

CONSTRUCT VALIDITY IN MEASUREMENT

A Pattern Matching Approach

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ABSTRACT

Construct validity refers to how well operationalizations in research reflect the theoretical constructs they are supposed to reflect. The multitrait-multimethod (MTMM) matrix framework proposed by Campbell and Fiske (Psychology Bulletin, 56, 81-105, 1959) is the most widely known and used method for establishing construct validity. In determining if there is construct validity using the MTMM approach, researchers should have some idea or expectation of the interrelationships among constructs and the methods used to measure them. Structured conceptualization can be used to articulate the expected relationships between constructs that are being measured. The resulting theoretical concept map can then be compared with correlations in the MTMM matrix using a pattern matching approach to assess the degree of construct validity evidenced.

Construct validity is the primary focus of this article. The procedure for establishing construct validity in measurement using a "pattern matching" approach is explored. In this approach, conceptualized theoretical patterns of construct interrelationships are matched with

obtained patterns of interrelation among constructs. Advantages of using pattern matching for establishing construct validity are outlined. Also, several different analyses for indicating a match between expected and obtained patterns are presented.

CONSTRUCT VALIDITY

A major conceptual view of construct validity is the nomological network presented by Cronbach and Meehl (1955). This nomological network assumes that there is an interlocking system of principles which constitutes a theory and establishes the relationship between theoretical constructs and observed measurements. The nomological net is an attempt to articulate and clarify the concept of construct validity. It requires that one explain relevant constructs and set them in a relational scheme with observed measures and other constructs. Within this framework, explicit statements about constructs are required in order to claim construct validity. Campbell and Fiske's (1959) multitrait-multimethod matrix (MTMM) framework approach is an example of making explicit statements of relationships about constructs and observed measures and this can be viewed

as one way to approach the development of the nomological net.

Multitrait-Multimethod Matrix (MTMM)

The underlying assumption of the MTMM is that different methods are being used to measure each construct. Within this framework, constructs are referred to as traits. A trait is a continuous latent variable that is inferred from observable data. The objective of a measure is to tap traits of interest, such as achievement, personality, or sociability. Method may be defined as a multiple-choice test, open-ended answer test, questionnaire, face-to-face interview, or unobtrusive data collection technique. Different rating scales may be viewed as different methods. Also, different item types of a multiple-choice instrument, such as analogy items

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or analytic reasoning items can be considered examples of different methods. Hence, the idea of method encompasses measurement instruments as well as variations within measures. The assumption that one method only reveals a part of a social or a psychological reality is a prevalent one. It is generally felt that a single measuring instrument is insufficient to comprehensively measure a construct. Furthermore, with only one method of measurement, a researcher has no way of distinguishing trait variance from unwanted method variance (Campbell & Fiske, 1959).

Trait variance is the variation within a measure which is attributable to the true value for that trait for a set of individuals. Method variance refers to variation in measures that is attributable to the effect of the method on the observed score. Trait variance is of primary concern in establishing construct validity, since a given measure should tap the theoretical construct without interference from method of measurement. What distinguishes method from trait is that the systematic variation due to method is undesirable. A researcher wishes to measure traits and not methods.

The rationale for using the multitrait-multimethod approach for construct validity is that if methods are independent and traits are accurate in their assessment, then the relationship among traits should stay the same across different methods. Also, any error due to method should be equally observable with each trait that is measured by that method. The Campbell and Fiske MTMM matrix describes a classification system where each measure represents a trait-method combination of one trait with one method. Campbell and Fiske make a distinction between two types of construct validity; convergent and discriminant. Evidence for these two types of construct validity is based on interpretation of the MTMM matrix. To understand the criteria on which the interpretation is based, an MTMM which has the same structure as the one discussed by Campbell and Fiske (1959) is presented in Figure 1 and represents a hypothetical case where there are three methods crossed with three traits. First, there must be convergence, or agreement among indicators which claim to measure the same construct. This is expressed by high correlations among assessments of the same trait with different methods as shown by the convergence diagonal illustrated by the C's in Figure 1. Second, there must be a divergence between measures of similar but conceptually different constructs. So, a researcher would expect a low correlation of measures of different traits. The same method triangles (M) and the heterotrait-heteromethod triangles (H) show this pattern. By having convergence among measures of the same trait and divergence of measures for different traits, the case for construct validity is supported. In general, it is expected that the reliability coefficients (R) are larger than the convergence diagonals (C). Also, the convergence di-

		METHOD 1			METHOD 2			METHOD 3		
TRAITS		A	B	C	A	B	C	A	B	C
1	A	R								
	B	M	R							
	C	M	M	R						
2	A	C	H	H	R					
	B	H	C	H	M	R				
	C	H	H	C	M	M	R			
3	A	C	H	H	C	H	H	R		
	B	H	C	H	H	C	H	M	R	
	C	H	H	C	H	H	C	M	M	R

