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DIMINISHING MARGINAL UTILITY OF THE 'NEXT' ATTRIBUTE: COGNITIVE COMPLEXITY & COMPLEX DECISIONS

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This paper reports an empirical investigation of *managerial effectiveness* in dealing with *ill-structured decision environments* as a function of *cognitive complexity* using a long duration, multi-faceted and dynamic computer simulated complex task presented to 45 managers from a large Indian metal processing unit. Four independent, domain specific cognitive complexity measures obtained through three different approaches were taken and later reduced through factor analysis to derive *differentiation, discrimination* and *integration* dimensions. Results revealed similar as well as distinctively different patterns of outcomes for the differentiation and integration dimensions. While effectiveness of managers in dealing with the simulated complex task showed both linear positive association as well as an 'inverted U' trend with increase in their differentiation capability, the integration dimension dominantly showed only the 'inverted U' trend. Noticeably, the discrimination dimension did not yield any significant or otherwise meaningful results. Findings point to the diminishing marginal utility of seeking additional attributes. The paper concludes by noting some of the specific features of this study and future research needs.

Keywords: Cognitive Complexity, Complex Problem Solving, Cognitive Map Computerized Simulation.

Birds with large brains and greater <u>*cognitive complexity*</u> *are better able to cope with novel environments (Marino, 2005:5306; emphasis added).*

In his youth and early political career [Nelson] Mandela fit the profile of a "pre-takeover revolutionist"…, characterized by undifferentiated thinking and conceptual simplicity. In a transformation wrought mainly during his more than 27 years in prison… Mandela developed ideological flexibility… <u>*Cognitive complexity*</u> *equipped Mandela, more so than many other revolutionaries, for the transition to post-liberalization leader. The same capacity for complexity enabled Mandela to fulfil the different roles of nationalist leader/competitive negotiator and of mediator/integrative negotiator (Lieberfeld, 2003:246; emphasis added).*

What makes some individuals more adept as change agents, integrative negotiators and transformation leaders, compared to others? Why are some individuals more at ease than others in complex, novel and dynamic decision environments and show higher proficiency in navigating them successfully? What makes some individuals more capable than others in generating clarity and insights in ill-structured, volatile and fluidic milieus? Questions like these abound in the minds of psychologists, organizational researchers and other behavioural sciences scholars, particularly as managerial - organizational contexts have been witnessing

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rapid, radical changes and novelties. Quite often, they lead to studies of factors related to the 'individual' that potentially have bearings on one's attitude to, and/or capability of, dealing with aspects such as risk, complexity, ambiguity, uncertainty, novelty, innovation and change. *Cognitive complexity* (Bieri, 1955; Schroder, Driver & Streufert, 1967) is one such a variable that has been attracting significant renewed research attention in this context.

Faced with challenges posed by newer organizing, technological, cross-cultural and other environments, organizational and behavioural researchers now look at cognitive complexity in diverse domains like *leadership* (Boal & Hooijberg, 2001; Green, 2004; Hoojiberg, Hunt & Dodge, 1997; Khatri, Ng & Lee, 2001), *strategic decision making* (Calori, Johnson & Sarnin, 1994); *legislators' voting behaviour* (Crichlow, 2002), *negotiation and peacemaking* (Lecomte, 2001; Lieberfed, 2003), and even *religiosity* (Tam & Shiah, 2004). Boal and Hoojiberg (2001:515-19) even classify the latest in strategic leadership research as studies "that explore behavioural and cognitive complexity" and believe they hold "great promise in furthering our understanding of…strategic leadership." Indeed a widely cited survey of Human Resources (HR) leaders of global organizations at the turn of this millennium placed the "ability to see the big picture and develop cognitive complexity" in the top five core competencies needed for HR leaders in the new economy (Business Times, 2000; Training Journal, 2000). In this paper, I report an empirical investigation of managerial effectiveness in navigating ill-structured decision environments or *solving complex problems* as a function of cognitive complexity.

COGNITIVE COMPLEXITY & COMPLEX PROBLEM SOLVING (CPS)

Originally conceived bipolar as 'cognitive complexity-simplicity' nearly 50 years ago (Bieri, 1955), cognitive complexity is viewed as the ability to distinguish or develop multiple perspectives of people, behaviours, ideas, situations and so on as relevant, and to bring together or integrate pertinent perceptions and perspectives among them appropriately to one or more orientations, behavioural intentions, decisions or actions. It relates to the *structure* of thoughts or thinking pattern, the emphasis being *how* a person thinks or structures her/his thinking, rather than *what* she/he actually thinks or the *content* of thoughts (Hunt, Butler, Noy & Rosser, 1978; Streufert & Nogami, 1989). According to Schroder et al. (1967), cognitive complexity manifests in three dimensions: *differentiation* (ability to identify distinct/discrete attributes of a problem/ situation), *discrimination* (ability to make finer distinctions among/within these attributes) and *integration* (ability to relate/combine the attributes in meaningful/effective ways). Among them, level of integration or ‘integration index’ holds the key to effective processing of information, varying in ‘gradations’ from a uni-dimensional, deterministic pattern to generating a large set of choices. This conception allows individuals to be placed in a ‘simple-complex’ continuum.

Researchers have studied cognitive complexity in many domains, adopting different orientations and for different purposes. One set of studies explore patterns between various personality variables and cognitive complexity. For instance Weger and Polcar (2000) found cognitive complexity of individuals with secure attachment style to be significantly a little higher than those with avoidant and anxious/ambivalent styles. Another set of studies have looked at aspects that impact or influence cognitive complexity development in individuals. For instance Duys and Hedstrom (2000) found significantly higher post-test cognitive complexity scores for counsellor trainees who underwent basic skills training, compared to the control group. A third set of studies are longitudinal explorations of cognitive complexity variations of negotiators, decision makers and leaders, and the resultant outcomes. Studies reveal significant decline in cognitive complexity of key leaders and decision makers before crises escalations occur manifesting in riots, bombings, suicide attacks, etc., and a rise prior to achievement of progress or success in negotiations and peacemaking (e.g. Lecomte, 2001; Raphael, 1982).

A fourth and major set of studies have explored the behavioural, attitudinal, performance and other outcomes in relation to cognitive complexity levels of individuals, groups and even organizations, the general tone of findings often being ‘higher the better.’ For instance in his study of how buyers process product and service related information in the marketplace, Mizerski (1978) found that people with simple causal complexity made stronger attributions, formed more extreme beliefs and produced more extreme affect, swayed by and in the direction of given information. Amernic and Beechy (1984) found Accounting students with higher cognitive complexity to perform significantly better in less-structured questions. In the realm of leadership, Hill (1969) argued that difference between low and high LPC (Least Preferred Co-worker; Fiedler, 1967) leaders lies in their cognitive orientation whereby the latter clearly distinguishes between task performance and the performer as well as makes finer distinctions of performance when making attributions, while the former tends to form overall judgements easily swayed to the negative side. Recently, Khatri, et al. (2001) found that followers with higher cognitive complexity made sharper distinctions between charisma and vision aspects of leadership.

