Validity of the Structural Properties of Text Based Causal Maps: An Empirical Assessment

Sucheta Nadkarni
University of Nebraska-Lincoln

V.K. Narayanan
Drexel University

Address correspondence to:

Sucheta Nadkarni, Ph.D.
Department of Management
University of Nebraska, Lincoln
Lincoln, NE 68588-0491
Phone: 402-472-8399
Fax: 402-472-5855
E-mail: snadkarn@unlnotes.unl.edu

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Abstract

Recently, text-based causal maps (TBCMs) have generated enthusiasm as a methodological tool because they provide a way of accessing large, untapped sources of data generated by organizations. Although TBCMs have been used extensively in organizational behavior and strategic management research, studies assessing the psychometric properties of TBCM measures are virtually non-existent. With the intention of facilitating large sample substantive research using TBCMs, we examine the construct validity of two most frequently employed structural properties of TBCMs: *complexity* and *centrality*. In assessing construct validity, we examine the internal consistency, dimensionality and predictive validity of the structural properties. Our results suggest that complexity is not a general cognitive attribute. Rather, it is indicative of domain knowledge. On the other hand, centrality, which reflects the degree of hierarchy characterizing the TBCM, is related to cognitive ability, and may reflect general information processing. Moreover, we found that complexity and centrality, but not cognitive ability, predicted student performance. We discuss the implications of these results.

Validity of the Structural Measures of Text-Based Causal Maps: An Empirical Assessment

Causal maps are graphical representations of the structure of individuals' idiosyncratic belief systems in a particular domain (Axelrod, 1976; Eden, 1992). Causal mapping was one of the first cognitive measurement techniques to be introduced into management research (Stubbart & Ramaprasad, 1988). It has been used extensively in organizational behavior and strategic management to study decision-making (Eden, Jones, Sims & Smithin, 1981), negotiation (Bonham, 1993), organizational cognition (Bougon, Weick & Binkhorst, 1977), and strategy (Barr, Stimpert & Huff, 1992; Calori, Johnson & Sarnin, 1994; Fahey & Narayanan, 1989). Recently, causal mapping has generated enthusiasm as a methodological tool because it provides a way of accessing large, untapped sources of data generated by organizations (Huff & Fletcher, 1990).

Research employing causal mapping has focused on the *content* and *structure* of cognition represented in the maps. The content of a causal map captures the meaning of specific concepts embedded in a causal map, whereas the structure of a causal map reflects the organization of the concepts in a map. Although the content of a causal map provides rich insights into the meaning embedded in a map, comparisons of the content of causal maps of individuals is very difficult due to peculiar and/or un-interpretable responses (Mohammed, Klimoski & Rentsch, 2000; Rentsch, Heffner & Duffy, 1994). As a result, the content of causal maps has been used primarily in qualitative and exploratory studies that focus on the description of context-specific causal maps. Since most techniques used to analyze content lack quantitative mechanisms for comparing causal maps across respondents, researchers have typically used structural measures of causal maps in comparative studies linking causal maps to other relevant constructs. Structural measures have been linked to learning (Carley & Palmquist, 1992), performance (Carley, 1997; Hackner, 1991), functional experience of managers (Laukkanen, 1994) and organizational scope (Calori et al, 1994). Currently, substantive research using structural properties of causal maps appears to be advancing from qualitative description to a hypothesis-testing mode that employs statistical inference based on data drawn from large samples (Calori et al., 1994; Hackner, 1991).

One of the prominent approaches to the elicitation and representation of causal structures is text-based causal maps (TBCMs). TBCMs are derived from systematic coding of documents or transcripts (Carley & Palmquist 1992; Levi & Tetlock, 1980). Thus, TBCMs rely on non-invasive and non-reactive data collection techniques that avoid the recall biases of interviews (Axelrod, 1976; Barr et al, 1992) as well as the danger that the very process of eliciting the map by means of interviews may change the cognitions of the participant. TBCMs are rich in descriptive detail and portray individuals' thinking about their environment in operational terms. This method provides a way to examine the variety and development of complex cognition over long periods of time (Barr et al, 1992; Fahey & Narayanan, 1989), and may be the only way to tap the thinking of individuals who no longer exist in the firm. Furthermore, compared to other methods of eliciting cognitive maps (e.g. repertory grid), TBCMs have been found to be more economical in terms of time and effort required of researchers and subjects (Brown, 1992). New developments in textual analysis softwares such as AUTOMAP (Eleanor, Diesner & Carley, 2001) provide a semi-automated way to construct causal maps. Further developments of such programs may considerably reduce the labor intensiveness that currently restricts the use of TBCMs in large sample studies.

Despite the increasing popularity of TBCMs, the move toward testing theoretical relationships using TBCMs is currently constrained by the *lack of development of sound measures* of relevant constructs. Although researchers have directed their attention to assessing the reliability of methods used to elicit and represent managers' causal maps, (Brown, 1992; Daniels & De Chernatony, 1995), the validity of the measures derived from TBCMs has received limited attention. Studies assessing the psychometric properties of text-based causal mapping measures are virtually non-existent in the literature (Mohammed et. al., 2000). This is a significant gap in the literature.

With the intention of facilitating large sample comparative studies with substantive intentions, we examine the construct validity of two most frequently employed structural measures of TBCMs: *complexity* and *centrality*. As pointed out by Schwab (1980), the systematic evaluation of construct validity enhances our knowledge of substantive relationships of a construct of interest. In assessing construct validity, we explore the internal consistency, dimensionality and predictive validity of *complexity* and *centrality* of TBCMs. This study makes three major contributions to causal mapping research. First, this study resolves the confusion prevalent in the literature on the dimensionality of complexity and centrality by empirically demonstrating that complexity and centrality represent *distinct* facets of causal structures. This distinction is critical in specifying theoretical relationships of complexity and centrality with other relevant constructs. Second, this study sheds some light on the on-going debate in the literature as to whether the structural properties of TBCMs capture *domain-specific knowledge* or *general cognitive attributes* of individuals (Bieri, 1961; Bieri & Blacker, 1956; Chi & Glaser, 1984; Streitz, 1988). The distinction between complexity and centrality established in this study may help resolve this debate. Finally, this study addresses the importance of the structural properties of causal maps in predicting performance. This points to the viability of employing complexity and centrality as outcomes in studies related to intervention (e.g. training) and strategic change (e.g. turnaround strategy).

The paper is organized as follows. In the following section, we define TBCMs, and identify the structural properties of causal maps most frequently employed in literature. In the third section, we enumerate the most frequently used measures of complexity and centrality and discuss the critical issues related to their construct validity. The fourth section describes the research methods employed in the study. In the fifth section, we report the results of our work. The final section discusses the results and provides implications of the results for future empirical work.

Theoretical Overview

Text Based Causal Maps

A text based causal map (TBCM) captures the *cognitive structures* of an individual by representing how domain knowledge is arranged, connected, or situated in his/her mind (Carley & Palmquist, 1992; Eden, Ackermann, & Cropper, 1992). The cognitive structure represents an individual's knowledge about a concept or type of stimulus including its attributes and the relations among those attributes (Fiske & Taylor, 1991). As representations of cognitive structures, TBCMs extract both concepts and relationships among concepts through the systematic coding of transcripts or documents representing the writings or statements of individuals (Mohammed et. al., 2000). The researcher interprets the materials, elicits the important concepts and generates the map. TBCM has been used extensively in foreign policy analysis (Axelrod, 1976) and organization science (Barr et al, 1992; Fahey & Narayanan, 1989).

Four major assumptions underlie the use of TBCMs as representations of individuals' mental models. First, TBCMs are *subjective* representations of the world (Carley & Palmquist, 1992; Johnson-Laird & Nicholas, 1983). In other words, TBCMs represent an individual's perception of the world and not the actual, concrete reality that is external to the individual. Second, TBCMs can be used to represent the assertions made by subjects in the text as *networks of concepts* (Axelrod, 1976; Carley & Palmquist, 1992; Eden, Jones & Sims, 1979). Third, TBCMs capture cognitive structures by focusing on both the concepts in a narrative and the relationship among those concepts (Carley & Palmquist, 1992).

