles. Additionally, each variable correlated higher with a different method measuring the same trait than with the same method measuring a different trait.

However, there is not a similar pattern of trait interrelations in all of the heterotrait triangles. This matrix consists of both large and small correlations scattered arbitrarily throughout the matrix. Although the data in this matrix do not support this criterion of discriminant validity, the other criteria for both discriminant and convergent validity are met.

Perceptual modality domain of learning style, 2 methods, 3 traits. An examination of this matrix indicates that the evidence for convergent validity is very weak for the auditory ($r = .50$, $p < .001$), emotive ($r = .33$, $p < .001$), and visual ($r = .13$, n.s.) traits. Additionally, the evidence of discriminant validity is very weak (even nonexistent). First, the coefficients in the validity diagonals are not higher than some of the values in their respective heterotrait, heteromethod triangles. Secondly, the variables did not correlate higher with a different method measuring the same trait than with the same method measuring a different trait.

Lack of support for discriminant validity is also found when analyzing the pattern of trait interrelations existing in all of the heterotrait triangles. This matrix consists of high and low correlations scattered haphazardly throughout the triangles. Therefore, neither convergent nor discriminant validity is supported by this matrix according to the Campbell and Fiske criteria.

Perceptual modality domain of learning style, 3 methods, 2 traits. An examination of this matrix indicates convergent validity between the ELSIE and LSP for the visual trait (r = .47, p < .001) and auditory trait (r = .50, p <.001). There is no support of convergent validity between the ELSIE and the LSI for visual and auditory traits, as well as between the LSP and LSI for visual and auditory traits.

According to the Campbell and Fiske (1959) criteria, there is contradictory evidence of discriminant validity. First, some of the coefficients in the validity diagonals are higher than the values in their respective heterotrait, heteromethod triangles, whereas other validity coefficients are not. For example, the correlation between the ELSIE and the LSP for visual (.47) is higher than the correlation between the ELSIE for the visual and auditory (-.44). However, the same correlation is lower than the correlation between the LSP visual and LSP auditory (-.64). Secondly, although some of the variables correlated higher with a different method measuring the same trait than with the same method measuring a different trait, the opposite also occurred.

Finally, the pattern of trait interrelations is not the same in all of the heterotrait triangles. On the contrary, this matrix consists of high and low correlations scattered haphazardly throughout the triangles. According to the Campbell and Fiske criteria, the data in this multitrait-multimethod matrix do not show strong support of either convergent or discriminate validity.

Physiological domain of learning style, middle-school sample. The Campbell and Fiske criteria indicate no convergent validity for this matrix as evidenced by the low nonsignificant correlations between the different methods measuring the same traits (-.01, .20, -.11, -.03). Also, there is no evidence of discriminant validity. First, the coefficients in the validity diagonals are lower than many of the values in their respective heterotrait, heteromethod triangles. For example, the correlations in the validity diagonal (-.01, .20, -.11, -.03) are smaller than many of the other correlations such as .26, .27, and 1.0.

Secondly, the variables did not correlate higher with a different method measuring the same trait than with the same method measuring a different trait. Finally, this matrix consists of high and low correlations scattered throughout the triangles in an erratic manner. Therefore, neither convergent nor discriminant validity is supported by this matrix according to the Campbell and Fiske criteria.

Physiological domain of learning style, college sample. With regard to the Campbell and Fiske (1959) criteria, there is no support of convergent validity (boldface in table), as is indicated by the nonsignificant correlations between the different methods measuring the same traits (.31, -.21, .43, -.08). Additionally, there is no evidence of discriminant validity. First, the coefficients in the validity diagonals are lower than many of the values in their respective heterotrait, heteromethod triangles. For example, the correlations in the validity diagonal (.31, -.21, .43, -.08) are smaller than many of the other correlations such as -.45, -.78, -.65, and 1.0.

Secondly, each variable did not correlate higher with a different method measuring the same trait than with the same method measuring a different trait. Finally, this matrix consists of high and low correlations scattered throughout the triangles. Therefore, neither convergent nor discriminant validity is supported by this matrix according to the Campbell and Fiske criteria.

CHAPTER V

DISCUSSION

The main purpose of this study was to provide reliability and construct validity data for the six instruments shown to be the most promising in measuring learning style: the LSI, the PEP, the LSP, the GRSLSS, the ELSIE, and the GEFT. Two additional objectives were:

1. To compare the respective reliability and validity of the three narrowly focused unidimensional scales with the three multidimensional scales.
2. To determine whether the instruments intended for both children and adult populations are equally reliable and valid for use with both age levels.