There have also been contentions, variations and results revealing no effects. For instance, while Weissenberg and Gruenfeld (1966, cited in Larson & Rowland, 1974) observed a curvilinear relationship between LPC and cognitive complexity, Ford, Miller and Moss (2001:1061) found individuals with higher cognitive complexity to be less effective in internet information search and retrieval, a finding they termed 'counterintuitive' being contrary to the general notion of higher the better. On the contentious side, while Mitchell (1970) observed a positive correlation between Fiedler's LPC score and cognitive complexity, a later effort to replicate the same did not yield supportive results (Larson & Rowland, 1974). Amernic and Beechy (1984) did not find cognitive complexity to make any difference in performance of accounting students in answering highly structured questions. Thus, while these variations and contentions highlight the *complexity* linked to cognitive complexity research, studies also suggest that cognitive complexity can be a significant variable in situations that demand higher levels of cognitive effort. One such domain gaining notable research focus since last decade is on how individuals and groups deal with complex or ill-structured decision environments (Dörner, 1980; Frensch & Funke, 1995; Simon & Associates, 1992; Sternberg & Frensch, 1991; VanLehn, 1989), or solve complex problems, a domain where the influence of cognitive complexity is yet to be well established.

Decision situations such as technology shifts, new product launches, re-engineering work processes, resolution of major conflicts, managing inter-organizational alliances, and managing large scale changes like downsizing, turnaround and transformation are characterized by relatively higher doses of novelty, ambiguity, uncertainty, complexity and dynamism. Often termed as *complex* or *ill-structured*, there exist no predetermined and explicit set of ordered responses in organizations to effectively deal with them (Mintzberg, Raisinghani, & Theoret, 1976).[2] They are ambiguous with incomplete problem-related

[2] Mintzberg, et al. (1976) use the term *unstructured* instead of *ill-structured*. Terms such as *ill-defined* (Newell & Simon, 1972), *wicked* or *ill-behaved* (Mason & Mitroff, 1972, 1981), *messy* (Ackoff, 1979) and *nonprogrammed* (Simon, 1997), have also been used. I use *complex* (Dearborn & Simon, 1958; Dörner, 1980) and *ill-structured* (Ungson, et al., 1981) interchangeably in this paper.

information, have to be continuously defined and redefined by managers, lack a well defined plan for obtaining desired outcomes, are amenable to multi-person influences and take long to reach solutions (Ungson, Braunstein, & Hall, 1981).

Effectively dealing with such decision situations is also a complex and long drawn process involving a continually changing judicious mix of thinking first, seeing first and doing first approaches (Mintzberg & Westley, 2001). Thinking first style is preferable when the issue(s) are clear, data is reliable and the context is structured, where a disciplined approach of planning and programming can yield desired results. Seeing first involves visioning, imagining and playing with ideas or alternatives, and is preferable when many elements have to be combined into creative solutions. Doing first involves venturing, experiencing and learning, and is best suited for situations that are novel, confusing and complicated. Considering the characteristics of ill-structured decision environments and the challenges involved in dealing with them effectively, it was hypothesized that:

Hypothesis 1: Cognitive complexity is positively associated with managerial effectiveness of navigation in ill-structured decision environments or of solving complex problems.

Elaborating this hypothesis based on the three dimensions of cognitive complexity:

Hypothesis 1a: Differentiation ability is positively associated with managerial effectiveness of navigation in ill-structured decision environments or of solving complex problems.

Hypothesis 1b: Discrimination ability is positively associated with managerial effectiveness of navigation in ill-structured decision environments or of solving complex problems.

Hypothesis 1c: Integration ability is positively associated with managerial effectiveness of navigation in ill-structured decision environments or of solving complex problems.

RESEARCH DESIGN

Sample

Briefly, data was collected in an interactive set up through computerized simulation of a multi-faceted, long duration, complex task. 45 managers from a large Indian metal processing unit participated. They came from seven hierarchy levels and six functions. At the time of this study the unit employed 4000^+ managers in 11 levels and $50,000^+$ staff/workers in 9 levels. The unit and parent organization were in the process of re-orienting and re-structuring following extensive liberalization by Indian government. Consequently, managers at all levels were faced with uncertain, novel and complex issues to deal with in their work. The time needed for data collection (5-6 hours per participant), consequent organizational constraints, and considerations of statistical analysis and data loss/defects influenced sample size. Data of 36 managers were finally analyzed.

Data Collection

Each participant reported at the simulation room between 9 and 11am. After initial familiarization and a brief introduction to the study, I conducted a loosely structured interview (described later). Following this, I presented the complex task as a computer simulated management game - *Manutex* (Schaub, 1988). Management games create experiential environments in which learning and behavioral change can be studied (Keys & Wolfe, 1990), and have been used for research in domains such as decision making, problem solving, group behavior and leadership. They provide a reliable alternative to field experiments with a high degree of situational control and avoid many issues of generalization associated with laboratory experiments (Brehmer & Dörner, 1993). *Manutex* is a total enterprise or top management game (Keys & Wolfe, 1990) or microworld (Brehmer & Dörner, 1993; Senge, 1990). It is an organization-wide simulation with large sets of decision variables from diverse functional areas and demand proper integration for effective navigation, and has been used in previous studies on complex problem solving (e.g. Dörner, 1990 & 1991; Ramnarayan, Strohschneider & Schaub, 1997). Since past studies had hinted of cognitive complexity being an ‘individual-domain’ specific characteristic (Gardner & Schoen, 1962; Scott, 1963; Vannoy, 1965; all cited in Larson & Rowland, 1974), the fit between a managerial sample and a total enterprise game involving organization-wide decision making was expected to be advantageous for this study.

The participant read a case description of *Manutex* – a small/ medium sized, ready-made garment manufacturing unit in Kuala Lumpur, Malaysia, employing 37 people in three levels and five departments, and capable of making seven products using three raw materials. The case provided a brief history of the unit, its work methods, human relations, product-market positions, inventory levels, financial details, and so on. It asked her/him to manage the full affairs of *Manutex* as its Head (CEO) for two years (24 simulated months)[3] in a real time of 2½ hours. *Manutex* simulation is a complex one, with a large range of in-built information, and allows a wide range of interventions or decisions to be implemented. The participant *had to specifically ask* for any information to be given. She/he could also take decisions on many of these aspects. I acted as her/his interface with the computer for providing the information sought and implementing the decisions taken. The simulation was followed by a feedback discussion lasting 30 to 40 minutes.

MEASURES

Assessing Cognitive Complexity

Researchers have adopted a variety of methods, instruments and tools to measure cognitive complexity. For instance in their studies of bird cognition and adaptive behaviour in new locations, Sol et al. (2005) used feeding innovation rate to measure cognitive complexity of birds. In the arena of politics and international relations, Crichlow (2002), Lecomte (2001), Liberfeld (2003) and Raphael (1982) adopted an ‘at a distance’ qualitative assessment method – while Crichlow analyzed US legislators’ remarks in Congressional records to link their cognitive complexity and voting behaviour, Liberfeld drew conclusions on Nelson Mandela’s cognitive complexity analyzing extensive biographical writings, and while Lecomte studied statements, interviews, speeches, etc., of Israeli and Palestinian leaders (Peres, Rabin & Arafat) to find linkages between their cognitive complexity variations and fluctuations in the Middle East peace process during 1993-’94, Raphael did the same for US-USSR Berlin Conflict spanning 1946-’62.

[3] Default decision cycle in *Manutex* is a simulated month. A participant gathers information and takes decisions necessary to run the firm in each cycle. She/he can repeat the same decisions in subsequent cycles or change the decision cycle to two or more months.