Approaches to the Construction of TBCMs

TBCMs are cognitive maps that are designed primarily to assess the causal structures and not the cognitive content (Mohammed et al, 2000). They have sometimes been described as content-free maps that represent the organization and structure of cognition (Eden et al, 1992; Calori et al, 1994). Since causal maps are idiosyncratic, to compare causal structure, it is crucial to standardize the content of the causal maps. Two different approaches have been employed in cognitive psychology literature to recast the subjective content of individual causal maps into a common content scheme that allows comparisons across individuals: *theory-driven* and *benchmarking.*

In the theory-driven approach, the subjective content in the individual causal maps is recast into theoretical categories salient in the domain represented by the maps (Carley & Palmquist, 1992; Fahey & Narayanan, 1989; Ford & Hegarty, 1984). Tying emergent categories to extant theory has been recommended to develop common and standard categories that are distinct and uniform in breadth and level of abstraction (Carley & Palmquist, 1992; Fahey & Narayanan, 1989; Ford & Hegarty, 1984), especially for domains with well-established theories.

The benchmarking approach has been used widely in expert-novice and educational psychology studies to compare the TBCMs based on 'ideal' concepts (Hong & O'Neil, 1992; Wilson & Rutherford, 1989). In these studies, a list of ideal concepts and links between concepts is developed based on the causal maps of one or a group of experts. This list is then used to compare the causal maps of individuals. Such a benchmarking approach is especially useful in studies linking causal maps to performance and learning.

Although standardization allows researchers to compare TBCMs across individuals, there are some dangers involved in standardization (Mohammed et al, 2000). This is because the researchers generate the maps rather than the participants (Walsh, 1995). In the case of theory-driven approaches, researchers select the domain theories as well as the theoretical concepts underlying these theories. Similarly, in the case benchmarking, researchers decide who the domain experts are and the rules for benchmarking. Inter-rater reliability is therefore critical in the process of standardizing the content of the maps. In both the approaches, the coders need to make several coding choices and these choices may alter the results.

<u>Structural Properties of TBCMs</u>

The structure of a TBCM refers to the configuration of the map and represents how the concepts are arranged, connected or situated in an individual's mind. The structural properties of TBCMs appear to be especially useful in large sample studies, since they are amenable to quantitative representation using network methods. The two structural properties of TBCMs most frequently used in literature are *complexity* and *centrality.*

Complexity captures the level of differentiation and integration in the map, i.e. the breadth and comprehensiveness in the articulation and elaboration of domain knowledge. Differentiation reflects the number of concepts in a map, whereas integration reflects the interconnectedness between the concepts. Complex maps reflect greater comprehensiveness of domain knowledge than simple maps, which consist of few concepts and sparse interconnections. Complexity of TBCMs has been linked to learning (Carley & Palmquist, 1992), performance (Carley, 1997; Hackner, 1991) and scope of organizations (Calori et. al., 1994). Centrality reflects the degree to which the map is hierarchical and focused on a single concept or few concepts in the map (Eden et. al., 1992). A highly centralized map is focused around a single concept, with most concepts in the map being directly or indirectly connected to this central concept either as a cause or an effect. Highly centralized maps display a clear sequence of relationships between concepts (Fiol & Huff, 1992). Studies in logic indicate that reasoning processes characterized by a clear sequence of 'if-then' relationships imply logical thinking (Winston, 1984). This implies that the higher the centrality, the greater the logical pattern and focus within the causal map.

<u>Measures of Complexity and Centrality</u>

Complexity has been measured by three indicators--comprehensiveness, density-1 and density-2, whereas centrality has been measured by two indicators--concept-level centrality and causal map-level centrality. Table 1 summarizes the empirical studies employing the different measures.

Insert Table 1 about here

The first measure of complexity--comprehensiveness--is defined in terms of the number of concepts in a causal map (Calori et al., 1994; Langfield-Smith & Lewis, 1989). It captures the differentiation facet of complexity. At the individual level, Carley and Palmquist (1992) used this measure to represent the complexity of a student's causal map at the beginning and end of a research writing course. The number of concepts in the student's causal maps at the end of the course (29) was higher than the number at the beginning of the course (23), leading the researchers to suggest that the student's conception of research writing expanded over the course of the term. At the group level, Carley (1997) found that high-performing groups had more concepts in their causal maps than low-performing groups.

The second measure of complexity--density-- captures the integration facet of complexity. It has been operationalized in two ways. The first, which we call density-1, is the ratio of the number of links between concepts to the total number of concepts in the causal map. At the individual level, Eden et al. (1981) used this measure to illustrate how the subjective model of a client in policy analysis can be represented using causal mapping. At the group level, Laukkanen (1994) found that the aggregated map of the distributor managers had higher density than that of the dealers. At the organizational level, Calori et al. (1994) found that the greater the scope of an organization, the greater the density of causal maps of CEOs. Density-2 is computed as the ratio of number of links in a map to all possible links. This measure has been adopted from social network analysis (Knoke & Kuklinski, 1982). In the strategic management literature, Fahey and Narayanan (1989) used this measure to trace how changes in the environmental complexity correlated with the density of the causal maps of executives.

Centrality has been operationalized by two measures, typically employing measures of social network analysis (Knoke & Kuklinski, 1982). The first measure, concept-level centrality depicts the relative importance of each concept in a map. A concept is considered to be most central if it has the most links (cause or effect) with other concepts. At the individual level, Ford &

Hegarty (1984) used this measure to identify the key concepts in the causal maps of students and managers. They reported a high level of agreement between the causal maps of a group of MBA students and a group of full time practicing managers concerning the overall causality of organizational context, structure and performance. At the group level, Bougon et al. (1977) found a strong association between the centrality of a concept in an 'etiograph' (content-free graph constructed from a causal map) and the level of the participants' perceived influence over the situation. Unlike concept-level centrality, the second measure--causal map-level centrality--evaluates the extent to which the configuration of a causal map is centralized around a single concept. Eden, Jones and Sims (1983) extended the concept of centrality to the level of a causal map. Here, in addition to accounting for the total number of concepts that are direct or indirect causes or effects, the average length of all the paths linking one concept to others in the same causal map is taken into account. The difference between the centrality score of the most central concept and that of all other concepts is the centrality of the map (Knoke & Kuklinski, 1982). Thus, a highly centralized map is focused around a single concept, with most concepts in the map being directly or indirectly connected to this central concept either as a cause or an effect. Eden et al. (1981) used this measure to compare the group level causal map of the policy analysis team with the individual level causal map of its client.

Hypotheses

Dimensionality

Extant literature is unclear on the dimensionality of the two facets of TBCMs-- complexity and centrality. One view implies that complexity and centrality capture the same facet of TBCM. Specifically, they represent opposite ends of a continuum such that as the complexity of the map increases, its centrality declines and vice versa (Eden et al, 1992). Social network literature however suggests that complexity and centrality reflect distinct facets of cognitive structures (Carley & Palmquist, 1992; Knoke & Kuklinski, 1982). Empirical studies examining the dimensionality of the TBCMs are virtually absent. As a result, little is known as to whether measures of complexity and centrality represent different ends of the same continuum or whether they capture distinct dimensions of TBCM.

Drawing on the social network theory (Carley & Palmquist, 1992; Knoke & Kuklinski, 1982), we argue that complexity and centrality represent conceptually distinct dimensions of TBCMs and not the two ends of the same continuum. First, complexity captures the differentiation or elaboration of domain concepts, neither of which is captured by centrality. Second, centrality and complexity represent different facets of organization (Carley & Palmquist, 1992). Centrality reflects the degree of *focus* and *hierarchy* in a causal map, whereas complexity reflects the *integration* of concepts. We therefore expect that:

H1: Complexity and centrality represent distinct dimensions of TBCMs.

