Team mental model characteristics and performance in a simulation experiment

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Abstract

Purpose – This paper aims to examine the relationship between the characteristics of strategic decision-making team's mental model and its performance. The authors propose that the relationship between mental models and performance is two-way, rather than one-way. Thus, performance feedback should, in turn, influence strategic behavior and future performance by either triggering or hindering the learning process.

Design/methodology/approach – The authors conduct the research in the setting of a simulation experiment. A longitudinal data set was collected from 36 teams functioning as strategic decision makers over three periods.

Findings – This study provides support for the positive impacts of both the complexity and centrality of a team's mental model on its performance. The authors also find that positive performance feedback reduces changes in complexity and centrality of team mental models due to cognitive inertia.

Originality/value – The study contributes to the literature by investigating the specific mechanisms that underlie mental model evolution. Different from the existing studies on team mental models that mainly focus on similarity of these shared cognitive structures, this study examines another two characteristics of team mental model, complexity and centrality, that are more relevant to the strategic decision-making process but has not been extensively studied in the team literature. In addition, this study reveals that performance feedback has different effects on team mental models depending on the referents – past performance or social comparison – which advances the understanding of the learning effects of performance feedback.

Keywords Team mental model, Organizational performance, Adaptive learning, Causal mapping

Paper type Research paper

Introduction

In the past three decades, there has been a proliferation of research in strategic management from a cognitive perspective (Narayanan *et al.*, 2011; Eggers and Kaplan,

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2009; Hockerts, 2015).12 In this perspective, strategic decision makers are assumed to be information workers (McCall and Kaplan, 1985) whose sense-making activities have a determining influence on strategic actions initiated by firms, and, hence, on organizational performance. This perspective gives central importance to the concept of managerial mental models that managers use to map the competitive landscape of their industries and to rationalize their strategic decisions. More recent research has started to investigate the connections between managerial cognition and firm level outcomes (Nadkarni and Narayanan, 2007; Blettner, 2011; Hockerts, 2015).

Firm performance depends on the extent to which strategists' mental models can accurately and promptly interpret the environment (Barr *et al.*, 1992; Eggers and Kaplan, 2009; Martins *et al.*, 2015). Top management team (TMT) literature has largely used characteristics at the individual level, such as age, tenure and functional background on the decision-making process as proxies for the underlying psychological variables to explain decision-making processes and organizational performance (Hambrick and Mason, 1984). There have been calls to focus on the team level of analysis, with particular emphasis on TMTs (Carpenter *et al.*, 2004; Carmeli, 2008). In addition, although the managerial cognition literature has emphasized the consequences of failure in mental model change (Blettner, 2011; Gary *et al.*, 2012; Uitdewilligen *et al.*, 2013), the specific mechanisms that underlie mental model evolution need more attention.

In response to these gaps in the literature, we attempt in this study to examine the efficacy of team mental model and its evolution in the strategic decision-making process by integrating behavioral decision theory (Guiette and Vandenbempt, 2013; Schwab, 2007; Gavetti *et al.*, 2012), managerial cognition literature (Blettner, 2011; Gary *et al.*, 2012; Uitdewilligen *et al.*, 2013) and team literature (DeChurch and Mesmer-Magnus, 2010; Gabelica *et al.*, 2014). Specifically, we examine:

- how different team mental models impact performance; and
- how team mental models change over a period through different feedback mechanisms.

To test the two-way linkages between a team mental model and its performance, we choose a longitudinal research design in a simulation setting. Based on data from 36 teams over three periods, our study provides evidence in support of the two-way relationships between mental models of strategic decision-making teams and performance. First, our results support the positive impact of centrality of a mental model on performance. Second, we find that positive performance feedback reduces changes in complexity and centrality of team mental models. Relatedly, performance feedback learning based on social comparison led to changes in mental models than from historic performance.

Literature review and hypotheses development

Top management team mental models and strategic decision making

One of the basic research questions in strategic management is why firms behave differently. In contrast to the traditional research streams of this field, where differences in firm behavior are attributed to objective and external reasons such as resources (Barney, 1991), industries (Hannan and Freeman, 1977) or transaction costs (Williamson, 1975), the cognitive school seeks to find differences between managerial teams that make strategic decisions. Managers as information workers

(McCall and Kaplan, 1985) deploy their mental models to absorb, process and disseminate information about issues, opportunities and problems (Walsh, 1995). Although individuals in different roles and positions may be involved in scanning, data processing and implementation activities, information converges for interpretation that directs actions at the level of the strategic decision-making team (Nadkarni and Narayanan, 2007). Indeed, the literature has recognized strategic schemas as integrative knowledge structures at the TMT level and suggested that strategic decisions emerge out of group-level activities rather than individual efforts (Klimoski and Mohammed, 1994). Thus, researchers have started to investigate the impact of TMT mental model on firm performance. Nadkarni and Narayanan (2007), for instance, examined the relationships between strategic schemas, strategic flexibility and firm performance using a sample from multiple industries. As they showed, such relationships are contingent upon industry conditions like clockspeed.

On the other hand, the team literature has also emphasized the relationship between team mental model characteristics and team level outcomes (DeChurch and Mesmer-Magnus, 2010; Gabelica *et al.*, 2014). As defined in the literature, team mental models refer to organized mental representations of the key elements within a team's relevant environment that are shared across team members (Mohammed *et al.*, 2010). The meta-analysis by DeChurch and Mesmer-Magnus (2010) has shown that team mental models are an important driver of effective team processes and performance, and such relationships can be moderated by the nature of emergence, form and content of team cognition and team types. The team literature has shown one dimension describing the emergence of team cognition – compositional emergence vs compilational emergence (Kozlowski and Klein, 2000); however, there is call for more research to investigate the antecedents to these shared cognitive structures (Fisher *et al.*, 2012). In the strategic decision-making teams such as TMTs, the formation of mental models could be challenging. Top managers as human beings are viewed as having bounded rationality with limited information processing capacity (Cyert and March, 1963; March and Simon, 1958; Gary and Wood, 2011), which may hinder the team's ability to perceive the environment precisely and interpret information accurately (Fahey and Narayanan, 1989). In addition, as strategic decisions are complex – sometimes based on ambiguous information (Schwenk, 1984), top managers are likely to perceive different pictures of the environment, and therefore, additional efforts may be needed to reach consensus among team members.

