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Product-moment correlation limitations and the appropriateness of confirmatory analysis to verify internal structure of a construct: A critical review

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ABSTRACT

Product-moment correlation is a popular technique among academicians for verifying a construct's internal structure. Despite its widespread adoption among students and its inclusion in widely used textbooks, the author argues that this technique is fundamentally flawed. This study aims to elucidate the shortcomings of that technique and demonstrates that Confirmatory Factor Analysis (CFA) as a more suitable approach. Specifically, CFA is advantageous because it utilizes only common variance, derives latent variable scores solely from verified indicators, and enables researchers to assess each indicator's ability to explain its corresponding latent variable.

INTRODUCTION

There's widespread concern about the disconnection between external business research and industry requirements (November, 2004: Quora, 2017). Mayer (1970) has raised this issue long ago. A vast amount of academic research has been published in numerous scholarly journals. Almost every article typically includes both practical and academic contributions. However, academic business research and business practice remain poorly connected.

Many factors contribute to the disconnection between academic business research and business practice (November, 2004). According to Mayer (1970) and Quora (2017), one factor contributing to this disconnect is the low validity of academic research. They argue that academic research conclusions often have low accuracy due to limitations in measurement tools and research methods.'

The product-moment correlation is often used to verify the relationship between observed variables and their constructs. This method involves calculating the total score of the observed variables and then analyzing bivariate correlation between each variable's score and the total score.

Despite its widespread use among undergraduate and graduate students, and its inclusion in nationally distributed textbooks, the author argues that this technique is fundamentally flawed. This study aims to explain the shortcomings of product-moment correlation to verify the internal structure of a multivariable construct and recommend appropriate technique for that purpose. Specifically, the objectives of this article are: (1) to elucidate the understanding of construct internal structure verification, (2) to discuss the limitations of product-moment correlation in verifying construct internal structure validity, (3) to recommend an appropriate technique for construct internal structure validity verification.

This article aims to advocate for proper research techniques in construct internal structure validity verification. Although changing researchers' deeply ingrained mindsets is currently challenging, the pursuit of valid research must continue, and this article contributes to that effort.

LITERATURE REVIEW

The Understanding of Construct

In research, a construct is a theoretical, abstract concept that cannot be directly observed or measured, but is used to explain or understand a phenomenon. To measure it, researchers break down the construct into operational variables, the number of which can be one (single variable construct) or several (multi-variable construct).

The internal structure of a construct verification, traditionally referred to as construct validity, indicates how observed variables (also called items or indicators) explain the construct, as reflected through correlations. expectation that the correlations with their construct are higher than the other construct.

When using a multivariable construct, researchers need to verify that the variables used are solid indicators of the construct (Hair et al., 2014). In the traditional approach, researchers ensured the construct met convergent validity. In the newer approach to validity analysis, AERA et al. (2004) stated that researchers need to verify evidence of the construct's internal structure validity.

Measurement models can be constructed and analyzed using structural equation modeling (SEM), which generates estimates called factor loadings. In this model, items correlate with both their own construct and other constructs, with the expectation that correlations with their own construct will be higher.

Product Moment Correlation Limitations and the Appropriateness of Confirmatory Factor Analysis to Verify Internal Structure of a Construct

There are three limitations of product moment correlation in verifying internal structure of a construct. First, the variance calculated in product-moment correlation is total variance. In fact, a variable's variance consists of common variance (variance shared with other indicators), unique variance (variance specific to the indicator), and error variance (variance due to measurement error). Ideally, internal structure validity verification should be based solely on common variance as can be found in Confirmatory Factor Analysis (CFA). Unique variance tends to reduce the correlation between one variable and another, while error variance reduces the accuracy of the correlation.

Second, factor scores are simply obtained by totaling the scores of its indicators. This approach become problematic when an indicator does not belong to the latent variable empirically and must be removed. While total scores can be used as a factor score, the appropriateness of each indicator involved should be empirically confirmed first so that the incators involved ideally are those whose common variance are higher than unique variance and error variance (Hair et al., 2014).

