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COMMENTARY

Lessons on measuring construct validity: A commentary on Delis, Jacobson, Bondi, Hamilton, and Salmon

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Abstract

This commentary expands on issues raised by Delis, Jacobson, Bondi, Hamilton, and Salmon, in their paper on the use of shared variance techniques to establish construct validity. Significant discussion is focused on method variance, and how this can distort the results of factor analysis. Solutions are offered for the appropriate use of factor analysis in construct validation. Examples are also provided of construct validation procedures that do not rely on correlational or shared variance techniques. (*JINS*, 2003, *9*, 947–953.)

Keywords: Construct validity, Factor analysis, Method variance

INTRODUCTION

Delis, Jacobson, Bondi, Hamilton, and Salmon (Delis et al., 2003) nicely demonstrate problems that can arise from using shared variance techniques such as pearson correlation and factor analysis, to evaluate the construct validity of neuropsychological tests such as the California Verbal Learning Test (CVLT) (Delis et al., 1987). Their article, in particular, raises issues that are important regarding the appropriate application of factor analysis to the process of construct validation.

Construct Validity and Shared Variance Techniques

A construct is a postulated attribute of people not directly measured or operationally defined, that is assumed to be reflected in test performance, for example, anxiety or memory (Cronbach & Meehl, 1955). Cronbach and Meehl describe a variety of procedures that can be used to evaluate construct validity, including contrasting groups that are hypothesized to differ on a construct, evaluating expected changes in a construct over time, and evaluating factors related to purported processes of the construct. Correlational procedures are also employed to evaluate construct validity, and Cronbach and Meehl (1955) present an example of a hypothetical test of anxiety, in which the construct validation process is largely based on the pattern of various significant versus non-significant correlations.

Correlational procedures, referred to as shared variance procedures by Delis et al., are the most widely used procedures for evaluation of construct validity (Delis et al., 2003; Nunally, 1978). Analysis of multi-trait, multi-method correlation matrices allows for demonstration of convergent and discriminant validity (Campbell & Fiske, 1959). Factor analysis provides empirical support for tests or test scores, as they relate to shared underlying common factors (the indirectly measured constructs of Cronbach & Meehl, 1955). In using factor analysis to evaluate the construct validity of tests of memory, these tests should load on an underlying memory factor, that is distinct from other underlying factors such as verbal intelligence or attention, otherwise, the memory tests are nothing more than another way of measuring verbal intelligence or attention (Larrabee et al., 1985; Larrabee & Curtiss, 1995).

Principal components analysis is a shared variance technique which takes scores from a larger set of related variables and reduces them to a smaller set of composite variables (component factors) that retain as much information from the original variables as possible (Fabrigar et al., 1999; Gorsuch, 1983). This contrasts with factor analysis, which is the preferred means of analyzing construct validity, due to principles of factorial causation and the determination of common and unique factors. Common factors are unobserved latent variables that are associated with more than

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one measured variable in a collection of test scores, and are presumed to account for the covariance among the variables (Fabrigar et al., 1999). Unique factors are latent variables that influence only one variable in a collection of test scores, and do not account for correlations among measured variables. Unique factors are assumed to have two components: a specific factor component that influences only one measured variable, and an error of measurement component that represents the unreliability in a measured variable (Fabrigar et al., 1999). Although Nunally (1978) has observed that factor analysis and principal components analysis often yield similar results, differences in results may occur when communalities are low or there are a restricted number of variables per factor (Fabrigar et al., 1999). Since both factor analysis and principal components analysis are shared variance techniques, this distinction will not be further addressed in the current commentary.

The paper by Delis et al. (2003) demonstrates two important considerations in using correlational procedures to evaluate construct validity. First, subject group differences can significantly affect correlations between test scores. In the Delis et al. paper this is demonstrated by the difference in magnitude of the correlation between total recalled over Trials 1–5 of the CVLT and Long Delay Free Recall for normal subjects, patients with early stage Huntington's Disease (HD) and patients with early stage Alzheimer's Disease (AD). Both the HD and normal subjects showed significant correlations between CVLT Trials 1–5 and Long Delay Face Recall, as would be predicted based on prior research on forgetting rate in HD (Delis et al., 1991) and by prior cross-sectional research on forgetting rates in normal subjects (Trahan, 1992; Trahan & Larrabee, 1993). By contrast, the AD subjects showed no significant correlation between Trial 1–5 and Long Delay Free Recall, again, as would be predicted by research demonstrating accelerated forgetting in early AD (Hart et al., 1988; Larrabee et al., 1993). Hence, the absence of a correlation between learning and recall for the AD patients can be seen as supporting the construct validity of separate scores for Trials 1–5, and for Long Delay Free Recall.