One of the earliest methods that is also currently used is the sentence or paragraph completion test (PCT) of Schroder et al. (1967) where participants complete unfinished sentence stems, incongruent adjectives for impression formation, etc., which are then coded to gauge cognitive complexity (e.g. Amernic & Beechy, 1984). Role Concept Repertoire Test or Repertory Grid, often called 'REP Test' (Bieri et al., 1966; Fransella, Bell & Bannister, 2003; Kelly, 1955) derived from personal construct theory of Kelly (1955) with a matrix format is also commonly used (Durand, 1979; Khatri, et al., 2001; Tam & Shiah, 2004). The matrix/grid has a set of elements/items on one axis and a set of bipolar constructs/dimensions on the other on which the participant rates/evaluates the elements. Cognitive complexity is then computed from these ratings. Computer programs to generate and analyze grids are also available.[4] Combinations of Rep Test and PCT have also been used (e.g. Green, 2004). Crockett's (1965) Role Categorization Questionnaire, a variant of Rep Test, is another cognitive complexity assessment tool (e.g. Adams-Webber, 2001; Duys & Hedstrom, 2000; Weger & Polcar, 2000).

Durand (1980), Larson and Rowland (1974), Mitchell (1970) and Mizerski (1978) analyzed how participants categorize given sets of stimuli (elements, objects, information, etc.) and then computed an index *H*[5] to measure cognitive complexity. The number of categories generated is also used. In fact Durand (1980) had to abandon *H* index due to statistical problems and adopt the number of categories as his cognitive complexity measure, and Larson and Rowland (1974) obtained a high correlation (0.99) between the two. An identical method proposed by Schroder et al. (1967) is to *track* the variety of information

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[4] See *The OMNIGRID Manual (GW-Basic Version)* by K.W. Sewell, J.O. Mitterer and J. Adams-Webber, *http://www.psyc.unt.edu/napcn/OMNIGRID/ Manual.Txt* & *http://www.psyctc.org/grids/omnigrid.htm*, & *A Manual for the Repertory Grid Using the GRIDCOR Programme* (Version 4.0) by G. Feixas and J.M.C. Alvarez, *http://www.terapiacognitiva.net/ record/pag/index.htm*. Sites accessed on Nov 8, 2005.

[5] The index *H*, known as Shannon-Weaver Diversity Index (referred to as Shannon-Weiner index or simply Shannon index also), comes from information theory, and is a quantitative indicator of uncertainty (order-disorder) in a system. It is also used as a measure of diversity or complexity of a system, usually in ecology studies. Mathematically its generic form is: $H = - \sum_{i=1}^{k} p_i \, Log_2 \, p_i$, where p_i is ratio of number of individuals in species/category *i* to the total population, and *k* the total number of categories/species. While Log to the base 2 is used in information theory, researchers prefer natural logarithm (Ln) in other domains such as ecology, and also use other mathematical variations of this generic form.

gathered and decisions made as individuals interface, interact or intervene with/in any milieu of research interest. A recent approach to measure cognitive complexity is *cognitive mapping* (Calori et al., 1994; Hackner, 1991). Cognitive map is a graphical network of meaningful sets of words termed *concepts* that describe a situation and relations among them termed *links* (Fiol & Huff, 1992). Structural analysis of maps yields cognitive complexity measures. Finally, since measuring cognitive complexity often becomes a complex affair in itself, researchers have also used shorter and easier to administer-analyze-interpret scales/items, or relied on purposefully generated evaluations by participants, particularly when cognitive complexity was not among the central variables or only one of a large set of variables of study (e.g. Ford et al., 2001).

This plethora of methods, instruments and tools, while cautions that cognitive complexity measurement could turn out to be a potential minefield, also indicates that cognitive complexity maybe a composite construct comprising of a number of distinct and possibly independent attributes “not all of which [are/can be] included in any single instrument” (Vannoy, 1965; cited in Larson & Rowland, 1974: 38), and points to the need for using multiple cognitive complexity measures and measurement methods. Durand (1980:141) is a case in point – replicating his earlier study using Bieri’s Rep test (Durand, 1979) with categorization technique and *H* index, he states: “To the extent, then, that one measure may produce results that are different from those obtained with another procedure, studies must be replicated using different complexity techniques so as to provide substantiating or unsubstantiating findings.” Further, a person could be high in cognitive complexity in an area where she/he has knowledge/experience and low in another where she/he doesn’t (Gardner & Schoen, 1962; Scott, 1963; both cited in Larson & Rowland, 1974). Hence Hooijberg, et al. (1997: 381) “advise sensitivity to the domain issue when [measuring cognitive] complexity” such that whatever the methods, instruments or measures finally chosen, they are “appropriate to the domain under investigation” (Larson & Rowland, 1974: 38).

Taking cognizance of these aspects, I generated four domain specific cognitive complexity measures, following three different approaches. The first method resulting in measure-1 involved *computing* an *H Index* (H_{idx}) from relative quanta and evenness of distribution of information gathered and decisions made by participants across major functional domains of *Manutex while* navigating the simulated task. The second method of *tracking* unique or distinctly diverse units of information gathered and decisions made by participants across all functional domains *while* navigating *Manutex* yielded measures-2 and -3. *Cognitive mapping* of participant's thoughts structuring on *Manutex prior to* the simulation formed the third approach generating measure-4.

Certain features of these measures need to be noted. First, they encompass the three cognitive complexity dimensions. Finer description later would show that H_{idx} alone or with measure-2 gauge differentiation, and measure-3 alone or with measure-2 assess discrimination. The fourth measure is of integration. Second, while H_{idx} computation and tracking are straightforward *objective computation*/*tally* processes, cognitive maps emerge out of a laborious *subjective interpretation* process. Finally, the first three measures are derived from actual behaviour of participants in the simulated task while the third is obtained outside, prior to, and independent of it. Hence, together, the four measures were expected to provide more reliable insights.

Approach-I (Measure-1): H Index computation. *Manutex* simulation contains a large range of in-built information and provision for making interventions. I took simulation data on the quanta of information gathered by each participant grouped under five functional categories (manufacturing, accounting/finance, marketing, raw materials & personnel). Similar data of decisions made was also obtained. I computed the Shannon-Weaver *H* Index as: $H_{idx} = -\ {}_{i=1}\Sigma^{k}\ p_i\ Ln(p_i)$, where, p_i = ratio of quantum of information gathered or decisions made in category *i* to the total amount of information gathered *and* decisions made, and k = total number of categories (here, $k = 10$). A participant gathering information or making decisions in just one of the 10 categories alone would end up with zero H_{idx} while another with dominance in a few categories would end with a low or moderate index. Higher evenness of spread across all the categories results in a higher index.

Approach-II (Measures 2 & 3): Tracking unique information and decision units. I tracked the *distinct* or *unique* units (and *not* quanta) of information gathered and decisions made by participants while navigating *Manutex*, at two levels. First, a participant could seek information on 53 aspects of *Manutex* and take decisions on 16. For instance she/he may try to learn how production needed to be planned and hence seek information on, say, current production, stock of finished goods, raw materials required, their availability, machines available, their operating and maintenance needs, etc. Each such specific aspect on which a participant gathered information or took decision on, the first time in the simulation, was counted as one unique unit (denoted as U_{idu}). Figure 1 illustrates relative positions of H_{idx} and U_{idu}. Perhaps U_{idu} is analogous to Durand's (1980) measure of cognitive complexity as the number of distinct categories. Hence considered exclusively, U_{idu} can be treated as measure of differentiation. But, since H_{idx} is a broader measure of categorization option is open to view H_{idx} and U_{idu} as two measures of differentiation, a suitable combination of the two as measure of differentiation, or H_{idx} as differentiation and U_{idu} as discrimination measures.