To accurately mirror the competition environment, TMT mental models need to change in line with the environment (Barr *et al.*, 1992). The behavioral decision theory literature has suggested that learning from performance feedback can be an effective mechanism that generates inferences, detects changes and help firms adapt to the environment (Jordan and Audia, 2012; Letmathe *et al.*, 2012; Lin, 2014; Nielsen, 2014). The team literature has also emphasized the need for understanding how teams use feedback to develop an intersubjective understanding that will influence their future decisions and actions (Gabelica *et al.*, 2012).

Reciprocal relationship between top management team mental models and performance

On the one hand, because organizational performance is a result of actions based on strategic decisions made on the basis of TMT mental models, the differences in the mental models regarding the environment, resources and processes necessary to succeed in that environment may lead to differences in their actual behaviors and ultimately influence organizational performance (Nadkarni and Narayanan, 2007). Indeed, the literature has underscored the consequences of failure in timely change in mental models (Blettner, 2011; Dane, 2010; Gary *et al.*, 2012). For example, within the context of the US airline industry, Blettner (2011) illustrates that Southwest Airlines performance could be attributed to strategic decision makers' resisting cognitive inertia by reallocating attention to completely different strategies rather than its current cost based strategy. In general, TMTs need to evaluate outcome responses to their decisions and draw generalizations regarding the causal relations between the decisions and the responses. The inferences are tested over repeated actions and adjusted according to the changes in the environment (e.g. new market trends, competitor's actions). Thus, the characteristics of TMT mental models are the result of TMT learning processes and should have an impact on future performance.

On the other hand, organizational performance is one piece of information that strategists typically use to justify their causal inferences and detect the changes in the environment. The role of favorable and unfavorable performance feedback has been emphasized in the adaption and learning process (Greeve, 2003; Lim and McCann, 2014; Nielsen, 2014). Performance feedback will either confirm or contradict the teams' expectations and lead strategists to reshape the content and structure of their mental models (Greeve, 2003; Nielsen, 2014). Strategic decision makers tend to interpret performance feedback by comparing it with historical and/or social comparison levels (Greeve, 2003), and then undertake error correcting changes in their mental models (Barr *et al.*, 1992). It is a simplified evaluation process due to bounded rationality, which transforms a continuous measure of performance into a discrete measure of success or failure (Jha and Lampel, 2014). Given the complexity and ambiguity in the setting of strategic decision-making, strategists ideally ought to repeatedly undertake such a learning-by-doing process to justify and reshape the strategic schema based on current and historical performance feedback. Thus, this study focuses on such reciprocal relationships between a TMT mental model and performance.

Top management team mental model characteristics and performance

Team mental models have been conceptualized as an emergent characteristic of teams that influences team performance through the decisions they make (Klimoski and Mohammed, 1994; Marks *et al.*, 2001). Organized knowledge of a team's task environment is identified as central to its shared mental model with content and structure being integral elements (DeChurch and Mesmer-Magnus, 2010). However, most of the studies including the recent ones have focused on the impact of team mental model similarity as well as its antecedents (Ayoko and Chua, 2014; Fisher *et al.*, 2012; Santos and Passos, 2013). For example, research suggests that the convergence or the level of similarity in the shared mental model determines effective team outcomes (Fisher *et al.*, 2012; Santos and Passos, 2013). The literature also finds that both leadership style and team diversity are factors that may increase the similarity of a team's mental model (Ayoko and Chua, 2014; Fisher *et al.*, 2012).

In strategic contexts, shared mental models provide managers with a common framework to interpret and respond to external events (Marks *et al.*, 2001; Kellermanns *et al.*, 2005; Carmeli, 2008). The literature in strategic management has examined two characteristics of mental models that are more relevant to the strategic decision-making process: *complexity* (Nadkarni and Narayanan, 2007; Xu, 2011) and *centrality* (Eden *et al.*, 1992). *Complexity* reflects the level of differentiation and integration in a strategic frame (Walsh, 1995). Differentiation refers to the number of concepts in a cognitive framework and integration captures the number of relationships between concepts (Bogner and Barr, 2000). *Centrality* reflects the level of focus and hierarchy in a strategy frame. Given our research context of strategic decision-making, we focus on the impacts of these two characteristics of TMT mental models on performance.

Complexity of top management team mental models and performance. A number of pioneering studies have been conducted to examine the relationships between complexity of TMT mental models and organizational performance. On the one hand, a decision-making team with a more complex mental model has the ability to collect and analyze large volume of information from the environment. In his exploratory study, Voyer (1993) classified 20 pharmaceutical companies into two groups using cluster analysis. He found that the companies in the group with better performance had more complex mental models of competition than those in other groups. This is not a surprising finding as the complexity of a mental model reflects, to some extent, the team's capability to process information. The complexity of a team's mental model reflects the differentiation in capturing the breadth of the environment, strategy and organizational concepts which are embedded in the frame, and also the degree of connectedness among these concepts (Nadkarni and Narayanan, 2007).

Further, the complexity of a mental model reflects the variation in beliefs concerning cause and effect relationships as the complexity of concepts and connectedness among concepts develop over time. Variation in beliefs will, in turn, urge the TMT to collect more information and to decide which causal relationships are crucial to strategic decision-making. In particular, when facing complex situations, strategists need to develop the ability to generate multiple interpretations of events (Crilly and Sloan, 2012). Higher cognitive complexity enables strategic decision makers to more rapidly assimilate external knowledge and add to existing concepts, which helps in the generation of new solutions to problems (Manral, 2011). In other words, the complexity of mental models should match the complexity of the environment. Bartunek *et al.* (1983) suggested that in complex situations, high cognitive complexity should lead to more accurate perceptions and more effective behaviors. Likewise, Nadkarni and Narayanan (2007) showed that complexity of a firm's strategic schema is positively related to its strategic flexibility and ultimately leads to better firm performance in dynamic environments. Brown and Eisenhardt (1998) found that firms were successful when using teams with high degree of cross-functional and cross-team communication. Essentially, cognitive complexity increases the amount of information noticed, elicits multiple viewpoints, generates alternative solutions, enables flexibility in decision making and actions and therefore is associated with enhanced performance.