First Objective

The first objective of this study was to provide psychometric data for the six most promising learning style instruments. This information is provided below.

Reliability

The majority of the reliability coefficients for the instrument subscales are moderate, although statistically significant. This provides some favorable evidence for the reliability of the scales. The lowest reliability coefficients were for the LSP scores from the middle-school sample. However, even these coefficients were moderate.

The reliability coefficients indicate that the instruments are consistent and would produce similar results for the same person when taken again one month after the initial testing session. Previous research findings regarding reliability of the instruments are compared to the results of this study below. Past reliability findings are found in Table 4. For the most part, overall reliability estimates from this investigation appear to be the same or better than those found in previous studies.

Edmonds Learning Style Identification Exercise

Test-retest reliability of the ELSIE in this study averaged .61, which is moderate. There is a very limited amount of research available regarding the reliability of the ELSIE. Yet, the little evidence that does exist indicates high test-retest reliability ranging from .95 to .99 (Curry, 1987). One reason for the lower reliability of the ELSIE in this study may be because of the small sample size (*N* = 92) used here, as compared to the larger sample size used in the previous study (*N* = 763).

Grasha-Reichmann's Student Learning Style Scales

The results of this study show that the average test-retest reliability of the GRSLSS was .76. This is in agreement with past research, which has indicated that the GRSLSS has moderately high test-retest reliability ranging from .76 to .83 (Blackmore, 1984).

Productivity Environmental Preference Survey

This study found moderate test-retest reliability (average r =.67) for this instrument. On the contrary, a study by Murray-Harvey (1994) found low reliability of the PEP subscales ranging from .20 to .64 (Murray-Harvey, 1994). Therefore, this study provides better support of the consistency of the PEP. The most probable reason for this may be because the Murray-Harvey study used a 12-month time interval between testing, whereas the present investigation used only a 1-month time interval. The difference in results found for the two studies would be expected, because test-retest reliability coefficients decrease as the retest time interval increases (Anastasi, 1988).

Learning Style Inventory

This study found moderate reliability for the LSI, with an average of .54. However, there is no evidence of test-retest reliability for this instrument provided in the literature (Hughes, 1992).

Learning Style Profile

The test-retest reliability of the LSP for the middle-school students in this study averaged .45, and the scores of the college sample averaged .72. These reliability coefficients are poor to moderate. Likewise, the LSP has reports of poor to moderate reliability ranging from .36 to .82 for children (Blixt & Jones, 1995; Nagy, 1995). No past research is available regarding the reliability the LSP for collage-age students.

Group Embedded Figures Test

Test-retest reliability for the GEFT was .80 for the middle-school sample, and .80 for the college sample in this study. No evidence regarding test-retest reliability is reported in the manual (Witkin et al., 1971). However, the results of this study are similar to a study cited by Curry (1987) in which test-retest reliability ranged from .78 to .92.

Validity

Internal Structure Construct Validity

The various exploratory factor analyses in this study had conflicting results. However, the evidence of internal structure is high for many of the scales, indicating evidence of constructs. Overall, more favorable evidence is provided here for the internal structure of the scales than in the existing literature.

Edmonds Learning Style Identification Exercise. The results of the ELSIE exploratory factor analysis in this study support the three distinct underlying constructs that were hypothesized. There is no previous research regarding the validity of the ELSIE (Curry, 1987; DeBello, 1989).

Grasha-Reichmann's Student Learning Style Scales. In this study evidence of good construct validity was provided by the exploratory factor analysis because the three underlying traits that were expected did emerge. However, past research has indicated that the validity of the GRSLSS is moderate (Curry, 1987). One reason for this discrepancy is because previous validity evidence is for concurrent and predictive validity, whereas this study assessed construct validity.

Productivity Environmental Preference survey. The results of the exploratory factor analysis on the PEP are in strong support of the construct validity of this instrument. In fact, all but one subscale loaded onto factors representing the hypothesized underlying constructs of the PEP. On the contrary, the validity of the PEP has been reported as being poor (Murray-Harvey, 1994). This may be because Murray-Harvey only hypothesized four constructs for the PEP (perceptual modality and physiological were collapsed) when doing a factor analysis, whereas this study conceptualized five constructs.