Insert Figure 1 about here

At the next level, a participant could seek information or take decision on each of the seven products (Figure 1). For instance she/he could choose to find out the sales of one or more products in the previous cycle or confine to the aggregate sales. When she/he opts for the former, the first time in the simulation, I counted it as an 'in-depth' or 'extensive' unique unit of enquiry (denoted as U_X_{idu}). For example, when she/he sought information on sales of shirts, trousers and jackets, I would add '1' to U_{idu} (indicating 'sales' aspect) and '3' to U_X_{idu} ('1' for each product), and similarly for decisions. Like H_{idx} and U_{idu}, option is open to treat U_{idu} and U_X_{idu} as two measures of discrimination, a suitable combination of the two as measure of discrimination (H_{idx} measures differentiation in both cases), or U_{idu} alone or with H_{idx} as differentiation and U_X_{idu} as discrimination measure.

Approach-III (Measure-4): Cognitive mapping. I gathered data for cognitive mapping prior to the simulation. First conceived by Tolman in 1948, a cognitive map, also termed as schema (Bartlett, 1932) or belief structure (Fiske & Taylor, 1984; Walsh, 1988) is a "graphic representation of a set of discursive representations made by a subject with regards to an object in the context of a particular interaction" (Cossette & Audet, 1992: 323). It represents patterns of organized personal knowledge (Weick & Bougon, 1986) and frames of reference (Fiol & Huff, 1992), and guides information processing (Eden 1988, 1992) and action (Dorner & Wearing, 1995) of the map holder. When a Cognitive map depicts 'cause-effect' relations among variables, it becomes a 'cause map' (Bougon, Weick & Binkhorst, 1977).

Cognitive maps of individuals vary in *content* and *structure* (Bougon et al., 1977; Laukkanen, 1994; Stubbart & Ramprasad, 1988). Variations in content arise as different people, faced with the same situation, tend to highlight and attend to different aspects. Structure of cognitive map denotes its configuration – the layout of concepts and links in the 'space' that the map is. A map with a large number of concepts and links would reveal a dense network compared to one with fewer concepts or fewer links. This structural difference can be captured on a *simple-complex* continuum such that any apt measure of map complexity, in essence, also becomes a measure of map holder's cognitive complexity. That measure could be number of concepts (C), links (L), or any suitable index of the degree of 'networking' such as 'L+C' or 'L/C'. While C, L and L+C are *mass* (or quantum) measures, L/C is the *density* (or ratio) measure. Calori et al. (1994) assessed cognitive complexity with C and L/C and Hackner (1991) used C, L+C and L/C. I chose L/C.

Mapping protocol involves one or more loosely or semi-structured interviews. While Calori et al. (1994) constructed maps from one unstructured interview, Langfield- Smith (1992) followed a two stages process, presenting salient concepts from first interview to the participant in the next sitting to elicit links. Cossette and Audet (1992), Hackner (1991) and Laukkanen (1994) followed more detailed procedures. Some researchers also show the map to the participant as a validity check. Considering the need for domain specificity in cognitive mapping (Cossette & Audet, 1992; Eden, 1988) and in cognitive complexity estimation (Hooijberg, et al., 1997; Larson & Rowland, 1974), I rooted my mapping protocol on the simulated task.

The participant read the case description of *Manutex* and intimated readiness for discussion in about 20 minutes. Adopting a loosely structured approach, I began by asking her/him to describe the situation of *Manutex*. As discourse progressed, at suitable junctures, I pursued with some broad directions like, 'State three issues/problems facing *Manutex*, explain factors critical for success of *Manutex*,' etc. It ended with a prompt to unreservedly express 'any random, wild, thoughts'. Since many participants had become at ease with the study context by then, some interesting and occasionally odd views were aired. As the researcher I realized that mapping interview also acted as an ice breaker, helping participants to overcome initial inhibitions of being an 'experimental subject' in front of a 'stranger,' enabling them to pursue the simulation later with more ease.

Following Cossette and Audet (1992), Hackner (1991) and Laukkanen (1994), I had intended to start with a loosely structured interview and to follow it with one or more sittings to elicit details. But I discarded this approach after doing it with first three participants, when a reflective review of my process of choosing concepts that 'I thought were significant' for further elaborations showed that I was, albeit unintentionally, creating differences in map complexity across participants. Without my intervention, all participants gave discourse in response to the same stimuli. Further, some participants also expressed constraints to be available for more sittings making it impossible to maintain uniformity. Hence, like Calori et al. (1994), I decided for one sitting with each participant. All 45 managers participated in the interview that averaged about 30 minutes and allowed the discourse to be recorded.

Effectiveness of Dealing with Ill-Structured Decision Situations

I used three factors – success, consistency and crises-free nature – to assess effectiveness. *Success* denotes tangible and intangible achievements like money, assets, good will, etc. *Consistency* indicates the process of problem solving being even and devoid of drastic fluctuations that could cause chaos or destruction to the system or its parts. *Crises* result from faulty planning, decision making with inadequate understanding of complexities involved, inaction, etc. and lead to failures (Frese & Zapf, 1994). Success was measured by: (a) Cash balance of *Manutex* firm at the end of Year 1, and end of the simulation, and (b) Average cash balance in the simulation. The statistical index of coefficient of variation (CV = *SD*/*M*) of cash balance, production and sales during simulation assessed *consistency*. Two measures: (a) Number of crises faced in the simulation, and (b) Number of decision cycles with crises, assessed crises-free nature.

DATA ANALYSIS

Final Sample

Although 45 managers participated, simulation had to be abandoned with three due to technical snags. 37 of remaining 42 completed one year (12 decision cycles) and 20 finished two years in 2½ hours, as instructed. After screening, data of 36 managers was found fit for analysis. They aged between 26 and 55 years (*M* = 39.5, *SD* = 8.56) with managerial experience of 5¼ to 33 years (*M* = 15.68, *SD* = 8). There was one lady manager. All were graduates and 26 had a higher degree/diploma – five MBAs, 11 postgraduates, 17 with postgraduate diplomas, and two with dual graduation. 15 participants had undergone advanced training on operational and managerial aspects in countries like Japan, UK, USA and Finland.

Cognitive Complexity Profile of Participants in the Study

Measure-1: H_{idx}. Ranged from 1.683 to 2.158 with mean 1.968 (*SD* = .115) Table 1 gives summary statistics and correlations of all cognitive complexity measures and related variables.

Measure-2: U_{idu}. Unique information units gathered varied from 17 to 34 (*M* = 25.08, *SD* = 5.22) and unique decision units varied from 5 to 12 (*M* = 8.36, *SD* = 1.87). Due to wide difference in range and SD of these two, instead of a simple addition, I added their normalized values to combine them into one measure. As an alternative, I computed their ratios in relation to maximum possible values and took the average as U_{idu}. Analysis yielded closely similar results.

Measure-3: U_X_{idu}. Extensive unique units of information gathered ranged from 41 to 110 (*M* = 74.11, *SD* = 17.6) and decisions made from 12 to 33 (*M* = 21.64, *SD* = 4.84). Similar to U_{idu}, I added their normalized values to get U_X_{idu}.

Insert Table 1 about here

Measure-4: L/C. Cognitive map preparation began with verbatim transcription of recorded interviews. A first reading of the discourse gave an idea of its contents and nature of flow. In the second reading, main aspects of *Manutex* verbalized by the participant were noted as concepts on a large sheet of paper forming tentative nodes. Simultaneously attempts were made to draw links between them, wherever the participant made explicit connections. Direction of a link was determined to be causal from node A to node B if A caused B, A preceded B in time, A was an input to B, or it made logical sense to put A before B (Huff, 1990). Fine-tuning and finalization of concepts and links occurred in the third reading, with special care taken to elicit implicit links, if any, that appeared to emerge over the entire discourse. In many cases, a fourth reading after 7 to 10 days and perusal of the map was done as a satisfaction check.