Nomological Validity

Nomological validity is demonstrated when the empirical relationships observed with a measure match the theoretically postulated nomological net of the construct (Schwab, 1980). We encountered two major obstacles in proposing a unique nomological net for complexity and centrality. First, there has been a dearth of research either specifying theoretical linkages or testing empirical relationships between centrality and other constructs. Although numerous studies in cognitive psychology have specified relationships between complexity and other constructs, studies linking centrality to other constructs are virtually absent. Second, as discussed earlier, there has been a lack of clarity on the distinctness of the two constructs. Given this paucity of research, we anchor the nomological net of centrality in the literature on cognitive structures. Since TBCMs capture cognitive structures (Carley & Palmquist, 1992), centrality should be related to the antecedents and consequents of cognitive structures.

Antecedents. We used cognitive ability as the primary antecedent in the nomological net of complexity and centrality. Cognitive ability, also called mental ability or intelligence, represents an individual's general ability to gather, retain and process information and to reason with information (Schneider & Angelmar, 1993). It reflects an individual's level of mental manipulation of words, figures, number, symbols, and logical reasoning (Gatewood & Field, 1994).

Two opposing views are prevalent in the cognitive development literature on the relationship between cognitive ability and complexity. First, some studies have strongly argued that cognitive ability captures a significantly different construct from complexity of cognitive structures (Chi & Glaser, 1984; Streitz, 1988). Cognitive ability provides a general assessment of the basic information abilities of individuals, whereas complexity captures an individual's understanding of a specific domain (Schneider & Schmidt, 1992). Moreover, cognitive ability refers to stable personality attributes (e.g. verbal, mathematical and spatial skills), which are not readily modifiable (Ryan & Sackett, 1987). On the other hand, cognitive structures are representations of domain knowledge of individuals that changes from time to time (Carley & Palmquist, 1992; Chi & Glaser, 1984). For example, studies have shown that complexity can be increased through instruction and training (Carley & Palmquist, 1992). Finally, cognitive ability is determined primarily by the internal attributes of an individual such as I.Q. level, whereas cognitive structures are determined both by internal abilities of individuals as well as external factors such as instruction (Carley & Palmquist, 1992) and work experience.

The second view argues that cognitive structures may reflect not only the domain knowledge of individuals, but also information processing capacity that may be extended to other domains. Bieri (1961) and Bieri and Blacker (1956) argued that a person who displays complexity in one domain is likely to formulate other domains in a complex manner. This view has also proposed that the general cognitive ability of individuals influences their domain-specific cognitive structures (Bieri & Blacker, 1956; Myers, 1982). Individuals possessing a high level of cognitive ability are able to perceive, recognize and process external stimuli more comprehensively and thoroughly than individuals with a low level of cognitive ability. As a result, individuals with high cognitive ability develop complex cognitive structures relating to specific domains. On the other hand, individuals with low cognitive ability tend to simplify the external stimuli and develop simple cognitive structures. The relation between cognitive ability and complexity has received some empirical support. Using a modified Rep test, Myers (1982) found a significant relationship between intelligence tests and complexity. Bieri and Blacker (1956) found a significant correlation between four of six Rorschach derived measures of complexity and intelligence scores. Thus, cognitive ability and complexity may be related.

H2: Complexity of TBCMs will be positively related to cognitive ability.

Since cognitive ability reflects the general ability of an individual to reason logically and process information effectively (Gatewood & Field, 1994), individuals with a high cognitive ability should be able to formulate problems, reason and process information more effectively than individuals with low cognitive ability. Studies on problem solving and reasoning abilities (Gentner

& Stevens, 1983; Hong & O' Neil, 1992; Wilson & Rutherford, 1989) have shown that the cognitive structures of students with efficient problem solving and reasoning skills show a hierarchical and logical pattern of organization. This suggests that individuals with high cognitive ability may process domain information using centralized cognitive structures.

H3: Centrality of TBCMs will be positively related to cognitive ability.

Consequences. Since complexity and centrality reflect the information processing capacity of individuals in a specific domain, we focus on academic performance as a consequence of the structural measures of TBCMs. Academic performance reflects the domain-specific academic achievements and abilities that are the outcome of learning (Eccles, 1994; Whetten & Clark, 1996). Extant literature suggests that academic performance captures two types of domain-specific abilities: conceptual and practical (Dehler, 1996; Whetten & Clark, 1996). The conceptual ability enables individuals to effectively identify, articulate and elaborate domain information and connect diverse areas of the domain. Practical ability refers to the degree to which individuals can effectively apply the domain concepts in problem solving situations through diagnosis and reasoning.

Complexity positively affects academic performance by facilitating efficient information processing of instructional materials. According to cognitive psychology research, complexity reflects the ability of an individual to deal with a wide variety of variables and determines his/her information processing capacity in that domain (Bieri, 1956; Mann, 1979; Varma & Krishnan, 1986). High-complexity individuals seek more information and make more causal attributions than low-complexity individuals. Consequently, these individuals can acquire, understand and articulate conceptual knowledge better than individuals with simple cognitive structures. Complex cognitive structures may also facilitate the application of concepts in problem solving situations. High complexity individuals are less likely to miss important variables in problem diagnosis and choice of problem solutions than individuals with simple structures (White & Frederickson, 1986; Wilson & Rutherford, 1989). This suggests that:

H 4: Complexity will be positively related to academic performance.

Relatedly, centrality may facilitate information processing and application in problem solving situations. Problem solving situations require individuals to understand cause-effect sequences of the problem variables, generate hypotheses (in the form of if-then logic) based on the causal sequences and to conduct analyses of the consequences arising from various combinations of these hypotheses (Marek, Griggs & Koenig, 2000). Lack of focused and sequential cognitive structures can increase the cognitive load in generating and testing such hypotheses, thereby leading to confusion and biases in arriving at problem solutions (Newstead & Griggs, 1992). Studies in psychology have found that individuals with clear and logically sequenced cognitive structures arrive at accurate and effective problem solutions by channeling attention to the appropriate combination of hypotheses (Hong & O'Neil, 1992; Marek, Griggs & Koenig, 2000; Newstead & Griggs, 1992).

H5: Centrality will be positively related to academic performance.

Method

Sample

Our sampling strategy reflected a trade-off among two competing criteria: 1) demands of sample size for statistical analysis versus feasibility as dictated by the labor-intensive nature of causal mapping, 2) the homogeneity of sample versus generalizability of our findings (diversity of sample). We were able to collect data from two *different* samples. First, we solicited data from 207 undergraduate students at a major Mid-western university enrolled in four sections of a course in organizational behavior and one section of a strategic management course. These sections were taught by four instructors. We received completed usable data from 165 (80%) of these students. Second, we solicited responses from 43 students enrolled in a strategic management course in an evening MBA program. We received completed data from 39 (92%) students. Our final sample consisted of 204 students: 165 undergraduate and 39 MBA students. The two samples differed in terms of educational background and managerial experience. A description of the two samples is presented in Table 2.

Insert Table 2

Data Collection

Causal mapping requires the elicitation of a text from respondents that can be used to extract the cognitive structures pertaining to a *specific* domain. The text may be elicited through interviews or respondents' written material. We chose to elicit written material since it was more feasible in a classroom situation and offered the most convenient medium of generating large samples. Respondents' analyses of cases represented the text from which causal maps were derived. Case analysis evaluates the ability to apply what the respondents have learned in course work to an actual business situation, analyze the situation and identify the critical issues/problems that must be addressed (Christensen, 1987). Thus cases demand cognitive effort, and analyses should reflect the domain of the course.

