The Effect of Forward and Backward Reasoning on Managerial Decision Making

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A thesis submitted to the
Faculty of Graduate Studies and Research
in partial fulfillment of the requirements of
the degree of Doctor of Philosophy

August 2009

Dedication

To my family,

Lubna, Bilal and Sofia

Acknowledgements

I would like to sincerely thank my supervisor, Sue Lajoie for her guidance, insights and support throughout my course work and thesis writing period. I am greatly appreciative of her patience and determination in ensuring that I completed this dissertation. I am also thankful to my thesis advisors, Bob Bracewell and Alenoush Saroyan for their valuable and timely feedback.

I am truly grateful to Danny Szpiro for inspiring me to pursue a doctoral degree and for his sound advice and continuous encouragement during my studies. A very special thanks to Don Nightingale and Margot Northey for their mentorship and support. I would not have been able to undertake this endeavour without their help. I am thankful to Arshad Ahmad for directing me to this PhD program. My thanks also to Mohammed Ali Khan for his wise counsel and moral support.

I would like to acknowledge the support I received from all my colleagues at Queen's School of Business. Julian Barling was most helpful in guiding me through research design and analysis. Julie Einarson and her team at Queen's Executive Development Centre provided me with great support in conducting the study experiments. Thanks to Tom Anger, Brent Gallupe, David Saunders, Darlene Holden, Jeff McGill, Yuri Levin, Peter Dacin, Jane Webster and, especially, John Moore and Bill Blake for their advice, assistance and encouragement.

I am deeply indebted to my parents, Surriya and Nasim Mufti for teaching me the value of education by being role models. I am eternally grateful to my wife, Lubna, my son, Bilal, and my daughter, Sofia for their care, love and unconditional support. It is to them I dedicate this thesis.

Abstract

Reasoning is the cognitive process used to solve problems and make decisions. This study examined the effect of forward and backward reasoning strategies used by expert managers to make a decision in an unfamiliar problem situation. Expert managers (n = 114) were randomly assigned to one of two reasoning strategy groups: Forward (n = 59) and backward (n = 55). Based on their experience and education, the managers were also categorized into two levels of expertise: Senior managers (n = 26) and middle managers (n = 88). All managers were asked to read a business case study, write their responses using a forward or backward reasoning template, and to identify their reasoning preference. Independent coders were used to code the responses and statistical procedures of ANOVA, binary logistic regression, MANCOVA, and discriminant analysis were used to analyze the coded data. The results showed that senior managers reported a strong preference for backward reasoning while middle managers did not have a specific reasoning preference. Both senior and middle managers in the forward reasoning group, made a risk-averse decision while both senior and middle managers in the backward reasoning group made a risk-taking decision, which resulted in a superior decision outcome. The results also indicated that reasoning strategy specifically influenced the decision outcome through the four factors of decision analysis: Strategic decision, alternatives, criteria, and action plans, with criteria and alternatives emerging as the most important predictors of reasoning strategy. Overall, these findings support cognitive science research in other domains that experts in familiar situations use forward reasoning but in unfamiliar situations revert to backward reasoning, which results in better outcomes. This study has provided further evidence that the common dimensions of expertise are generalizable and replicable in the domain of management.

Résumé

Le raisonnement est le processus cognitif servant à solutionner des problèmes et à prendre des décisions. Cette étude a examiné l'effet des stratégies de raisonnement en chaînage avant et arrière (forward or backward reasoning) utilisées par des gestionnaires spécialisés pour prendre une décision en situation de problème inhabituel. Nous avons divisé au hasard les gestionnaires (n = 114) en deux groupes de stratégie de raisonnement : en chaînage avant (n = 59) et en chaînage arrière (n = 55). De plus, nous les avons regroupés en deux niveaux d'expertise selon leur expérience et leur éducation : les gestionnaires supérieurs (n = 26) et intermédiaires (n = 88). Nous leur avons tous demandé de lire une analyse de rentabilisation et de rédiger leurs réponses à l'aide d'un modèle de raisonnement en chaînage avant ou arrière, puis de préciser leur préférence. Nous avons fait appel à des codeurs indépendants pour traiter les réponses et procédures statistiques d'analyse de variance (ANOVA), de régression logistique binaire et d'analyse de covariance à variables multiples (MANCOVA); de plus, nous avons procédé à une analyse discriminante des données codées. Les résultats ont montré que les gestionnaires supérieurs ont exprimé une nette préférence pour le raisonnement en chaînage arrière (backward reasoning), alors que les gestionnaires intermédiaires n'ont rapporté aucune préférence particulière. Les gestionnaires supérieurs et intermédiaires du groupe de raisonnement en chaînage avant (forward reasoning) ont pris une décision prudente, tandis que les gestionnaires supérieurs et intermédiaires de l'autre groupe ont pris une décision impliquant un risque, ce qui a entraîné un résultat décisionnel supérieur. Les résultats ont aussi indiqué que la stratégie de raisonnement a particulièrement influencé le résultat décisionnel par l'entremise des quatre facteurs d'analyse des décisions : stratégie, alternatives, critères et plans d'action. Ce sont les critères et les alternatives qui se sont distingués comme les plus importantes variables explicatives de la stratégie de raisonnement. Dans l'ensemble, ces constatations confirment la recherche en science cognitive menée dans d'autres domaines selon laquelle les experts utilisent le raisonnement en chaînage avant lorsqu'ils font face à des situations familières et qu'ils se tournent vers le raisonnement en chaînage arrière en situation inhabituelle, ce qui entraîne de meilleurs résultats. Cette étude apporte une preuve supplémentaire du fait qu'on peut généraliser et reproduire les attributs communs de l'expertise dans le domaine de la gestion.

Table of Contents

List of Tables

Introduction

How do expert managers make decisions? What sort of reasoning do they use to make an important decision in a complex situation that they have not experienced or encountered before? Do they rationally analyze the available information first and then make their decision, or do they naturally make an intuitive decision and then validate that decision by analyzing the available information? Is there a difference in the decision outcome depending on the reasoning approach they use? This thesis proposes to answer these questions by examining and comparing two contrasting reasoning approaches – forward and backward – for managerial decision making. An expert manager is someone who has significant business experience and holds an upper-level position in an organization (Kotter, 1982). In today's fast changing and uncertain business environment, managers are constantly required to make decisions, important and difficult choices that can greatly change the current and future performance of the organization (Mintzberg, 2004). Unlike other professions, most managers are not required to have formal business management education (Kharuna, Nohria, & Pernice, 2005). Nonetheless, given the amount of their work experience, which is usually more than ten years, and the depth of their industry and domain knowledge, upper-level managers can be considered as experts in their fields (Prietula & Simon, 1989).