Based on the above arguments, we propose:

H1. The complexity of a TMT mental model is positively related to performance.

Centrality of top management team mental models and performance. A centralized cognitive map will generate a strategic schema centralized around a few "core" concepts (Eden *et al.*, 1992; Kiss and Barr, 2015; Nadkarni and Narayanan, 2007). Core concepts represent those concepts that are developed through gradual elaboration and feedback over a long period (Carley and Palmquist, 1992). A highly centralized map depicts a clear distinction between the core and peripheral set of knowledge structures. When strategy frames are driven primarily by a single dominant logic, strategists may make decisions more effectively and efficiently because they focus primarily on a narrow set of core strategic concepts relevant to the environment. In particular, increasing centrality may be beneficial in the context where a firm's operation is stable and predictable. In such an environment, the same logic and reasoning may be repeatedly used to filter out irrelevant information, and the firm can focus on factors that are central to its industry. This in turn facilitates efficient and speedy decision and action implementation.

Therefore, we propose:

H2. The centrality of a TMT mental model is positively related to performance.

Interactive impact of complexity and centrality. Mintzberg (1979) contended that senior managers at the top management level use the processes of generalization and discrimination in the decision-making process. Generalization is the application of prior experience to a current situation, which is likely to positively influence performance when the current situation is correctly perceived similar to the past. Discrimination, on the other hand, is the non-application of prior experience to a current situation, when the current situation differs from the past. Discrimination should positively influence performance when dissimilar events are perceived correctly (Haleblian and Finkelstein, 1999). When the mental model becomes too complex or too centralized, it is likely that managers will encounter difficulties in appropriate generalization and discrimination, which will make the decision making process less efficient.

A complex mental model may not always be beneficial because sometimes, too much information is an unnecessary burden and hinders the team's ability to make right decisions. First, managers are subject to thinking in a boundedly rational manner (Cyert and March, 1963; March and Simon, 1958). As the complexity of a team mental model increases, a limit may be reached beyond which the team cannot process information and implement strategic actions successfully. Thus, when a mental model is characterized by increasing complexity but low centrality, the decision-making process may be delayed. In formulating responses to new events, the team may fail to discriminate certain peripheral concept(s) that it should have because these concepts have been deeply embedded in the mental models. Furthermore, it may become difficult to generalize as well. Simple core elements may have been hidden or forgotten due to employee changes, aversion to the topics or unclear relationships (March and Olsen, 1975). When confronted with a new situation that is generalizable (i.e. the event may have some new features, but really is a repeat occurrence of the past), the firm may treat it as a completely new event (i.e. inappropriately discriminate) and undertake unnecessary investment and actions.

On the other hand, a highly focused mental model presents challenges in discrimination when managers have to deal with new events, which may have no resemblance to their past set of dominant experiences. When mental models become highly focused, they are likely to reinforces rationalizing a dominant perspective discouraging discussion around new alternatives (Crilly and Sloan, 2012). Because variety in perspectives is absent, few peripheral concepts are incorporated as part of the mental model, which make the team to be rigid in formulating decisions in response to environmental changes. Indeed, research has suggested that high centrality leads to cognitive inertia, which precludes firms from absorbing new knowledge and experimenting with new alternatives (Hodgkinson, 1997; Nadkarni and Narayanan, 2007).

When the complexity and centrality play out in conjunction, their interaction may enhance the effectiveness of a strategic decision-making process. The impact of a mental model's increasing centrality may be increasingly positive when the mental model is also complex. That is, the simultaneous increase in complexity and centrality will help a team not only learn from its past experience but adapt to the changes as well. So, when the team faces an event that is generalizable, a centralized map will facilitate efficient retrieval of inferences based on the core concepts. On the other hand, when the team has to deal with an event that appears to have little connection or resemblance with past experience(s), the variety in inferences resulting from increased complexity will force the team to consider periphery concepts and inferences and engage in discussion and evaluation of various sets of alternatives to find a solution. Based on the argument, we propose:

H3. The complexity and centrality of a TMT mental model have an interactive impact on performance. That is, when a mental model's centrality is high, its complexity is more positively related to performance; when the mental model's centrality is low, its complexity is less positively related to performance.

Performance feedback and changes in mental models

Mental models keep changing but become increasingly stable as industries evolve over time (Tripsas and Gavetti, 2000). This kind of dynamic change in mental models can be subscribed to the learning ability of decision makers, at least in the short run. As mentioned previously, strategic schemas are reflections of team mental models; thus, learning effectiveness depends upon an active set of team processes through which TMTs acquire, share, combine and apply knowledge.

According to behavioral decision theory, performance feedback is a salient information cue that triggers adaptive learning process (Cyert and March, 1963; Lant *et al.*, 1992; Gavetti *et al.*, 2012; Lant and Hewlin, 2002; Nielsen, 2014). The team literature also suggests that feedback is critical to group learning and performance by helping a team evaluate and respond to the external environment (Gabelica *et al.*, 2012). Feedback can also facilitate team interdependence and shared mental model growth (Gabelica *et al.*, 2012). Once performance falls below the aspiration level for any particular goal, problematic search is triggered. That is, by comparing performance with aspiration levels, strategists can categorize performance as success and failure. Behaviors associated with success will be repeated and behaviors associated with failure will be dropped (Levitt and March, 1988). In addition, decision makers tend to make strategic changes and promote exploration of new strategies when facing failures (Boeker, 1989). Central to this trial and error learning process is how TMTs interpret performance feedback against the aspiration levels. The interpretation can manifest in two ways:

(1) comparison with one's own historic performance; and

(2) social comparison with reference groups.

Both comparisons may bring about the learning or change in interpretation. Although historic performance is used routinely as benchmark to determine whether current performance is satisfactory (Cyert and March, 1963; Levitt and March, 1988; Chen, 2008), social comparison processes become salient in scenarios when a firm's declining performance is similar to or even better than others'. In these scenarios, managers tend to make causal attributions to factors beyond their control (i.e. external environment) and interpret poor performance as non-negative feedback, letting go off the learning opportunity.