Ensuring map reliability is highly important (Huff, 1990). To assess *inter-mapper reliability*, the standard inter-rater agreement, a doctoral student of management in advanced thesis stage with interest in qualitative research prepared the maps of 5 participants, randomly chosen. He had trained himself in mapping by reading Huff (1990), Bougon, et al. (1977), Weick and Bougon (1986), Eden (1992), etc. Comparison of our maps concurred in about 80% concepts and 70% links without consensus discussion. To assess *map-remap reliability*, the concurrence between maps made by the same person at different points in time, I made the maps of 5 randomly chosen participants afresh after 3 to 4 months. Comparison showed agreement in about 90% concepts and 80% links. Lower accord in inter-mapper compared to map-remap, and on links compared to concepts in both cases, reveals the interpretive subjectivity involved in mapping. Descriptive statistics of the maps reveal that while links ranged from 30 to 112 ($M = 61.34$, $SD = 21.71$), concepts ranged from 33 to 104 ($M = 63.69$, $SD = 19.43$). Their sum ranged from 63 to 216 ($M = 125.03$, $SD = 40.92$) and ratio between 1.131 and .833 ($M = .953$, $SD = .077$).

Regression Analysis

Data analysis involved regressions in two phases. I began by relating each cognitive complexity measure with CPS effectiveness measures. But, when some scatter plots indicated curvilinear effects, I introduced the square term. The four cognitive complexity measures were then reduced through factor method to cognitive complexity dimensions. Second stage analysis involved regressions with factor scores. Multicollinearity was checked with tolerance values, variance inflation factor, eigen values and condition indices. Heteroscedasticity and normality were taken care of through residuals analysis. Outliers were spotted using box plots, Cook' distance and leverage values and a few extremes were remedied exercising strict statistical and sample specific considerations. Multicollinearity observed for H_{idx} and L/C was resolved using *Z* scores.

RESULTS - I

H Index (H_{idx}) & Problem Solving Effectiveness

H Index was positively associated with *success* in navigating the simulated task (Table 2). Individuals with higher H_{idx} achieved higher cash balance at the end of year 1 and completed the simulation with higher average earnings ($R = .34$ & $.36$ respectively, $p < 0.05$).

Two success indices also showed significant quadratic effect of 'inverted U' form (Table 3) – i.e. success increased with increase in H_{idx} up to a certain point and then showed signs of decline. Only limited support emerged for *consistency* – Coefficient of Variation (CV) of cash balance declined with increase in H_{idx} (R = -.32, $p < 0.1$, Table 2), indicating increasing consistency in outcomes. Both *crises* measures showed significant negative associations (R = -.41 & -.37, $p < 0.05$, Table 2) implying that problem solving became increasingly free of crises with increasing H_{idx}. Their quadratic 'U' trends (Table 3) indicated that as H_{idx} increased problem solving showed signs of becoming smooth and crises-free but crises reappeared as H_{idx} reached higher values.

Insert Tables 2 & 3 about here

Unique Information and Decision Units (U_{idu}) & Problem Solving Effectiveness

Results similar to that for H_{idx} were seen for U_{idu}. Linear positive associations with all *success* measures (Table 2) indicate that individuals with higher cognitive complexity were more successful in navigating the simulated task. Significant curvilinear effects of 'inverted U' form (Table 3) indicate that with increase in cognitive complexity, individuals tended to create successful outcomes up to a certain point, after which there were signs of decline. *Consistency* measures, similar to H_{idx}, threw up partial results – only CV of production decreased significantly with increase in U_{idu} (R = -.29, $p < 0.1$, Table 2), indicating increasing consistency in outcomes. Both *crises* measures showed significant linear decreasing trend (Table 2). Only the actual number of crises showed a quadratic 'U' form (Table 3), indicting increasingly trouble free problem solving with increase in U_{idu} and pointing towards emergence of crises at higher levels.

Unique Extensive Information and Decision Units (U_X_{idu}) & Problem Solving Effectiveness

No significant relations, neither linear nor quadratic, were observed between U_X_{idu} and any of the problem solving effectiveness measures.

Links/Concepts (L/C) & Problem Solving Effectiveness

Unlike H_{idx} and U_{idu} where linear associations were observed, L/C dominantly showed only curvilinear trends (Tables 2 & 3). All *success* indices showed 'inverted U' form (Table 3) –

cash balance at the end of Year 1 (R^2 = .17, F = 3.26, p < 0.1) and at the end of simulation (R^2 = .15, F = 2.76, p < 0.1), and average cash balance during the simulation (R^2 = .19, F = 3.73, p < 0.05) increased with increase in L/C, reached a high, and then began to decline. Results supportive this trend were obtained for both *crises* measures (Table 3) implying that problem solving became increasingly crises-free with increase in L/C, but crises began to reappear at the higher end. Contrasting results were obtained for *consistency* in problem solving.

Thus, in general, results of analysis with individual cognitive complexity measures show either a positive linear association with success in navigating the simulated complex task and/or an increase in success up to a certain point followed by a declining trend. Trends opposite to that of success were observed for crises measures – either a negative linear association and/or an initial decline in crises with increase in cognitive complexity followed by a rise – which in effect further strengthen the positive role of cognitive complexity in problem solving effectiveness. Hence, though inconclusive results were observed for consistency measures, *Hypothesis 1* gets reasonably good support. However, the declining trend at the higher end of cognitive complexity has to be included. Following this, I conducted factor analyses of the four cognitive complexity measures.

Factor Analysis

Conceptually and logically, it was reasoned earlier that the four cognitive complexity measures could be assessing differentiation, discrimination and integration dimensions. I ran factor analyses to see if there was statistical support for this. Table 4 gives extraction results of principal component analysis and varimax rotation with Kaiser normalization. Two factors extraction loaded H_{idx}, U_{idu} and U_X_{idu} on Factor 1, and L/C on Factor 2. Unmistakably Factor 1 is differentiation ($Diff_{2F}$), and Factor 2 is integration (Int_{2F}). Three factors extraction loaded H_{idx} and U_{idu} on Factor 2, U_{idu} and U_X_{idu} on Factor 1, and L/C on Factor 3. The loadings pattern evidently makes Factor 2 differentiation ($Diff_{3F}$), Factor 1 discrimination ($Discr_{3F}$), and Factor 3 integration (Int_{3F}). With this statistical confirmation of the three dimensions, I repeated all regressions with the factor scores.

Insert Table 4 about here

RESULTS - II

Differentiation & Problem Solving Effectiveness

***Diff$_{2F}$* (Factor 1 of 2).** *Success* measures showed linear positive associations (Table 5; Figure 2) – individuals with higher differentiation capability tended to make higher cash balance at the end of year 1 (R = .33, p < 0.1) and higher average cash balance in the simulation ((R = .51, p < 0.01). Quadratic model was significant only for cash balance at the end of simulation, showing a 'inverted U' trend. Only limited support was obtained for *consistency* – CV of cash balance alone decreased with increase in Diff$_{2F}$ till some level and then increased (R^2 = .23, F = 4.7, p < .05). Both *crises* measures showed significant linear results in the expected direction (R = -.46 & -.45, p < 0.01), implying problem solving became increasingly crises-free with increasing differentiation.

***Diff$_{3F}$* (Factor 2 of 3).** While all *success* measures showed significant positive associations (Table 5), *consistency* measures showed partial support with only CV of production showing a significant declining trend (R = -.31, p < .1). Both *crises* measures showed significant declining trend (R = .34, p < .05). No quadratic model emerged significant.

