Cognitive biases, modeling and performance: an experimental analysis

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Abstract

Producing (or constructing) strategic decisions entails numerous cognitive and other bounds on human rationality, which often cause systematic errors and biases. Yet among the economic and management models used in strategic planning, few try to explain why decision makers remain so stubbornly and extravagantly irrational, ignoring logic, principles of optimization, and even postulated self-interest. One explanation may be the difficulty of extending methods used to study individual choice and decision-making behavior to dynamic group settings. This experimental analysis assessed the impact of cognitive simplification processes on the performance of 118 graduate business students who worked in a simulated strategic context. Randomly assigned to twenty-four teams, the subjects run international conglomerates with multiple actors, feedback loops, non-linearities, and time lags and delays. The teams' interaction, expectations, choice and model selection produced results that systematically diverged over time. Within a crossed factorial design, these results support the hypothesis that cognitive biases interact with strategic management models to influence performance. Poor performers chose models that reinforced their cognitive limits and bounds. Conversely, good performers constructed models which helped them recognize and overcome the negative effects of cognitive simplification processes. They produced effective decisions, not by optimizing functions, but through searching for recognizable patterns when they received feedback.

Introduction

Writers in the field of strategic management generally recognize that human cognitive limitations affect strategic decisions. Those responsible for an organization's strategic decision situation face a task of extreme complexity and ambiguity. The complexity of the task appears almost infinite, while the matching human and organizational information processing capabilities are usually limited. One of the central features of strategic decision situations is their lack of structure (Mintzberg, Raisinghani & Theôret, 1976). The strategic decision-making process entails novelty, complexity and openendedness. Strategy and policy makers usually begin with little comprehension of the situation and their understanding deepens as they work on it (Mintzberg *et al.*, 1976: 265). The complexity of strategic decision situations makes strategic decision-making an ill-structured process (Mason & Mitroff, 1981: 10-13). Because strategic decision situations have no clear formulation, it is extremely difficult to either describe the nature and structure of a situation, or determine the criteria by which a certain course of action should be chosen. Complex strategic decision situations involve uncertainty and ambiguity for the decision makers.

Michael (1973) suggests that when environmental uncertainty cannot be minimized by organizational action, managers may alter their perceptions of the environment so that it appears more certain. This happens because the psychological state of uncertainty regarding important decisions is very painful. As a result, decision makers may repress awareness of the uncertainty and act on a simplified model of reality which they construct. Morecroft sees this phenomenon enabled by five information filters surrounding the strategic decision-making process (1988: 306). The first filter represents people's cognitive limits and Simon's (1976) notion of bounded rationality: people are unable to process all the information that a strategic decision situation may present; they decide on the basis of a few sources of information processed according to quite simple rules of thumb. The outer four filters in Morecroft's framework represent the ways in which an organization actually conditions the information made available to its constituents. These four filters provide a "psychological environment" which limits the range of factors considered and supplies only "relevant" information.

In a manager's day-to-day work, the lack of pertinent and well-structured information generates potential pitfalls for strategic thinking and makes planning and learning from experience difficult. To the rescue come some important developments in "problem-forming" methods that managers increasingly view as "sources of new knowledge" or as "tools for learning" about business and social systems (De Geus, 1988). These are improvements in the symbols and software used for mapping and model structuring; behavioral decision theory ideas which help to capture the knowledge of decision makers into models; improvements in methods of simulation and scenario analysis that enable modelers and model users to gain better insight into dynamic behavior; and emphasis on small transparent models, on games and on dialogue between "mental models" and simulated scenarios. For example, system dynamics are now used by management teams to create "microworlds" or "incubators for knowledge" (Papert, 1980) that allow structuring informed debates about strategic change, in a process where models and simulated scenarios become an integral part of management dialogue (Morecroft, 1988).

As a result of these developments, business educators face increasing demands in the "capstone" business policy course. The fast pace of change in the global business environment dictates that business policy teachers integrate problem-forming with conventional case studies in order to adequately prepare students for the world of work. A conventional business policy case provides general information on a selected company: the problems it faces, the industry it competes in, its products and markets, its history, its organization and administration, and the personalities of its leaders. This information initiates debate and dialogue, which lead to the situation's clarification and, eventually, to recommendations for action (Christensen, Andrews, Bower, Hamermesh & Porter, 1987). What the conventional approach to case analysis (by argument) provides is a context of drama and realism where the interplay between information and debate produces a consensus for action. However, focusing on mere observations involves a possibility of substantial *misinterpretation* (Copeland, 1958). The risk is even greater if the conventional approach to case studies remains the still point in a complex, dynamic, and rapidly changing global environment. Conversely, problem-forming methods which include descriptions of policy functions, algebra, and simulated scenarios provide discussants with additional, more pertinent, and better structured information on strategic decision situations.

Mintzberg *et al.* (1976) and more recently Nutt (1984) show that some managers do not formally and explicitly diagnose strategic decision situations. Indeed, the most popular organization behavior model which legitimizes the return to basics and sticking to the knitting (Peters & Waterman, 1982) is "logical incrementalism" (Quinn, 1980). This same model was called "the science of muddling through" (Lindblom, 1959) a few years back, and it can still be used by managers who assume their firms will remain immune to the turbulent forces of global competition. Through the use of problem-forming methods, such as Scenario-driven Strategic Information Mapping (S-dSIM), decision makers who do not escape to and reaffirm the dogmas of the quite past will be able to consider most of the important factors that influence a firm's problematic. This should also lead to improved performance and a better strategic posture for their organization.

This study examined the impact of nine cognitive biases (CBs) and the effect of S-dSIM on the relative performance of 118 graduate business students who worked under the experimental conditions of a simulated strategic context. Randomly assigned to twenty-four teams, the subjects run international conglomerates with multiple actors, feedback loops, non-linearities, and time lags and delays. The interaction, expectations, choices and teams' model selection produced results that systematically diverged over time. Within a crossed factorial design, these results support the hypothesis that cognitive biases interact with strategic management models to influence performance. Poor performers chose heuristics that reinforced their cognitive limits and bounds. Conversely, good performers constructed models which helped them recognize and overcome the negative effects of cognitive simplification processes. They produced effective decisions, not by optimizing functions, but through searching for recognizable patterns when they received feedback.

There are those who argue that inferences cannot be drawn about executives' performance at real world decision making from students and laboratory decision making tasks (Ungson, Braunstein & Hall, 1981). However, laboratory research investigating the effects of cognitive biases using tasks more representative of the ill-structured situations encountered in strategic decision making has been advocated as the most fruitful approach for several questions in strategic management (Schwenk, 1984 & 1982). Many call for renewed investigations designed to provide data at the micro level that provide direct evidence about the behavior and performance of decision makers and the ways in which they go about making their decisions (Coleman, 1987; Simon, 1984; Sterman, 1989).