Third, the statistical decision regarding significance or insignificance in the r coefficient of an indicator differs from the decision regarding verified or non-verified internal structure evidence. Statistical decision of significance is dichotomous: significance or insignificance. In contrast, the decision of validity verification is based on the ability of an indicator to explain its latent variable (AERA et al., 2004). Specifically, this involves determining whether an indicator and other indicators that belong to a latent variable share a high common variance, exceeding the unique variance and error variance. If the unique variance and error variance exceed the common variance, an indicator has low ability to explain a latent variable (Hair et al., 2014).

With total variance, product moment correlation has no power to show the ability all indicators to explain their latent variables. In regression, the coefficient of determination indicates the ability of an independent variable to explain a dependent variable. However, in correlation, the coefficient of determination is not known, so the ability of one or all indicators to explain the latent variable cannot be defined. The ability of an indicator to explain latent variables can be determined using confirmatory analysis. For example, if factor loading = 0.5, then its ability to explain the latent variable is expressed by the variance extrated (VE), namely VE = FL2 = 0.25, meaning error variance (EV) = 1 - VE = 0.75. Should such an indicator be removed from the model? If the average variance extrated (AVE) = 0.5 or more, then the indicator can be included. Conversely, if including it reduces the AVE to less than 0.50, then the indicator should be removed.

Many researchers have used a critical value as the boundary between validity and invalidity, similar to determining whether a correlation is significant or insignificant based on its magnitude. For example, for a sample of 150 people, the critical r value is 0.134. The minimum required r value can be illustrated by $r^2 = 0.134^2 = 0.018$. Although r^2 doesn't represent a coefficient of determination in this context, it helps to illustrate how poorly an indicator with r = 0.134 explains its construct. In the confirmatory factos analysis with SEM measurement model, an item can still be included even if the factor loading (FL) is 0.50 (Hair et al., 2014). With this value, the item explains only 25% of the variance (obtained from the square of the FL), with the remaining 75% representing measurement error and unique variance. Such items can still be used if the average variance extracted (AVE) from all items is at least 0.50 (Hair et al., 2014). In contrast, with product-moment correlation, researchers cannot determine the percentage of the latent variable (representing the construct) that is explained by the items.

Confirmatory Factor Analysis

A construct internal structure verification is used to verify that a variable has strong relationship with other variables of a construct (AERA et al., 2004). Confirmatory factor analysis (CFA) is the technique for that purpose (Schreiber et al., 2006).

Confirmatory factor analysis (CFA) and exploratory factor analysis (EFA) are both factor analyses, but in exploratory factor analysis (EFA), the data is explored to determine the number of factors underlying the variables involved. The EFA identifies the number of factors according to the number of variables. Although ultimately only a limited number of factors are valid, the correlation between each variable and all other factors is calculated in the analysis.

In confirmatory factor analysis (CFA), the factor analysis focuses only on one pre-specified construct. Although the EFA can be used to check the cohesion of the pre-specified variables accuravy. There are many experts believe that CFA is the best testing tool for that purpose. Therefore, in reputable international journal articles, confirmatory factor analysis (CFA) is generally the technique for testing internal structure of a construct.

Structural Equation Modeling (SEM) is the primary technique of CFA (Hair et al., 2016; Schreiber et al., 2006). This technique has two models: a measurement model and a structural model. The measurement model describes the relationship between observed variables and their constructs. The structural model analyzes the structural relationships between one construct and another according to the research framework. The combination of the two models is called the complete SEM model.

The example of measurement model is presented in Table 1. In this table, the authors displayed the relative advantage of OVO, a financial technology. The items are developed based on the understanding of relative advantage construct according to Rogers's (1995) diffusion of innovation theory. Then, the relative advantage construct is expressed visually into a latent variable 'ra' for empirical testing (Figure 1).