R - Reliability of method

C - Convergence diagonal

M - Same Method triangles

H - Heterotrait-Heteromethod triangles

Figure 1. Structure of a hypothetical multitrait-multimethod matrix with three traits and three methods.

agonals are expected to be higher than values in same method triangles (M), while the (M) triangles are expected to have larger correlation coefficients than the triangles representing different traits measured with different methods (H). In order to assure the measurement of a trait with independent methods, one has to be able to trace theoretical patterns in measurement across different methods. Similarly, a method effect can be established as a pattern of measurement consistent across traits but not across methods (Wothke, 1984). In the MTMM framework, the researcher must articulate some expected patterns of interrelationships between traits and methods to compare with relational patterns that are characteristic of the MTMM. This comparison should reveal the similarity of expected patterns and the patterns underlying the MTMM.

In summary, the notion of construct validity as conceived by Cronbach and Meehl cannot be expressed in just a single coefficient. The establishment of construct validity requires several pieces of evidence, not all of them quantitative. Campbell and Fiske's MTMM matrix is the most widely recommended method for establishing the construct validity of measurement. Simple rationalizing or theorizing about the nature of a construct and its relations to other constructs is not sufficient for establishing construct validation. Measures which are taken to be observable expressions of a construct are expected to yield data that are consistent with how one expects constructs to be interrelated. Campbell and Fiske's MTMM was developed based on these requirements and continues to be the most widely recommended method for establishing the construct validity of measurement.

A pattern matching approach for construct validity

has been proposed by Trochim (in press). As previously mentioned, researchers should have some idea or expectation of how constructs are interrelated. Trochim suggests the use of a structured conceptualization method that is helpful in articulating the expected relationship between constructs that are to be measured. This method focuses on theorized expected patterns of mea-

surement interrelationships and how they are verified using actual obtained data. Generally, the primary task in this approach is to match patterns of theoretical constructs' interrelationships with operationalized obtained data patterns. The next section describes a hypothetical example of pattern matching and how it may be used to establish construct validity in measurement.

PROCEDURE

Data

In this example, data from Campbell and Fiske's (1959) synthetic multitrait-multimethod matrix serve as the operationalized obtained pattern of interrelationships among measures (see Figure 2). These data adhere to the multitrait-multimethod criteria that were previously described. The Campbell and Fiske matrix is then compared to four theoretical matrices which also meet the multitrait-multimethod criteria and which could be generated by a variation of the structured conceptualization approach. By differing the degree to which method and trait relationships are specified, each of the four generated matrices represents a different theoretical pattern of measurement interrelationships. A hypothesis is made that the more theoretical information a researcher is willing to specify about the interrelationship of methods and traits, the better the researcher is able to demonstrate construct validity. In this case, for instance, it is expected that theoretical matrices which specify more information about method and trait patterns of interrelationship will more closely approximate the obtained Campbell and Fiske matrix. The assumption is made that a better match with the obtained correlation matrix pattern indicates greater construct validity of measures.

To summarize, the interrelationship of measures in the Campbell and Fiske synthetic matrix represents the obtained correlational pattern, while the four other matrices represent different theoretical specification of the patterns of relationships.

		METHOD 1			METHOD 2			METHOD 3		
TRAITS		A	B	C	A	B	C	A	B	C
1	A	100								
	B	58	100							
	C	38	37	100						
2	A	57	22	9	100					
	B	22	57	10	68	100				
	C	11	11	46	59	58	100			
3	A	56	22	11	67	42	33	100		
	B	23	58	12	43	66	34	67	100	
	C	11	11	45	34	32	58	58	60	100

Figure 2. Campbell and Fiske's (1959) hypothetical multitrait-multimethod matrix.

Deriving Theoretical Patterns

A method matrix and a trait matrix are used to specify the four theoretical patterns (see Figure 3). Three methods and three traits are assigned to each matrix corresponding to the structure of the Campbell and Fiske matrix. The choice of three methods and three traits is more a function of convenience and attempting to duplicate the Campbell and Fiske matrix than of some theoretical consideration. We can develop the theoretical MTMM matrices by specifying the expected method and trait relationship separately in these four 3 x 3 matrices. For instance, if we believe that traits are all equally interrelated, we would construct a matrix which reflects this. In Figure 3, the 2's along the method main diagonal are noticeably smaller than the 4's along the trait matrix main diagonal. This difference is not a crucial one. It is done in order to satisfy a requirement for construct validity, the trait variance is dominant over method variance. The selection of specific diagonal values of the four theoretical patterns is in part to avoid