Cognitive Biases (CBs)

Cognitive psychologists and behavioral decision theorists have identified a wide range of cognitive processes which serve to simplify decision makers' perceptions of strategic decision situations and render the strategic decision-making process manageable (Hogarth, 1980; Hogarth & Makridakis, 1981; Slovic, Fischoff & Lichtenstein, 1977; Taylor, 1975; Tversky & Kahneman, 1974). The processes used are cognitive biases, but some researchers prefer the term "heuristics", because the term "biases" suggests that these processes generally have a negative impact on strategic decisions. Tversky & Kahneman (1974), Winkler & Murphy (1973) and other behavioral decision theorists observe that these processes may actually improve decisions as organizations display effective decision-making despite people's cognitive limits and over-abundance of information (Morecroft, 1988; Simon, 1976) . However, as useful as these heuristics may be, sometimes lead to severe and systematic errors (Tversky & Kahneman, 1974: 1125).

Drawing on this literature, Schwenk (1984) conjectures about cognitive simplification processes frequently encountered in problem-forming and decision making under uncertainty. Assuming that the formulation of strategic decision situations begins with the recognition of gaps between expectations or standards and performance (such standards may be based on past trends, projected trends, standards of global competitors, expectations of internal and external stakeholder groups, or even theoretical models), Schwenk (1984) selected nine groups of cognitive biases (CB1 through CB9) and, according to the decision-making stage they may affect, he proposed the following classification:

Stage I: GOAL/PROBLEM-FORMING

CB1 *Prior hypothesis bias* and *adjustment & anchoring*. Under their influence strategic decision-makers tend to perceive fewer gaps than their data indicate.

CB2 *Escalating commitment*. Under its influence strategic decision-makers tend to minimize the significance of gaps, and they tend not to make full use of these gaps as a basis for changes in strategy. Strategic decision makers may even become more committed if they receive feedback indicating failure than when receiving feedback indicating success of a change in strategy.

CB3 *Reasoning by analogy*. Even if the significance of a gap is recognized, strategic decision-makers tend to define the factors causing the gap through an analogy to a simpler situation.

Stage II: ALTERNATIVES GENERATION

CB4 *Single-outcome calculation*. In searching for a solution to a strategic decision situation, strategic decision-makers tend to generate and bolster a single alternative rather than several alternatives.

CB5 *Inferences of impossibility* and *denying value tradeoffs*. Strategic decision-makers tend to deal with non-preferred alternatives by denying that they serve any values better than the preferred alternative, and by over-estimating the difficulty in implementing them.

CB6 *Problem set*. Under its effect and that of unchallenged assumptions, strategic decision makers who attempt to generate more than one alternative tend to generate very few.

Stage III: EVALUATION AND SELECTION

CB7 *Representativeness*. Under its influence, strategic decision makers tend to overestimate the accuracy of their predictions of the consequences of alternatives.

CB8 *Illusion of control*. Under its influence, strategic decision-makers tend to over-estimate the importance of their own actions in ensuring the success of alternatives.

CB9 *Devaluation of partially-described alternatives*. Strategic decision makers tend to exhibit a preference for alternatives described in great detail, even though partially-described alternatives score higher on their evaluation criteria.

Schwenk's purpose of discussing the possible operation of these processes in strategic decision making was not to criticize the quality of strategic decisions but, rather, to generate ideas about the ways decision makers actually deal with complexity, ambiguity, and uncertainty. However, his focus on processes which have been encountered both in laboratory and/or field settings does offer a basis for selecting those biases which have some probability of affecting decision making in strategic decision situations.

Scenario-driven Strategic Information Mapping (S-dSIM)

The problem-forming method tested in this paper is Scenario-driven Strategic Information Mapping (S-dSIM). S-dSIM consists of several interdependent components and its purpose is to help managers and/or business students formulate a firm's strategic decision situation; its "mess" of problems or "problematic". The components include the method of rational argumentation (Mason & Mitroff, 1981), the nominal group structure (Van de Ven & Delbecq, 1974) -slightly modified to incorporate Rapoport's (1967) suggestions, the Strategic Assumption Surfacing and Testing (SAST) approach advanced by Emshoff, Mitroff & Kilman (1978) and Mitroff & Emshoff (1979), and comprehensive situation mapping (Acar, 1983; Acar, Chaganti & Joglekar, 1985). The method of rational argumentation teaches participants how to present claims (with implications that lead to recommendations) on the nature and structure of a strategic decision situation to other group members during a case discussion. It forces participants to provide the underlying data and reasoning processes (warrant) that support their claim, and a safety valve: conditions under which their claim will not be valid (Brightman, 1987). The nominal group procedure requires that each person within a team independently generate his/her analysis of a case or problematic. Each person then presents his/her case analysis to the other group members. No discussion is permitted during these round-robin opening arguments. After everyone has made an opening presentation (with claim and implications, data, warrant, and safety valve), each of the protagonists in the debate presents the other person's claim on the nature and structure of the problematic, to the satisfaction of that person. This forces each debater to acknowledge and understand the opposing view, a critical ingredient to a dialectical interchange aimed at unearthing critical strategic assumptions (Figure 1).