We chose respondent analyses of the Dashman Company case (Glover & Hower, 1952) for deriving causal maps. The case portrayed the situation faced by a newly appointed vice president of purchasing, as he tried to centralize the purchasing function in the company that had historically operated in a decentralized mode. Our choice of the Dashman case was based on four reasons. First, Dashman is a classic case that has acquired long-standing usage in many business schools in courses that deal with organization behavior or strategy implementation. Second, the instructors judged the content of the case and the timing of the analysis to be appropriate for the course they were teaching in terms of the specific course objectives. Third, the case is one-and-one-half pages long, thus sufficiently concise for respondents to comprehend without difficulty. Finally, the case allowed varying interpretations by the respondents regarding causes of problems and challenges and allowed them to draw from a broad range of organizational behavior concepts.

Open-ended questions that covered both diagnostic and prescriptive aspects (Mintzberg & Quinn, 1998) of the case were posed in order to the respondents to elicit their responses to the Dashman case. The case analyses were part of a course assignment, and carried a grade to ensure respondent involvement in the analysis. Finally, the respondents were asked to submit a two-page case report. The decision pertaining to page length reflected a trade-off among three criteria. First, we wanted to create a situation similar to the one the respondents would have faced if they had been asked to write an analysis in an actual work setting; indeed concise and succinct presentation is considered a requisite of effective business writing (Sorenson, Savage, & Hartman, 1993). Second, to facilitate inter-student comparisons, a standard upper limit on the length of the response was desirable. Third, however, causal mapping literature suggests that the structural measures of causal maps are sensitive to the length of the narratives in an interview setting (Eden, 1992). After consultation with the instructors, two pages were deemed to be adequate for a comprehensive analysis of the Dashman case.

Data for this study were collected at three different time periods, with similar procedures being used for both the undergraduate and evening MBA student samples. First, midway through the semester, personality, cognitive ability and demographic data pertaining to the students were collected. Two weeks later, the participants were assigned the Dashman Company Case and were instructed to analyze the case and submit a two-page essay at the end of the following week. Since the five sections of the student sample were taught by four different instructors, a time was selected when all sections had covered approximately the same number of chapters. Third, a week later, student responses to the Dashman Company Case were collected. Finally, at the end of the semester, grade data (including data on individual components of the grade) were obtained from the respective instructors.

TBCMs were constructed from the narratives, and the structural measures of the maps were related to 1] cognitive ability and 2] course grades (Stone, 1978).

Derivation of TBCMs

Following Axelrod (1976), the causal maps were derived from the student essays in a four-step procedure, which is described in Figure 1. The raters involved in each stage of the causal mapping procedure were not involved in the study either directly (authors) or indirectly (instructors or undergraduate/graduate students), neither were they aware of the hypotheses of the study. Moreover, the rating was done blindly wherein the names of the students were erased from the cases before giving them to the raters.

Insert Figure 1 about here

In the first step, two raters independently identified statements from the student essays that explicitly contained a cause effect relationship. Examples of key words used in identifying causal statements included ‘if-then’, ‘because’, ‘so’ and ‘as.’ Inter rater reliability was assessed using Kendall's coefficient of concordance (W=0.80). In the second step, the causal statements identified in the first step were broken into ‘causes’ and ‘effects’ to identify the ‘raw causal maps.’ This step yielded 80 raw (uncoded) concepts from the students’ narratives.

In the third step, a coding scheme was developed to code the raw cause and effect phrases. As discussed earlier, it is important to control the content of the raw causal maps to facilitate comparison of the causal structure of TBCMs. We used the *benchmarking*[1] approach (Hong & O’Neil, 1992; Wilson & Rutherford, 1989) to develop a common coding scheme to compare the causal maps of the subjects. This approach is aimed at determining the accuracy of the *content* of the causal map by using the causal map of an expert as a benchmark. Concepts in the causal map of an expert are considered ‘accurate’ or ‘ideal and concepts not salient in the maps of the expert are ‘inaccurate’ or ‘irrelevant’ concepts. The distinction between accurate and inaccurate maps is especially useful in the computation of complexity and centrality. For example, a causal map may contain a number of inaccurate or redundant concepts that may increase the complexity of the map. Inclusion of inaccurate and redundant phrases may create a bias in measuring the complexity and centrality of a map. In such cases, a complex map may not necessarily be an accurate map. To ensure that only accurate and relevant concepts in students’ case analysis are included in computing the structural measures of causal maps, a coding scheme was designed to identify a list of concepts that are most critical to the case. We used the comprehensive list of 24 critical issues in the Dashman Co. Case identified by Hodgson & Dill (1970), the authors of the Dashman case, in their discussion of the case in *Harvard Business Review*. The issues included organizational structure, personnel management, communication procedure, human relations, and long-term versus short-term goals. This list is shown in Appendix A. Hodgson and Dill (1970) used this list of issues to assess the degree to which company managers effectively organized their thoughts on the case. This prescriptive list of concepts was therefore useful in filtering accurate and relevant concepts in the essays from inaccurate and redundant concepts in student essays. We also showed the list to the different instructors and requested them to add any additional concepts or issues that they thought were appropriate and relevant to the case. The instructors did not make any additions to or deletions from the list of concepts.

Of the 80 raw concepts that emerged from the student case reports, only 12 (15%) raw concepts could not be recast into any of the 24 concepts in Hodgson and Dill's list of concepts and were excluded in the computation of complexity and centrality. To check for the overgeneralization bias, we conducted two additional analyses. First, we reran the regression analyses after including the 12 'irrelevant' concepts in the computation of complexity and centrality. Second, we recomputed complexity and centrality based on the 80 raw concepts that directly emerged from the student reports and reran the regression analyses. The regression results of these two analyses were consistent with the regression results shown in Table 5 suggesting that the overgeneralization bias was not a threat in the current study. These results are reported in Appendix B.

Finally, three raters independently recast the causes and effects in the essays into the concepts in the list identified by Hodgson and Dill (1970) ($\underline{W}$=0.84).

Measures

*Structural measures of TBCMs***.** To evaluate the face validity of complexity and centrality, we employed the pretest sorting technique suggested by Anderson and Gerbing (1991). The five measures were sorted into two constructs by one senior faculty member and three Ph.d. students in cognitive psychology and two practicing psychological counselors. We provided the subjects with the five measures on separate cards and asked them to sort the measures by the two constructs: complexity and centrality. There was complete convergence among the five subjects in assigning each measure to the appropriate construct, suggesting acceptable face validity for the measures of centrality and complexity.

The measures of complexity and centrality were computed from the causal maps using a computer program called Netanalysis. The three measures of complexity were comprehensiveness (number of concepts) and density-1 (number of links between concepts divided by number of concepts in the map) and density-2 (number of links between concepts divided by the total possible links between the concepts). Centrality was measured by concept-level centrality and causal map level centrality (Eden et. al., 1992; Knoke & Kulinki, 1982). Centrality of each concept in the causal map was measured by adding the total number of concepts to which a specific concept in the map is linked either directly or indirectly. Each successive layer of concepts was assigned a diminishing weight (i.e., a distance decay function). For example, a concept directly linked to the central concept was given a weight of 1. Concepts in the next layer were assigned a weight of ½, concepts in the next subsequent layer were assigned a weight of 1/3, and so on. The centrality of a concept was the weighted average length of all the total paths that link it to other concepts in the map. The causal map level centrality was computed as the centrality of the most central concept minus the centrality of all other concepts in the map scaled by the total number of possible links between the concepts in the map.

Appendix C illustrates TBCMs that are high and low on complexity and centrality. For example the low complexity TBCM has only six concepts and three links between concepts, whereas the high complexity TBCM has 14 concepts and 22 links between concepts. Low centrality TBCM has 8 concepts and four links, with four concepts having the same number of links going in or coming out of them. Hence no single concept is central to the map. Since all concepts have the same level of centrality, the causal map-level centrality is zero. On the other hand, high centrality TBCM is focused around the concept '*Selection of New VP from Outside the Organization'* with most of the links in the map going in or coming out of this concept. This map, therefore, has a high degree of centrality, with '*Selection of New VP from Outside the Organization'* being the central concept.