When Delis et al. (2003) subjected the various CVLT scores of a large sample of mild AD patients to principal components analysis, the factor structure differed from the factor structure for a previously-reported mixed neurologic sample as well as for a normal sample (Delis et al., 1988), largely because of the different correlation between trials 1–5 and long-delay for the AD relative to HD and normal subjects. Delis et al. observed that the factors from the principal components analysis for the mixed neurologic and normal subjects give a misleading view of Trials 1–5 and Long Delay Free Recall representing the same underlying construct, whereas the principal components factors for the AD sample provide a different explanation, with Trials 1–5 and Long Delay Free Recall measures loading on separate factors.

Delis et al. (2003) discuss the importance of considering the effects that group composition can have on correlational procedures, including the result of producing a different factor structure. They also discuss the problem of method variance in relation to distortion of factor solutions.

Method Variance

Method variance refers to variance or covariance attributable to the method of measurement, as opposed to covariance attributable to an underlying factor/construct (Campbell & Fiske, 1959). In the current author's experience, method variance is one of the most frequent sources of distortion in factor analyses of objective test scores. The effects of method variance can be seen in the original CVLT principal components analysis (Delis et al., 2003) reproduced in Table 4 of their current article. When one includes multiple scores from the same test stimuli in the same factor analysis, these scores can be highly intercorrelated, merely by virtue of being derived from the same shared test stimuli, in this case, the sixteen words of the CVLT. Hence, it is no surprise that for the normal Ss and Mixed Neurologic patients in Table 4, List A 1–5 Total Recall, Short Delay Free and Cued Recall, and Long Delay Free and Cued Recall, all load on the same factor.

The data from Delis et al.'s (2003) Study I, nicely demonstrates the method variance problem. For their normal subjects, Trials 1–5 and Long Delay Recall correlated .81, and they obtained a correlation of .85 between these two variables for their HD subjects. These correlations are almost *identical* to the 21 day test-retest reliabilities reported on page 84 of the CVLT–II manual (Delis et al., 2000) for trials 1–5: .82, and for long delay recall: .88. The fact that the Trial 1–5 and Long Delay Free Recall correlations are essentially identical to the test-retest reliabilities of Trials 1–5 and Long Delay Free Recall clearly demonstrates the method variance problem: the scores are based on the *same list of words*, and Long Delay Free Recall effectively represents a "Trial 9" (allowing for the cued recall trial at short delay). As Delis et al. also show, the behavioral pathology of AD (rapid forgetting) is more powerful than method variance (i.e., it attenuates the correlation between Trials 1–5 and Long Delay Free Recall).

Tables 1, 2, and 3 further demonstrate the effects of method variance on factor solutions. Table 1 demonstrates the loadings for a principal components analysis including WAIS VIQ and PIQ, the Halstead Reitan, and WMS–R (Leonberger et al., 1991). Including TPT Total Time, Memory and Location and WMS–R Immediate and Delayed Visual Reproduction in the same factor extraction shows that these three scores have among the highest loadings on Factor I. Including the immediate and delayed recall items for WMS–R Visual and Verbal Paired Associates, and Logical Memory I and II in the same principal components analysis leads to separate Visual Paired Associate, Logical Memory, and Verbal Paired Associate "factors."

By contrast, Table 2 shows the results of a factor analysis of data conducted by Leonberger et al. (1992), based on the WAIS–R, HRNB, and WMS–R, including the immediate

Table 1. Factor loadings of the WMS–R Immediate and Delayed Subtests, the Halstead-Reitan Neuropsychological Battery, VIQ and PIQ

	Factor						
Measure	1	2	3	4	5	6	7
Mental Control		.67	−.34				
Figural Memory	.35						.71
Logical Memory				.94			
Visual P. A.					.78		
Verbal P. A.				.30		.71	
Visual Reproduction	.67				.30		
Digit Span		.77					
Visual Memory Span		.41				−.35	.58
Logical Memory II				.91			
Visual P.A. II					.76		.30
Verbal P.A. II		.33	−.30			.69	
Visual Reproduction II	.75						.32
Category	−.36				.60		.31
TPT Total Time	−.80						
TPT Memory	.78						
TPT Location	.72					.37	
Speech Perception		−.70				−.33	
Seashore Rhythm		−.37	.83				
Tapping Dominant			.80				
Trails B	−.32	−.40	.72				
Verbal IQ		.79					
Performance IQ	.69	.37					