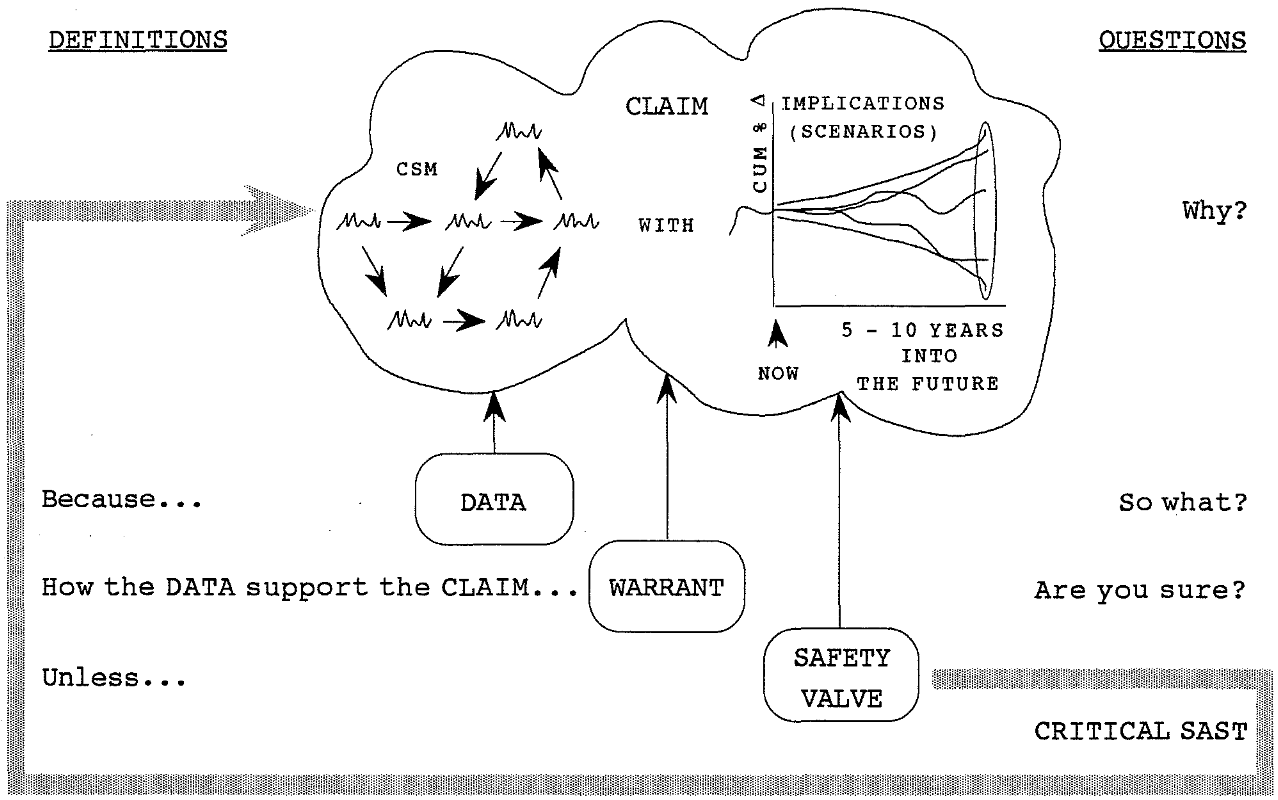

Fig. 1. The Scenario-driven Strategic Information Mapping (S-dSIM) problem-forming method.

Through the process of specifying conditions under which the claim and its implications will not hold (safety valve), participants unearth and specify assumptions implicit to their understanding of the nature and structure of the strategic decision situation (e.g., assumptions about events, attributes, and stakeholder objectives and values). This S-dSIM component exploits the SAST process which can handle a) strongly different strategic options; b) forces of continuity, tradition, and organizational inertia (i.e., resistance to change); and c) in-depth analyses so a team is less vulnerable to non-penetrating thinking, and does not fall victim to unconsciously-made yet critical implicit assumptions.

Each participant provides his/her claim on the nature and structure of the problematic along with the claim's implications (i.e., scenarios) using comprehensive situation mapping (CSM). CSM is a sophisticated extension of influence diagramming (ID) that overcomes its limitations without introducing undue complexity. An influence diagram offers a graphic map of the web of qualitative interrelationships bearing on a business problematic (Diffenbach, 1982; Maruyama, 1963; Weick, 1979). Its purpose is to make the dynamics of the interrelationships more visible, more explicit, and thus more comprehensible. It is a desk-top tool that can be used individually or collectively. CSM is also a desk-top tool that, in addition to providing a graphic representation of the network of causal influences, allows tracing interrelationships quantitatively in the form of change scenarios appended to the map itself.

In CSM, a short name is written for each variable that represents a possible source of change in itself or in the level of other variables. Factors which may prevent the transmission of change under certain conditions are also included. The elements of the problematic (variables and factors) are connected with *three* types of arrows: a *double-line* arrow is used to connect a sender and a receiver of change when the sender of the arrow is sufficient, by itself, to transmit a change to its received; *single-line* arrows are used when two or more senders have to vary in order to generate a change in a receiver; when the sender is a factor which could prevent the receiver from changing under any influence, a *dotted-line* arrow is used to express this condition. When there is a time lag involved in the transmission of change, or when the change induced in the receiver of an arrow is not comparable in sign or proportion to the change generating it, the extent of time lag and the change equivalence coefficient are written next to the arrow. Thus, in CSM, change transmittance coefficients express the ratio of the induced percentage change to the one generating it (Acar, 1983).

Methods

This section describes how the effects of the nine CBs and the S-SIM problem-forming method on the relative performance of student teams were assessed in a controlled class experiment followed by statistical analysis. While tests using real life settings are highly desirable, the systematic control of experimental data makes it easier to identify situations and determine when a particular method can be expected to perform better than another. The experiment described here was plausible because it was carried out with graduate business students recruited from a Business Policy class, and they participated in the study in partial fulfillment of a course requirement.

Experimental Design

The purpose of the experiment was three-fold. *First,* to test if prominent cognitive simplification processes can substantially influence the performance of student teams. That is, to test whether the differences in the performance of teams that encountered a particular set of cognitive biases was significantly different from the performance of teams that did not experience that set. *Second,* to examine if the performance of student teams that used Scenario-driven Strategic Information Mapping (S-dSIM) was significantly different from the performance of teams that did not rely on such processes in currying out their decision-making task. *Third,* to test for possible interaction effects between prominent cognitive biases and the use (or not) of S-dSIM on the relative performance of the 24 teams.

The task was a business strategy simulation package in which each company was managed by a team of four to five students (Smith & Golden, 1989). A total of 118 graduate business students from a university in New York City participated in the experiment. The participants were assigned to a total of 24 teams, each a multi-divisional firm competing in the dynamic information systems industry. There were two levels of decision making: each team had to make decisions for both the corporation as a whole and each of its three strategic business units (SBUs). Each team had to make pricing, marketing, research and development (R&D), human resources, and capacity decisions for each SBU. The corporation decisions entailed acquiring debt (loans and bonds) and equity financing, paying dividends, buying and selling business units, acquiring new ventures, determining types of needed market research, and responding to management incidents. Throughout the simulation teams were expected to establish objectives, formulate strategy, and make the required decisions dictated by their plans. These decisions were submitted periodically and they were input into the computer, which produced a report for each team concerning the firm's sales and profits.

Before they assumed their decision-making roles, the students were exposed to the strategic management models in Hatten & Hatten (1987) and in Smith & Golden (1989), the components of the S-dSIM problem-forming method, and Schwenk's (1984) work on cognitive biases CB1 through CB9. During this phase of preliminary training, which lasted eight weeks, eight case studies from the Hatten & Hatten text were used to demonstrate, discuss and clarify the differences between cognitive biases CB1 through CB2, the intricacies and application of strategic management models, and the S-dSIM components. These training sessions were closely monitored and controlled so that participants did not voice their judgement or preference on any of the models, problem-forming components, or cognitive biases involved.