Learning Style Inventory. This investigation provided good support for the construct validity of the LSI, as indicated by the exploratory factor analysis results. Four strong learning style factors emerged from the exploratory factor analysis, including emotional, sociological, and perceptual modality domains. Additionally, there was an adequate physiological factor, including high loadings of two out of three of the physiological subscales. Little past research is available regarding the validity of the LSI. The evidence that is available suggests that a previous factor analysis used to assess the construct validity of the LSI has unclear results, with a 32-factor solution, which may be the reason for the discrepancy with this study (Hughes, 1992).

Learning Style Profile. The exploratory factor analyses for both the middle-school and college samples provide some support of the construct validity of the LSP. For the middle-school sample, nine factors were extracted from the analysis, with only four being somewhat interpretable. Two of these factors may be interpreted as cognitive learning style factors. Additionally, an environmental and perceptual modality factor emerged. However, there were no clear factors for the sociological, emotional, and physiological dimensions of learning style.

For the college sample, of the eight factors that were extracted only four were somewhat interpretable. Two of these factors may be interpreted as physiological learning style factors. Additionally, one factor can be interpreted as cognitive and another factor as perceptual modality. Yet, no clear factors emerged for the sociological, emotional, and environmental dimensions of learning style.

Past research shows no evidence of construct validity for the LSP. The manual illustrates the factor analysis used to construct the instrument, yet no further analysis was done to assess the instrument's validity.

Cross Validation of Convergent Construct Validity

Although many of the instruments seem to have good internal structure, convergent validity evidence is contradictory. This suggests that even though each instrument is measuring certain unique constructs, these constructs may not be the same across instruments.

Factor analyses. The overall factor analysis for the middle-school sample extracted seven factors, five of which were interpretable. Factor 1 is emotional, factor 3 is cognitive, factors 4 and 6 are perceptual modality, and factor 7 represents the physiological domain of learning style. This analysis provides good support for the construct validity of the constructs.

However, the overall factor analysis for the college sample does not provide as much support for construct validity of the constructs as the middle-school analysis. Of the seven factors extracted, only one was interpretable.

Besides providing evidence of construct validity for the various learning style domains by factor loadings, these analyses also provided some evidence of convergent validity for various subscales of the instruments. Almost all factors in both the middle-school and college analyses had at least one pair of converging subscales and many factors had several pairs of converging subscales. This is additional evidence of construct validity of the constructs because many similar subscales of different instruments measured the same underlying constructs.

Subscale correlations. When considering the instruments separately, the results of the correlations of the ELSIE with other tests are low, indicating either poor construct validity, or this scale measures perceptual modality differently than the LSP and LSI. Correlations of the GRSLSS and other instruments are also low. This implies that either the construct validity of the GRSLSS is low, or that this instrument is measuring sociological learning style differently than the other instruments.

However, correlations between subscales of the PEP and the other instruments do provide support of good construct validity for the PEP. Likewise, there were high correlations of the LSI subscales with other instruments. Additionally, correlations between subtests of the LSP with other instruments provide some evidence of construct validity for the LSP.

The GEFT has been reported in past research to have good validity (Curry, 1987; Rule & Grippin, 1988). Yet, the correlations of the GEFT and the LSP analytic subscale are moderate for both the middle-school sample (r =.47) and the college sample ($\underline{r}$ =.51). This indicates that either the construct validity of the GEFT is questionable, or that these instruments may be measuring analytic cognitive learning style differently.

Overall, the correlations of same subscales of different instruments are low to moderate. This contradicts the evidence of construct validity from the exploratory factor analysis of the middle-school sample. Additionally, the low correlations for the physiological learning style domain contrasts the results of the overall exploratory factor analysis of the college sample. This analysis resulted in only one clearly interpretable factor, which is physiological in nature. One reason for this discrepancy may be that the correlations between the physiological subscales were inflated in the factor analysis because of the presence of all of the other instrument subscales.

There are two explanations for those results which indicate low convergent validity of the instruments. First, the instruments in this study may be assessing different constructs. However, another interpretation is that they are measuring different aspects of the same construct.

Convergent and Discriminant Construct Validity

The multitrait-multimethod matrices provided specific indications as to which constructs were being measured in the same manner by all instruments.

