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Assessing Indicant Directionality of a Media Consumption Construct Using Confirmatory Tetrad Analysis

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Abstract

When assessing the psychometric properties of measures and estimate relations among latent variables, many studies in the social sciences (including marketing) often fail to comprehensively appraise the directionality of indicants. Such failures can lead to model misspecification and inaccurate parameter estimates (Jarvis et al. 2003). In order to further assess the correct directionality of a ‘media consumption’ construct’s indicants, this paper employs confirmatory tetrad analysis (CTA). Previous studies advocate this construct being best viewed as formative. However, our CTA suggests it could be modelled using a reflective orientation. We then conclude the paper drawing recommendations for future studies advocating that when assessing item directionality researchers should implement pre and post hoc tests.

Literature Review

When analysing questionnaire items and relations between latent variables, every social researcher makes decisions concerning the directionality of all path relationships. At the level of construct validity this involves assessing indicant directionality before testing structural relations. Firstly, the present study discusses the antecedent literature concerning theoretical and empirical approaches available for testing directionality. Secondly, the construct employed in the present analysis, that is ‘mass media consumption information exposure’, is discussed. In doing so we put particular emphasis on the origin of the construct before we test whether it should be treated either as a formative or reflective latent variable (LV). Thirdly, a CTA is undertaken with this LV, and results are presented. Finally, discussion focuses on recommending practical guidelines that researchers might follow when implementing research of the type discussed.

Directionality Assessment Methods

Two main types of indicators are discussed in the structural modelling literature, viz., reflective (effect) and formative (causative). The present section of the paper discusses these indicators and a third less common hybrid indicator. The first of the indicator types we examine are termed reflective measures or a Mode A representation (see Figure 1a). As the term implies, the indicants reflect the unobservable LV. Bollen and Lennox (1991) see reflective indicators as dependent on a LV. As the LV determines its indicators, the causal direction flows from the LV’s to the reflective item indicators and is represented by arrows flowing from the LV to the indicators as shown in Figure 1a. Fornell and Bookstein (1982, p. 292) believe that “constructs such as ‘personality’ or ‘attitude’ are typically viewed as underlying factors that give rise to something that is observed. Their indicators tend to be realized then as reflective.” Changes in the LV would necessarily lead to a corresponding change in all reflective indicators. One of the conditions of reflective indicators is that they should be highly correlated with one another. Each LV is considered a unidimensional construct.

Williams et al. (2003, p. 906) viewed formative indicators “as causes of the construct, such that variation in the measures produces variation in the construct [italic added]”. Some
authors refer to formative indicators as causal indicators (Bollen and Lennox 1991) that create emergent constructs (see Figure 1b). This is also commonly known as a Mode B representation. When using formative indicators we represent a distinctive dimension of the construct, indicating that the construct must be a multidimensional concept. The classic example is socio-economic standing (SES) being comprised of education, occupation, and income. Fornell and Bookstein (1982) considered the variables measuring the “marketing mix” to be formative, as would the belief evaluation in the Fishbein and Ajzen (1975) attitudinal model (adapted from Jarvis et al. 2003). Therefore, the correlations among the indicators are not necessarily high. A change in the LV may result from a change in any one of the indicators, while the others remain unchanged. In order to adequately capture a formative construct, ideally the universe of pertinent items should be included in the questionnaire because removing one indicator from the model would lead to dire repercussions as it “changes the composition of the latent variable” (Bollen and Lennox 1991, p. 308). Thus the implication is that the complete set of relevant indicators should be included in measuring such constructs.

Another concern with formative measures is the requirement that indicators ought to be relatively independent of one another, in which case it is important to check for multicollinearity. Kleinbaum et al. (1988) suggest that indicators should not exhibit variance inflation of more than the common cut off of 10. Another analytic limitation is that formative indicators cannot be analysed using exploratory factor analysis as the indicators should be reflective in nature if this method is to be utilised. In addition, standard tests of unidimensionality, reliability and validity cannot be used with formative constructs. Validity is often only supported with the formative index related within a nomological structure or by analysing an appropriate MIMIC (multiple indicator multiple cause) model (Diamantopoulos and Winklhofer 2001). Indicator elimination with a formative model should therefore be considered very carefully as the conceptual meaning of the construct can significantly change.

**Figure 1a-c: Alternative First Order Construct Specifications**

![Figure 1a-c: Alternative First Order Construct Specifications](image)

Finally, it is possible to have a hybrid type of indicator, Mode C in Figure 1c, which may include both formative and reflective indicators as representations of the one construct (Chin and Newsted 1999). Discussion of Mode C representation is beyond the scope of this paper. The correct specification of path directionality is imperative for researchers. In addition to influencing the conclusions drawn from modelling, decisions such as the choice of an appropriate data analysis method and the nature and number of items that are necessary in the questionnaire representing a particular construct, are also affected. Bollen and Lennox (1991) believe that if the indicators are reflective, a small sample of measures from the population of measures of the construct is sufficient to represent the construct.