To reinforce learning through feedback (Kopelman, 1986; Locke Cartledge & Koeppel, 1968), each team had to compose and submit structured reports on two of the eight cases covered. Each report contained three interrelated sections: an executive summary of the team's work with recommendations, a problem-forming section (with claim and implications, data, warrant, and safety valve), and a section which diagnosed cognitive biases encountered by the team in their analysis of each case. Before applying S-dSIM to the cases in the text, the students were first taught how to interact with comprehensive situation mapping (CSM), so they could generate their own causal graph of a strategic decision situation. The CSM mechanics were demonstrated through "John Farmer", an up-to-date mini-case which is widely used in American colleges and universities (Alvarez, 1980). Moreover, each student had to apply CSM and run strategic change scenarios to show the implications of his/her claim on the nature and structure of the "Baskin Robbins" problematic, another mini-case adapted from Bovée & Thill (1989: 221).

The purpose of all these pre-test exercises was to create homogeneous groups in terms of their ability to: use strategic management models in case analysis, implement the S-dSIM problem-forming method, and diagnose cognitive biases CB1 through CB9 when encountered. Thus, the subjects were well informed and had some experience with complex decision situations prior to their participation to the business strategy simulation of Smith & Golden (1989). Throughout the pre-test exercises students were able to learn from their mistakes and improve their performance because they were required to make numerous conjectures on which they received outcome *and* process feedback soon after they submitted their work.

During the simulation experiment students were also able to learn from their mistakes and improve their performance because they were required to make numerous predictions based on more clearly identified data and received outcome feedback soon after the submission of their decisions, this time from the computer. The one difference from the pre-test exercises was that the teams could now choose whether they would use the S-dSIM components or not in competing against other teams. It was made clear to the participants that they could treat the simulation experiment either as an opportunity for the continuous practice of S-dSIM, or as the unique opportunity to simply get a "hands on" experience with manipulating strategic variables in a dynamic setting. Based on the guidelines by Smith & Golden (1989), the end results of the simulation experiment could not affect anyone's course grade by more than five percent. After six rounds of the simulation, each student was asked to complete a final questionnaire assessing prominent cognitive biases encountered by his/her team during the simulation experiment, and the team's emphasis on S-dSIM components. After completing the questionnaire, subjects were debriefed on the simulation experiment and thanked for their participation.

This design is a variation on the classic post-test-only control group design (Campbell & Stanley, 1963). Teams that rated a cognitive bias as not prominent (CB*i*=1, *i*=1,...,9) provided a control against which the performance of teams that rated the same cognitive bias as most prominent (CB*i*=2) could be contrasted. In addition, teams that chose not to use the S-dSIM problem-forming method (PROBFORM=1) provided a control against which the performance of Scenario-driven Strategic Information Mapping users (PROBFORM=2) could be contrasted. Random assignment to groups and the relatively short duration of the experiment controlled for primary threats to validity, such as maturation, regression toward the mean, and mortality, but not selection bias.

A controversy exists among information comprehension researchers with respect to individual characteristics that may cause selection bias. Clark (1975), Kolb (1974), and Levie & Lentz (1982) suggest that factors such as age, experience, education, visual literacy, verbal ability, and learning style can have a profound impact upon message reception and processing. They point out that individual differences may compound the difficulty of understanding the general effect of a causal graph (such as CSM) upon message reception: a message transmitted by symbols and software used for mapping and model structuring may be redundant or incongruous for one person but not so for another. Allen (1978), Freedman & Stumpf (1980), Smeltzer & Vance (1989), Stumpf & Freedman (1981), and Wexley (1984) find a lack of interaction effects between information processing and individual differences. In this study, each team had to diagnose which cognitive biases it encountered, and had to decide whether or not to use the S-dSIM problem-forming method. Thus, the proposed interaction effect between information processing and individual differences could not be ignored.

Subject Characteristics

The characteristics of the 118 participants are given in Table 1. The sample is biased in favor of part-time, male students, majoring in Finance, and working full-time in middle management positions. The brain orientation of the subjects was assessed using Raudsepp's (1981) left brain/right brain inventory. This inventory determines whether subjects are right brain oriented, left brain oriented, or use both hemispheres when dealing with facts, ideas and issues. Based on the inventory, the sample is biased in favor of double dominant students who are capable of both processing verbal and numerical information sequentially in a linear fashion, and of grasping complex images of holistic relational configurations and structures.

Table 1. Student characteristics (n=118)

Characteristic	Frequency	Percentage	Mean	Standard Deviation
Age			28.522	4.818
Brain Orientation				
Left	40	33.9%		
Double Dominant	59	50.0		
Right	19	16.1		
GMAT Score			571.296	75.950
Gender				
Female	35	29.7%		
Male	83	70.3		
Job Title				
Full-time Student	19	16.1%		
First-line Supervisor	18	15.3		
Engineer	7	5.9		
Operator	6	5.1		
Technician	10	8.5		
Middle Manager	54	45.8		
Upper Manager	4	3.4		
Major				
Accounting	11	9.3%		
Finance	75	63.6		
Information Systems	4	3.3		
Management Systems	8	6.8		
Marketing	20	16.9		
Managerial Problem Solving Styles				
Information Gathering Method (Sensation-Intuition)			-8.137	18.414
Information Evaluation Method (Feeling-Thinking)			4.814	16.653
Social Desirability (SD) Index (0-4)			1.661	1.023
Work Experience			6.475	4.006

The managerial problem-solving styles of the participants were assessed using the Myers-Briggs Type Indicator test (Myers & McCaulley, 1985). This test has been validated with a large number of studies and provides reasonably accurate scores that remain relatively constant for some time (Hellriegel, Slocum & Woodman, 1989: 91-92). It determines a subject's orientation in terms of four psychological functions involved in information gathering and evaluation: sensation, intuition, thinking, and feeling. According to Jung (1923), individuals gather information either by sensation (S) or intuition (N), but not by both simultaneously. These two functions represent the orientation extremes in information gathering. Similarly, the feeling (F) and thinking (T) functions represent the orientation extremes in evaluating information. Each individual's dominant function is normally backed up by one (and only one) of the functions from the other set of paired opposites. Though the sensation-thinking (ST) combination characterizes best the people in today's Western industrialized societies, Jung also believed that individuals tend to move toward a balance, or integration of the four psychological functions. With a few notable exceptions, and a slight but expected bias toward the sensation-thinking (ST) type, the study's subjects were well balanced among the four psychological functions (Figure 2).