Confirmatory factor analysis. Two of the six confirmatory factor analyses converged and allowed for interpretation. However, these results are questionable due to problems with the variances and covariances of the residuals. The LISREL estimates provided by the CFA of the college sample, environmental learning style domain analysis indicated support for construct validity because they were high for traits and low for methods. However, the fit indices for this analysis did not support the model. Additionally, neither the LISREL parameter estimates nor the fit indices supported the construct validity of the three method, two trait perceptual modality model that was hypothesized.

Taken at face value, the results of the confirmatory factor analyses provide little evidence of construct validity for any of the subscales examined. This was expected for the perceptual modality and physiological domains, because the original correlations in the matrices indicated little systematic convergent or discriminant validity between the subscales. Instead, high and low correlations seemed to scatter arbitrarily throughout the matrices. Only the environmental matrices suggested construct validity, which was evidenced by the high monotrait-heteromethod correlations.

Furthermore, the results of the confirmatory factor analyses are disconcerting in that four analyses did not converge and the remaining two had variance and covariance problems. The most obvious reason for these problems would be that the hypothesized models are not adequate to describe the data. However, this is most likely not the reason for the problems with convergence. Although many researchers (Brannick & Spector, 1990; Kenny & Kashy, 1992; Marsh, 1989; Marsh & Hocevar, 1983; Schmitt et al., 1977; Widaman, 1985) have proposed confirmatory factor analysis as the preferred and most popular method of analyzing multitrait-multimethod matrices, similar convergence problems have been noted by others.

Several researchers (Brannick & Spector, 1990; Kenny & Kashy, 1992; Marsh, 1989) have found that these CFA problems may be intrinsic in the analysis. Brannick and Spector reanalyzed 18 published studies with the block-diagonal model multitrait-multimethod matrices using CFA. The block-diagonal model multitrait-multimethod correlates trait and method factors among themselves as well as with each other, which corresponds to Campbell and Fiske's (1959) conceptualization of the model (Kenny & Kashy, 1992). Of these analyses, 12 failed to converge, 3 showed identification warnings, and 17 had either negative error variances, correlations greater than 1.0, loadings greater than 1.0, or a matrix of factor correlations that was not positive definite, even though none of the individual correlations were greater than 1.0.

One difficulty with using CFA for multitrait-multimethod matrices is that estimation problems result when the model is underidentified and no unique mathematical solution exists for each parameter. Another problem can result when the model is misspecified with regard to correlations between trait and method factors (Kenny & Kashy, 1992; Marsh, 1989). Unfortunately, it is difficult to determine if these problems were encountered when doing this analysis because the output does not state if they have occurred. The results of the CFA analyses in this study support the argument cautioning researchers from discarding their hypothesized model as a result of CFA findings.

Campbell and Fiske criteria. The multitrait-multimethod matrices were also analyzed with regard to the Campbell and Fiske (1959) criteria. According to the criteria, correlations in the middle-school and college matrices of the environmental domain provided support of both convergent and discriminant validity. However, when considering the domains of perceptual modality and physiological learning style, there was no support for either convergent or discriminant validity as evaluated by the Campbell and Fiske criteria. This indicates that the ELSIE, LSP, and LSI do not measure perceptual modality learning style in a similar manner. Likewise, the LSP, LSI, and PEP most likely do not assess the physiological learning style construct in the same way.

Summary. Results of the CFA supported the convergent and discriminant construct validity of only the college sample, environmental domain. Similarly, the Campbell and Fiske (1959) criteria also supported the construct validity of this multitrait-multimethod matrix. Additionally, the Campbell and Fiske criteria supported the construct validity of the middle-school sample for the environmental domain. One reason the construct validity of this matrix was supported by the criteria and not by the CFA may be because of problems with the CFA analysis. Another reason for the discrepancy of results may be because the monotrait-heteromethod correlations were not as high for the middle-school matrix as the college sample matrix.

Second Objective

The second objective of this investigation was to compare the respective reliability and validity of the three narrowly focused unidimensional scales with the three multidimensional scales.

Learning Style Profile Analytic Subscale Versus the Group Embedded Figures Test

The first comparison concerns the multidimensional LSP to the unidimensional GEFT. First, the respective validity of the scales can be compared. Based on the psychometric data provided by the exploratory factor analyses, the internal consistency of the LSP is acceptable, and therefore, one can assume that the analytic subscale is measuring a unique construct. Given this, one might question the relation of this construct with that proposed by the GEFT. The cross-instrument validation using exploratory factor analysis supports the claim that the two instruments are measuring the same construct for the middle-school sample. This can be seen by the fact that the LSP analytic subscale and GEFT both loaded high on the same factor. Therefore, because both the multidimensional and unidimensional instruments are measuring the construct as well, one might assume that they could be used interchangeably.