There are only a handful of studies that have examined managerial decision making from a cognitive science perspective (Gijselaers & Arts, 2003; Isenberg, 1986; Kimball, 1995; Wagner, 1991). Although rational analysis is the method prescribed to managers (Langley, Mintzberg, Pitcher, Posada, & Saint-Mercury, 1995), studies have shown that managers actually use a variety of approaches when solving complex problems and making decisions. Managers use a combination of methods, such as intuition, analysis, and action to make decisions (Isenberg, 1986), and generally do not use explicit or scripted procedures but rely on tacit knowledge to understand and solve problems (Wagner, 1991). In management practice, intuition is often proposed as one of the defining characteristics of expertise and usually viewed as a mode of a decision making process that differs from a rational or analytical process (Dane & Pratt, 2007). Expert managers use intuition effectively to solve problems and make decisions that involve high complexity and short time horizons (Hayashi, 2001; Isenberg, 1984), and the effective use of intuition is considered as a differentiating factor between expert and novice managers (Agor, 1986). According to cognitive scientists, expert knowledge is domain specific and organized in meaningful patterns or schemas (Chi, Feltovich, & Glaser, 1981). These schemas allow experts not only to rapidly and reliably retrieve information but also to process it quickly and accurately (Glaser & Chi, 1988). Expertise is developed through deliberate practice, training that is focused and consciously monitored (Ericsson, 1996), so that the knowledge acquired is highly connected and articulated enabling inference and reasoning (Glaser, 1996). Simon (1987) noted that "it is a fallacy to contrast 'analytic' and 'intuitive' styles of management. Intuition and judgment – at least good judgment – are simply analyses frozen into habit and into the capacity for rapid response through recognition" (p. 63).

Cognitive science has adopted a dual process approach highlighting two types of problem solving modes (Epstein, 2002; Hogarth, 2001; Sloman, 1996). One mode is analytical, rational and explicit, and the other is intuitive, experiential and implicit (Epstein, 1990). Although the use of intuition is critical in differentiating upper-level (expert) managers from lower-level (novice) managers (Agor, 1986; Harper, 1989), this mode of reasoning has not been extensively studied in managerial decision making. The analytical mode has “garnered the lion’s share of research in managerial decision making” (Dane & Pratt, 2007, p. 36), even though it has been argued that skilled decision makers often do better when they trust their intuitions than when they engage in detailed analysis (Klein, 2003). Intuition works in familiar circumstances because it relies on previous and similar experience. But what happens if managers use intuition to make a decision in an unfamiliar situation? Would reliance on intuition in a novel situation lead to superior or inferior decision outcome? “The problem comes when the automatic [pattern] matching of the new situation to an old one is based on apparent characteristics of the new situation that do not accurately reflect the underlying causal drivers of a good choice” (Russo & Carlson, 2003, p. 385). In other words, the underlying causal drivers of the new situation may not be the same as other situations a manager has previously experienced. In such novel situations, studies from other domains, especially medicine, have shown that both experts and novices tend to use analysis-based reasoning strategies (Twycross & Powls, 2006).

Behavioural economists have classified intuition and reasoning into two different types of decision making systems. System 1 is intuition-based and system 2 is analysis- or reasoning-based (Kahneman, 2003b). Researchers have further classified system 2 reasoning into two types: Forward and backward. In forward reasoning, an individual works from presently available data, using a chain of inferences, towards a solution or decision (the final goal). While in backward reasoning, an individual begins with a hypothetical solution or decision and then uses available data to confirm or justify it (Lamond, Crow, & Chase, 1996). Research in medicine has shown that experts use forward reasoning (from data to hypothesis) in familiar and normal circumstances but revert to backward reasoning (from hypothesis to data) or mixed (backward and forward) reasoning when faced with unfamiliar or complex situations (Arocha, Wang, & Patel, 2005). Given the differences between medicine and management (i.e., lack of requirement of formal management education in order to practice and a large variety of problem situations), it is unclear if managers use a similar reasoning strategy (i.e., backward or mixed) when faced with making a decision in an unfamiliar and/or complex situation, and if there are differences in decision outcomes depending on the reasoning strategy they use. A search of business management literature did not yield any studies specifically on the effect of forward and backward reasoning to decision making. Given the lack of such research an opportunity exists to examine managerial decision making from a reasoning (i.e., cognitive) perspective. Findings from other domains, such as medicine, provide a reference to examine and compare the use and differences between forward and backward reasoning processes in the domain of business management. Results of such studies will inform both academicians and practitioners in advancing their understanding of problem solving and decision making.

The purpose of this study is to determine the effect of forward and backward reasoning on managerial decision making. In a series of controlled experiments, expert managers were given a complex business case study from an industry that they did not have any experience in, and were required to use either forward or backward reasoning to state a decision, as well as list alternatives, criteria and action plans. The type and quality of the decisions made, and the number of relevant alternatives generated, criteria considered, and action plans produced by the participants were compared to determine if there were significant differences between these two reasoning strategies. This dissertation contains a review of literature from research in management and educational psychology. It includes a description of the methodology used to conduct the experiments, and provides a statistical analysis of the results. This is followed by a discussion of the results with reference to the literature review. All relevant documents are attached as appendices.

Literature Review

According to the Cambridge Handbook on Thinking and Reasoning, "making a decision is often a problem that requires reasoning" (Holyoak & Morrison, 2004, p. 3). Reasoning is a cognitive process through which people solve problems and make decisions. Researchers in cognitive science and business management have studied reasoning from two different perspectives. Research in cognitive science has investigated the cognitive processes of experts and novices in terms of how they identify and solve problems in various domains (Lesgold, 1988; Pretz, Naples, & Sternberg, 2003). Management research has focused on the evaluative process of decision making, called decision analysis, which examines how managers generate alternatives and consider criteria (March, 1994; Walsh, 1995). Problem solving and decision making are considered parts of the overall reasoning process. Problem solving is the process of problem identification and development of possible solutions, and decision making is the evaluation of the alternatives against a set of criteria for the selection of the best possible alternative (Simon & Associates, 1986).