However, formative measures typically require a large number of items to adequately tap into the construct conceptual domain. Often, formative indicators are treated as an index where regression analysis is employed to group the measures. Diamantopoulos and Winklhofer
(2001) provide guidelines regarding formative index construction. One popular method for creating formative indices is one that was used by Reinartz et al. (2004). The indicator type also determines the applicability of certain data analysis methods. While methods such as covariance-based structural equation modelling (thereafter CBSEM) and exploratory factor analysis are generally used to operationalise reflective indicators, and formative models can be estimated in CBSEM models, there are issues that must be addressed to achieve adequate model identification (Diamantopoulos 2006, Jarvis et al. 2003). Chin (1998, p. ix) has recognised that, “a common and serious mistake often committed by researchers is used to inadvertently apply formative indicators in a (covariance-based) SEM analysis [italic added].” This approach is supported by Jarvis et al. (2003) based on their analysis of CBSEM studies reported in the top four marketing journals (Journal of Marketing, Journal of Marketing Research, Journal of Consumer Research and Marketing Science) over a 24 year period (1977-2000). Their analysis found that 29% of constructs were modelled incorrectly as reflective rather than formative indicators. In short, formative indicators are often neglected despite their being most appropriate in many instances (Bollen 1989). Researchers have experienced problems and received criticism when they have addressed reflective and formative issues post hoc (e.g., Nueberg et al. 1997). Edwards and Bagozzi (2000, p. 155) argue that

[p]rocedures have been developed to identify and estimate models that specify constructs as causes or effects of measures. However, these procedures provide little guidance for determining a priori whether constructs should be specified as causes or effects of their measures. Moreover, these procedures address few of the possible causal structures by which constructs and measures may be related.

Researchers have an obligation to discuss these issues during the theoretical development stages of their research and if the issues are not clear-cut, then appropriate quantitative tests should be used as a decision aid. Jarvis et al. (2003) provide a comprehensive series of theoretical decision rules to assist in the determination of whether the measures and constructs ought to be treated as reflective or formative. The authors proffer a “logic check” for the researcher to determine issues of directionality before the data is collected and subsequently analysed. For example, the authors suggest that, if the construct is made up of mutually exclusive types of behaviour, where dropping an indicator may alter the meaning of a construct, then this should be treated as formative. Alternatively, researchers may conduct a confirmatory test called CTA or often referred to as confirmatory vanishing tetrad test (cf. Bollen and Ting 1993, 1998; Ting 1995). It is this test that is explained and applied within this paper. Researchers may benefit from using a combination of both approaches in their analyses.

Mass Media Consumption Information Exposure

The construct of interest in the present study is Mass Media Consumption Information Exposure, comprising behaviours that are initiated in order to acquire new or novel information. Hirschman (1980) labels this domain ‘Actualised Novelty Seeking’, highlighting that it is the ‘initiation’ of information seeking behaviours that forms the focus of the construct, not the ‘content’ of the information obtained. For example, a consumer may read a newspaper in an ‘attempt’ to acquire novel information, but it might be that no new information is actually ‘acquired’. Hirschman (1980) contends that indices of one’s attempt to acquire new information can be formed by summing the scores across a variety of consumed information media, and so the present study follows this path, consistent with Manning et al. (1995). Specifically, the behaviours making up the construct include consumption of television, radio, press, cinema, and the Internet. Stella (2008) has treated the
mass media consumption construct as a composite formative measure since it is represented by mutually exclusive types of behaviour that may be correlated, but need not be in order to satisfy the conceptual nature of the construct. For example, behaviours such as listening to the radio and watching TV are mutually exclusive, where a person may watch TV and not listen to radio, but they need not do both in order to be a higher consumer of media and be exposed to more information. Similarly, if one of the items measuring this construct were excluded, then this would change the conceptual nature or meaning of the construct. For example, if Internet use was excluded from the measure, then the present study would be missing measurement of a key media channel (Stella 2008).

Methodology

In the analysis reported herein, CTA was used to investigate the directionality for indicators associated with the media consumption construct. This approach was chosen over other data driven quantitative tests including Exploratory Vanishing Tetrad Analysis ([EVTA thereafter] Glymour et al. 1987), Cohen’s Path Analysis (Cohen et al. 1993, Callaghan et al. 2007) and CBSEM techniques via nested $\chi^2$ tests analysis techniques. As Cohen’s Path Analysis and nested CBSEM test are best implemented with structural and/or path models, CTA was selected as the preferred method. It is instrumental to note that “Tetrad refers to the difference between the product of a pair of covariances and the product of another pair among four random variables (Bollen and Ting 2000, p. 5).” While EVTA iterates all path combinations, CTA is confirmatory in the sense that the model to be tested is specified in advance. In this case it is a congeneric model (Jöreskog 1971). A tetrad for four variables $g$, $h$, $i$, $j$ is defined as:

$$\tau_{ghij} = \sigma_{gh} \sigma_{ij} - \sigma_{gi} \sigma_{hj}$$

where $\sigma$ indicates the population covariance of the subscripted variables. When $\tau_{ghij}$ is zero, that is referred to as vanishing tetrad (Bollen and Ting 1993). The analysis procedure followed the steps recommended by Bollen and Ting (2000, p. 5) in: (a) specifying the most plausible models of the relationship between indicators and LV’s, (b) identifying the model-implied vanishing tetrads for each model, (c) eliminating redundant vanishing tetrads, and (d) performing a simultaneous vanishing tetrad test. Based on this we first generated the implied covariance matrix through a CBSEM program (step (a) in Ting 1995). The main covariance structure estimation was undertaken using Mplus 5 (Muthén and Muthén 2008). However, all analyses were also cross-validated using PRELIS 2 (Jöreskog and Sörbom, 2006a), LISREL 8 (Jöreskog and Sörbom, 2006b) and AMOS 7 (Arbuckle 2006). The CTA test was then run through a SAS macro that automatically performs steps (b), (c) and (d) above. The null hypothesis is that the tetrad is equal to zero. That is, the difference between the product of a pair of covariances and the product of another pair of four random variables is zero. Rejecting this hypothesis would suggest a possible problem with the proposed model. A result that fails to reject the null hypothesis would indicate “support to the model that implies vanishing tetrads in the test” (Ting, 1995, p. 165). In other words, a significant result ($\chi^2$ p-value < .05) would indicate that there is a formative specification.

Ting (1995) constructed the original CTA macro, called CTA-SAS. It uses the model implied population covariance matrix which is derived from Mplus (or LISREL or AMOS) for the model under consideration and produces a test statistic similar to an asymptotic $\chi^2$ distribution with degrees of freedom equal to the number of nonredundant tetrads tested. This test is based on the data meeting the assumption of multivariate normality. The assumption of multivariate normality is not always met and Hipp et al. (2005) have recently developed a new revised form SAS macro which takes this into account. It utilises the polychoric
correlation matrix (PCM) and asymptotic covariance matrix (ACM) as well as the implied population covariance matrix. Such estimation is more appropriate to polytomous data (Jöreskog 1990). By using the PCM and ACM the estimation takes into account the ordinal structure of the data in a more accurate way (Jöreskog and Sörbom 1993). This newer macro also works with continuous data.

**Results and Discussion**

To determine whether to apply the newer Hipp et al. (2005) macro an assessment of data normality was undertaken. As shown in the following table there would be sufficient evidence that the assumption of multivariate normal data may be violated.

<table>
<thead>
<tr>
<th>Table 1 Test of Multivariate Normality for Continuous Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skewness</td>
</tr>
<tr>
<td>Value</td>
</tr>
<tr>
<td>19.706</td>
</tr>
</tbody>
</table>

The Hipp et al.’s (2005) macro was run and the CTA result was \( \chi^2 =14.814 \) with 10 df, \( p=.138 \). Therefore, the test reveals that the possibility of this construct being reflective cannot be ruled out. This would imply that the theorising in earlier stages of conceptual and definitional development would have to have solid reasoning for choosing a formative specification. It is not that this construct should not be modelled as formative in future based on this tetrad result but the researcher should address mixed results in more extensive discussions thereafter. As it exists the conceptual argument for this construct being treated as formative is sound. The contribution of this work is about the process researchers ought to follow when establishing directionality. That is, theoretically driven with the use of post hoc testing. The implementation of this type of analysis is not always straightforward due to the required formatting and shifting of data output between software packages. Transferring the relevant saved binary PRELIS file matrices into an ASCII text format using another program bin2asc.exe was found to be cumbersome. Accordingly, we recommend others utilise Mplus to run such analyses. We further suggest that researchers implement data driven directionality tests post hoc as a standard analytical procedure. The procedure will become easier to complete when it is released as a “point and click analysis tool” option in SmartPLS (Ringle et al. 2005) using bootstrapping advantages (Gudergan et al. 2008). Although CTA was only run on a single construct, in the present analysis the technique also offers some clear advantages when testing nested structural models. These advantages are outlined in Bollen and Ting (2000) and in a branding context in Wilson et al. (2006, 2007). It is our contention that researchers are currently at risk of inherently focussing too intently on the vast array of fit measures and predictive diagnostics that currently exist within available CBSEM and PLS output at the expense of considering directionality issues post hoc. An investigation of alternative and equivalent structural models is necessary if studies are to be more highly regarded. Kline (1998) suggests that this should be standard research practise. In the theoretical development and model building stages of research many assumptions are made about causal direction and may not be subsequently revisited. A more recent recommendation by Coltman et al. (2008) is that all researchers ought follow extensive theoretical development and also investigate directionality hypotheses for constructs and models post hoc (Venaik 1999). Not considering directionality issues with alternative models post hoc may be a small problem when the model is based on extremely well established theoretical underpinnings. Alas, this is often not the case.
References