However, the low correlations between these scales indicate that the instruments are measuring different aspects of the cognitive learning style construct. Additionally, the LSP analytic subscale and GEFT did not even load on the same factor for the overall exploratory factor analysis of the college sample. These results indicate that the LSP and GEFT are not measuring the same dimensions of analytic cognitive learning style for this sample.

The reliability of the GEFT and the LSP analytic subscale is shown in Table 25. The reliability of the GEFT is higher than the LSP analytic subscale for both the middle-school sample and the college sample. The lower

Table 25

Test-Retest Reliability of the Learning Style Profile Analytic Subscale and the Group Embedded Figures Test

Instrument	Test-retest reliability
GEFT (middle-school)	.80
LSP Analytic (middle-school)	.61
GEFT (college)	.84
LSP Analytic (college)	.55

reliability for the LSP for both samples may be because only a few items of this scale measure this dimension, rather than the entire test of the GEFT. Another reason for the discrepancy for the college sample may be the smaller sample size for the test-retest reliability of the LSP ($\underline{n}$ = 9) versus the GEFT ($\underline{n}$ = 39). Regardless of the reason, the lower reliability of the LSP suggests that this instrument may measure a person's analytical learning style less consistently than the GEFT.

Based on the results, if the goal is to measure the overall analytic construct, but not focus on specific aspects, the GEFT may cautiously be used interchangeably with the LSP. In this case, because the GEFT has higher test-retest reliability than the LSP, one might choose the GEFT because it is a more consistent measure of analytic cognitive learning style. However, if one is interested in assessing the overall analytic cognitive construct, the LSP and GEFT should not be substituted for one another because they appear to assess different aspects of analytic cognitive learning style.

Learning Style Profile and Learning Style Inventory Versus the Edmonds Learning Style Identification Exercise

A second comparison can be made between the multidimensional LSP and LSI instruments and the unidimensional ELSIE. In terms of the validity of these instruments, the separate instrument exploratory factor analyses indicate that all three instruments have good internal structure. Therefore, the instruments adequately assess the perceptual modality learning style constructs that they purport to measure. Likewise, the cross-instrument validation using exploratory factor analysis provides some support of the construct validity of the perceptual modality construct. This can be seen by the fact that the perceptual modality subscales from the three instruments loaded together on several factors. Based on this evidence, both the multidimensional and unidimensional instruments are measuring the perceptual modality construct equally well, and one might want to use them interchangeably.

However, the correlations between subscales of instruments, as well as the convergent and discriminant validity provided by the multitrait-multimethod matrices, indicate that the instruments are measuring the perceptual modality construct differently. One reason for this may be because the ELSIE has an additional perceptual modality measure of "written word" and the LSP and LSI additionally measure tactile ability.

The test-retest reliability coefficients for the perceptual modality subscales of these instruments can be seen in Table 26. As illustrated, the reliability of the three scales is about the same, ranging from poor to moderate. Based on the reliability, none of these instruments is a more consistent indicator of perceptual learning style.

The ELSIE, LSP, and LSI should not be substituted for one another when assessing perceptual modality learning style because they assess different aspects of this construct. Additionally, the reliability evidence does not suggest any reason to chose one instrument over another when assessing this learning style domain.

Learning Style Profile and Productivity Environmental Preference Survey Versus the Grasha-Reichmann's Student Learning Styles Scales

A final comparison can be made between the

Table 26

Test-Retest Reliability of the ELSIE, LSP, and LSI Perceptual Modality Subscales

Instrument	Test-retest reliability
ELSIE visual	.65
ELSIE auditory	.67
ELSIE emotive	.54
LSP visual	.47
LSP auditory	.35
LSP emotive	.40
LSI visual	.38
LSI auditory	.41

multidimensional PEP and LSP instruments and the unidimensional GRSLSS. Concerning validity, the separate instrument exploratory factor analyses indicate that all three instruments have good internal structure. Therefore, these instruments do assess a sociological learning style as they purport. However, the cross-instrument validation using exploratory factor analysis does not provide support of the construct validity of the sociological learning style construct. This is because the sociological subscales from the three instruments did not load together on any factor. Additionally, the correlations between subscales of the instruments and the convergent and discriminant validity evidence provided by the multitrait-multimethod matrices indicate that the instruments are measuring the sociological learning style construct differently. A cause of this difference may be the additional aspects of sociological learning style assessed by the GRSLSS such as participant and competitive.