Note: Loadings of .30 or higher, orthogonal rotation. Adapted from Leonberger et al. (1991, p. 86). $N = 135$.

recall subtests of the WMS–R, TPT Total Time, Category Test Trials I–VI, and WAIS–R subtests instead of VIQ and PIQ (note: at least two variables are necessary to define an underlying factor, Gorsuch, 1983; with most recommending at least 3 variables per factor, see Fabrigar et al., 1999; hence, Leonberger et al., 1991 could not identify the factors typically found for WAIS–R subtests by using VIQ and PIQ alone). Table 3 shows the factor analysis based on the delayed trials of the WMS–R, TPT Location, Category Subtest VII, and the WAIS–R subtests.

The factors in Tables 2 and 3 are easily interpretable as visual cognitive ability, verbal cognitive ability, memory, attention, and psychomotor speed. These five factors explain the data more clearly that the seven factors in Table 1: TPT/Visual Reproduction, attention, psychomotor speed, Logical Memory I and II, Visual Paired Associates I and II, Verbal Paired Associates I and II, and visual attention/memory.

Extraction of factors based on method variance is also evident in the work of Mirsky and colleagues on the elements of attention (Mirsky et al., 1991). Although the construct of attention may well encompass the four elements postulated by Mirsky et al. of focus-execute, shift, sustain and encode, the principal components analyses of tests reported by Mirsky et al. (1991) cannot be used to support the presence of these elements. This is because two of the four elements, shift (flexibility factor) and sustain (vigilance factor), are each defined by multiple scores from one test (Categories, Percent Correct, and Errors from the Wisconsin Card Sorting Test load on the flexibility factor; Correct responses, Commission Errors and Reaction Time from the Continuous Performance Test load on the vigilance factor). To appropriately use factor analysis to support their theory, Mirsky et al. need to factor analyze multiple measures of each of the four separate elements of attention, using only one score from each of the multiple tests.

Factor Analysis and Construct Validity

The past ten years have reflected a significant increase in the use of confirmatory factor analysis, to evaluate the construct validity of neuropsychological tests. In exploratory factor analysis, one must assume that all common factors are correlated (or in some applications, uncorrelated), all observed variables are directly affected by all common factors, unique factors are uncorrelated with one another, all observed variables are affected by a unique factor, and all common factors are uncorrelated with all unique factors (Long, 1983). Confirmatory factor analysis allows the investigator to place constraints on the factor analysis that are not possible in exploratory factor analysis (Kline, 1998; Long, 1983). These constraints determine which pairs of common factors are correlated, which observed variables are affected by which common factors, which pairs of unique

Table 2. Factor loadings of the Wechsler Memory Scale–Revised, the Wechsler Adult Intelligence Scale–Revised, and the Halstead-Reitan Neuropsychological Test Battery: Analysis of Immediate Recall Scores

	Factor				
Measure	1	2	3	4	5
Wechsler Memory Scale–Revised					
Mental Control		.36	.45		.35
Figural Memory				.31	
Logical Memory I		.33		.66	
Visual Paired Associates I	.37			.50	
Verbal Paired Associates I				.73	
Visual Reproduction	.64				.33
Digit Span			.67		
Visual Memory Span	.51		.32		
Wechsler Adult Intelligence Scale–Revised					
Information		.82			
Vocabulary		.88			
Arithmetic		.55	.42		
Comprehension		.76			
Similarities		.74			
Picture Completion	.65				
Picture Arrangement	.58				
Block Design	.77				
Object Assembly	.80				
Digit Symbol	.45			.31	.52
Halstead-Reitan Neuropsychological Test Battery					
Category Test (I–VI)	−.53				
Tactual Performance Test (total time)	−.59				
Speech Sounds Perception Test			−.40		−.39
Rhythm Test			−.61		
Finger Tapping Test (dominant hand)					.33
Trail-making Test (Part B)	−.46				−.56

Note. Loadings of .30 or higher, orthogonal rotation. Adapted from Leonberger et al. (1992, p. 243).
N = 237.

factors are correlated, and which observed variables are affected by a unique factor (Long, 1983). Different factor models can be statistically tested for goodness of fit, with conclusions regarding the most appropriate model that are statistically based.