Cumulative studies in strategic management have observed the phenomenon of cognitive inertia, namely, managerial mental models often lag behind changes in the internal and/or external environment (Hoon and Jacobs, 2014; Narayanan *et al.*, 2011; Reger and Palmer, 1996). When TMTs interpret performance feedback as positive, the adaptive learning process may be hindered due to cognitive inertia. On the one hand, once current mental models are confirmed by positive performance feedback, strategists lack motivation to collect new information or to consider alternative causal linkages, as they believe they have already found the championed ones. This is important because, in familiar environments, habituated mental models may be sufficient to guide managerial action as they may enable a more economical use of managerial skills and resources (Reger and Palmer, 1996). However, in environments characterized by frequent changes, this may be detrimental to firm performance. Positive performance that confirms or exceeds expectations may prevent managers from paying attention to changing competitive, technological and regulatory conditions. Consequently, important changes or additions in knowledge that need to be accommodated in the mental models may be ignored. On the other hand, poor performance questions the adequacy of the knowledge concepts and relationships that managers are familiar with and thus motivates them to search for solutions. It is more likely that managers scan broadly for alternative solutions and update their mental models under poor performance feedback than under good one. Indeed, the team studies have found that past negative performance stimulates teams to become reflexive by interpreting and making sense of their performance, current strategies and knowledge integration processes (Gabelica *et al.*, 2014; Schippers *et al.*, 2013).

Therefore, we propose:

H4a. Negative performance feedback interpreted through historic performance comparison is related to more changes in the complexity and centrality of a TMT mental model than positive performance feedback.

H4b. Negative performance feedback interpreted through social comparison is related to more changes in the complexity and centrality of a TMT mental model than positive performance feedback.

Methodology

The simulation setting

Our hypotheses were tested in the setting of a simulation experiment – the MARKSTRAT marketing strategy simulation (Larreche *et al.*, 2010). The MARKSTRAT marketing strategy simulation is a comprehensive model of marketing dynamics that incorporates knowledge from prior marketing research and real-world experience (Lant and Hewlin, 2002). In a typical MARKSTRAT game, six teams function as TMTs of individual companies within an industry and compete against each other for up to seven or eight periods. There are five market segments, each with different consumer preferences and purchasing behaviors. In each period, TMTs must make decisions regarding product development, product introduction and withdrawal, production levels, advertising strategies, distribution channels, pricing and market segmentation. TMTs are allowed up to 14 analysis tools, such as a consumer survey, multi-dimensional scaling and industry benchmarking, to forecast performance, analyze the environment and assess competitors. At the end of each period, teams are informed of the simulation results for that round, including sales results for each brand, net profits and stock prices. This encouraged the teams to compete against each other, fostering industry competition and importantly created a shared goal amongst teams to enhance their firms' performance.

The simulation setting of MARKSTRAT is exceptional in that it provides a high level of realism (Larreche *et al.*, 2010). Such realism in MARKSTRAT has led to its being adopted as a research and pedagogical resource in both universities and corporations (Larreche *et al.*, 2010). Indeed, a number of studies have been conducted in the MARKSTRAT setting (Kilduff *et al.*, 2000; Debruyne *et al.*, 2010; Marinova, 2004). We believe that MARKSTRAT is particularly useful for our study for a number of reasons. First, it is a dynamic, competitive decision-making exercise in which participants make decisions as a team, receive feedback in real time and have the opportunity to learn from the feedback as a team and change their strategy in the next round. Second, complex algorithms built into MARKSTRAT make the relationships between organizational actions and outcomes highly unpredictable, creating a level of complexity and uncertainty faced by real TMTs. Third, MARKSTRAT provides a convenient setting to track the dynamics of strategists' mental models, and outcomes and feedback can be traced accurately over time (Lant and Hewlin, 2002).

Data collection process

Due to the challenges involved in getting access to TMTs and performing controlled research, student-based simulations provide a defensible substitute to study the strategic decision-making processes. Indeed, computer simulations have been commonly used in business schools in the USA as a pedagogical approach to teach strategic decision-makings. Thus, we, following the prior studies (Lant and Hewlin, 2002; Gary and Wood, 2011), chose to collect the data from marketing strategy courses at a mid-size business school in the Eastern part of the USA. The middle size and the geographic location of the business school provide a diversified student body for the research. In total, we collected data from 36 teams in six MARKSTRAT industries. Each team consisted of three to five members. Importantly, students were randomly assigned to the different teams. Random assignment of individuals to teams controlled for a number of intervening factors that could explain TMT performance, due to differences in initial conditions such as strategies, prior experience and access to information through reports generated by the simulation. Randomization as well as the MARKSTRAT simulation setting also ensured that no team has a systematic advantage over others, and each team has equal opportunities to develop strategies that may lead to successful performance.

Our study focused on the task team mental model (Mathieu *et al.*, 2008), as we were interested in understanding how teams differ in the task of strategic decision-making. Decision-making teams possess high level of informational interdependence, so that teams have to exchange ideas, information, expertise and integrate knowledge to solve problems (DeChurch and Mesmer-Magnus, 2010; Chang and Lin, 2014). The basic team norms were set by the course requirements, and we do not expect team norms to be significantly different between teams.

The participants were instructed about the dynamics of the game in the first class and were required to analyze the information in a realistic fashion as TMT for a company. All teams received identical information about how to play the game. Playing the game was part of course requirement and contributed to a non-trivial portion of course grade, and therefore, the decision tasks involved were meaningful to the participants and taken seriously. Pilot rounds were conducted to ensure they understood the dynamics and played the game seriously.

In each game, teams competed with each other for six rounds. At the end of Rounds 1, 3 and 5, performance data (e.g. profits, competitive ranking) were collected at the team level. At the end of Rounds 2, 4 and 6, after the decisions for that round had been made, each team was asked to elaborate the rationale for their decisions for that round in a written report. The students were required to discuss their rationale and complete the report together in class as a team. Instructions were clearly provided to ensure that students expressed their group rationale. Incentives for group deliberation and decision-making included instructor observation of team behaviors in the classroom, which was an explicit factor in grading. Based on 36 teams for three periods, we received a total of 105 reports at the team level. Three reports were unusable because of missing information.