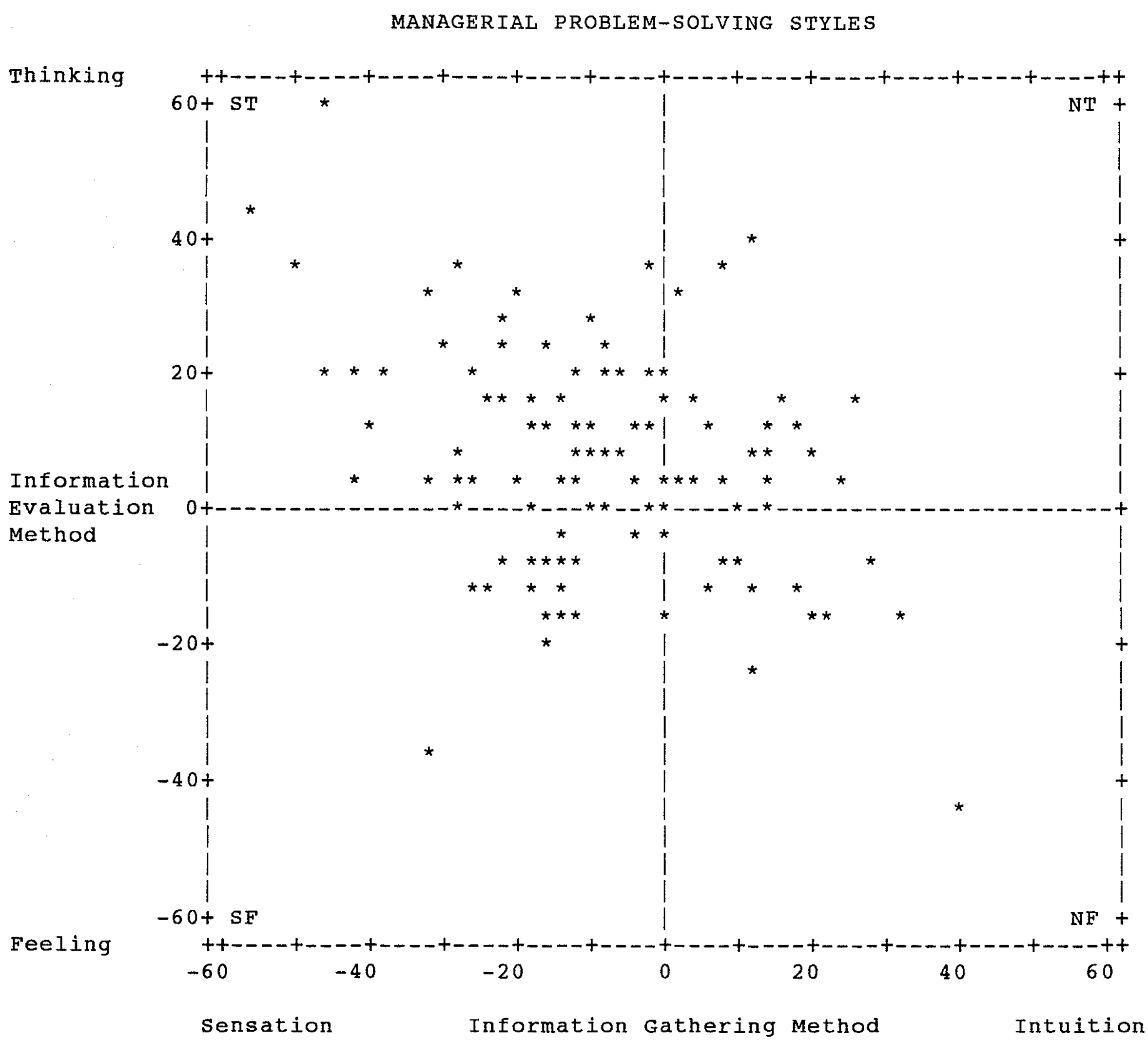

Fig. 2. The managerial problem-solving styles grid of the 118 graduate business students.

In addition to the above assessments of individual differences, a small set of items measuring social desirability (SD) was included in the study. The purpose of these items was to test for any possible selection bias effects owing to the SD set. Included in the survey were the following four SD items taken from Smith (1967: 91): 1) Do you like everyone you know? 2) Have you envied the good luck of others at times? 3) Have you taken advantage of someone at times? 4) Have you ever felt you were being punished without justification? It is assumed for these items that the "true" response is known in each case: that everyone dislikes at least some other people (s)he knows, that everyone has envied or taken advantage of another person, and that every-one has felt unjustly punished at some time or another. Moreover, it is assumed that the reason for not admitting the truth of these items is a tendency to make oneself appear more socially acceptable than one is in fact, or a reluctance to admit negatively evaluated facts about oneself. Thus, the number of items on which an individual fails to admit the "truth" is taken as an index of his or her social desirability set. The average score of the 118 individuals in the study's sample is shown in Table 1.

Experimental Analysis

The purpose of the statistical investigation was also three-fold. *First,* to assess the impact of cognitive biases CB1 through CB9 on team performance. That is, to test whether the performance of teams that rated a cognitive bias as not prominent (CBi=1, i=1,...,9) was significantly different from the performance of teams that rated the same cognitive bias as most prominent (CB*i*=2). *Second*, to asses the impact of the Scenario-driven Strategic Information Mapping on performance. That is, to test whether the performance of teams that chose not to use the S-dSIM problem-forming method (PROBFORM=1) was significantly different from the performance of teams that used S-dSIM (PROBFORM=2). *Third*, to test for possible interaction effects between the cognitive biases CB1 through CB9 and the use (or not) of S-dSIM on the relative performance of the 24 teams.

The performance points on the administrator's report at the end of the sixth trial period represented the relative performance (PERFORM) of each team. This was the team's common stock price multiplied by 10 and rounded up to be used for ranking. According to Smith & Golden (1988), the stock market price in their simulation is indicative of a team's operating profits, but does not overly reflect short-term gains from the disposal of assets (viz., the sale of an SBU). Other performance measures suggested by Smith & Golden are return on investment (ROI), and return on sales (ROS): the ratio of net operating profits (NET) to sales volume (SALES). Based on their suggestions, the impact of cognitive biases CB1 through CB9 and S-dSIM on the performance of the 24 teams was assessed on the criterion values of five dependent variables: SALES, NET, ROS, ROI, and PERFORM (relative performance points).