Managerial Decision Making

Decision making research in management has evolved from the discipline of classical economics, which focuses on the concept of decision making process in terms of how managers assess decision alternatives and criteria (Eden & Spender, 1998). The human as a rational decision maker is a key assumption of classical economics and the subjective expected utility (SEU) model provides the standard for rational decision making. In this model, decision-making behaviour is based on self-interest known as rational choice theory (Halpern & Stern, 1998). Individuals are assumed to be goal oriented and expected to make complete calculations to reach logical decisions that maximize utility. Sub-optimal decisions are regarded as deviations, and sub-optimal decision makers are referred to as rational fools (Sen, 1977). Simon (1957) challenged rational choice theory by arguing that it is practically impossible for someone to acquire and process all of the information in a complex situation, such as in business management, to make a fully rational decision. In practice people are content with making decisions that are simply good enough. He rejected the ideal of the all-knowing economic man capable of making decisions that bring the optimum results in favour of the real-life administrative man who chooses actions that lead to satisfactory results. He called this practical view of human decision making bounded rationality and described the good enough outcomes as satisficing. Given these limitations on cognitive capacity, managers tend to simplify some parts of the complex problems they face, which is inconsistent with the rational model of human decision making behaviour.

Kahneman and Tversky's (1979) prospect theory proposed that business decision makers are highly sensitive and attentive to how choices are presented or framed. Managers make decisions based on their tolerance for risk and how they perceive a given opportunity or threat. Their choices are often much simpler and tied to whether a chosen action might result in a gain or loss from the status quo or some other starting point of reference. If the reference point is defined such that an outcome is viewed as a gain then managers will tend to be risk averse, but if an outcome is viewed as a loss then managers will inclined to be risk seeking. According to March and Shapira (1995), managers prefer to avoid risk rather than treat it as a tradeoff for greater rewards, and will attempt to reduce risk by seeking more information and even substituting imagination for missing information.

Management research has also focused on how decision makers create and use mental models to recognize and represent information (Burns, 2005). This research has acknowledged one of the primary concerns of researchers regarding problem recognition and definition. Klein (1997) showed that decisions are made by recognition of typical situations rather than by a comparison of all available options. Gigerenzer and Selten (2001) discovered that simple rules of thumb or heuristics help people make quick decisions. They referred to this fast-paced decision making as intuition, which takes advantage of certain capacities of the brain that have developed through time, experience, and evolution. They found that people often rely on simple cues in the environment. In most situations, when people use their instincts they are heeding these cues and ignoring other unnecessary information. Researchers have even urged managers to make a virtue of their limited time and knowledge by mastering heuristics or fast and frugal decision making (Gigerenzer & Goldstein, 1996).

Mintzberg (1973) discovered that managerial work is surprisingly fragmented and full of interruptions. Instead of solving problems in a rational way, managers respond prematurely to complex events. They often act rather prematurely when making decisions often without taking into account all of the information and options available to them. Given the dynamic nature of the business environment, researchers have found that experienced managers have limitations in absorbing available information, making correct judgments, interpreting evidence and learning from past experience (March & Simon, 1958; Walsh, 1995). March (1991a, 1991b) concluded that in even familiar business environments, managers at all levels learn lessons inadequately, recall memories incompletely, and estimate futures inaccurately.

Managers continuously adapt to their dynamic environment by frequently changing their decision making behaviours. These cognitive interpretations of rationality are referred to as behavioural decision theory (Halpern & Stern, 1998). Although behavioural decision theory provides a more realistic description of managerial decision making than rational choice theory, it still does not provide meaningful insights into the cognitive processes of managerial decision making. Most of the insightful research on managerial work such as Mintzberg's (1973) is fundamentally behavioural in nature. As Mintzberg did not have access to modern analytical techniques from cognitive science, he even labelled his own studies as rather sketchy (Gijselaers & Arts, 2003).

During the mid-1980s, management researchers started to consider the cognitive perspective in decision making. This perspective recognized that in reality managers face unique issues, ambiguous facts, anecdotes, and rumours, which challenge their ability to make good decisions (Walsh, 1995). As such, the focus of research in the recently formed and growing field of managerial cognition is on how managers actually represent situations, process information, and solve problems (Gijselaers & Arts, 2003; Wagner, 1991). Simon and Kaplan (1989) divided cognitive science study into three levels: (a) in the abstract, (b) in computers, and (c) in humans. They stated that human decision making is the most difficult of the three to study as it takes place in complex environments with incomplete information, and under conditions of uncertainty. Business environments are very complex and uncertain, and it is this concern with the environment and the manager's response that defines the field of managerial cognition (Wagner, 1991). In this context, the manager is "a key actor who invents or creates a bounded field of decision possibilities which is then navigated in the process of choice" (Eden & Spender, 1998, p. 3).

According to the proponents of managerial cognition, the behavioural decision making approach does not provide insights into the cognitive processes underlying those behaviours (Eden & Spender, 1998). Their argument is that thoughts cannot be interpreted by simply observing behaviours and that a cognitive-oriented approach is needed to understand the thinking processes underlying decision making behaviour. While the managerial cognition perspective rejected assumptions that managerial decisions can be made using hyper-rational approaches, it also criticized the inadequacy of the bounded rationality model and prospect theory. Carroll (2002) stated that "psychologists themselves have been taken to task for assuming that all decisions are 'choices' that are 'given' in a bounded space and time" (p. 575). Initial managerial cognition studies not only validated findings from earlier cognitive science research they also provided further insights into managerial decision making. Prietula and Simon (1989) reaffirmed their past work by stating that management experts, just like experts in any other domain, combine analytical reasoning with intuitive judgment that has been sharpened by experience over a long period of time. In terms of further insights into the cognitive nature of decision making, studies by Isenberg (1986), Johnson (1988), and Wagner (1991) discovered unique findings in the business management domain.

Isenberg (1986) asked 12 senior managers from six different corporations and three college undergraduates to think aloud while solving a generic business case study problem where they were asked to discuss their plan of action. Analysis of verbal protocols showed that, compared to undergraduate students, senior managers began action sooner, used more reasoning, asked for less specific information, made more inferences from given information, and were generally less reflective about what they were thinking or doing. The preference of early action over reasoning and reflection was the surprising finding in this study. Senior management thinking seems to take place in the form of plausible reasoning and is adapted to dealing with uncertain problem situations. Given the uncertainty of the business environment, senior managers tend to experiment with early action to generate more information for further reasoning and reflection. Johnson (1988) reported that empirical research in decision making theory is not consistent with studies in expertise and problem solving in other domains. Based on a review of literature from the domains of law, and academia, he noted that experts in these domains did not perform impressively compared to novices. He was concerned that current research has barely started to consider issues of expertise in management. Specifically, he stated "researchers have failed to examine the specific facets of experts' cognitive abilities" (p. 209). Wagner (1991) observed problem solving approaches used by students and experienced managers solving business case studies. He found that "there are no formal procedures or guidelines to govern case analysis or evaluation of problem solutions" (p. 179), and what skilled performers really need to know in order to solve these complex case problems is often tacit. Tacit management knowledge is highly personal, hard to articulate, and difficult to communicate to others (Nonaka, 1994). According to Wagner, tacit knowledge is "knowable only indirectly through careful study of what managers do when they solve problems as opposed to what they say they do" (p. 182).