Causal mapping process

In this study, we use causal mapping to capture team mental models. Causal mapping is one kind of cognitive maps that represents a network of causal relationships embedded within an individual's mind, which could help reveal basic rationales used in strategic decision-making (Curseu *et al.*, 2010; Narayanan and Armstrong, 2005). The causal maps were derived from the team written reports in three steps in this study. First, two raters independently identified causal statements in each written report following the guidelines suggested by Narayanan and Armstrong (2005). Some of the key words used in identifying causal statements are *because*, *since*, *so*, *in order to* and *if-then*. The agreement between the two raters was 86.35 per cent (Cohen's Kappa = 0.719, $p <$ 0.001). Any disagreement between the raters was discussed until a mutually satisfactory code was assigned. All of the causal statements and linkages were recorded in the original language of the students.

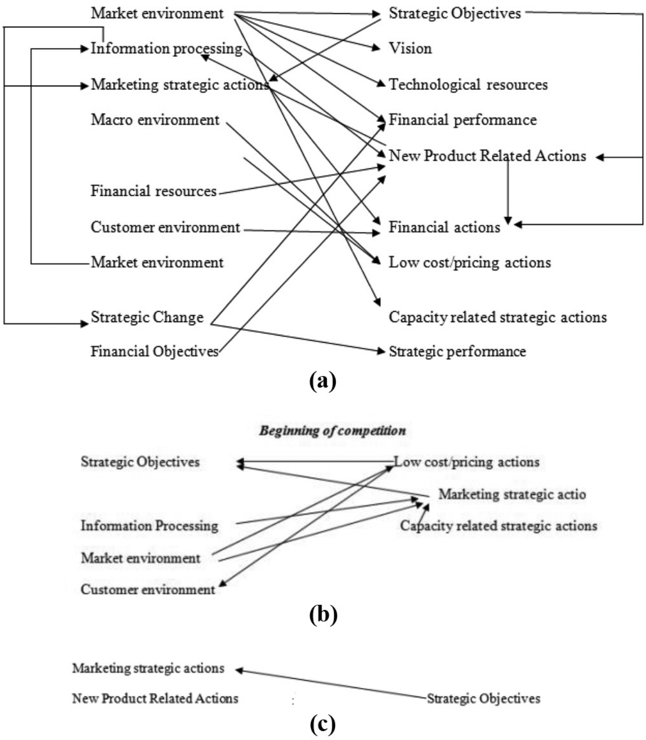
The second step in constructing causal maps was the identification of relevant concepts from the raw statements (Narayanan and Fahey, 1990). Carley and Palmquist (1992) argue that aggregating actual raw phrases from the text into generalized concepts can be used to move the coded text beyond explicitly articulated ideas to implied or tacit ideas and can avoid misclassification of concepts due to peculiar wording on the part of individuals. This begins with grouping frequently mentioned words in the raw causal maps, and then placing these groupings into hierarchical categories based on theoretical or logical relevance. Many of the categories were borrowed from the study of Nadkarni and Narayanan (2007), but as the actual narratives contained additional concepts, we added several more. Altogether, 130 relevant concepts were identified and classified into 21 major categories[1].

In the final step, the causes and effects derived from the second steps were recast into concept level to reveal the causal maps for each team in different periods. In Figure 1, we have provided illustrations of causal maps.

Measures of the variables

In line with prior studies examining decision-making by teams in a simulation setting (Lant and Hewlin, 2002), all of the data were gathered at the team level of analysis.

Performance. We use two kinds of measures to represent performance. First, performance is measured by net profits at the end of each period (round). In addition, we also created a dichotomous variable to capture the rank change from the last period to the current one as a relative performance measurement. If a team's competitive rank went up in the next period, a value of 1 would be assigned to this dichotomous variable. If the competitive rank kept the same as in the previous period and was above average, the value of 1 would also be assigned. On the other hand, if a team's competitive rank went down or still performed below average, a value of 0 would be assigned. There are 71 observations of the changes in competitive rank from the $t-1$ period to t period,



Notes: (a) High complexity, high centrality;
(b) moderate complexity, moderate centrality;
(c) low complexity, low centrality

Figure 1.
Sample causal maps

among which 35 observations have improved competitive ranks or remain high ranks, and 36 decreased ranks or kept low ranks.

Performance feedback. As discussed earlier, performance feedback can be interpreted against different aspiration levels. To measure performance feedback interpreted against historic performance, we used the changes in profits from period $t-1$ to period t. Performance feedback interpreted through social comparison is measured by the same dichotomous variable that described in the previous paragraph capturing the changes in competitive ranks. The value of 1 represents a positive performance feedback from the previous period, while a value of 0 represents a negative/poor performance feedback.

Complexity of the causal map. We used two measures to capture the complexity of a causal map: *comprehensiveness* and *density*. Comprehensiveness was measured as the total number of concepts in a causal map (Nadkarni and Narayanan, 2007). Density refers to the ratio of extant causal links to the total possible causal links in the causal map, which was used to capture the connectedness between concepts. The change in complexity of the causal map is calculated by the difference in the value of the causal map density between two periods. The density scores were calculated by the UCINET software (Borgatti *et al.*, 1999).

Centrality of the causal map. Centrality of each causal map is calculated using the UCINET software (Borgatti *et al.*, 1999). The measure of degree centrality at the graph level is used in the regressions.

Controls. We controlled the team and time effects by using panel regression techniques. In the regressions, we controlled for the effects of previous performance and the starting budgets on current performance. In addition, team intellectual capability was controlled in the regressions. Teams with high average levels of cognitive ability learn more due to broader and deeper levels of attentional resources (Ellis *et al.*, 2003). Thus, we expect that team cognitive ability influences the ability of the team to acquire skills in learning the simulation, dealing with large amount of information in the complex MARKSTRAT environment and developing problem solving strategies. Because the average measure of team cognitive ability is a better predictor of team performance than measures such as standard deviation (Day *et al.*, 2004), we used average grade point average (GPA) of teams as a proxy to account for systematic differences in cognitive capabilities among teams. We also controlled for market research intensity of each team during its decision-making process to account for differences in scanning processes of teams. Managers discover important events and trends outside their organizations through environmental scanning (Gary and Wood, 2011; Hambrick and Mason, 1984), which is a first step in the problem solving sequence (Daft and Weick, 1984). Because scanning influences managerial perceptions that influence subsequent strategies and actions, it is a central activity in the strategic decision making (Fahey and Narayanan, 1989). In MARKETSTRAT, there are 14 market research methods. In the survey, the teams were asked to indicate the extent to which each research method had been used based on a scale of 7 points. Then, the scores of the 14 items were averaged to measure a team's market research intensity.