Differentiation dimension, thus, generally shows dominantly linear association with problem solving effectiveness – *success* increased and *crises* declined with increase in differentiation ability of decision makers. Thus, although inconclusive results are seen for *consistency*, *Hypothesis 1a* gets reasonably good support. However, the declining trend at the higher end of differentiation would need to be noted.

Insert Table 5 & Figure 2 about here

Discrimination & Problem Solving Effectiveness

No significant relations, linear or quadratic, were observed between discrimination ability and any of the problem solving effectiveness measures. *Hypothesis 1b* is not supported.

Integration & Problem Solving Effectiveness

***Int$_{2F}$* (Factor 2 of 2).** A different pattern of results came up for integration (Int$_{2F}$) compared to differentiation (Diff$_{2F}$), showing a dominance of quadratic models (Table 6, Figure 2). Only CV of sales showed significant linear association (R = .41, p < .05) but implied increasing *inconsistency*. All *success* indices showed a 'inverted U' trend – higher achievements with increase in integration ability followed by a declining trend at the higher end. CV of production showed a supportive trend (R^2 = .5, F = 14.06, p < .01), indicating increasing stability in production with increase in integration followed by setting in of fluctuations. One of the two crises measures also showed a similar trend (R^2 = .17, F = 3.27, p < .1).

Int$_{3F}$* *(Factor 3 of 3). Results similar to above and different from differentiation (Diff$_{3F}$) were observed (Table 6). All *success* indices showed a 'inverted U' trend of higher accomplishments with increase in integration ability followed by a decline at the higher end. While CV of production showed a supportive trend (R^2 = .51, F = 14.78, p < .01) indicating increasing stability in production with increase in integration followed by setting in of variability, CV of sales revealed a reverse trend. Actual number of faced by participants first declined with increase in integration and then began to go up at the higher end (R^2 = .18, F = 3.47, p < .05).

Integration dimension, thus, dominantly shows curvilinear association with problem solving effectiveness – increasing success and declining crises with increase in integration ability of decision makers, followed by a reversal of this trend at the higher end of integration. Inconclusive results are seen for *consistency*. This suggests that for *Hypothesis 1c*, the support is not for linear positive association but for a curvilinear trend with declining trend at the higher end.

Insert Table 6 about here

DISCUSSION

This paper reports findings from a computerized simulation study that investigated the influence of cognitive complexity of decision makers on their effectiveness of navigating ill-structured decision environments or solving complex problems. Cognitive complexity was assessed in three different but domain specific ways yielding four measures. Analysis indicates an increase in problem solving effectiveness with increase in cognitive complexity of individuals – with increase in cognitive complexity, individuals emerged more successful with enhanced achievements and ended up facing fewer crises. Although mixed results were seen for consistency in navigating the complex task, there was some indication towards problem solving becoming more even. Declining effectiveness at the higher end of cognitive complexity was indicated. Some distinctive differences were revealed in the relations between the three cognitive complexity dimensions and problem solving effectiveness. Differentiation ability of individuals dominantly showed a positive linear trend with effectiveness while integration ability dominantly revealed an ‘inverted U’ trend. Discrimination ability did not show any significant results in this study. There was also an indication of declining effectiveness at the higher levels of differentiation.

The nature of results obtained for differentiation clearly shows that, to enhance problem solving effectiveness, it is essential for individuals to enlarge the diversity of understanding of the situation by looking into its various aspects, and also to enlarge the spectrum of action or intervention. However, the emergence of quadratic models indicate a decline in effectiveness at the higher (maybe at very high) levels of differentiation capabilities. While a straightforward explanation for this would be that getting into too many details is either *unnecessary* for being effective and/or *unmanageable* leading to loss of focus, coherence, persistence, and so on, a perusal of the results obtained for discrimination and integration dimensions could help us take a more informed stand between the *unnecessary* and the *unmanageable* aspects.

We find that discrimination dimension showed no significant relations with effectiveness, an aspect evident from analysis with the individual cognitive complexity measure of U_X_{idu} as well. This null effect finding provide some reliable empirical evidence, that, for achieving a satisficing solution in situations characterized by higher doses of complexity, dynamism, ambiguity and uncertainty, it is unnecessary to spread the attention too far and wide. Attention to a judicious or requisite variety seems to hold the key to success. Restating this differently, the marginal utility of getting into an additional detail in the form of a new dimension or attribute often tends to diminish, once the problem solver (decision maker, leader or manager) has taken care to unravel a desirable level of diversity. Quite often, in ill-structured situations, it is only through trial and error, or experimentation, that decision makers maybe able to get an idea as to which factors or features, of the many that she/he would be dealing with, will turn out to have diminishing marginal utility.

Distinctively, the integration dimension dominantly showed an inverted U trend – effectiveness increasing with increase in integration capability of participants, reaching a high, and then tending to decline at the higher end of integration values, indicating that both the low and the high extremes were dysfunctional. Since integration measure in this study came from cognitive maps of participants, we could turn to the conceptualization of maps as a network of concepts and links to explain the observed pattern. On one extreme would be a map with concepts alone, each standing in isolation without links to any other, leading the individual to make disjointed, fragmented or no sense at all of the situation. The following observation of Dörner and Wearing (1995: 37) based on studies using computerized simulations support this: “Typically our poor subjects reiterate that they have no idea as to what to do... because they are not able to recognize things and events as special instances of an abstract concept... they remain isolated for them... A subject with such a model... will arrive at a decision well, but it will be a simple decision not connected to other aspects of the system. The subject will not exhibit concerted decision making behaviour, whereas a subject with the network... [of relationships] will.” On the other extreme would be a map with each concept linked to all the others, one with high density.

Actual maps of individuals fall short of this extreme. As we move from a map with only concepts to the denser end, new links get added, new concepts come in, some old ones go out and some get modified, enabling an individual to make alternative explanations, develop multiple scenarios and pursue an array of actions. However, when the integration index increases to larger values, the maps get denser and more fine-grained. This could potentially manifest in highly detailed navigation strategies, leading to highly effective outcomes. However, it is possible that such elaborated strategies may not be actually required to effectively deal with the complex situation faced. This could lead to frustration and loss of motivation for some individuals resulting in lower effectiveness. On the other hand, even when congruence exists between higher map density and the complex reality of the situation, there is the danger of getting lost in nuances with a highly fine-grained structure. Since navigating ill-structured situations is usually not an one shot affair but a prolonged process involving prioritization of issues, planning, action, monitoring of outcomes, taking corrective/newer actions, and so on, this could place stressful cognitive demands on the problem solver over time, which in turn can result in fatigue and forgetfulness (Dörner &

Wearing, 1995). Due to any or all of these reasons effectiveness at very high levels of integration abilities would have tended to decline. Thus, both *unnecessary-ness* and *unmanageability* along with some of the dysfunctional aspects of emotional and cognitive coping seem to contribute to declining effectiveness of problem solving at the higher end of cognitive complexity.

Some salient features of this study

Considering the laborious and time consuming methodology of cognitive mapping and long duration simulation of a complex task, although inevitable, two limitations of this study are its relatively small sample size and single organization sample. However, this study has some salient features. First, it used multiple, independent and domain specific measures of cognitive complexity, a conscious action adopted following the advice of previous researchers. Second, these measures were conceptually and logically presented as measuring the three dimensions of cognitive complexity, and it was later confirmed through factor analysis. Third, it clearly highlights the significance of cognitive complexity in leading to effectiveness in dealing with ill-structured decision environments. Since research shows that cognitive complexity of individuals can be developed through education, training, field experiences, and so on, the findings here have application in the domains of teaching, training and development of managers and leaders to become successful and effective problem solvers. Finally, this study being done with a group of managers the generalizability of its findings is likely to be better. The findings clearly point to the need for further research to ascertain if very high levels of differentiation, and particularly integration, capabilities are really dysfunctional.