Findings from these three studies (i.e., early focus on action, non-significant expert-novice differences, and inability to communicate tacit knowledge) have suggested that the domain of business management might be more complex as compared to other domains. One possible reason for this complexity is that, unlike many other professions such as medicine or law, management spans multiple domains. Any business organization is in fact a dynamic system that is made up of several functional components (e.g., marketing, sales, operations, accounting, human resources, and information systems) within the company (Senge, 1990). Perhaps it is this multidisciplinary nature of management that makes it more complex to study from a decision making perspective. The multidisciplinary orientation means that business managers are required to think both functionally and strategically (Kotter, 1982). Thinking strategically means having an understanding of the various functions in the business as well as the linkages among these various functions. The additional requirement of cross-functional knowledge is certainly unique to management expertise and is considered a domain of its own, referred to as general management.

A search of literature using ”expertise general management senior managers” as keywords yielded only one relevant study, a doctoral thesis (Kimball, 1995), which looked at expertise from a general management orientation. Kimball reported that general managers organize their thinking about problems in terms of dynamic systems. She asked five effective and five non-effective senior managers to think aloud while solving three general management case studies and assessed their verbal protocols along systems dynamics or cross-functional dimensions. The effective groups showed significantly better systems thinking skills compared to the less effective groups. She concluded that "cognitive constructs of 'systems thinking' can be operationalized and is a useful way of understanding the nature of expertise in senior executives" (p. 110).

Wagner (1991) noted that the "rational approaches represented only a small part of the total picture of managerial problem solving" (p. 182), and predicted that future findings about the "art of problem solving will differ from the principles of rational problem solving" (p. 182) in terms of situational context, complexity of process, and tacit knowledge. Surprisingly few studies exist that have even examined the knowledge structure of management experts (Gijselaers & Arts, 2003). It is, therefore, critical to review past research in cognitive science and educational psychology as both fields have a more developed research base in problem solving.

Expert Problem Solving

Research in cognitive science and educational psychology has provided an in-depth understanding of the problem solving process. This process can be fundamentally described as a search through a problem space. A problem space contains an initial and a goal state and problem solvers apply a series of operators to work their way through intermediate states from the initial state to the goal state. In practice, instead of systematically considering all solution pathways, people tend to rely on a small number of mental procedures called heuristics to go from the initial to the goal state (Newell & Simon, 1972). Researchers have defined two basic types of problems spaces: Well-defined and ill-defined (Mayer & Wittrock, 2006; Simon, 1973). In well-defined problem spaces, the initial state, the goal state and the operators are clearly specified. Such problems can be solved through strong methods such as pre-determined algorithms. The advantage of studying well-defined problem spaces is that the problem is usually explicit and an optimal solution exists for that problem. Examples of well-defined problems include long division (Mayer & Wittrock, 2006) and tower of Hanoi (Pretz et al., 2003), as well as checkers and backgammon (Sutton & Barto, 1998). Greeno (1978) categorized well-defined problems into three types: inducing structure, arrangement, and transformation. Inducing structure problems (e.g. analogies) are solved by discovering relational patterns among objects in the problem. Arrangement problems (e.g. anagrams) are solved by generating partial solutions and rearranging the objects. Transformation problems (e.g. theorems) are solved by means-ends analysis, which requires a sequence of operations to be understood and performed on an initial state to reach a given goal state.

In ill-defined problem spaces, the initial state, the goal state and the operators are not clearly specified. These problems are solved by weak methods such as planning, problem decomposition, and backward chaining, which may or may not lead to a solution. According to Simon (1973), most everyday problems are ill-defined, else we would not think of them as problems and simply apply an algorithm to find the solution. Specific examples of ill-defined problems range from chess (de Groot, 1965) and physics (Chi, Glaser, & Rees, 1982) to medicine (Lesgold, 1988), history (Wineburg, 1998), and law (Lawrence, 1988).

Initially, cognitive science research was focused on how experts solve well-defined problems and the earlier studies made significant contributions to understanding the basic nature of expertise (Posner, 1988). Building on the encouraging results from well-defined domains, researchers began investigating problem solving in ill-defined domains. Ashley, Chi, Pinkus, and Moore (2004) further defined an ill-defined problem in terms of the following characteristics: 1) it lacks a definitive answer; 2) the answer is heavily dependent upon the problem's conception; and 3) problem solving requires both retrieving relevant concepts and mapping them to the task at hand. Most of the initial experiments took place in laboratory-like conditions allowing researchers to control some aspects of the complexities associated with ill-defined problems. A number of insights have been gained from studies in ill-defined domains such as chess, physics, medicine, history, and law. These studies indicate that, in addition to having a meaningful knowledge structure, some higher-level functions – such as information assessment, reasoning, and biases – also differentiate experts from novices.

Chess researcher de Groot (1965) asked grandmasters and novices to choose the best possible move from the middle of a game. Although all players contemplated a similar number of moves and countermoves, grandmasters considered moves that were of much higher quality. de Groot attributed this difference to the grandmasters' experience and ability of recognizing meaningful chessboard patterns and associated better moves, rather than general searching abilities (i.e., information processing, and strategies). Similarly, Chase and Simon (1973) found that experts possess superior abilities to recall legitimate chess configurations from memory. Interestingly, this difference between experts and novices disappeared when they were shown randomized chessboard setups. Chase and Simon concluded that superior performance of stronger chess players depends on their ability "to encode the positions into larger perceptual chunks, each consisting of a familiar sub configuration of pieces" (p. 80). This important finding suggested that possessing large quantities of domain knowledge is necessary but not sufficient for effective problem solving.

Using classical physics problems, Chi and Glaser (1980) found that expert knowledge is represented at a deep or principled level while novice knowledge is represented at a more superficial level. In a follow-up study, Chi et al. (1982) determined that, when solving problems, expert physicists tend to use forward chaining methods (i.e., thinking deductively), group equations (i.e., chunking), and spend more upfront time qualitatively analyzing the problems. These results reinforced the existence of a special knowledge structure, as proposed earlier by Chase and Simon (1973), which sets apart problem solving capabilities between experts and novices. As cited in Bransford, Brown, and Cocking (2000), similar differences between experts and novices have been verified in a number of well-defined problem domains, including mathematics (Bassok, 1996; Blessing & Ross, 1996; Schoenfeld & Herrmann, 1982) and computer programming (Adelson, 1984).