		METHOD			TRAIT		
		2	1	1	4	1	1
		1	2	1	1	4	1
		1	1	2	1	1	4

x

		METHOD 1			METHOD 2			METHOD 3		
TRAITS		A	B	C	A	B	C	A	B	C
1	A	8								
	B	2	8							
	C	2	2	8						
2	A	4	1	1	8					
	B	1	4	1	2	8				
	C	1	1	4	2	2	8			
3	A	4	1	1	4	1	1	8		
	B	1	4	1	1	4	1	2	8	
	C	1	1	4	1	1	4	2	2	8

Figure 3. Procedure for deriving theoretical patterns by cross-multiplying trait and method matrices.

degenerate multidimensional scaling solutions (Davison, 1983). The theoretical patterns of interrelationship are indicated in the off diagonal values. In Figure 3, the assumption is made that methods and traits are equally interrelated. To obtain the full MTMM for a theoretical specification, the theoretical method and trait patterns are multiplied to produce an MTMM that meets the Campbell and Fiske criteria for establishing construct validity.

As previously mentioned, the four theoretically derived matrices represent varying degrees of specification of the method and trait interrelationship as illustrated by Figure 4. In the first pattern, methods and traits are theorized to be equally interrelated. The second pattern illustrates methods as not being equally interrelated while traits are. Traits are not assumed to be equally interrelated but methods are in the third pattern. Finally, a theoretical assumption is made that both methods and traits are not equally interrelated in the fourth example. In all cases when interrelationships are not equal, values for the matrices are based on the apparent patterns in the Campbell and Fiske MTMM. In practice, however, the researcher would specify expected relationships on the basis of theory.

Configural Similarity

The multitrait-multimethod matrices from the four different theoretical patterns are compared to the Camp-

	Interrelationship		METHOD	TRAIT
	Method	Trait		
1.	NO	NO	$\begin{bmatrix} 2 & 1 & 1 \\ 1 & 2 & 1 \\ 1 & 1 & 2 \end{bmatrix}$	$\begin{bmatrix} 4 & 1 & 1 \\ 1 & 4 & 1 \\ 1 & 1 & 4 \end{bmatrix}$
2.	YES	NO	$\begin{bmatrix} 3 & 1 & 1 \\ 1 & 3 & 2 \\ 1 & 2 & 3 \end{bmatrix}$	$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$
3.	NO	YES	$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$	$\begin{bmatrix} 3 & 2 & 1 \\ 2 & 3 & 1 \\ 1 & 1 & 3 \end{bmatrix}$
4.	YES	YES	$\begin{bmatrix} 3 & 1 & 1 \\ 1 & 3 & 2 \\ 1 & 2 & 3 \end{bmatrix}$	$\begin{bmatrix} 7 & 2 & 1 \\ 2 & 7 & 1 \\ 1 & 1 & 7 \end{bmatrix}$

Figure 4. Theoretical patterns for different specifications of trait and method interrelationships.

bell and Fiske matrix. The maps generated by multidimensional scaling of the theoretical matrices are then compared to a map generated by using the correlations from the obtained Campbell and Fiske synthetic matrix. First a multidimensional scaling analysis was conducted (Davison, 1983; Kruskal & Wish, 1978) on the multitrait-multimethod correlation matrix. The analysis renders a two dimensional map where every method and trait is represented in relation to every other method and trait as shown in Figure 5. The figure also shows the map derived for one of the four theoretical patterns described above. Here, the theoretical map (which is at the bottom of Figure 5) represents the example of assuming equal trait interrelationship only. As expected, the theoretical map illustrates pictorially how the traits and methods cluster together.

Each point on the map represents one of the nine method-trait combinations from the MTMM. In viewing the map in Figure 5, we can see the patterns of interrelationship among methods and traits. The Campbell and Fiske obtained map reveals distinct method