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FIGURE 1
Illustration of Information Seeking Options in Manutex Simulation
and Relative Positioning of the Three cognitive complexity Measures H_{idx}, U_{idu} & U_X_{idu}

MANUTEX

Information[a]

1. **Products**
2. Raw Materials
3. Personnel
4. Machine
5. Money (Accounts & Finance)
6. Delegation
7. Demand (Market)

1. **Production**
2. Priority
3. Prices
4. Stock
5. Quality
6. Production Target
7. Sales
8. Raw Materials Requirement
9. Machine Requirements
10. Store Worker Requirements

1.Trousers
2. Shirts
3. Blouses
4. Coats
5. Skirts
6. Jackets
7. T-Shirts

Level-1: H_{idx} **Level-2: U_{idu}** **Level-3: U_X_{idu}**

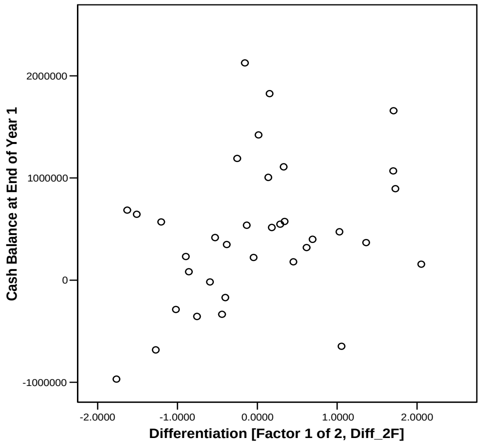
[a] Similar options available to participants for making interventions or decisions as well in the simulation. H_{idx}, U_{idu} and U_X_{idu} were computed by considering both information seeking and decision making behaviour.

FIGURE 2

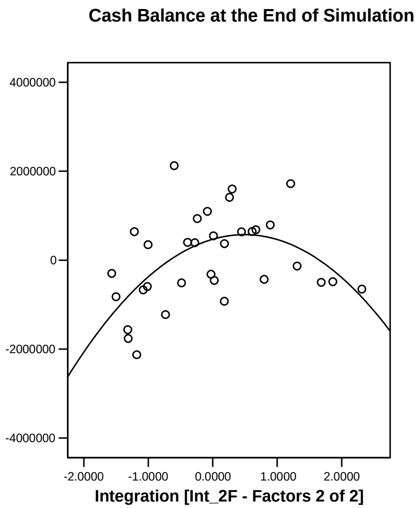
Sample Figures Depicting Typical Trends of Relations between

Cognitive Complexity Dimensions and Problem Solving Effectiveness

Differentiation & Success



Integration & Success



Integration & Inconsistency

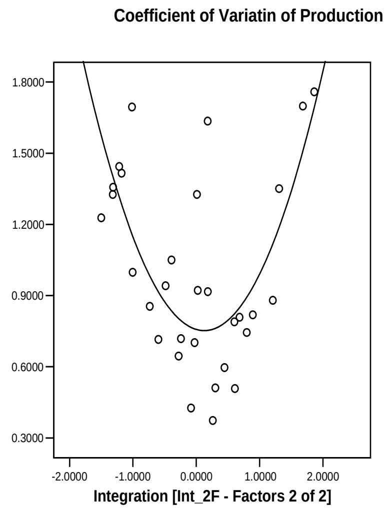


TABLE 1

Descriptive Statistics and Pearson Correlations among the Four Cognitive Complexity Measures and Their Related Variables

Cognitive Complexity Measures And Related Variables[a]	***M***	***SD***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1. H Index (H_{idx}, *Measure* 1)	1.97	.11												
2. Unique Information Units	25.08	5.22	.34*											
3. Unique Decision Units	8.36	1.87	.64**	.66**										
4. Unique Information & Decision Units	33.44	6.60	.45**	.98**	.80**									
5. *Z* of Unique Information & Decision Units (U_{idu}, *Measure* 2)	0.00	1.82	.54**	.91**	.91**	.98**								
6. Extensive Unique Information Units	74.11	17.60	.19	.50**	.55**	.55**	.58**							
7. Extensive Unique Decision Units	21.64	4.84	.48**	.23	.61**	.36*	.46**	.69**						
8. Extensive Uniq. Info & Dec. Units	95.75	21.25	.27	.47**	.60**	.54**	.59**	.99**	.80**					
9. *Z* of Extensive Unique Information & Decision Units (U_X_{idu}, *Measure* 3)	0.00	1.84	.36*	.40**	.63**	.50**	.57**	.92**	.92**	.97**				
10. Links	61.34	21.71	-.29†	-.14	-.32†	-.20	-.25	-.15	-.30	-.19	-.24			
11. Concepts	63.69	19.43	-.29†	-.14	-.34*	-.20	-.26	-.14	-.33	-.19	-.25	.98**		
12. Links + Concepts	125	40.91	-.29†	-.14	-.33†	-.20	-.26	-.15	-.31	-.19	-.25	.99**	.99**	
13. Links/Concepts (L/C, *Measure* 4)	0.95	0.08	-.13	-.01	-.06	-.02	-.04	-.07	-.02	-.06	-.05	.63**	.46**	.56**

*** $p \leq 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p \leq 0.1$, 2-tailed.

[a] *n* = 36 for variables 1 to 9, and *n* = 35 for variables 10 to 13.

TABLE 2

Pearson Correlation between Cognitive Complexity & Problem Solving Effectiveness Measures

Problem Solving Effectiveness Measures		**Correlation with cognitive complexity measures**			
		$\boldsymbol{H_{idx}}$ **(n = 34)**	$\mathbf{U_{idu}}$ **(n = 36)**	$\mathbf{U\_X_{idu}}$ **(n = 36)**	**L/C (n = 35)**
	Success in Problem Solving				
1	*Cb_12*: Cash balance at the end of 12 decision cycles (Year 1)	$.34^{*}$	$.40^{*}$	.12	.18
2	*Cb_Es*: Cash balance at the end of simulation	.23	$.27^{\dagger}$	.17	.17
3	*Cb_EsAv*: Average cash balance in the entire simulation	$.36^{*}$	$.34^{*}$	.05	.20
	[*In*]*Consistency in Problem Solving*				
4	*Cv_Cb*: Coefficient of variation of cash balance during simulation[a]	$-.32^{\dagger}$	-.04	.12	-.20
5	*Cv_Pr*: Coefficient of variation of production during simulation[b]	-.19	$-.29^{\dagger}$	.05	.00
6	*Cv_Sl*: Coefficient of variation of sales during simulation[c]	.03	.17	-.00	$.37^{*}$
	Crises in Problem Solving				
7	*Cr_Es*: Total number of crises faced during simulation	$-.41^{*}$	$-.30^{\dagger}$	-.01	.02
8	*Cr_mEs*: Decision cycles with crises in the simulation	$-.37^{*}$	$-.28^{\dagger}$	-.02	-.02

* $p < 0.05$, † $p \leq 0.1$, 2-tailed.

[a] $n = 31$, [b] $n = 32$, [c] $n = 33$.