In a series of studies comparing experienced (expert) and resident (novice) radiologists, Lesgold (1988) found that experts considered a broader range of issues and explored extensive chains of reasoning when interpreting a radiology chart. Novices, on the other hand, focused mostly on the anatomical features included in the chart. Experts took into account both the breadth and depth of the informational environment, leading Lesgold to conclude that experts exercise a deep form of generalization and discrimination when assessing new information. Wineburg (1998) compared historians (experts) from various backgrounds and students (novices) by having them examine historical documents. The experts excelled in using that information as evidence to explain their arguments and draw conclusions. Unlike students, historians with specialties elsewhere made an effort to understand the overall situation and resisted the urge to simplify. This finding suggested that past experiences strongly affect current problem solving abilities. This link between past experiences and current problem solving has also been found in the domain of law. Lawrence (1988) reported that values developed from prior experience – i.e., biases – affect how the expert judges interpreted specific cases, and this became the main factor distinguishing expert judges from novices. For Lawrence, these implicit theories had a major impact on not only the final decision but also on the judicial problem solving process. He discovered that “experience also brought with it ideas about what to look for, and ways to follow up leads in the data” (p. 256).

Simon (1973) stressed the importance of distinguishing well-structured (well-defined) and ill-structured (ill-defined) problems. Problems that are well-defined for experts are initially at least ill-defined for novices. More importantly, even for experts, ill-defined problems often cannot be solved through the use of general problem solving skills. Effective problem solving, especially in ill-defined domains, requires a high level of domain-specific expertise. In addition to basic processing capability and knowledge organization, experts have to be aware of their current reasoning process, the relevance of the reasoning process within the big picture, and biases from their past experience. Experts can be identified as outstanding individuals in their domain. They consistently and significantly perform better than less outstanding individuals in their domain and other people in general (Ericsson & Smith, 1991), especially in their ability to automatically and rapidly respond to familiar situations (Ericsson, Prietula, & Cokely, 2007). By definition, experts have the ability to think and act more effectively about problems in their domain. This implies that “understanding expertise is important because it provides insights into the nature of thinking and problem solving” (Bransford et al., 2000, p. 31).

Expertise research is based on theories from the multidisciplinary field of cognitive science. Simon and Kaplan (1989), in an article on the foundations of cognitive science, described this field as “the study of intelligence and intelligent systems, with particular reference to intelligent behaviour as computation” (p. 1). They identified intelligence to be “closely related with adaptivity – with problem solving, learning, and evolution” (p. 1). From its origins in Gestalt psychology, along with contributions from linguistics and computer science, problem solving became a subject of study in the 1950s (Newell & Simon, 1972). Gestalt theorists proposed that there are characteristics of stimuli that cause the mind to interpret the problem through certain representations. Subsequent interest and collaboration among scholars from a variety of disciplines encouraged widespread scientific inquiry into human thinking and launched the research area of cognitive science.

The advent of the digital computer presented an appropriate metaphor for the human mind: a system of information processing and storage. A significant amount of research has since been conducted on solving ill-defined problems using computer-based artificial intelligence systems (Lynch, Ashley, Aleven & Pinkwart, 2006). Newell and Simon (1972) described the human mind as a task-oriented, symbolic processing system. They established a language for cognitive science by describing the workings of the human mind through terms such as problem space, representation, interpretation, and methods. Laird, Newell, and Rosenbloom (1987) described a software-based production system called Soar, which can represent human cognition using a computer. Soar builds on earlier work by Newell and Simon (1972) on the general problem solver (GPS), which simulated human cognition using a computer-based software program. Simon (1973) suggested that within an artificial intelligent system, such as GPS, problems in ill-defined spaces can be solved by giving them more structure thus turning an ill-defined problem into a well-defined one. An increase in structure appears to be the key to achieving a solution as all algorithms depend on the structure of the content. He noted, however, that real problem solving occurs while providing an ill-defined problem with structure. Newell (1990) proposed Soar as a theoretical model in which all cognitive acts are search tasks in a problem space. Using declarative and procedural knowledge, as well as weak and strong methods of reasoning, Soar is theoretically capable of solving both well- and ill-defined problems.

To understand the basic nature of expertise, however, findings from both well-defined and ill-defined domains need to be represented in a unified model. Expertise researchers have synthesized these findings in terms of how declarative knowledge is represented in the mind and how the procedural knowledge is used by the mind. In a classic book-length review of the subject, Glaser and Chi (1988) listed seven characteristics of expertise. Compared to novices, experts: (a) excel mainly in their domain; (b) perceive large meaningful patterns in their domain; (c) are faster overall in solving problems; (d) have superior short- and long-term memories; (e) represent problems in their domain at more principled levels; (f) spend a great deal of time analyzing a problem qualitatively; and (g) have strong self-monitoring skills. According to Ericsson et al. (2007), what consistently distinguished expert from novices was the habit of engaging in deliberate practice – a sustained focus on tasks that they could not do before. Experts continually analyzed what they did wrong, adjusted their techniques, and worked arduously to correct their errors. Through deliberate practice, novices can develop their abilities and skills to achieve expert performance. The journey to expert performance requires the guidance of an expert teacher or coach, who can provide honest and timely feedback. It also demands would-be experts to develop their inner coach and eventually drive their own progress.

Research into thinking processes showed that it is practical experience over a long period of time – usually a minimum of ten years – that separates experts from novices (Chase & Simon, 1973). The influence of this experience was observable in at least three specific areas: (a) extensive and richer memories; (b) robust and flexible strategies; and (c) efficient and effective performance. Compared to novices, experts have better organized content knowledge, and have faster and more flexible problem solving methods within their domains. Most importantly, although a certain amount of innate intelligence is a prerequisite for many fields of endeavour, research has shown that experts differ largely on the basis of extensive experience and learning in the field (Ericsson & Smith, 1991). Experience, according to Simon (1987), allows the acquisition of tacit knowledge in the form of previous analyses that are stored in memory and can be rapidly drawn upon. In this process, a complex set of associated information becomes available to the unconscious mind in chunks. References to the importance of experience to rapid recall, or intuition, are consistently found in management literature (Agor 1986; Bennett 1998), and supported by on-going research (Anderson, 1999; Burke & Miller, 1999; Isenberg, 1984; Khatri & Ng, 2000). Research in cognitive science has noted that intuitive reasoning can outperform analytical reasoning in studies of non-verbal communication (Ambady & Rosenthal, 1992), judgment (Wilson & Schooler, 1991), and problem solving (Berry & Broadbent, 1988; Schooler & Melcher, 1995). Simon's (1987) review of the research showed that "experts frequently arrived at problem diagnoses and solutions quickly and intuitively, without being able to explain how they came to their conclusions" (p. 57).