Cognitive ability. Cognitive ability was measured by the Wonderlic test. The Wonderlic test measures general cognitive ability of an individual, with subtests measuring verbal, quantitative and spatial aptitudes (E.F. Wonderlic and Associates, Inc., 1983; Hunter, 1989). The test is psychologically equivalent to the two dominant measures of general cognitive ability in the research literature--the Wechsler Adult Intelligence Scale (WAIS) (r=0.93) and GATB (r=0.90) (Hunter, 1989). However, unlike WAIS and GATB that are very lengthy tests, Wonderlic requires subjects to complete 50 questions in 12 and a half minutes and is therefore time effective. Studies have indicated that Wonderlic has a reliability of 0.73 to 0.95 and an internal consistency of 0.88 to 0.94 across different questions (Dodrill, 1983).

Academic performance. We used student course grade as the measure of domain-specific academic performance. Student course grades have been used as a measure of student performance in previous validation studies (Adams, 1970; Borg, 1979; Kleitman, 1963; Skinner, 1985). Each of the five instructors based the grades on three components: three tests, three case analyses (in addition to Dashman) and class participation. The three tests were in the form of multiple choice questions, definitions, short answers and essay questions that tested students' conceptual understanding of the organizational behavior and strategic management concepts. Case analyses assignments (excluding the Dashman case) required students to analyze, diagnose and provide solutions to practical organizational issues. To avoid common method bias, we excluded the case analyses scores of the Dashman case from the grades. Finally, class participation was measured through student attendance and instructor evaluation of their contributions in class discussions. The tests constituted 40-50 percent of the final grade, the case analyses constituted 30-40 percent of the final grade, whereas class participation represented 20-30 percent of the final grade.

At the end of the semester, grade data (including test, case analyses and class participation grades) for participants were obtained from each instructor. The data were coded so that it was possible to link the individual subject code with the grade and the instruction group to which the student belonged.

Control variables. We used two control variables in our analyses: relevant personality variables and instructor. Prior research implies that two personality traits may relate to academic performance: conscientiousness and openness to experience (Mount & Barrick, 1994). The Goldberg (Big 5) personality indicator is an established instrument to measure conscientiousness and openness to experience with reportedly high reliability (Goldberg, 1990). The coefficient alphas of the two dimensions in our data set were: conscientiousness (0.82) and openness to experience (0.78). We also used instructor as a control variable because past research has suggested that instructional style affects both cognitive structures of students (Dehler, 1996; Hong & O' Neil, 1992) and student performance (Miner, Das & Gale, 1984). Four dummy variables were created to partial out the effects of differences in the four instructors in the undergraduate sample as well as the differences across the two samples (undergraduate and MBA). The four dummy variables were labeled: instructor-1, instructor-2, instructor-3 and instructor-4 respectively. The MBA sample was assigned the value of zero for each dummy variable.

Data Analyses

Cronbach's alpha was used to assess the internal consistency of the three measures of complexity and two measures of centrality. Principal components factor analysis with Varimax and Oblimin rotation was used to assess the convergent and discriminant validity of the five measures of complexity and centrality. Hierarchical regression analysis was used to investigate the effect of cognitive ability on complexity and centrality controlling for sample, instructor and the two personality variables. Hierarchical regression was used to explore the influence of centrality and complexity on student course grades while controlling for instructor, sample, cognitive ability and the two personality variables.

Results

The means and standard deviations of and correlations among the study variables are presented in Table 3. The correlation among the three measures of complexity is higher than their correlation with the two measures of centrality. The correlation difference test showed that the correlations among the three measures of complexity were significantly higher than their correlation with the two measures of centrality. Similarly, correlations between the two measures of centrality were significantly higher than their correlation with the three measures of complexity as indicated by the correlation difference test. The results of the correlation difference test are shown in Appendix D. As shown in Table 3, complexity measures are not correlated with Wonderlic, but centrality measures were significantly correlated with Wonderlic ($p< 0.05$). Neither complexity nor centrality measures were significantly related to conscientiousness and openness to experience. Both complexity ($p<0.001$) and centrality ($p<0.05$) measures were significantly correlated with course grade. Neither Wonderlic nor personality variables were related to course grade.

Insert Table 3 about here

We evaluated the internal consistency of the three measures of complexity and two measures of centrality using coefficient alpha. The coefficient alpha for comprehensiveness, density 1 and density 2 was 0.92, whereas the alpha for concept-level centrality and causal maps level centrality was 0.94. These results indicate an acceptable level of internal consistency for complexity and centrality.

We assessed the dimensionality of the five measures of causal mapping using the principal components factor analysis separately with Varimax and Oblimin rotation. The results of the analyses for both samples are presented in Table 4. As shown in the table, the factor analysis with Varimax rotation yielded two factors with Eigen values of 2.72 and 2.21 respectively. Comprehensiveness, density-1 and density-2 have high factor loadings on Factor I (0.95, 0.90 & 0.94 respectively) and low factor loadings on factor II (0.28, 0.32. & 0.40 respectively) Similarly, concept-level centrality and causal map-level centrality loaded highly on Factor II (0.95 & 0.93 respectively) and low on Factor I (0.31 & 0.26 respectively). The factor analysis with Oblimin rotation also yielded two factors with Eigen values of 2.59 and 2.19 respectively. Comprehensiveness, density-1 and density-2 show high factor loadings on Factor I, whereas concept-level centrality and causal map-level centrality measures show high loading on Factor II. The inter-factor correlation in the factor analysis with Oblimin rotation indicates a lack of significant correlation between the two factors (-0.04) providing additional evidence of distinctiveness of the two dimensions.

Insert Table 4 about here

Since the five measures represented the two underlying dimensions of complexity and centrality, in our assessment of nomological validity, we aggregated the three measures of complexity and two measures of centrality into two composite measures of complexity and centrality by averaging the z scores of the individual measures[2]. The correlation between the aggregated measures of complexity and centrality was low (0.29, n.s.).

The results of hierarchical regression conducted to examine the relation between cognitive ability and the structural measures of causal maps are presented in Table 5. Dummy (instructor and sample) variables were strongly related to complexity and centrality. Wonderlic had a significant positive relation with centrality ($\beta = 0.41$, $p<0.001$), but not with complexity. Conscientiousness was not related to either complexity or centrality measures, but openness to experience ($p<0.10$) was weakly related to centrality only. These results do not lend support to hypothesis two, but support hypothesis three.

Insert Table 5 about here

The results of the hierarchical regression relating to complexity, centrality and course grade are shown in Table 6. We examined the relationship of structural measures with overall course grade. Instructor variables did not explain a significant amount of variance in course grade. Neither Wonderlic nor conscientiousness was related to course grade, whereas openness to experience was weakly related ($p<0.10$) to course grade. Both complexity ($\beta=0.45$, $p<0.001$) and centrality ($\beta=0.26$, $p<0.05$) were significantly related to course grade. The results lend support to hypotheses 4 and 5.