The test-retest reliability for the sociological subscales of these instruments is shown in Table 27. The reliability of all three instruments is equally high, indicating that there is no reason (based on reliability) to choose one instrument over another to measure sociological learning style.

The GRSLSS, LSP, and LSI should not be substituted for one another when assessing sociological learning style because they assess different aspects of this construct. Likewise, the reliability evidence does not suggest any reason to chose one instrument over another when assessing this learning style domain.

Third Objective

The third objective of this study was to determine whether the instruments intended for both children and adult populations are equally reliable and valid for use with both age levels. For this objective, only the LSP and GEFT are relevant, because only these two instruments were used with

Table 27

Test-Retest Reliability for Sociological Subscales of the LSP and LSI and the GRSLSS Subscales

Instrument	Test-retest reliability
GRSLSS independent	.64
GRSLSS dependent	.71
GRSLSS avoidant	.77
GRSLSS collaborative	.89
LSP grouping	.84
LSP verbal risk	.90
PEP alone/peers	.74

both samples. The average test-retest reliability for the LSP scores for the middle-school sample was .45, whereas the college sample produced an average test-retest reliability of .72. Based on this result, the LSP appears to be more consistent (over a 1-month time interval) for college students. The test-retest reliability for the GEFT, however, was close for the middle-school and college samples (.80 and .84, respectively). This indicates that the GEFT is a more stable instrument across age levels.

With regard to construct validity, the LSP correlated with the GEFT about the same for both the middle-school and college samples (.47 and .51, respectively). Additionally, when the construct validity was assessed for the LSP separately to determine internal structure, the same amount of clear-cut factors emerged for the middle-school sample as the college sample. This implies that the internal structure construct validity for the LSP is the same when used with a middle-school or a college population.

Finally, for the exploratory factor analysis including all instruments done on the middle-school scores, the LSP analytic and GEFT loaded on the same factor. However, with the college sample, these scales loaded onto different factors. This indicates that the two instruments may be assessing analytical cognitive learning style differently when used with different populations.

These results may be related to Piaget's stages of cognitive development. According to Piaget, children move toward the formal operations stage of cognitive development during adolescence (Merrell, 1994). This stage involves cognitive abilities such as the use of formal logic and abstract problem-solving techniques. It is possible that the majority of middle-school subjects used in this study had not yet reached this stage of cognitive development. If they had not yet attained any of these abilities, they would score about the same on the LSP analytic subscale as the GEFT. However, by college age, the students may have attained some of the formal operations, but not all formal thought. Or, they may not have learned how to use all of these operations, thereby having stronger abilities in some analytical areas than other areas. This would result in different analytical abilities, thus causing different scores on the LSP and the GEFT.

In sum, based on the reliability estimates and correlations between instruments from this study, the LSP and GEFT are equally good scales for both middle-school and college ages. Additionally, the internal structure of the LSP is equally good for middle-school and college populations. Finally, the cross-instrument validation of constructs indicates that the two instruments may be assessing analytical cognitive learning style differently when used with different populations.

CHAPTER VI

CONCLUSION

Psychometric data were provided for the six most promising learning style instruments currently available. This information can be summarized as follows.

Test-retest reliability was moderate for most of the learning style scales. Generally the results indicate that the validity of the instruments is low. The internal structure of many of the scales was good, as indicated by the separate exploratory factor analyses. This means that most of the instruments do measure unique learning style domains. However, either the scales measured different aspects of the particular learning style constructs, or they measured different constructs. This is evidenced by the results of the subscale correlations and the overall exploratory factor analysis for the college sample. Only the middle-school exploratory factor analysis including all scales and the environmental multitrait-multimethod matrices showed any support for the construct validity of the instruments.

When compared to the existing literature regarding the psychometric properties of these instruments, the results of this investigation provide some more favorable evidence for the construct validity of three instruments (GRSLSS, PEP, and LSI) than past research. However, the validity evidence for the GEFT is less favorable in this study than in past studies. Finally, the construct validity findings of this study for the ELSIE and the LSP could not be compared to previous research, because there is no existing literature regarding the construct validity of these scales.