In a more recent review, Bransford et al. (2000) synthesized six key principles of expert knowledge. Experts differ from novices as they: (a) notice features and meaningful patterns of information; (b) have a great deal of content knowledge that reflects deep understanding; (c) conditionalize their knowledge on a set of circumstances; (d) are able to flexibly retrieve information with little attentional effort; (e) may not have the ability to teach others; and (f) have varying levels of flexibility in their approach to new problems. In essence, expert knowledge can become so automatized and stored into routines that experts themselves may not be able to delineate its separate components for explaining their knowledge and teaching others.

In summary, expertise can be defined by three interrelated domain-specific structures: Knowledge, cognitive functions, and mental representations. Knowledge includes the internal organization of information as well as deductive and inductive reasoning (Patel & Groen, 1991). The cognitive function includes strategies for problem solving and the ability to anticipate and evaluate results (Glaser & Chi, 1998). Representation includes the capacity to generate external representations of a problem and to reflect on the problem when making decisions. These three structures interact with each other during problem solving and decision making processes, and the level of expertise increases as these structures develop and interact with each other in more advanced ways (Ericsson & Charness, 1994). This definition provides a framework for defining the capabilities of experts in other domains, such as medicine and management. Problem solving studies from ill-defined domains have shown that experts possess both expansive domain knowledge and extensive procedural knowledge (Chi et al., 1982), and it is this combination that allows experts to assess information both at deeper and broader levels, and to engage in an appropriate reasoning process to find effective solutions.

Forward and Backward Reasoning

Business management literature refers to two systems of decision making and draws a distinction between the processes employed in making these decisions (Sloman 1996). Although the terminology used to define these two systems varies, the characteristics of the two systems are described in a similar manner. Epstein (1994) described the two systems as experiential and rational, and Sloman (2002) characterized them as associative and rule-based. Stanovich and West (2000) have simply labeled them as system 1 and system 2. According to Kahneman (2003b), system 1 is intuition-based, and decision making in this system is fast, parallel, and automatic. System 2 is analysis- or reasoning-based, and decision making in this system is slow, serial, controlled, and potentially rule-governed. The operations of both systems deal with stored contents that are based on conceptual representations of past experiences. The most important difference between these two systems is the degree of exerted effort. System 1 is effortless and does not suffer interference when combined with other tasks, whereas system 2 is effortful and is demanding in terms of mental activity. Table 1 categorizes the two decision making systems by process and effort.

Table 1

Decision Making Systems

	System 1 (Intuition)	System 2 (Reasoning)
Process	Fast, parallel, and automatic	Slow, serial, and controlled
Effort	No	Yes

Studies have indicated that managers arrive at their decisions quickly and intuitively but are often unable to explain the process of coming to the decision (Simon, 1987). Experts acquire skills through learning and practice and by compiling knowledge in a way that allows them to the access it quickly and automatically. This characteristic is called automaticity and it refers to doing something so well that one would not have to think about doing it (Anderson, 1992). For example, an experienced driver relies on automaticity to drive a car during normal weather and traffic conditions, while engaging in other activities such as talking to a passenger or listening to music. In contrast, a novice needs to concentrate on the step-by-step sequence of operations that requires mental effort, which can be easily disrupted by a distraction (Sanfey & Chang, 2008). Experts often find it challenging to explain the sequence of operations they use intuitively as it is difficult for them to decompose their complex and compiled knowledge. As mentioned earlier, these two forms of thinking are also referred to as system 1 and system 2 (Kahneman, 2003b; Stanovich & West, 2000) and they can often compete with each other. For example, in an unfamiliar and complex situation, system 1 can automatically propose an intuitive decision but system 2 reasoning can then be employed by the decision maker to evaluate the situation slowly and deliberately and if convinced that the intuition is wrong can correct or override the intuitive judgment (Sanfey & Chung, 2008).

Cognitive science literature further classifies reasoning, or system 2, into two basic and contrasting modes: forward and backward. According to Patel, Arocha, and Zhang (2005), data-driven reasoning (i.e., from data to hypothesis) is defined as forward reasoning and hypothesis-driven reasoning (i.e., from hypothesis to data) is defined as backward reasoning. These two modes of reasoning were earlier described by Newell and Simon (1972) in terms of forward and backward chaining and have been noticed in physics experts (Chi et al., 1981; Larkin, McDermott, Simon, & Simon, 1980) and medical experts (Patel, Arocha, & Kaufmann, 1994; Patel & Groen, 1986, 1991). Researchers had initially applied cognitive science methods to investigate physicians' clinical competence, developing a model of hypothetico-deductive reasoning (backward reasoning) which proposed that physicians reason by generating and testing a set of hypotheses to explain clinical data (Elstein & Shulman, 1990; Elstein, Shulman, & Sprakfa, 1978).

Patel and Groen (1986), however, discovered that experts who accurately diagnosed clinical problems actually used forward reasoning (from data to hypothesis). This was in contrast to novice subjects who used backward reasoning and misdiagnosed or partially diagnosed the same problems. This finding challenged the viability of the hypothetico-deductive model (or the backward reasoning model), which did not differentiate between reasoning patterns of experts and non-experts. Specifically, Patel and Groen found that expert physicians, like physicists, reported using forward reasoning to solve routine problems in their area of expertise, whereas novices or experts from other domains reported using either backward reasoning or a mixture of forward and backward reasoning. Similar results were found in other expert-novice studies. When solving familiar problems, expert clinicians used data-driven, or forward, reasoning and due to their depth of knowledge even skipped steps in determining the diagnosis. But novices used hypothesis-driven, or backward, reasoning resulting in complicated reasoning patterns (Patel, Arocha, & Kaufman, 1994; Patel & Groen, 1991). Larkin et al. (1980) found that expert physicists reasoned forward by using the information from the problem and physics principles to determine the solution. Students, or novices, used superficial features from the problem, determined a solution and reasoned backwards to justify the solution. Expert and novice reasoning have since been studied extensively in the domain of medicine. This includes deductive and inductive reasoning, hypothesis testing and clinical reasoning, and forward-driven and backward-driven reasoning (Patel, Arocha & Zhang, 2005). Cardiology experts with accurate diagnoses were found to use forward reasoning through a network of causal rules derived from an underlying knowledge base. On the other hand, experts with inaccurate diagnoses used a mixture of forward- and backward-reasoning in explaining their misdiagnoses. This would suggest that, at least for routine problems in physics and medicine, the acquisition of expertise is associated with the increased use of forward reasoning (Norman, Brooks, Colle, & Hatala, 1999).