Table 1. The Operationalization of OVO' Relative Advantage

Latent Variable	Indicators	Items
Relative Advantage (adv)	ADV1	I feel the OVO app makes virtual payments easier.
	ADV2	I think the OVO app saves time when making payments.
	ADV3	I feel the OVO app makes my activities and work much easier.
	ADV4	I feel the OVO app is quick to use.
	ADV5	I know the OVO app has a feedback feature (criticism and suggestions).

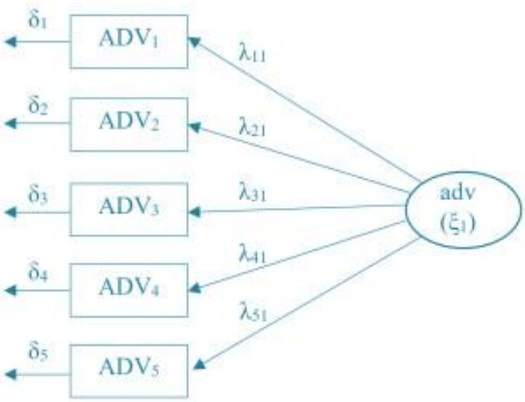

Figure 1. The visualization of Latent Variable 'adv' and its indicators.

Aspects that reflect a construct are called variables. When structured to be measurable, variables are called operational variables or observational variables. When presented in the form of ready-to-response questions, observational variables are transformed into question items (statements), often abbreviated to items.

The relationship between the indicators and their latent variables can be both reflective and formative. In a reflective relationship, the latent variable's value exists prior to its manifestation; the indicators merely reflect it. For example, in the construct of consumer loyalty, based on Aaker (1991), consumers loyalty are reflected by satisfaction, liking, brand advocacy behavior, willingness to recommend the brand to other buyers, and willingness to repurchase the brand.

In a formative relationship, the operational variables' values determine the construct's value. For example, according to Ajzen and Fishbein (1980) attitude toward a brand is formed by the belief (βi) that the brand possesses the i-th attribute and the evaluation (e_i) of the attribute's importance to the individual. Roberts et al. (2010) reported that most research, approximately 97%, uses a reflective model, especially in operations management. This discussion will focus on the reflective model.

In short, the limitations of product-moment correlation and the advantages of CFA are presented in Table 2.

Table 1. The Limitations of Product-Moment Correlation and the Advantages of the CFA for Construct' Internal Structure Verification.

	Product Moment Correltion	Confirmatory Factor Analysis
Information used	Total variance	Common variance
Factor score	Obtained by adding up the scores of all indicators regardless of whether the indicators in question are confirmed to be included in a latent variable or not.	Obtained only from its verified indicators
Decision	Statistical significance or insignificance of the r coefficient of each incator	Verification of each indicators (verified or non-verified) made by judgment using factor loading (FL) and average variance extracted
The Ability of the Indicators to explain their construct	With product moment correlation, the researcher cannot check the power of each indicators to explain latent variables	With CFA, the researcher can analysis an indicator ability to explain its latent variable using variance extracted and collective ability of all verified indicators using averaged variance extracted (AFE)

DISCUSSION

Verification of internal structure evidence verification aims to examine the internal relationships between question items of a construct (AERA et al., 2004). As is known, variance consists of unique variance, common variance, and total variance. Correlations between variances should be based on common variance. Common variance increases the number indicating a strong relationship between one variable and other variables within a construct, while unique variance decreases it. Product-moment correlation uses the total variance, which is the common variance and unique variance, while CFA uses common variance (Hair et al., 2014).

CONCLUSION

Product-moment correlation is inappropriate technic to verify internal structure of a construct. Its limitation for that purpose are as follows (1) the variance calculated in product-moment correlation is total variance; (2) factor score are simply obtained by totaling the scores of its indicators; and (3) with product moment correlation, the researcher cannot check the power of each indicators to explain latent variables

Confirmatory factor analysis (CFA) is the appropriate technic to verify internal structure of a construct. Its advantage are as follows: (1) use common variance; (2) factor is obtained only from its verified indicators; and (3) with CFA, the researcher can analysis an indicator ability to explain its latent variable using variance extracted and collective ability of all verified indicators using averaged variance extracted (AFE).

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