Insert Table 6 about here

To further understand the nature of the link between structural measures of TBCMs and academic performance, we examined the relationships between structural measures and individual components of course grade. Recall that course grade consisted of test scores, case analyses and class participation. These three components may capture different facets of domain specific abilities. Tests typically focus on conceptual ability (Miner et al, 1984), whereas case analyses emphasize the practical ability of students (Miner et al, 1984). In our sample, course grade was significantly correlated with test grade ($r = 0.41$, $p = 0.01$) and case analysis grade ($r = 0.38$, $p = 0.05$); test grade and cases analyses grade were also significantly correlated ($r = 0.37$, $p = 0.05$). Although class participation grade was correlated with test grade ($r = 0.33$, $p = 0.05$), it had no significant relationship to either course grade or case analysis grade. The results of these analyses are shown in Table 7

Insert Table 7 about here

As shown in the table, cognitive ability is not related to either test grade or class participation and is only weakly related to case analyses grade ($\beta=0.21$, $p<0.10$). Complexity has a significant relation with test grade ($\beta=0.54$, $p<0.001$), case analyses grade ($\beta=0.27$, $p<0.05$) as well as class participation ($\beta=0.31$, $p<0.05$). The correlation difference test indicates that complexity has a significantly stronger relationship with test grade than with case analyses ($t=2.34$, $p<0.05$). Centrality is significantly related to case analyses ($\beta=0.46$, $p<0.001$), but only weakly related to test grade ($\beta=0.22$, $p<0.10$). Centrality does not have a significant relation with class participation. The correlation difference test shows that centrality has a stronger relationship to case analyses than complexity ($t=2.12$, $p<0.05$), a result that is also suggested by the magnitudes of the beta coefficients.

Although these results are not definitive, they point to an interesting pattern of relationships between structural measures and academic performance. As we have discussed before, complexity and centrality may capture different facets of causal structures. Complexity may facilitate efficient information acquisition, which is evident in its significantly strong relationship to test grades. On the other hand, centrality may prompt effective application of domain knowledge to problem situations. This may explain the strong relationship between centrality and case analyses grade.

We present the nomological net that we reconstructed from the results in Figure 2. As shown in the figure, the complexity of cognitive structure derived from TBCM's is related to both conceptual and practical performance, whereas centrality is related only to practical performance. Cognitive ability, an indicator of general information processing capability, is only related to centrality. It is likely that some context related factors may influence complexity. Thus, centrality and complexity exhibits different patterns of relationship to different types of performance.

Insert Figure 2 about here

Discussion

The results from this study yielded two key insights on structural measures of TBCMs. First, complexity and centrality represent *distinct* dimensions of TBCMs and not two ends of the same continuum. Second, structural measures of TBCMs predicted academic performance, whereas cognitive ability was *not* related to academic performance. These results have some interesting implications for future studies employing TBCMs.

Distinctness of complexity and centrality

Some studies have hinted that complexity and centrality may represent different ends of a continuum (Eden et al, 1992), whereas other studies have emphasized the distinctness of the two dimensions (Knoke & Kuklinski, 1982; Carley & Palmquist, 1992). This is one of the first studies to empirically examine the distinctness of the two constructs. The results of the exploratory factor analysis conducted in this study clearly point to the distinctness of the two constructs. This distinction between complexity and centrality sheds some light on the ongoing debate as to whether cognitive structures represent domain-specific understandings or whether they represent general cognitive attributes (Bieri, 1961; White & Frederiksen, 1986). This study shows that complexity and centrality have different patterns of relationships to general cognitive ability as well as to the different facets of academic performance. Complexity represents breadth of domain understanding that facilitates information acquisition in that domain. On the other hand, centrality, representing the hierarchy and focus in causal structures, facilitates application of domain knowledge to problem situations. This ability to apply knowledge structures fostered by centrality may be closely related to components of general cognitive ability such as logical and analytical reasoning, rather than domain understanding. On the other hand, complexity represents the breadth of conceptual understanding in the domain and thus may not relate to general cognitive ability.

Complexity was not related to general cognitive ability. One explanation of this result may be the domain-specificity of complexity that is a function of several factors other than general cognitive ability. In our study, we found that two contextual factors had a significant relation with complexity: experience and mode of instruction. There were significant differences in the complexity of students exposed to different instructors (refer to Table 5). Similarly, the MBA sample consisting of working managers had significantly higher complexity than undergraduate students with no managerial experience ($p<0.01$). These explanations are consistent with prior literature on the role of contextual factors in the acquisition of domain information (Amernic & Beechy, 1979; Carley & Palmquist, 1992). Additionally, as shown in table 7, complexity was strongly related to class participation, which may indicate the level of student interest in the course. Student interest has been shown to facilitate information acquisition (Kirk, Cummings & Golstein, 1962; Tobias, 1994). These contextual factors were the only predictors of complexity (see Table 5). Our results suggest that centrality facilitates efficient application of domain knowledge to problem situations. It is likely that problem-solving situations require both application of domain knowledge and reasoning abilities. The logical and analytical skills, reflected in general cognitive ability (Wonderlic), may enable an individual to organize domain concepts into hierarchical and focused causal structures. This hierarchy and focus may, in turn, facilitate effective problem solving. This may explain why centrality had a significant relationship with cognitive ability, in addition to contextual factors.

Cognitive ability, Structural Measures and Academic Performance

The results of our study suggest that complexity and centrality were positively related to domain performance and cognitive ability was not related to domain performance. This is a surprising result given the strong relationship between cognitive ability and performance (Schmidt, 2002). There are two plausible explanations for this result. First, the ability to achieve superior academic performance is contingent on domain specific information processing capacity rather than the general information processing capacity captured by cognitive ability (Chen & Olson, 1989; Piaget, 1972). Some studies have shown that general intelligence in university students was only weakly related to their academic performance in a specific domain (Chen & Olson, 1989). Students possessing high levels of cognitive complexity are likely to be efficient in both acquisition and application of information in that domain (Chi & Glaser, 1984).

Second, the results of our study suggest that centrality was strongly related to the case analyses grade, but not related to either the test or the class participation grade. Cognitive ability was weakly related to case analyses grade only, but not related to test or class participation grade. To examine the potential mediating effect of centrality in the relationship between cognitive ability and case analyses grade, we conducted partial correlation analyses. Cognitive ability was significantly related to both case analyses grade (simple $r = 0.37$, $p<0.05$) and centrality (simple $r = 0.59$, $p<0.001$). However, the partial correlation between cognitive ability and case analyses grade was not significant after controlling for centrality. The partial correlation between centrality and case analyses grade was significant (partial $r = 0.44$, $p<0.01$) after controlling for cognitive ability. Similarly, the partial correlation between centrality and cognitive ability was significant (partial $r = 0.41$, $p<0.01$) after controlling for course grade. This suggests that centrality may mediate the relationship between cognitive ability and case analyses. The reasoning and logical skills represented in the general cognitive ability may enable individuals to develop hierarchical and focused causal structures in problem solving. This centrality of causal structures may ultimately lead to efficient solutions.

Limitations

Several limitations of the study warrant acknowledgement. We acknowledge the limitations of TBCMs as a technique of capturing knowledge structures. TBCMs assume that domain knowledge of individuals can be represented in the form of a causal network and causality is the primary forms in which information is perceived, understood and interpreted (Huf, 1990). This may lead to exclusion of other important facets of cognitive structures that may not be captured by causal structures (e.g. categorization). Another primary danger of TBCM is that a coder may impute his/her own assumptions into the coding. We had to make a large number of coding choices, and these choices can dramatically alter the resultant analysis (Carley, 1997). To reduce this contamination of the coding process, we used raters who were not involved in the study either directly or indirectly and checked the inter-rater reliability at every stage of the causal mapping process. Moreover, we tested the stability of the causal structure across different approaches to standardizing the content of the maps (theory-driven and benchmarking). Nevertheless, it is not possible to completely eliminate the coding bias.

Future Directions

The results of this study offer several opportunities for future research. First, the study needs to be replicated with different data-gathering methods (e.g., interviews) to assess the sensitivity to method and over time in order to establish the reliability of causal maps. Second, this study needs to be replicated in actual managerial settings to enhance the generalizability of the findings. Third, we evaluated the predictive validity of the complexity and centrality by focusing on academic performance. Future studies may investigate the relation of complexity and centrality to other important facets of performance such as employee reliability, work quality, administration and interpersonal orientation (Mount & Barrick, 1994).