Backward reasoning tends to be used by both experts and novices in unfamiliar and challenging situations. Patel, Groen, and Arocha (1990) found that when faced with atypical or complex problems, expert physicians started to use backward reasoning. Interestingly, in such situations, novices who used backward reasoning seemed to have produced better results; novices who reasoned backwards made better medical diagnosis than novices who reasoned forward (Norman et al., 1999). Patel et al. (2005) concluded that "pure forward reasoning is only successful in constrained situations, where one's knowledge of a problem can result in a complete chain of inferences from the initial problem to the problem solution" (p. 732). Expert forward reasoning breaks down in solving uncertain and/or complex problems. In an experiment with expert cardiologists and endocrinologists, Patel et al. (1990) found that when solving problems outside their domain, these experts abandoned forward reasoning and reverted to backward reasoning strategies. A critical point to note here is that expert physicians who made accurate diagnosis, in unfamiliar problems situations, actually used a hypothesis-driven or backward reasoning approach. In those cases, the non-salient cues induced the backward reasoning process. Table 2 categorizes novice and expert reasoning strategies in familiar and unfamiliar problem situations.

Table 2

Reasoning Strategies

Level of Expertise	Problem Situation	
	Familiar	Unfamiliar
Novice	N/A[a]	Backward Reasoning
Expert	Forward Reasoning	Backward Reasoning

[a]All problem situations are considered unfamiliar to novices

Previous research has suggested that forward and backward reasoning are different cognitive processes that may lead to different outcomes, but there has been little investigation of these differences in business management. Rollier and Turner (1994) conducted an experiment with 64 professional project planners to investigate retrospective thinking (i.e., backward reasoning) versus prospective thinking (i.e., forward reasoning) as a technique for idea generation. In a planning task, significantly more ideas were generated in the retrospective thinking mode than in the prospective mode, and the ideas generated using retrospectively were not found to be of greater quality. Einhorn and Hogarth (1987) determined that when managers make decisions, they think both backward and forward whether they know it or not. In this context, thinking backward was defined as looking for patterns, linking events, and searching for metaphors that explain causes and effects, and thinking forward was defined as weighing variables, making calculations, and preparing alternative plans (Goldstein & Einhorn, 1987). According to Rollier and Turner, backward thinking worked well if one used more than one metaphor to describe a situation, resisted the temptation to infer a cause from just one clue, and looked for unexpected causes to explain effects. Forward thinking worked well if one knew when to rely on the computations and analyses and how to compensate for the errors in the computations and analyses.

Although there is some research in management on the use of reasoning strategies, it is confined to specialized subjects such as accounting (O’Donnell, 2004) and project planning (Rollier & Turner, 1994). There are no published studies in the domain of general management – upper-level management concerned with the business enterprise as a whole – that describe how expert managers reason in decision making situations. Research literature often classifies managers into the three levels of management: (1) junior; (2) middle; and (3) senior (Pavett & Lau, 1983; Stewart, 1982). Unlike medicine or other certified professions, practising as a management professional does not require formal education or accreditation (Khurana et al., 2005) and it is unclear if a level of management can be used as a proxy for expertise. This has resulted in a business world of expert managers with a diverse set of knowledge and skills in general management and decision making. According to Pfeffer and Sutton (2006), “almost anyone can (and many people do) claim to be a management expert; and a motley crew of sources – Shakespeare, Billy Graham, Jack Welch, Attila the Hun – are used to generate management advice” (p. 1). For example, the lack of disciplined thinking in the Isenberg (1986) study mentioned in an earlier section, where senior managers strongly preferred action over reasoning, hints at a deeper level of difference between management and a professional domain such as medicine. Drucker (2003) termed management a liberal art, claiming it deals less with the theory of knowledge and more with the practice of application. In fact, managerial decision making in practice is often considered “less of a science, and more of an art and craft” (Mintzberg, 2004, p. 360).

In summary, forward and backward reasoning are different yet interacting methods of problem solving and decision making (Pellegrino, Chudowsky, & Glaser, 2002). Forward reasoning is an example of a strong method of problem solving that relies on a deep knowledge of the problem space and domain. Because backward reasoning is used when the decision maker is unknowledgeable of the domain, it can be considered as example of a weak method as it relies on general strategies for problem solving. Johnson-Laird and Shafir (1993) conducted a critical review of reasoning and decision making and recommended researching the interactions and linkages between these two aspects of cognition. They also prescribed reproducing the complexity and uncertainty of real-world situation in laboratory-like settings to study the true nature of reasoning and decision making. Woll (2002) further recommended studying “how cognitive processes and knowledge structures operate in the real-world and to use more naturalistic methods for studying these phenomena” (p. 506).

Issues in Research

According to Carroll (2002), decision making research is advancing beyond behavioural studies: “It is starting to embrace sensemaking along with calculation (Weick, 1995), pattern matching as well as choice models in naturalistic decision making (Zsambok and Klein, 1997), expressions of identity that underlie preferences (March, 1994), and construction or improvisation in social practice (Hutchins, 1995; Lave, 1988)” (p. 575). Two streams of research – situated cognition and social cognition – are now prominently featured in the managerial cognition literature. This confirms a strong influence from organizational learning, a field that has its roots in social psychology and, according to Casey (2003), is now considered as part of managerial and organizational cognition. Argyris (1977) linked managerial cognition to organizational cognition by defining organizational learning as the process of detection and correction of errors. In his view, organizations learn through individuals acting as agents for them, and the individuals’ learning is either facilitated or inhibited by the organization’s environment.

Findings from situated and social cognition have advanced research in managerial cognition. Although a manager has to ultimately make the final decision as an individual, he or she often has to consult with other individuals in the organization as the problem space often involves a broader context and many people. A manager has to understand the breadth of the situation and solicit input and buy in from many people, which can complicate the problem solving process. For example, decision makers have a tendency to maintain their relationships with others – friendly or hostile – when making decisions. Social cognition researchers are concerned about how people make sense of other people and themselves. Although it builds on top of fine-grained analysis from cognitive theory and methods, social cognition research nevertheless differs from individual cognition research. Fiske and Taylor (1991) elaborated that "compared to objects, people are more likely to be causal agents, to perceive as well as being perceived, and intimately to involve the observer's self" (p. 22). In a business organization, learning can take place at different levels – individual, group, and organization – and contextual factors such as organizational strategy, structure and culture can influence the process of learning (Fiol & Lyles, 1985).