Although confirmatory factor analysis is a powerful data analytic tool, it does not replace exploratory factor analysis. This is particularly true when there are no prior exploratory factor analyses available to guide the selection of different models to be tested with confirmatory factor analysis. This is important when a test revision such as the WMS–III appears, that contains totally new subtests such as Family Pictures, and Face Memory (Wechsler, 1997). Moreover, exploratory analysis using marker variables (i.e., variables previously found to consistently identify factors such as verbal intelligence, verbal memory, attention; see Larrabee & Curtiss, 1995; Larrabee et al., 1985) also allows a quick evaluation of whether the sample under investigation is a representative sample. If the marker variables do not appear on the factors as expected, the sample may be fundamentally different than samples employed in previously published research.

Since factor analysis relies on correlations and/or covariance matrices, anything affecting correlation (covariance) can have a distorting effect on the subsequent factor structure. Again, this was demonstrated in the present paper by Delis et al., as a function of the attenuation of the correlation between Trials 1–5 and Delayed Free Recall in the AD sample, and as a function of method variance in the Normal and Mixed Neurologic Samples.

Moreover, employing test scores that are restricted in range by floor effects (due to testing of very impaired patients) or ceiling effects (due to testing young, extremely intelligent normals) can attenuate test correlations and distort factor structure. Restriction in range can produce spuriously low factor loadings and correlations among factors (Fabrigar et al., 1999). Although statistical procedures are available to identify the presence of skewed data, and which allow transformations to normalize data, these procedures do not substitute for the information provided by established marker variables identified in prior programmatic factor analytic research. In one (unpublished) factor analysis conducted to evaluate the construct validity of the Rey Osterrieth Complex Figure Test, the current author ob-

Table 3. Factor loadings of the Wechsler Memory Scale–Revised, the Wechsler Adult Intelligence Scale–Revised, and the Halstead-Reitan Neuropsychological Test Battery: Analysis of Delayed Recall Scores

	Factor				
Measure	1	2	3	4	5
Wechsler Memory Scale–Revised					
Mental Control		.36		.46	.31
Figural Memory			.36		
Digit Span		.31		.69	
Visual Memory Span	.50			.34	
Logical Memory II		.31	.67		
Visual Paired Associates II	.32		.60		
Verbal Paired Associates II			.76		
Visual Reproduction II	.55		.49		
Wechsler Adult Intelligence Scale–Revised					
Information		.82			
Vocabulary		.88			
Arithmetic		.56		.42	
Comprehension		.76			
Similarities		.74			
Picture Completion	.62				
Picture Arrangement	.59				
Block Design	.76				
Object Assembly	.80				
Digit Symbol	.42		.40		.50
Halstead-Reitan Neuropsychological Test Battery					
Category Test (VII)	−.51		−.35		
Tactual Performance Test (Location)	.54		.31		
Speech Sounds Perception Test			−.34	−.42	−.32
Rhythm Test				−.59	
Finger Tapping Test (Dominant hand)					.37
Trail-making Test (Part B)	−.43		−.33		−.47

Note. Loadings of .30 or higher, orthogonal rotation. Adapted from Leonberger et al. (1992, p. 243).
$N = 237$.

tained a factor structure that made no sense, because the marker variables did not define factors reported in prior investigations. On further analysis, the data (collected from another site) were based on patients in subacute rehabilitation for severe closed head injury or stroke, and test score means demonstrated significant floor effects.

Confirmatory factor analysis, in which the error terms of test scores are allowed to correlate, has been employed as a control for method variance when immediate and delayed recall memory scores are included in the same factor analysis (Price et al., 2002; Wilde et al., 2003). Price et al. (2002) obtained non-positive covariance matrices and boundary solution violations for their Models 3 and 5. The boundary solution error was triggered by correlation estimates of .99 or greater between the immediate and delayed factors for their model 3. The authors attributed these problematic solutions to the linear dependency among the immediate and delayed subtests, and model specification error. Price et al. (2002) suggested that the factor structure of the WMS–III may be more accurately represented by using entirely separate models of immediate and delayed memory (i.e., separate factor analyses of immediate and delayed memory test scores). Similarly, Wilde et al. (2003) also obtained boundary solution errors for models including immediate and delayed scores in the same confirmatory factor analysis, using correlated error terms, and specifying separate immediate and delayed factors. The authors attributed these data analytic problems to the high correlation between immediate and delayed factors on the WMS–III.