Data analysis

Given the nature of our dependent variables, we used panel linear regressions and logistic regressions to test our hypotheses. To test the interactive effect of the complexity and centrality, we used the hierarchical regression process. The interaction between the complexity and centrality was centered before entering the regressions. All the analysis was completed using STATA 11.

Results

The descriptive statistics of our sample and the correlations between major variables are presented in Table I. Some of the correlations between the independent variables are high (>0.70). To rule out the multicollinearity, we calculated the variance inflation factors (VIFs) based on the ordinary least squares regressions using the same independent variables. All of the VIFs are in the acceptable range (<3.5).

Table II summarizes the results concerning the relationships between the teams' causal maps in the t period and performance of the t period. Our results show no significant impacts of either complexity (both comprehensiveness and density) or centrality on the performance measured directly by financial performance in profits (Models 2 and 3). Nor does their interaction (Model 4). When the performance is measured by relative performance in rank changes, both the density and centrality of a team mental model have significant positive impacts on the team's performance in the simulation competition. Thus, our results provide evidence in support of *H1* and *H2* ($b = 92.283$, $p < 0.05$; $b = 23.639$, $p < 0.001$). However, the moderation effect of the centrality on the relationship between the complexity and performance change is not significant (Model 8). Thus, *H3* is not supported.

Table III presents the results pertaining to *H4a* and *H4b*, which predict relationships between performance feedback and changes in strategists' mental models. To test these two hypotheses, we regressed the changes in comprehensiveness, density and centrality from $t - 1$ to t on two kinds of performance feedback: *historic performance* (change in profits) and *social comparison performance* (change in ranks). Our results show no significant relationships between historic performance and the changes in comprehensiveness, density or centrality of TMT's causal maps. Thus, *H4a* is not supported. On the contrary, rank had significant negative impacts on the changes of both density ($b = -0.007$, $p < 0.01$) and centrality ($b = -0.053$, $p < 0.01$). That is, when the student teams functioning as strategic decision makers received positive performance feedback by comparing their competitive ranks to their competitor's (e.g. improved competitive rank change), they tended to change their team mental models less than those that received negative performance feedback. Thus, *H4b* is supported.

Post hoc analysis

To discern possible differences in mental models that could be linked with risk propensity, we conducted post hoc analysis on a particular strategic behavior–Vodite product introduction. In MARTKETSTRAT, the firms/teams may compete in two product markets: the already developed Sonite market where firms encounter less risk and the unexplored, hence riskier, Vodite brand. The simulation allows teams to enter products in the Vodite brand only the third round onwards. All together nine teams introduced products in the riskier Vodite market, with eight teams introducing the product in the last period, and, only one team introduced the product in the second period.

We performed post hoc analysis to test for differences in complexity and centrality between teams that introduced the product and those that did not using the two-sample Wilcoxon tests. Teams were divided into high and low performing groups based on the

Table I. The descriptive statistics of the sample and correlations among major variables

Variables	*N*	Mean	SD	1	2	3	4	5	6	7	8	9	10	11
1. Financial performance in profits	108	31,707	18,072	1.00										
2. Performance feedback-change in profits	72	10,415	14,431	0.836**	1.00									
3. Performance feedback-rank change	72	0.486	0.503	0.515**	0.569**	1.00								
4. Complexity – Comprehensiveness	105	10.657	3.000	−0.094	−0.062	−0.033	1.00							
5. Complexity – Density	105	0.018	0.009	−0.059	−0.061	−0.136	0.857**	1.00						
6. Centrality	105	0.141	0.052	−0.093	−0.106	−0.068	0.534**	0.701**	1.00					
7. Comprehensiveness change	68	−0.074	3.529	−0.024	0.034	−0.071	0.702**	0.569**	0.434**	1.00				
8. Density change	68	0.001	0.010	0.032	0.064	−0.280*	0.544**	0.498**	0.554**	0.746**	1.00			
9. Centrality change	68	0.002	0.067	0.013	−0.041	−0.286*	0.349**	0.406**	0.720**	0.470**	0.727**	1.00		
10. Budget	108	12,624	5,869	0.895**	0.766**	0.411**	−0.066	−0.018	−0.022	−0.000	0.087	0.121	1.00	
11. Team GPA	105	3.004	0.276	−0.027	0.026	0.051	0.132	0.097	0.231*	−0.085	0.018	0.061	0.063	1.00
12. Market research intensity	105	4.778	1.048	0.333**	0.267*	0.143	−0.081	−0.177	−0.189	−0.096	−0.180	−0.061	0.252**	0.063

Notes: *Significant at the 0.05 level; **significant at the 0.01 level

Table II. Impacts of complexity and centrality of the causal maps (t period) on performance (t period)

Variables	Financial performance$_t$ (Panel linear regressions) Model 1	Model 2	Model 3	Model 4	Relative performance$_t$ (Logistical regressions) Model 5	Model 6	Model 7	Model 8
Controls								
Budget$_t$	0.087	0.055	0.071	0.095	1.657***	1.870***	1.918***	1.881***
Previous performance-rank$_{t-1}$	−0.323***	−0.329***	−0.337***	−0.358***	0.463$^+$	0.471$^+$	0.410	0.329
Team GPA	−0.079	−0.163	−0.110	−0.231	0.235	0.501	−0.793	−0.288
Market research intensity$_t$	0.030	0.021	0.020	0.025	0.037	0.148	0.278	0.273
Time dummy	0.656***	0.606***	0.610***	0.574***	1.427*	1.633*	1.652*	1.789*
IVs								
Complexity$_t$ − Comprehensiveness		0.031		0.061		−0.349$^+$		−0.182
Complexity$_t$ − Density		−15.613		−29.916		197.72***		35.799
Centrality$_t$			−0.479	2.023			23.639***	26.884*
Moderator								
Comprehensiveness × Centrality				1.738				0.571
Density × Centrality				−433.258				675.719
Number of observation	72	69	69	69	72	69	69	69
Number of groups	36	36	36	36	36	36	36	36
Wald χ^2	75.49***	69.53***	71.60***	75.50***				
Overall R^2	0.566	0.563	0.561	0.585				
LR χ^2					19.30***	26.54***	28.90***	31.94***
Pseudo R^2					0.194	0.278	0.302	0.339