Third, the distinctness of the two properties implies that they may be important in different task situations. One such characteristic is the routineness of the task (Perrow, 1970). Routine tasks are characterized by low variety and high task analyzability. In such task situations, logical reasoning and analyses is more important than acquisition of new information. Consequently, centrality may be more important than complexity in routine task situations. On the other hand, non-routine task situations are high on variety and unpredictability. Non-routine tasks require individuals to have the ability to deal with a large number of domain variables and to acquire new information effectively. The ambiguity and uncertainty of causal relations among domain variables may preclude individuals from developing hierarchical structures in arriving at solutions. In such task situations, complexity may be more important than centrality. Future studies may want to examine the differences in complexity and centrality across routine and non-routine task domains. Another implication of the distinctness of complexity and centrality is whether centrality is more stable than complexity. Extant research has argued and empirically demonstrated that an individual's complexity is not fixed but can be developed into higher levels (Amernic & Beechy, 1979; Carley & Palmquist, 1992). However, if centrality is related to the general information processing ability, then we can expect it to be relatively stable if not fixed in comparison to complexity. This distinction is especially relevant to interventions (e.g. training) aimed at changing individual capabilities. Future studies can investigate the differences in the stability of the two structural properties using pre-test/post-test design.

Finally, the predictive validity of complexity and centrality points to the viability of employing these constructs in measuring job performance. Complexity can be employed in conjunction with other measures such as general cognitive ability in selection, recruitment and performance evaluations. Additionally, complexity of an individual is generally not fixed but can be developed into higher levels (Amernic & Beechy, 1979; Carley & Palmquist, 1992). Change in complexity is therefore especially useful in intervention studies (e.g. training). Similarly, centrality can be employed in job situations that require strong reasoning skills and application of knowledge (e.g. auditing).

In conclusion, this study represents a first step in validating the structural measures of TBCMs. Indeed no single study can provide conclusive evidence of validity, and our study is no exception. We hope that the insights provided by the current study regarding the distinctness of complexity and centrality as well as the strong relationship between structural measures of TBCMs and domain performance spurs additional research that helps improve our understanding of the set of issues and relationships surrounding cognitive attributes, structural measures of TBCMs and performance.

Endnotes

[1] We also computed complexity and centrality using a coding scheme based on the theory-driven approach. A list of 19 theoretical concepts was generated from the OB text books used by the instructors. We reran the regression analysis relating complexity and centrality based on the theory-driven approach to cognitive ability and course grades. The regression results of this analysis were consistent with the regression results shown in Tables 5, 6 & 7. We did not include these results because of page restrictions. These results are available from authors upon request. The stability of the complexity and centrality across the two types of coding further points to the 'content-free' nature of TBCMs emphasized in prior literature.

2 The results of the hierarchical regression relating individual items of complexity and centrality to antecedents (Goldberg personality indicator and Wonderlic) and consequent (course grade) are consistent with the results reported in Tables 5 and 6.

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Table 1. Summary of studies using the structural measures of causal maps

Construct	Operationalization	Level of Analysis	Studies Employing the Operationalization
A. Complexity	1. Comprehensiveness: Number of concepts in a causal map	Individual	Adams-Webber, 1979; Brown, 1992; Carley & Palmquist, 1992; Cossette & Audet,1992; Eden et al., 1981; Eden et al., 1992; Langfield-Smith & Lewis, 1989
		Group	Carley, 1997; Eden et al., 1981; Laukkanen, 1996
		Organizational	Calori et al., 1994; Hackner, 1991
	2. Density 1: Number of linkages in a causal map divided by the number of concepts	Individual	Carley & Palmquist, 1992; Eden et al., 1981; Langfield-Smith & Lewis, 1989
		Group	Carley, 1997; Eden et al., 1981; Laukkanen, 1994
		Organizational	Calori et al., 1994; Hackner, 1991; Reger, 1990
	3. Density 2: Number of linkages in the causal map divided by the total possible linkages in the map.	Organizational	Fahey & Narayanan, 1989; Narayanan & Fahey, 1990
A. Centrality	1. Concept-level centrality: Number of links (direct and indirect) with other concepts in a cognitive map.	Individual	Cossette & Audet, 1992 ; Ford & Hegarty, 1984; Nozicka et al., 1976;
		Group	Bougon et al., 1977
	2. Causal map-level centrality: The average length of all the paths linking the most central concept to other concepts in a cognitive map.	Individual	Cossette & Audet, 1992; Eden et al., 1981
		Group	Eden et al., 1981

Table 2. Descriptive statistics of the undergraduate and evening MBA student samples

Demographic Variable	Undergraduate Student Group (n=165)	Evening MBA Group (n=39)
1. Age	Mean=22.67 SD=4.72	Mean=5.14 SD=9.02
2. Sex Male Female	 62% 28%	 70% 30%
3. Race Caucasians Others[1]	 77% 23%	 65% 35%
4. Undergraduate Major Business Non Business	 63% 37%[2]	 35% 65%[3]
5. Experience in Managerial Positions (No. of Years)	Nil	5

[1]Others include Hispanics, Asians and African Americans
[2]Other undergraduate majors for undergraduate students include communication studies, sports management and economics
[3]Others undergraduate majors for evening MBA students include engineering, science, information systems, liberal arts and economics

Table 3. Means, standard deviations and correlations among study variables

VARIABLES[1]			Intercorrelations Among Study Variables (n=204)								
	M	SD	1.	2.	3.	4.	5.	6.	7.	8.	9.
Personality variables											
1. Conscientiousness	5.91	0.97	--								
2. Openness of Experience	6.02	0.91	0.03	--							
Cognitive Ability											
3. Wonderlic	28.92	4.31	0.07	0.31^{*}	--						
III. Structural Measures											
Complexity:											
4. Comprehensiveness	15.86	3.06	0.03	0.11	-0.09	--					
5. Density -1	1.21	0.61	0.06	0.07	-0.02	0.68^{***}	--				
6. Density -2	0.03	0.02	0.04	0.13	-0.12	0.64^{***}	0.71^{***}	--			
Centrality:											
7. Concept-level Centrality	0.45	0.23	0.02	0.31	0.39^{**}	0.25	0.32	0.31	--		
8. Causal map-level Centrality	0.03	0.02	0.18	0.29	0.42^{**}	0.23	0.29	0.27	0.81^{***}	--	
IV Performance											
9. Course Grade	4.23	0.71	0.03	0.12	0.09	0.58^{***}	0.51^{***}	0.44^{**}	0.37^{*}	0.39^{*}	--

[1] Since the instructor variables were dummy variables, we did not include them in the correlation table

$^{*}p< 0.05$ $^{**}p< 0.01$ $^{***}p < 0.001$

Table 4. Results of Factor Analysis

Structural Measures	Varimax loadings		Oblimin loadings	
	Factor I	Factor II	Factor I	Factor II
Total sample (*n* = 204)				
1. Comprehensiveness	0.95	0.28	0.91	0.22
2. Density 1	0.90	0.32	0.92	0.28
3. Density 2	0.94	0.40	0.94	0.29
4. Concept-level centrality	0.31	0.95	0.15	0.94
5. Causal map-level centrality	0.26	0.93	0.24	0.91
Eigen value	2.72	2.21	2.59	2.19
Inter-factor correlation for oblimin rotation				
Factor I	--	--	1	
Factor II	--	--	-0.04	1

Table 5. Hierarchical Regression results[a] for models testing the antecedent of Structural Measures of TBCMs

Variables entered:	Complexity (*n*=204)			Centrality (*n*=204)		
	B	SE B	β	B	SE B	β
Step 1:						
Instructor-1	0.22	0.03	0.31***	0.04	0.00	0.25**
Instructor-2	0.00	0.00	0.36***	0.00	0.00	0.21**
Instructor-3	0.47	0.11	0.24**	0.01	0.00	0.19*
Instructor-4	0.19	0.04	0.21**	0.04	0.02	0.17*
Conscientiousness	0.00	0.00	0.09	0.00	0.00	0.13
Openness of Experience	0.00	0.00	0.16	0.08	0.03	0.19*
Δ R^2			0.14***			0.17****
Step 2:						
Wonderlic	0.11	0.15	0.14	5.12	1.79	0.41****
			0.04			0.22****
Δ R^2			0.11			0.32****
Adjusted R^2						