TABLE 3

Regression Analysis between Cognitive Complexity & Problem Solving Effectiveness Measures: Quadratic Effects

Effectiveness Measures		H_{idx}[a] (*n* = 34)				U_{idu} (*n* = 36)				L/C[a] (*n* = 35)			
		β_1[b]	β_2	R^2	$F_{2,31}$	β_1	β_2	R^2	$F_{2,33}$	β_1	β_2	R^2	$F_{2,32}$
Success in Problem Solving													
1	Cb_12	$.37^{*}$	-.19	.15	$2.80^{\dagger}$	$.47^{**}$	$-.39^{*}$	.30	7.25^{**}	.27	$-.38^{*}$	.17	$3.26^{\dagger}$
2	CB_Es	$.29^{*}$	$-.50^{**}$	.30	6.71^{**}	$.33^{*}$	$-.31^{\dagger}$	.17	3.34^{*}	.26	$-.35^{*}$	.15	$2.76^{\dagger}$
3	AvCB_Es	$.40^{*}$	$-.36^{*}$	.25	5.30^{*}	$.41^{*}$	$-.40^{*}$	.26	5.95^{**}	$.30^{\dagger}$	$-.40^{*}$	.19	3.73^{*}
[*In*]*Consistency* in *Problem Solving*													
4	Cv_Cb[c]	$-.32^{\dagger}$	.18	.14	2.13	-.06	.09	.01	.13	-.30	.30	.12	1.86
5	Cv_Pr[d]	-.19	.03	.04	.54	$-.31^{\dagger}$	.10	.09	1.58	-.02	$.56^{**}$	.32	6.80^{**}
6	Cv_Sl[e]	.02	.06	.00	.06	.19	-.15	.05	.85	$.42^{*}$	$-.33^{*}$	.24	4.84^{*}
Crises in Problem Solving													
7	Cr_Es	$-.46^{**}$	$.43^{**}$	.35	8.23^{**}	$-.36^{*}$	$.32^{\dagger}$	.19	3.80^{*}	-.10	$.47^{**}$	.21	4.15^{*}
8	Cr_EsM	$-.43^{**}$	$.44^{**}$	.33	7.81^{**}	$-.33^{\dagger}$	.25	.14	$2.74^{\dagger}$	-.11	$.38^{*}$	.14	$2.51^{\dagger}$

** $p \leq 0.01$, * $p \leq 0.05$, † $p \leq 0.1$, 2-tailed.

[a] *Z* values used in regression, [b] β_1 and β_2 are standardized coefficients of linear and quadratic terms respectively.

[c] *n* = 31, [d] *n* = 32, [e] *n* = 33.

TABLE 4

Results of Factor Analysis of the Four Cognitive Complexity Measures

Measures of Cognitive Complexity		**2 Factors Extraction: Rotated Factor Matrix[a]**			**3 Factors Extraction: Rotated Factor Matrix[a]**		
		Factor 1 of 2	**Factor 2 of 2**		**Factor 1 of 3**	**Factor 2 of 3**	**Factor 3 of 3**
H_{idx}		.771	-.182		.163	.945	-.088
U_{idu}		.877	.021		.624	.617	.034
U_X_{idu}		.794	.034		.949	.159	-.037
L/C		-.040	.991		-.018	-.058	.997
Initial Eigenvalues (% of Variance)		2.014 (50.36)	.998 (24.96)		2.014 (50.35)	.998 (24.96)	.610 (15.25)
Cumulative % of Variance		50.36	75.31		50.35	75.31	90.56
Rotation Eigenvalues (% of Variance)		1.996 (49.90)	1.016 (25.41)		1.317 (32.92)	1.302 (32.54)	1.004 (25.10)
Cumulative % of Variance		49.90	75.31		32.92	65.46	90.56

[a] Extraction Method: Principal Component Analysis; Rotation Method: Varimax with Kaiser Normalization; Kaiser-Meyer-Olkin measure of sampling adequacy = .644; Bartlett test of sphericity: Approx. chi-square = 24.508, df = 6, p = .000.

TABLE 5

Differentiation Dimension and Problem Solving Effectiveness: Linear and Quadratic Effects

	Problem Solving Effectiveness Measures	Correlations		Quadratic Effects – $Diff_{2F}$ (Differentiation - Factor 1 of 2)				Quadratic Effects – $Diff_{3F}$ (Differentiation - Factor 2 of 3)			
		$Diff_{2F}$	$Diff_{3F}$	β_1[a]	β_2	R^2	$F_{2,32}$	β_1	β_2	R^2	$F_{2,32}$
	***Success** Measures*										
1	Cash Balance, end of Year 1	.33†	.31†	.38*	-.20	.15	2.83†	.33†	.06	.10	1.80
2	Cash Balance at the End	.13	.31†	.23	-.43*	.19	3.78*	.29	-.07	.10	1.83
3	Average Cash Balance	.51^{**b}	.34*	.52**	-.18	.29	6.14^{**b}	.32†	-.06	.12	2.23
	***Consistency** Measures*										
4	CV of Cash Balance	.02	-.12	-.08	.49**	.23	4.70*	-.08	.11	.02	.41
5	CV of Production[b]	-.20	-.31†	-.22	.05	.04	.69	-.38*	-.20	.13	2.28
6	CV of Sales	.10	.06	.14	-.16	.04	.60	.16	.27	.07	1.13
	***Crises** Measures*										
7	Number of Crises Faces	-.46^{**b}	-.34*	-.46**	.09	.22	4.12^{*b}	-.31†	.08	.12	2.19
8	Decision Cycles with Crises	-.45^{**b}	-.34*	-.46**	.11	.22	4.13^{*b}	-.29	.14	.13	2.45

** $p < 0.01$, * $p < 0.05$, † $p \leq 0.1$, 2-tailed.

[a] β_1 and β_2 are standardized coefficients of linear and quadratic terms respectively.

[b] n =33.

TABLE 6

Integration Dimension & Problem Solving Effectiveness: Linear and Quadratic Effects

	Problem Solving Effectiveness Measures	**Correlations**		**Quadratic Effects – Int_{2F} (Integration - Factor 2 of 2)**				**Quadratic Effects – Int_{3F} (Integration - Factor 3 of 3)**			
		Int_{2F}	**Int_{3F}**	β_1[a]	β_2	R^2	$F_{2,32}$	β_1	β_2	R^2	$F_{2,32}$
	***Success** Measures*										
1	Cash Balance, end of Year 1	.19	.21	.30†	-.43*	.21	4.26*	.27†	-.38*	.18	3.63*
2	Cash Balance at the End[b]	.27	.32†	.42*	-.51**	.31	6.74**	.42**	-.49**	.34	7.70**
3	Average Cash Balance	.19	.23	.30†	-.41*	.19	3.87*	.29†	-.37*	.19	3.68*
	***Consistency** Measures*										
4	CV of Cash Balance	-.17	-.21	-.22	.15	.05	.88	-.23	.13	.06	1.01
5	CV of Production[c]	-.08	-.11	-.18	.71**	.50	14.06**	-.17	.71**	.51	14.78**
6	CV of Sales	.41*	.42*	.42*	-.15	.20	3.89*	.46**	-.26†	.24	5.11*
	***Crises** Measures*										
7	Number of Crises Faces	.02	-.01	-.09	.43*	.17	3.27†	-.09	.43*	.18	3.47*
8	Decision Cycles with Crises	-.00	-.04	-.01	.20	.04	.70	-.10	.34†	.11	2.06

** $p < 0.01$, * $p < 0.05$, † $p \leq 0.1$, 2-tailed.

[a] β_1 and β_2 are standardized coefficients of linear and quadratic terms respectively.

[b] $n = 33$, [c] $n = 31$.