Notes: $^+p < 0.10$; $*p < 0.05$; $**p < 0.01$; $***p < 0.001$

Table III. Results of panel linear regressions on the impacts of performance feedback on the changes in complexity and centrality of the causal maps

Variables	$\Delta Complexity_{t-1,t}$ (Comprehensiveness)			$\Delta Complexity_{t-1,t}$ (Density)			$\Delta Centrality_{t-1,t}$		
	Model 9	Model 10	Model 11	Model 13	Model 14	Model 15	Model 16	Model 17	Model 18
Controls									
$Budget_{t-1}$	−0.011	−0.221	0.135	0.000	−0.000	0.002	0.002	0.017	0.015^{+}
Time dummy	−0.152	−0.195	0.004	−0.003	−0.003	−0.001	−0.016	−0.013	−0.002
Team GPA	−1.047	−1.025	−1.046	0.001	0.001	0.001	0.014	0.012	0.014
Marrrket research intensity	−0.046	−0.042	−0.055	0.001	0.001	0.001	0.012	0.012	0.011
IVs									
Performance feedback – change in profit $_{(t-2,t-1)}$		0.000			0.000			0.000	
Performance feedback – change in ranks$_{(t-2,t-1)}$			−0.597			−0.007**			−0.053**
Number of observation	68	68	68	68	68	68	68	68	68
Number of groups	35	35	35	35	35	35	35	35	35
Wald χ^2	0.49	0.66	0.84	2.19	2.17	9.73^{+}	3.96	6.60	13.80*
Overall R^2	0.008	0.011	0.013	0.034	0.034	0.136	0.059	0.096	0.180

Notes: $^{+}p < 0.10$; $*p < 0.05$; $**p < 0.01$; $***p < 0.001$

comparison of their ranks in the third period to the industry average. Three teams from the low performing group and six teams from the high performing group introduced products in the Vodite brand. The results are presented in Table IV. We did not observe significant differences in the causal map measures for high and low performing teams that did and did not introduce the product. However, we found significance for difference in complexity and centrality changes for teams that made Vodite product entry and those that did not ($Z = 1.771$, $p < 0.1$; $Z = 1.846$, $p < 0.1$). A qualitative examination for differences in concepts between the teams' causal maps showed that, at least for two of the high performing teams that introduced the Vodite product, new product related actions were associated with fewer concepts such as strategic objectives, strategic performance and marketing strategic actions. These teams may have implemented the action as part of a planned strategy, justified also by higher investments in advertising and sales. On the contrary, new product-related actions in the below average teams' causal maps were associated with greater number of concepts. As compared to the former group, these firms exhibited a leaner advertising and sales investment profile. It is possible that these teams may have adopted this risky move for their survival in the game.

Further, 12 teams with high performance chose not to make an entry in the Vodite market. A likely explanation is risk aversion. Learning theory suggests that decision makers of organizations performing far from historical and social aspiration levels may be more willing to accept the uncertainty and risk associated with a wide range of organizational behaviors including strategic reorientation and product innovation (Lant *et al.*, 1992; Greeve, 2003). As introducing the Vodite product exposes the teams to considerable uncertainty, many teams may have not included this move as part of their repertoire of strategic actions for fear that it may jeopardize their current positions.

Discussion and conclusion

The objective of this study is to examine the relationship between the mental model of strategic decision-making teams and their performance in the setting of a simulation experiment. We propose that the team mental models and performance show a reciprocal relationship. In other words, the different features of the team's mental model may lead to different levels of performance, and in turn, performance feedback may influence the formation and change in mental models.

In this study, we focus on two major characteristics of a TMT mental model – complexity and centrality. To examine the relationships of interest, we chose a longitudinal design within the setting of a simulation experiment. Our results show significant direct impacts of both complexity and centrality on a team's relative performance. Our finding is consistent with existent managerial cognition literature

Comparison	Z-test
Difference in complexity	0.037
Difference in centrality	−0.128
Difference in the change of complexity	1.771*
Difference in the change of centrality	1.846*

Note: $^*p < 0.10$

Table IV. Results of two sample Wilcoxon tests–teams introducing Vodite product (9 teams) vs not (27 teams)

(Bartunek *et al.*, 1983; Voyer, 1993), and also more persuasive since it is based on longitudinal data. Moreover, in a simulation experiment, all teams start with the same resources and compete in the same environment. Thus, this setting helps prevent certain confounding effects that may arise in a field study and lowers the possibility of a spurious relationship between the teams' mental models and organizational performance.

Our study, however, shows that the impact of complexity becomes insignificant when both complexity and centrality are presented in the regression. In addition, the interaction between complexity and centrality has no significant impacts on team performance. These results not only highlight the importance of centrality of a team's mental model in the decision-making process but also suggest that the impacts of centrality be independent of other characteristics of the team's mental model such as complexity.

Compared to centrality, complexity of a mental model seems less salient in the decision making process, or its impact may be conditional upon other factors. For instance, the complexity of a mental model should match with that of the environment in order to make effective strategic decisions. When facing a more complex (i.e. heterogeneous) environment, managers should perceive greater uncertainty and have greater information processing requirements than managers facing a simple environment (Dess and Beard, 1984). The complex mental model would contribute to strategic flexibility in actions, thereby improving performance (Eisenhardt and Martin, 2000; Nadkarni and Narayanan, 2007; Xu, 2011). However, when the environments are not changing rapidly, increased flexibility can be detrimental to firm performance (Ferrier, 2001) because it can be inefficient as firms expend unnecessary resources in actions that are uncalled for in relatively stable environments. For example, different stages of the industry life cycle differ in the complexity and the uncertainty of the environment.

Our simulation setting with multiple rounds provided a scenario similar to the industry life cycle. In the beginning of the simulation, the participants are new to the simulation and unfamiliar to the competitive environment, and the resource allocation processes and the norms of coordination have yet to be established. Thus, increased complexity of the team mental model enables the team to collect information more exhaustively and implement a variety of actions during the initial stages of the game. However, as the participants become familiar with the simulation, there is a good probability that the team would have learned their competitive environment, mastered the resource allocation rubrics and developed a working norm among them. In the later stage, the environment they face becomes relatively stable and less complex. Increasing complexity in their mental models may cause them to scan too broadly and make overly drastic and uncalled for decisions. As such, it is likely that after a point, increasing complexity would not help improve performance.