The study's participants used nine-point Likert-type scales to evaluate the prominence of CB1 through CB9, and their teams' emphasis on S-dSIM during the simulation experiment. It turns out that nine-point scales give a more accurate representation of the way in which people think and compare similar elements (Saaty, 1977). In general, qualitative distinctions are meaningful in practice and have an element of precision when the items being compared are of the same order of magnitude or close together with regard to the property used to make a comparison. If this last condition is satisfied, and if the items are slightly different from each other, then the psychological limit of 7±2 items in a simultaneous comparison suggests that nine points are needed to distinguish these differences (Miller, 1956).

Although the prominence of each cognitive bias was assessed on the basis of a single-item scale (1 = not prominent, 9 = most prominent), PROBFORM was a three-item scale with a Cronbach's α=0.7257. The three items questioned each team's emphasis on: strategic assumption surfacing and testing (SAST), structuring strategic decision situations through CSM, and running strategic change scenarios (1 = no emphasis, 9 = most emphasis). The average inter-item correlation for the three scale items was 0.1257. By breaking the teams' average responses at the mean value of each scale, it was possible to distinguish between teams that rated a cognitive bias as not prominent (CB*i*=1, *i*=1,...,9) and teams that rated the same cognitive bias as most prominent (CB*i*=2), and between teams that chose not to use the S-dSIM problem-forming method (PROBFORM=1) and teams that used S-dSIM (PROBFORM=2).

Although the experiments were properly designed and conducted with randomization procedures throughout, the experimental data obtained from the 24 student groups had to be checked for possible confounding effects. In order to remove any extraneous variation from the dependent variables, to increase measurement precision, and based on the three-stage classification of Schwenk (1984), a series of analysis of covariance (ANCOVA) designs was used. In ANCOVA designs, the term covariate is used to designate a metric independent variable (viz., age, GMAT score, work experience, etc.), and the term factor is used to designate a nonmetric, categorical independent variable (viz., brain orientation, gender, major, etc.), as in the simpler analysis of variance (ANOVA) context. In this study, covariate and factor effects were of equal interest without any priority established between them. Thus, the decomposition of explained variance in the dependent variables (SALES, NET, ROS, ROI, and PERFORM) was quite similar to a regression analysis involving both metric and dummy variables as predictors.

Thus, the statistical tests were based on the variability of these five dependent variables and its respective decomposition. In this context, three classes of hypotheses were tested at the conservative level of significance α=0.05. The three classes of hypotheses are listed as follows:

H_1: There is no difference in the average performance (measured in SALES, NET, ROS, ROI, or PERFORM) of teams that rated a cognitive bias as not prominent (CB*i*=1, *i*=1,...,9), and teams that rated the same cognitive bias as most prominent (CB*i*=2).

H_2: There is no difference in the average performance (measured in SALES, NET, ROS, ROI, or PERFORM) of teams that did not emphasize the S-dSIM problem forming method (PROBFORM=1), and teams that emphasized S-dSIM (PROBFORM=2).

H_3: The interaction effects of the cognitive biases CB1 through CB9, and the interaction effects of cognitive biases and PROBFORM on the average performance of the 24 teams are all equal to zero.

The SPSS^X sub-program MANOVA (Norusis, 1985) was used to implement the series of analysis of covariance designs, and to contrast those criteria for which a significance difference in the means of the student groups was determined by analysis of variance. The ANCOVA designs allowed controlling for possible confounding effects (viz., the GMAT score and other individual differences). The contrasts resulted in sets of one-tailed t-tests. It must be noted that contrasts should be applied only if significant differences in group means have been demonstrated by analysis of variance (Neter, Wasserman & Kutner, 1985). If the null hypothesis of equal means cannot be rejected by analysis of variance, and contrasts are applied to the group means, spurious significant contrasts may occur. Moreover, the tests of the means could *not* have been made by using simple t-tests; by using the method of contrasts, the $(1-\alpha)100$ percent level of confidence (95%) was maintained for each set of contrasts by increasing the level of confidence for each contrast in the set.

Results

The primary focus of the investigation was to test for any significant differences in the profiles of the five performance criteria: SALES, NET, ROS, ROI, and PERFORM. Upon completion of the simulation experiment, the mean values assigned to these criteria (dependent) variables for each team, clearly constituted an experimental data set with unequal samples for which the random assignment method was used (rather than random sampling). $SPSS^X$ caught the linear dependence of ROS on NET and SALES and indicated that multivariate tests should not be used. The preliminary univariate F-tests with df=23/94 revealed significant differences ($p<0.0001$) between the 24 teams in terms of SALES, NET, ROS, ROI, and PERFORM. These preliminary tests were also used to control for possible confounding effects due to the individual difference covariates and factors listed in Table 1.

Following the procedure outlined in Smith (1967: 89), the Pearsonian product-moment correlation coefficients were calculated between each individual's total SD index score and each opinion item in the questionnaire. The resulting set of correlation coefficients was then scanned to see if any of them were significantly related at the 0.01 or 0.05 levels of probability. No items satisfying either condition were found. As a result, it was assumed that the SD set had no significant influence on the student responses to any of those items and hence no corrections for SD were necessary. Similarly, the preliminary analyses did not reveal either any significant main effects or any significant interactions between the information processing covariates and the individual difference factors of Table 1. Based on the lack of main and/or interaction effects between information processing and individual differences, the independent variates and factors of Table 1 were excluded from subsequent analyses.

Table 2. Significant results of analysis of variance ($\alpha = 0.05$).

Dependent Variable	Covariates and Factors	df*	Computed F-ratio	Significance of F-ratio	R^2
SALES	CB9	1/22	6.509	0.018	0.228
NET	PROBFORM	1/22	4.665	0.042	0.175
ROS	PROBFORM	1/22	5.530	0.028	0.201
PERFORM	PROBFORM	1/22	4.486	0.046	0.169
	CB3*PROBFORM	1/20	5.009	0.037	0.392
	PROBFORM	1/20	6.844	0.017	
	CB3	1/16	8.093	0.012	0.563
	CB1*CB3	1/16	9.479	0.007	
	NET	1/15	6.021	0.021	0.670

* $df = 1/22 \Rightarrow$ univariate design; $df = 1/20 \Rightarrow$ two-factor ANOVA design; $df = 1/16 \Rightarrow$ three-factor ANOVA design; and $df = 1/15 \Rightarrow$ three-factor ANCOVA design. These factorial designs were based on the three-stage decision-making classification of Schwenk (1984).