*p< 0.10 ***p< 0.05 **p < 0.01 ****p< 0.001

[a] Demographic variables were not included in the hierarchical regression analysis since there was no relation between demographic variables and structural measures in either sample

Table 6. Hierarchical Regression results[a] of models testing the consequences of the Structural Measures of TBCMs

Variables entered:	Course Grade (n=204)		
	B	SE B	β
Step 1:			
Instructor-1	0.02	0.01	0.24*
Instructor-2	0.19	0.15	0.12
Instructor-3	0.22	0.25	0.09
Instructor-4	0.07	0.11	0.11
Conscientiousness	0.18	0.11	0.15
Openness of Experience	0.03	0.01	0.21*
ΔR^2			0.12*
Step 2:			
Wonderlic	0.00	0.01	0.09
ΔR^2			0.02
Step 3:			
Complexity	1.47	0.21	0.45****
Centrality			0.26**
ΔR^2			0.18****
Adjusted R^2			0.27****

$^{*}p< 0.10$ $^{**}p< 0.05$ $^{***}p < 0.01$ $^{****}p < 0.001$

[a]Demographic variables and Goldberg Personality Indicators were not included in the hierarchical regression analysis since there was no relation between these variables and course grade in either sample

Table 7. Hierarchical Regression results[a] of models testing the relationship between Structural Measures and Individual components of Course Grade

Variables entered:	Test Grade (n=204)			Case analysis Grade (n=204)			Class participation Grade (n=204)		
	B	SE B	β	B	SE B	β	B	SE B	β
Step 1:									
Instructor-1	0.02	0.00	0.27^{*}	1.46	0.49	0.22^{*}	0.67	0.54	0.09
Instructor-2	0.07	0.12	0.05	0.01	0.03	0.08	1.89	1.57	0.07
Instructor-3	0.15	0.09	0.12	0.08	0.05	0.15	0.01	0.02	0.04
Instructor-4	0.24	0.21	0.06	0.00	0.01	0.03	0.04	0.07	0.02
Conscientiousness	0.14	0.09	0.11	0.01	0.00	0.19	0.05	0.08	0.04
Openness of Experience	0.15	0.17	0.06	0.14	0.06	0.23^{*}	0.01	0.00	0.21^{*}
ΔR^2			0.05			0.05			0.04
Step 2:									
Wonderlic	0.02	0.01	0.13	0.03	0.01	0.21^{*}	0.47	0.59	0.06
ΔR^2			0.01			0.04^{*}			0.02
Step 3:									
Complexity	0.04	0.00	0.54^{****}	0.45	0.19	0.27^{**}	0.00	0.00	0.31^{**}
Centrality			0.22^{*}	0.04	0.00	0.46^{****}	0.04	0.02	0.19
ΔR^2			0.16^{***}			0.23^{****}			0.14^{**}
Adjusted R^2			0.19^{***}			0.26^{****}			

$^{*}p < 0.10$ $^{**}p < 0.05$ $^{***}p < 0.01$ $^{****}p < 0.001$

[a]Demographic variables were not included in the hierarchical regression analysis since there was no relation between these variables and course grade in either sample.

[1] [1] We also computed complexity and centrality using a coding scheme based on the theory-driven approach. A list of 19 theoretical concepts was generated from the OB text books used by the instructors. We reran the regression analysis relating complexity and centrality based on the theory-driven approach to cognitive ability and course grades. The regression results of this analysis were consistent with the regression results shown in Tables 5, 6 & 7. We did not include these results because of page restrictions. These results are available from authors upon request. The stability of the complexity and centrality across the two types of coding further points to the 'content-free' nature of TBCMs emphasized in prior literature.

Figure 1

An illustration of the four step procedure of constructing causal maps

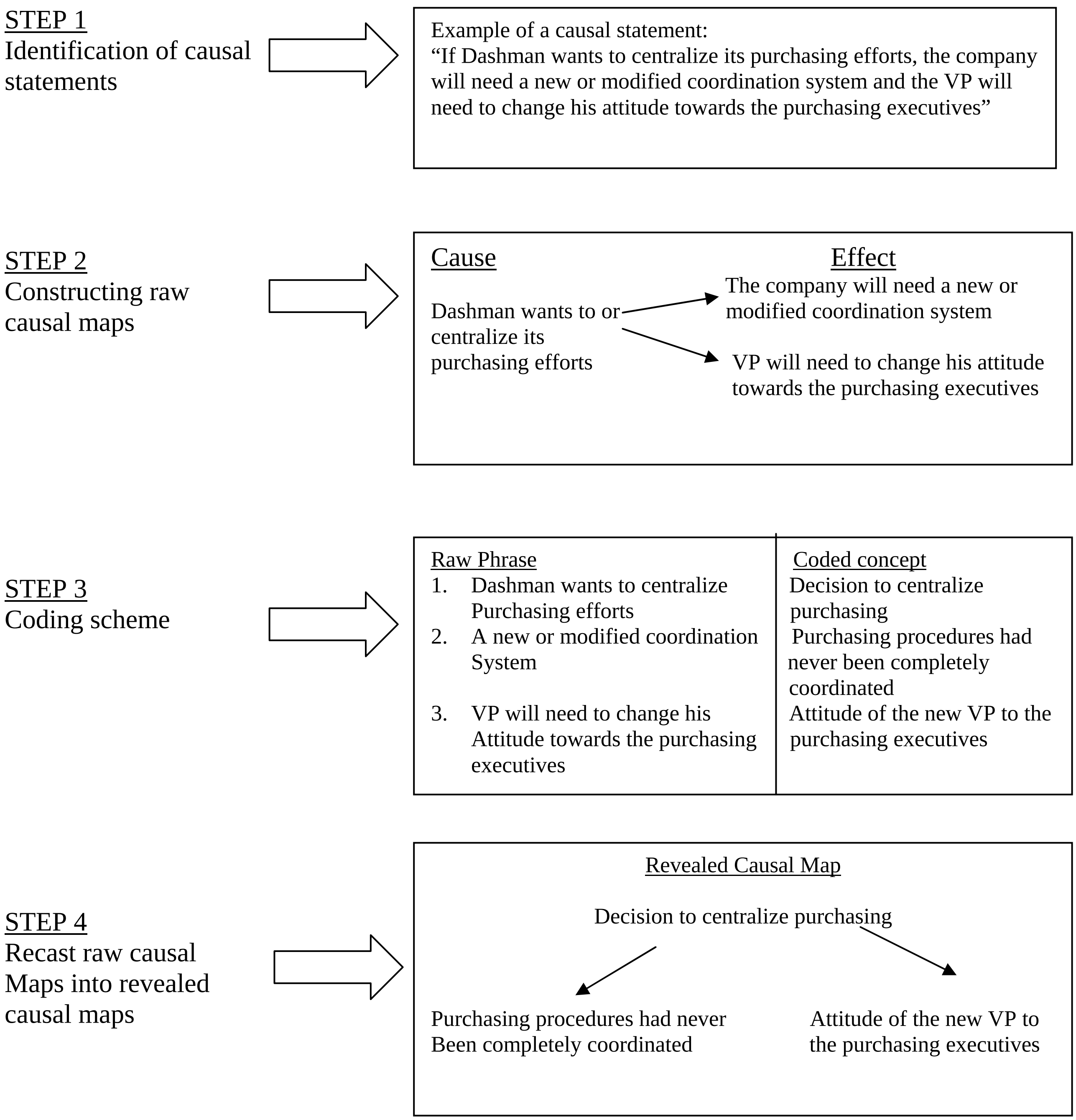

Figure 2

Nomological net yielded by the results of our study