Performance feedback is a salient information cue that may influence strategic behavior (Baum and Dahlin, 2007; Lant and Hewlin, 2002). In this study, we focus on the impacts of performance feedback interpreted through two different mechanisms:

(1) comparison with historic performance; and

(2) comparison with reference groups.

In particular, we propose that positive performance feedback might hinder the learning process due to cognitive inertia. Consistent with our prediction, we observe the existence of cognitive inertia in terms of fewer changes in complexity and centrality of mental models when teams obtained positive performance feedback after comparing their rank changes with other competing teams. However, no significant relationships are found between performance feedback interpreted against historic performance in profits and the changes in mental model. The inconsistent findings regarding the two kinds of performance feedback may be due to the benign simulation environment where the market size kept growing and most of the teams experienced increasing profits overtime. Under such circumstances, the aspiration levels formed through social comparison becomes salient than those formed through self-comparison. In addition, the phenomenon of cognitive inertia did not take place in every team. In our sample, of the ten teams with continuously improving performance for all three periods, six teams had decreased complexity, while four teams continuously increased the complexity of their mental models over time. Alternatively, we conjecture that positive performance feedback confirms the learning methods the team used to collect information and analyze the environment. Therefore, it is likely that the complexity and centrality of the mental model might increase because the team repeated what it deemed to be the correct learning methods. Future research is needed to identify these factors and investigate their impacts on the formation of team mental models as well as performance.

Our results may also suggest that negative performance feedback would more effectively provoke the learning process than positive performance. In other words, through the learning process, teams with negative performance feedback may change more in the complexity and the centrality of their mental models than teams with positive performance feedback. If outcomes contradict current beliefs, strategists are required to reevaluate their current mental model, which urges strategists to collect new information from the environment and to think about alternative explanations. It is likely that strategists eliminate some of the concepts from their current mental models according to the performance feedback. But, as they have failed to find the championed concepts and linkages, they must broaden their mental models by collecting and screening more information and considering a diverse set of potential relationships. Strategists may also put more effort in distinguishing core concepts in the strategy frame.

Implications for theory, policy and practice

Our study contributes to the management research on teams and strategic cognition in several ways. First, our study is one of the first to explicate the mechanisms of team mental model changes as a result of performance feedback. In doing so, we address the call to examine influence of feedback on team performance (Gabelica *et al.*, 2012), specifically in strategic decision-making contexts. As anecdotes shown, such trial and error learning process has been attributed to the business model innovations at 3Com (Martins *et al.*, 2015). Further, we contribute to the team mental model literature by advancing the understanding of complexity and centrality as attributes of team mental models in addition to similarity and accuracy (Mohammed *et al.*, 2010). Finally, the study shed light on the growing research steam of team reflexivity (Schippers *et al.*, 2013; Gabelica *et al.*, 2014). Because reflexivity is beneficial to improve team performance by enabling conscious deliberation upon decision-making strategies over a long period, team mental model changes are likely to indicate the usage of reflective strategies.

The findings of this study also have implications for policy and practice. First, our study suggests negative performance feedback can be a more effective trigger for team learning compared to positive performance feedback. Thus, when facing successes, TMTs should be more cautious of cognition inertia than when facing failures. As part of guided reflexivity, more interventions may be used to help teams deliberately reflect upon the past positive performance in solving complex problems by linking cause-effect relationships to specific strategic options or outcomes (Gabelica *et al.*, 2014; Gary and Wood, 2011). Second, our findings highlight the importance of a TMT mental model's centrality in the decision making process. Although it is essential to emerge a complex team mental model in tune with the competition landscape and general environment, TMTs should focus on identifying core concepts and make efforts in establishing connections among concepts rather than simply adding more concepts.

Limitations and future studies

For future research, it will be interesting to investigate the direct linkage between a team's aspiration level and the changes in its mental model. According to the trial and error learning model, performance information is compared to aspiration levels to determine success or failure. Therefore, when the team receives performance feedback, it can either make an adjustment in its mental model and change its strategic action or change the aspiration level to reduce the discrepancy between performance and its goal. Unfortunately, in this study, we could not collect the data pertaining to the team's aspiration levels. Instead, we measured performance feedback as the change in performance from the $t - 2$ period to the $t - 1$ period, and assumed that every team should try to, at least, maintain its profits or rank in the competition, if not improve them. Thus, a negative change in performance would imply that the team fell below its aspiration level and a positive change would imply that it reached its goal. However, this may not be the case. The improvement in performance may fall below the aspiration level and become negative performance feedback. Therefore, future research should examine whether performance feedback is positive or negative by comparing performance with aspiration levels directly.

Although our focus is on the relationships between the TMT mental model and firm performance, we realize that there are other factors that may also influence TMTs' decision-making such as team process improvement (Kirkman *et al.*, 2004), team learning behaviors (Edmondson, 1999) and cognitive task performance (Jehn and Shah, 1997). For example, it is likely that TMTs fail to go through phases of divergent and convergent thinking, which are essential for creative teams to adapt effectively and generate solutions to changing conditions (Cirella *et al.*, 2014). In addition, studies on work groups have suggested the importance of group diversity in explaining team performance (Fisher *et al.*, 2012). This line of literature suggests that diversity enables access to broad cognitive resources leading to the creation of substantive tasks and processes, thereby influencing the quality of decision-making (Jehn and Bendersky, 2003).

Conclusion

Using a longitudinal data set from a simulation experiment, this study provides evidence of the association between TMT mental models and performance. Specifically, the two characteristics of a TMT mental model – complexity and centrality influence the decision-making process as well as performance. We also found that negative performance feedback enhances changes in the complexity and centrality of a TMT mental model. Importantly, performance feedback has different effects on TMT mental models depending on the referents – past performance or social comparison. Although these results are encouraging, more work is necessary to link cognitive phenomena to team and organizational performance. Reflecting Gabelica *et al.* (2014), we suggest that a better understanding of team performance can be developed by drawing on theories of individual learning and opening the blackbox of team mental model dimensions.

Note

1. The content of the concepts and the structure of the categories are available upon request.

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