Table 2 shows the significant results of the ANCOVA designs used to test the classes of hypotheses H_1 through H_3. With the level of significance set at α=0.05, the *F*-ratio value in the table indicates that there is a significant difference in SALES between teams that rated devaluation of partially described alternatives as not prominent (CB9=1) and teams that rated the same cognitive bias as most prominent (CB9=2). The corresponding one-tailed contrast verified that the average SALES of teams that encountered devaluation of partially described alternatives was significantly lower than teams that did not. Similarly, the *F*-ratio value in the table indicates that there is a significant difference in PERFORM between teams that rated reasoning by analogy as not prominent (CB3=1) and teams that rated the same cognitive bias as most prominent (CB3=2). The corresponding one-tailed contrast verified that the performance points of teams that encountered reasoning by analogy were significantly less than teams that did not.

The *F*-ratio values in Table 2 show that the use of the S-dSIM problem-forming method caused significant differences in the performance of teams in terms of NET, ROS, and PERFORM. The corresponding significance values attest to the stability of the univariate factorial designs. Subsequent one-tailed contrasts indicated that teams that emphasized Scenario-driven Strategic Information Mapping (PROBFORM=2) performed much better than teams that did not (PROBFORM=1) in terms of net profit (NET), return on sales (ROS), and performance points (PERFORM). The sharp positive slopes of the dummy regression lines in Figures 3(b), 3(c), and 3(d) demonstrate the positive effect of S-dSIM on the average performance of teams in terms of NET, ROS, and PERFORM, respectively.

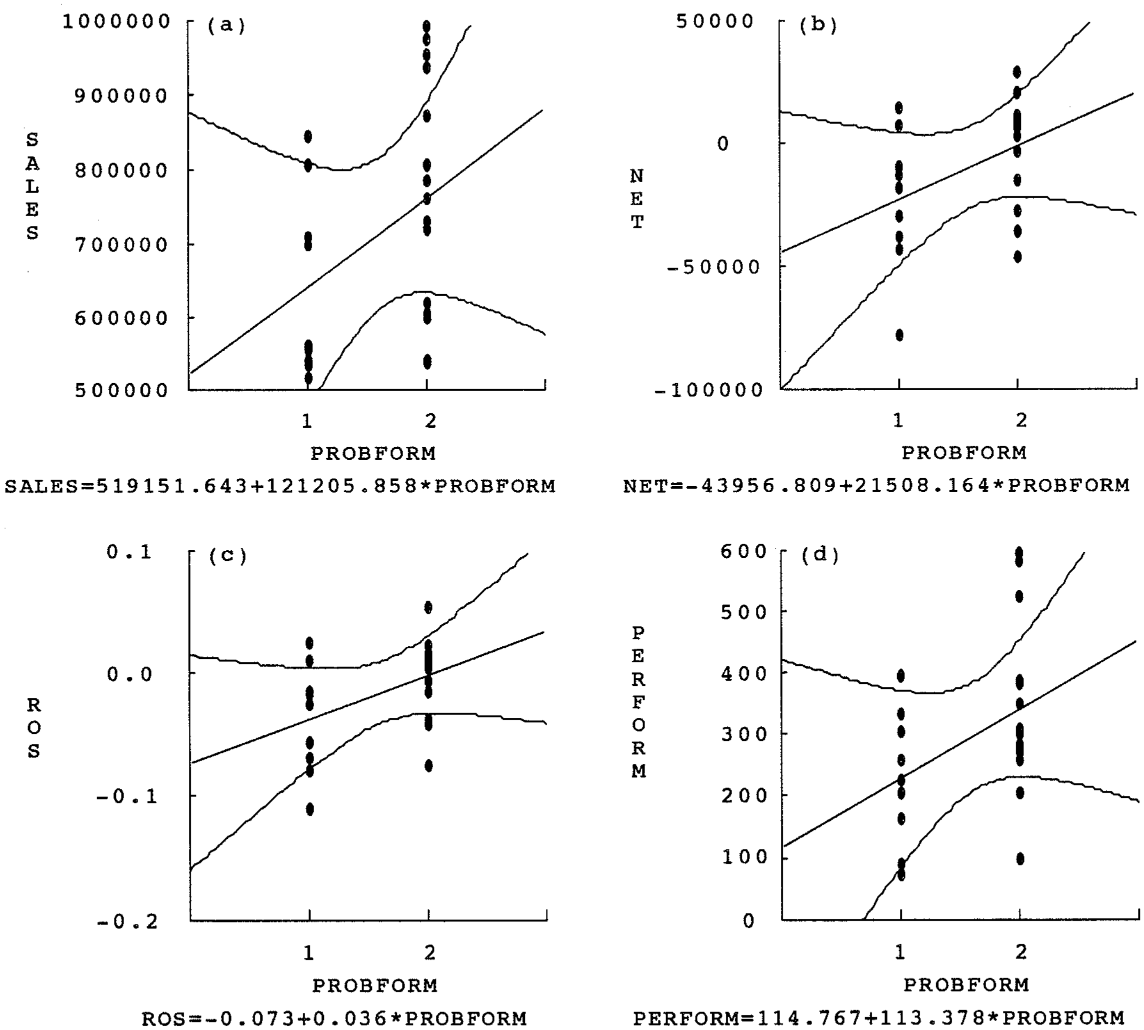

Fig. 3. Effects of S-dSIM (PROBFORM=2) on (a) SALES, (b) NET, (c) ROS, and (d) PERFORM.

Perhaps the most interesting among the results of Table 2 are the interaction effects of: (a) prior hypothesis bias and adjustment & anchoring and reasoning by analogy (CB1*CB3), and (b) reasoning by analogy and emphasis on the S-dSIM (CB3*PROBFORM), on the performance points of teams (PERFORM). The CB1*CB3 interaction effect on PERFORM was found significant in a three-factor ANOVA design, where 56.30% of the variability in performance points (PERFORM) was accounted for. This strong interaction effect on PERFORM is shown by the mean curve plots of Figure 4(a). The figure attests to the fact that, overall, teams that did nor encounter either CB1 or CB3 were the best performers. Among teams that did not reason by analogy (CB3=1), the performance of teams with prominent prior hypothesis bias and adjustment & anchoring (CB1=2) was inferior to the performance of teams without (CB1=1). However, among teams that reasoned by analogy (CB3=2), the performance of teams with prominent prior hypothesis bias and adjustment & anchoring (CB1=2) was superior to the performance of teams without (CB1=1).