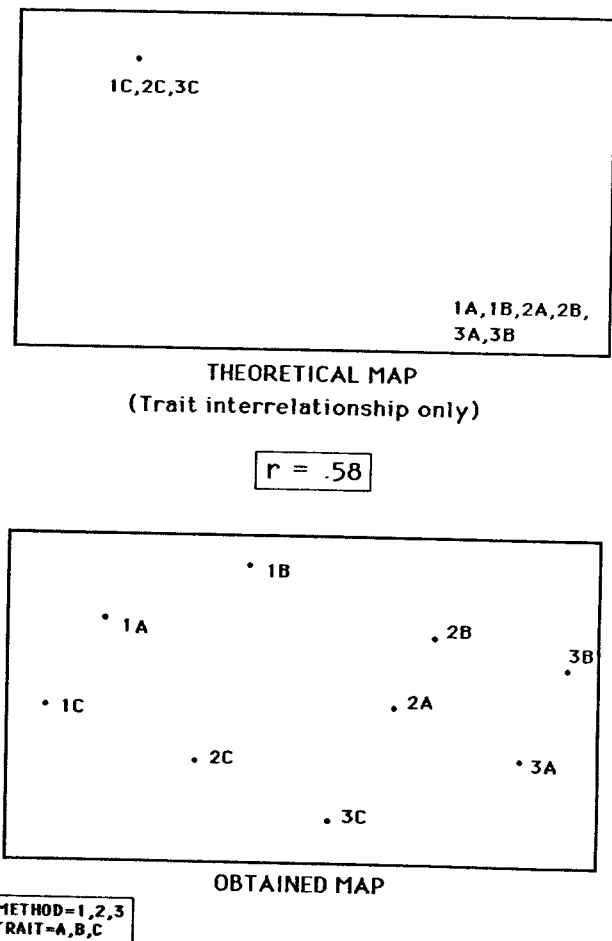


Figure 5. Pattern matching for construct validity where trait interrelationships alone are specified.

and trait clusters, while the theoretical map shows a separate clustering of the more dominant C-trait and a cluster of the A and B traits.

Figure 5 is an example of a theoretical map that reflects a theoretical pattern where methods are interrelated differently and traits are equally interrelated. The configural similarity between these two maps (i.e., the theoretical and obtained) is derived by using a Pearson's Product Moment Correlation of Euclidean distances between the points on each map (Davison, 1983; Guttman, 1968; Kruskal, 1964). This correlation coefficient is an indicator of how similar the two multidimensional maps are, and it indicates the match between

the obtained and theoretical patterns of measure interrelationship. If the configuration of points on two maps are similar, the pattern of Euclidean distances will be similar, thereby increasing the correlation. While other methods of assessing configural similarity of multidimensional maps have been proposed (Gower, 1975; Schonemann & Carroll, 1970), the Pearson Product Moment Correlation appears to be a more familiar and understandable method. When using the Pearson correlation, higher coefficients indicate greater similarity between the maps. In other words, high coefficients are indicative of a pattern match and greater evidence for construct validity.

RESULTS

The four theoretical patterns which assumed different degrees of trait and method interrelationship produced different correlation coefficients when matched with the Campbell and Fiske obtained matrix (see Figure 6).

The degree of similarity in the maps increased as more information about how traits and methods are related is taken into consideration. The first example where the least amount of information was assumed about method and trait interrelationships produced an r equal to .34. When methods were not assumed to be equally interrelated, the r increased to .54. Assuming differential interrelationship of traits produced an $r = .58$. Finally, under the assumption that both methods and traits are not equally interrelated, the highest coefficient of .71 was obtained. By including more specific information about the interrelationships among traits and methods, the fourth theoretical pattern most closely approaches the pattern of the Campbell and Fiske correlational matrix. The higher correlation coefficient of the fourth pattern indicates greater similarity between

the two maps. This evidence supports the assumption that when more information is specified about the theoretical expected patterns of interrelationships among traits and methods, one is able to obtain higher estimates of construct validity.

	INTERRELATIONSHIP		SIMILARITY
	METHOD	TRAIT	r
1.	NO	NO	.34
2.	YES	NO	.54
3.	NO	YES	.58
4.	YES	YES	.71

Figure 6. Similarity (pattern match) correlations between theoretical and obtained maps for four different trait and method specifications.

CONCLUSION

Pattern matching based on mapping techniques may be a useful approach for establishing construct validity. After theorizing the expected patterns of how traits and methods are interrelated, an attempt to verify these patterns using obtained data becomes the objective of pattern matching. This strategy offers several advantages. First, the logic of pattern matching as described here is consistent with the logic of the MTMM framework. Second, pattern maps represent the relationships among traits and methods, while providing an opportunity for exploring the effects of trait and method factors and interaction between them. Third, by utilizing multidimensional scaling one is able to take ordinal-level estimates of theoretical interrelationships and scale these into interval level theoretical patterns. A researcher might articulate pattern relationships by sorting or ranking or rating the measurement concepts and the

multidimensional scaling analysis will scale these non-interval input data, thereby laying the foundations for correlations between patterns. Finally, pattern matching provides a single indicator (r) of construct validity. Prior to this, the interpretation of an MTMM was done simply by visually assessing the obtained correlation matrix.

Given these advantages, pattern matching which is based on structured conceptualization appears to be a viable approach for examining construct validity. Of course, this approach needs to be tested on a broader range of examples—both simulated and real—before we can recommend it with confidence. Nevertheless, if pattern matching proves to be a reliable method for assessing construct validity in measurement, the current strategies used by researchers to establish construct validity may be changed dramatically.

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William M.K. Trochim
Guest Editor

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William M.K. Trochim
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