Delis et al. (2003) offer one possible solution for evaluating the distinction between learning (immediate recall) *versus* memory (delayed recall), using confirmatory factor analysis, and employing multiple memory tests, each of which has immediate and delayed recall conditions. The analysis proposed by Delis et al. would include immediate recall from one half of the tests, and delayed recall from the other half, in the same factor analysis, then reverse the variable selection in a second confirmatory factor analysis. A conceivable design for such an investigation would include marker variables for Verbal Cognitive Ability (e.g., WAIS–III Information, Vocabulary, Similarities), Visual Cognitive Ability (e.g., WAIS–III Block Design, Picture Completion, Matrix Reasoning), and Attention/Working Memory (e.g., WAIS–III Digit Span, Letter-Number Sequencing, Arithmetic). To measure Learning and Memory, Six Verbal (Verbal 1, 2, 3, 4, 5, 6) and Six Visual/Nonverbal (Visual 1, 2, 3, 4, 5, 6) memory tests would be necessary. Confirmatory models could be tested that compared learning scores from Verbal Memory 1, 2, 3 and Visual Memory 1, 2, and 3 loading on a factor separate from a delayed recall factor defined by delayed recall scores from Verbal Memory 4, 5, 6 and Visual Memory 4, 5, and 6. This could be followed by a second confirmatory factor analysis, in which the delayed scores from Verbal and Visual 1, 2, and 3 would define the delayed factor, and the learning scores from Verbal and Visual 4, 5, and 6 would define the learning factor.

The above design, suggested by Delis et al. (2003) and the current author, could reduce method variance sufficiently to allow a true test of whether or not learning *versus* delayed recall scores reflect separate factors. Note that method variance may not be completely eliminated, as several tests may share similar *methodology*, even though the *stimuli* are different; for example, list learning methodology such as CVLT–II and AVLT, or design reproduction from memory, such as the Rey-Osterrieth Complex Figure and WMS–III Visual Reproduction.

What becomes clear from the preceding example, is that variable selection, and the number of variables required, is extensive, to simply test whether there are separate learning and memory factors. It is difficult to conceive of a similar confirmatory factor analytic design that would allow simultaneous investigation of the multiple dimensions of learning and memory represented on the CVLT (e.g., cued recall, percent retention, intrusions, etc.), as one would need an inordinately large number of memory tests, each assessing dimensions similar to those assessed by the CVLT. Hence, for a complex, multi-measure test such as the CVLT, factor analysis may not be the method of choice for construct validation. Delis et al. (2003) also make this point, contrasting the applicability of factor analysis for evaluating more global constructs, with the inappropriateness of factor analysis for evaluating more intricate, inter-related cognitive processes mediated by distinct brain regions.

Delis et al.'s (2003) recommendations regarding the need to assess different and relatively homogenous groups of patients are well-taken, demonstrated nicely by the different relationship between learning and recall in their AD *versus* normal and HD subjects. In this vein, and as noted by Delis et al. (2003), confirmatory factor analysis does allow for comparisons of covariance structure with multiple sample confirmatory factor analysis (see Byrne, 1994, chapters 8, 9, and 10, and Kline, 1998, section 7.8).

CONCLUSIONS

In summary, the paper by Delis et al. (2003), and the current commentary, clarify the need to carefully consider both subject population and variable selection before conducting correlational or factor analytic procedures. Researchers should keep in mind potential effects of differing neurobehavioral disorders on correlations between test scores, and be well aware of the distorting effects of method variance caused by factoring several scores based on the same test procedure or test stimuli. Factor analysis remains a powerful tool for evaluating the construct validity of neuropsychological tests, when appropriately conducted. Confirmatory factor analysis can significantly extend the analysis of construct validity by allowing statistical contrasts of competing models. Researchers should not eschew exploratory factor analysis, however, particularly in areas of test development that are lacking in previously-conducted factor analytic investigations.

For complex tests that yield a multitude of scores derived from the same stimuli, such as the CVLT, factor analysis may not be the most appropriate procedure to evaluate construct validity. In these circumstances, the investigator must conduct other analyses, following methodology suggested by Cronbach and Meehl (1955), including contrasting groups hypothesized to differ on a construct, for example, evaluating forgetting rates or recognition discriminability in HD, AD, and alcoholic Korsakoff's disorder (Delis et al., 1991). As suggested by Delis et al. (2003), the investigator can employ a cognitive experimental approach in small homogeneous subject groups, corresponding to Cronbach and Meehl's (1955) evaluation of factors related to purported processes of the construct (see Butters & Cermak, 1980, for a systematic cognitive experimental approach in amnesia, and chapter 7 in Delis et al., 2000 for similar studies supporting the construct validity of the CVLT). In closing, shared variance procedures such as factor analysis are not flawed as construct validation techniques; rather, the flaw is in the inappropriate use of shared variance techniques.

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