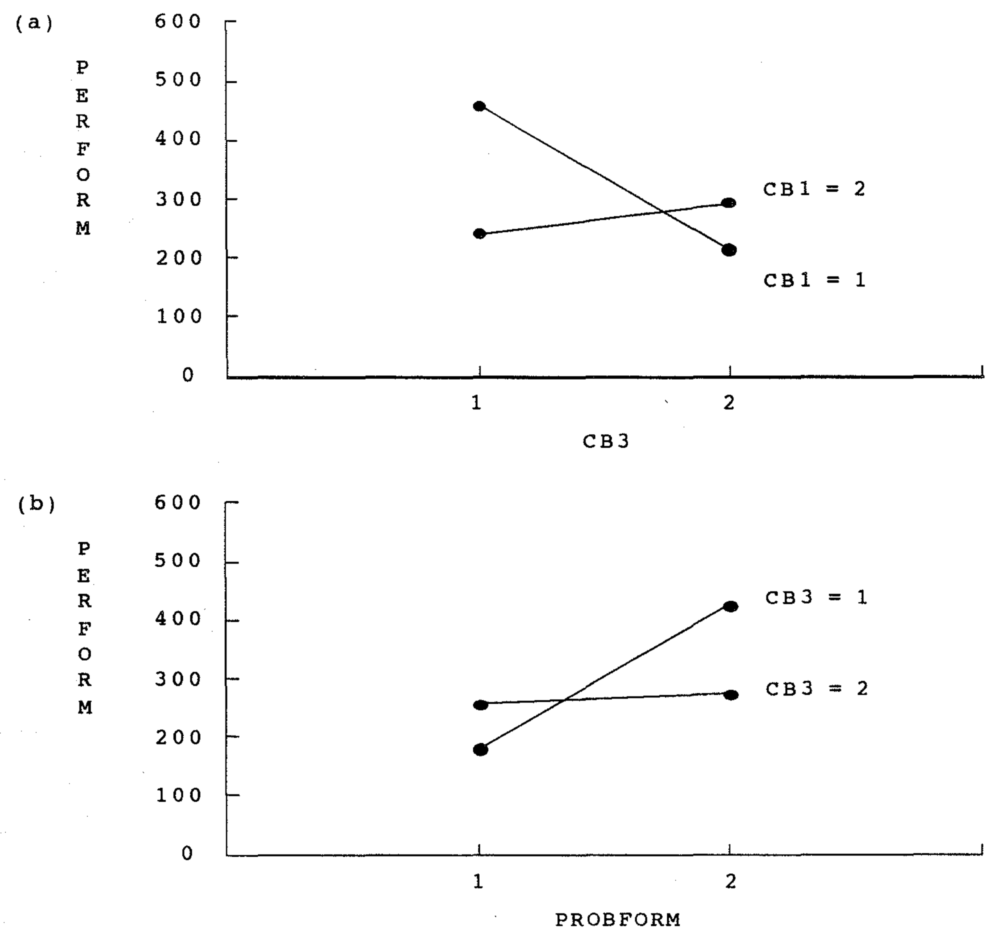

Fig. 4. The interaction effects of (a) CB1*CB3, and (b) CB3*PROBFORM on PERFORM.

The CB3*PROBFORM interaction effect on PERFORM was found significant in a two-factor ANOVA design, where 39.20% of the variability in performance points was accounted for. This strong interaction effect on PERFORM is shown by the mean curve plot of Figure 4(b). The figure attests to the fact that, overall, teams that emphasized the S-dSIM problem-forming method (PROBFORM=2) performed better than participants who chose not to use Scenario-driven Strategic Information Mapping (PROBFORM=1). Among teams that used the S-dSIM problem-forming method (PROBFORM=2), those that did not reason by analogy (CB3=1) performed better than those that did (CB3=2). Conversely, among teams without S-dSIM (PROBFORM=1), those that reasoned by analogy (CB3=2) performed better than teams that did not (CB3=1).

Conclusion

The study examined both the impact of nine cognitive biases (CB1 through CB9) and the S-dSIM problem-forming method on the relative performance of 118 graduate business students who worked under the experimental conditions of a simulated strategic context. Randomly assigned to twenty-four teams, the subjects run international conglomerates with multiple actors, feedback loops, non-linearities, and time lags and delays. The interaction, expectations, choices and teams' model selection produced results that systematically diverged over time. Within a crossed factorial design, these results support the hypothesis that cognitive biases interact with strategic management models to influence performance. Poor performers chose heuristics that reinforced their cognitive limits and bounds. Conversely, good performers constructed models which helped them recognize and overcome the negative effects of cognitive simplification processes. They produced effective decisions, not by optimizing functions, but through searching for recognizable patterns when they received feedback.

The results of the study indicate that in the absence of a problem-forming method, reasoning by analogy is at least one process that can help define a problematic. Yet decision makers who reason by analogy in a complex and dynamic environment will not perform as well as those who don't. According to Dijkstra, one of the characteristics of the Middle Ages was that reasoning by analogy was rampant, and "...by developing a keen ear for unwarranted analogies, one can detect a lot of medieval thinking today..." (1989: 1399).

The data also indicate that decision makers who use problem-forming methods of the S-dSIM variety, and who work with causal graphs (ala CSM) should outperform those who don't. The S-dSIM problem-forming method helps build consensus for action. Its components lead to a negotiated perception of a situation that decision makers in a group can live with. Yet S-dSIM is likely to correct for cognitive simplification processes and the development of "groupthink" through its safety valve that unearths and challenges critical and divergent assumptions. CSM can be used individually or collectively as a desk-top tool to map the web of interrelationships bearing on a strategic decision situation or context. Its purpose is to make the dynamics of the interrelationships more visible, more explicit, and thus more comprehensible. As a sophisticated extension of ID, CSM allows representing and distinguishing between "necessary" and "sufficient" causal relationships. CSM possesses modeling flexibility allied with computational capability that allow capturing the causalities involved in the transmission of change and presenting them to higher authorities (Acar *et al.*, 1985).

The study's findings add insights to the effect of text illustrations on information processing. The first guideline in the Levie & Lentz (1982) review was that pictorial embellishments will not necessarily enhance the comprehension of information. However, the results of this study suggest that causal graphs can enhance the comprehension of information presented in a business decision situation. The substantial improvements in the performance of teams that emphasized the S-dSIM problem-forming method signify that problem-forming with causal graphing, scenarios, and strategic assumption surfacing and testing can have a significant effect on strategic performance. It should be noted that this research is culturally specific to the Northeast region of the United States. Generally, the use of graphics and visuals differ from one culture to another. Japanese business people, for example, are much more accustomed to using graphics in their business environment than are business people in the United States (Gritzmacher, 1987; Smeltzer & Vance, 1989).

Finally, the study's findings support the research of Allen (1978), Freedman & Stumpf (1980), Smeltzer & Vance (1989), Stumpf & Freedman (1981), and Wexley (1984) who point out the lack of interaction effects between individual differences and information processing. Controlling for individual differences did not alter the significance levels of the computed F-ratio values, which signifies a lack of any confounding effects attributable to individual differences.

* * *

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