The test-retest reliability estimates for the GRSLSS, LSP, and GEFT in this study appear to be in accordance with those found in previous inquiries. However, the PEP had higher reliability in this study than in past research. Finally, the reliability of the LSI could not be compared to previous research because there is no existing literature regarding the test-retest reliability of this scale.

Implications of Findings

This inquiry provided some evidence in favor of the internal structure construct validity of all of the instruments. Therefore, educators and researchers may feel confident that these instruments are assessing unique learning style constructs.

However, although the overall middle-school factor analysis containing all instruments provided some evidence of construct validity for the learning style constructs, the rest of the analyses did not. The implication is that one should be careful when choosing one of these instruments, because either they do not measure the constructs in the same manner, or they are not measuring the same constructs at all. Therefore, it is necessary for the researcher or educator selecting the instrument to know exactly what aspects of the particular learning style under investigation he/she wishes to assess. However, because the validity evidence of the scales is generally weak, educators should be cautious when using any of these instruments to assess the various domains of learning styles.

Finally, because the results of the reliability analyses provided by this study are generally in accordance with existing literature, previous reliability evidence is strengthened.

The comparison of the multidimensional scales with the unidimensional scales also has implications for educators and researchers. Based on the results of this study, the multidimensional and unidimensional instruments did not seem to measure the same underlying learning style constructs. This was indicated by lack of construct validity for the constructs as found by the subscale correlations, factor analyses, and multitrait-multimethod matrices. Therefore, these instruments should not be used interchangeably. Because of this, educators and researchers need to be clear as to exactly what aspects of the particular learning style domain under investigation they wish to measure.

If one is interested in particular aspects of the domain to be assessed, the instrument should be selected based on the domain aspects of interest. However, if there is no particular preference concerning the aspects of the domain being measured, either the multidimensional or unidimensional instrument can be used, because they are equally reliable and have equally valid internal consistency construct validity. In this case, one should choose which instrument to use based on the amount of time available and the amount of information desired. If there are time constraints, the educator or researcher should use the shorter, unidimensional instruments. However, if time is not a factor, the multidimensional instruments will provide an equally good indicator of the learning style dimension of interest, as well as considerably more information regarding other learning style domains.

A final implication of this study concerns the use of the LSP and GEFT with different age groups. The results of this study indicated that the LSP is more consistent with college students than with a middle-school population. Therefore, educators and researchers should use caution when using this instrument with middle-school students. However, the GEFT appears to be equally reliable and valid for both middle-school and college populations.

Additionally, the cross-instrument validation of constructs indicated that the two instruments may be equally good for measuring middle-school students, but not for college students. Therefore, discretion should be used when administering either of these instruments to college students because the validity of the cognitive construct assessed by these scales is questionable.

Limitations

There are three major limitations to this study. First, only one aspect of reliability and one type of validity were assessed. This is a limitation because additional reliability evidence could provide vital information regarding the internal consistency of the instruments. Additionally, evidence of content-related validity is important because it assesses whether the items of an instrument reflect the full domain of learning style content it is supposed to measure.

This investigation was further limited by statistical problems related to the confirmatory factor analyses. Because of these difficulties, little information could be added from these CFA analyses to the overall psychometric data provided by this study. However, as discussed previously, the problems were not necessarily due to poor models, but may be because of inherent problems with using CFA to analyze multitrait-multimethod matrices. Because of this statistical limitation, the multitrait-multimethod matrices were also analyzed in terms of the Campbell and Fiske (1959) criteria.

Finally, the generalization of this study is limited. The results of this investigation can be generalized to only middle-school students in Cache Valley, Utah, and to college students at Utah State University studying to become teachers.

Future Studies

There are many instruments currently available that assess student learning styles. Only six of these scales were examined in this study. One recommendation for future researchers is to do a similar study as this one using different learning style instruments. Other suggested instruments include those found in Table 1.

Another direction to take would be to further consider the age variable. For example, one could administer the LSI and the PEP to both children and adults to see if one of these scales (or both) is reliable and valid for both ages. This was done with the LSP and GEFT in this study.

Another suggestion for future research is to use a larger and more diverse sample. Both the middle-school and college samples used in this study are from Logan, Utah, which is a mostly middle-class White population. Learning styles might differ for people of different ethnicity. Therefore, the reliability and validity of these instruments may be either higher or lower for other, more diverse populations.

Finally, this study only assessed test-retest reliability and construct validity. Research is also needed to establish other types of reliability and validity for these instruments. This should include parallel forms and internal consistency reliability, as well as content and concurrent validity.

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