The managerial and organizational field is still evolving into a formal discipline. For example, Meindl, Stubbart, and Porac (1994) raised two basic questions for researchers in this field: "(a) what is an appropriate construct system for describing managerial and organizational cognition? and (b) what is an appropriate way to treat level-of-analysis issues in cognitive research?" (p. 290). The elementary nature of these questions shows a need for considering both managerial (i.e., individual) cognition and organizational (i.e., social) cognition views when studying expertise in management. In a comprehensive survey of the field, Walsh (1995) divided the managerial and organizational cognition literature into two streams: (a) content and the attributes of knowledge structures; and (b) affect of knowledge on processes and outcomes of managers and their organizations. The inquiry into knowledge structure and processing shows a striking parallel to the earlier expertise studies in psychology and educational psychology. This suggests that managerial and organizational cognition research has benefited from earlier studies of expertise in other disciplines, and should continue to benefit from current and future studies. Schön (1982) proposed the idea of examining decision making in workplace and workplace-like (i.e., naturalistic) environments. He encouraged researchers to explore how accomplished professionals and managers carry out on-the-spot experimentation to solve unique problems in their own environments, and how that experimentation is like and unlike the controlled experimentation of laboratory scientists. Schön (1992) stated that “in such explorations as these, grounded in collaborative reflections on everyday artistry, we will be pursuing the description of a new epistemology of practice” (p. 10).

There are several unresolved issues regarding such research in naturalistic environments. Although certain problems can be defined and controlled for study in a laboratory setting, most real-world problems are neither well-defined nor well-controlled. Indeed, problems in naturalistic settings have unclear problem statements, complex goals, and the very nature of the problem can change during the solution process (Simon et al., 1986). Kotovsky (2003) acknowledged this difficulty by stating that “thinking in one manner or another is affected by virtually all of the equipment a person brings to bear on a problem, as well as the full range of environmental influences that define the problem, its problem space, and its solution” (p. 12). This issue has continued to challenge expertise researchers. Pretz et al. (2003) stated that “problem-solving research has not revealed a great deal about the processes involved in problem recognition, problem definition, and problem representation” (p. 9), i.e., the opening stages of the problem solving cycle. Decision making and expertise research in naturalistic settings raises another issue: The quality of solution is dependent on acceptance from other experts in that domain. In domains such as education and management, there is usually little agreement about the best solution for many given problems. As such, issues such as problem representation and reasoning processes become even more critical in gaining that acceptance (Voss, 1988).

Researchers generally agree that expertise is achieved through years of sustained practice supported with self-reflection and constructive feedback. However, maintaining this discipline requires a great deal of motivation. Ericsson and Charness (1994) suggested that "a better understanding of social and other factors that motivate and sustain future expert performers at an optimal level of deliberate practice should have direct relevance to motivational problems in education" (p. 753). In recent years researchers have considered this and other issues in studying problem solving within naturalistic settings. These include problem representation (Ericsson, 2005; Pretz et al., 2003), metacognition (Zimmerman & Campillo, 2003), creativity (Lubart & Mouchiroud, 2003), insight (Davidson, 2003), and incomplete information (Stanovich, 2003). Kotovsky (2003) argued that using an either-or approach such as well-defined vs. ill-defined, creative vs. non-creative, insightful vs. non-insightful, adequate-information vs. inadequate-information, will provide only a glimpse into the whole picture. He suggested that "in the study of problem solving, as in all science, there is a right way and a wrong way to go about it and the correct way may lie somewhere in between." (p. 382). Sternberg (1997) described such a middle way by synthesizing the different views of expertise into a unified model. He combined the three original views (a) information processing, (b) domain knowledge, and (c) knowledge representation, with views from his own triarchic theory of intelligence (d) analytical ability, (e) creative ability, (f) automization, and (g) practical ability. He then added in an eighth view (h) implicit theories, from the social cognition perspective to acknowledge that “an expert is an expert by the virtue of being labelled as such” (p. 151) by others. Based on these eight views, Sternberg presented the ninth, (i) synthetic view. He articulated that “on this [synthetic] view, expertise is a prototype, and is rarely reached in its purely prototypical form. Rather, people have aspects of expertise, namely, the eight aspects” (p. 151).

Given this synthesized yet incomplete depiction of experts, cognitive science researchers have started to study reasoning and decision making in real-world situations using advanced methods of observation and analysis. Two aspects of this current research initiative are worth noting: naturalistic decision making (Montgomery, Lipshitz, & Brehmer, 2005) and cognitive task analysis (Chipman, Schraagen, & Shalin, 2000). Presently most of the work is in the domain of military tactical decision making but some is being applied to study crisis-oriented situations in health care and other emergency-services domains.

Naturalistic decision making research refers to the study of problem solving in real-world environments. The following eight factors (Orasanu & Connolly, 1993) characterize the complexities and pressures of naturalistic decision making situations: (a) ill-structured problems; (b) uncertain dynamic environments; (c) ill-defined or competing goals; (d) absence of action and feedback loops; (e) time stress; (f) high stakes; (g) multiple players; and (h) organizational goals and norms. This comprehensive list continues to serve as a solid basis for determining what is included and missing in current problem solving studies (Montgomery et al., 2005). This list is being considered by contemporary researchers for both individual and team-based decision making situations.

Research at the individual level has focused on how decision makers create and use mental models to recognize and represent information (Burns, 2005). This focus acknowledges one of the primary concerns of problem solving researchers regarding problem recognition and definition. Klein's (1997) recognition-primed decision theory stated that decisions in naturalistic settings are made by recognition of typical situations rather than by comparing all available options.

Given most decisions in naturalistic settings involve multiple players, another major theme focuses on team-based decision making. This stream of research showed an influence from studies in situated and social cognition. Here most of the work is on understanding the concept of shared mental models in team decision making situations (Allwood & Hedelin, 2005; Berggren, 2005; Johansson, Granlund, & Waern, 2005; Kline, 2005; McLennan, Pavlou, & Omodei, 2005). In addition, researchers have investigated the influence of cultural factors (Klein, 2005; Vaughan, 2005) on team-based decision making processes. Cannon-Bowers and Salas (2001) stated that in order to be successful, expert teams must possess a high level of shared cognition, a shared understanding, and conceptualization of expectations, strategies, and processes. They also proposed a framework that included team cognition in the form of teamwork competencies in terms of knowledge, skills and attitudes (Cannon-Bowers & Salas, 1997).

An ongoing concern in naturalistic decision making research has to do with constructing generalizable findings and research (Klein 1997; Montgomery et al., 2005). Lajoie (2003) acknowledged that there are many different paths to expertise and recommended the use of modern techniques such as cognitive task analysis to study trajectories and transitions towards expertise. Interestingly, cognitive task analysis seems to be the methodology of choice for a number of naturalistic decision making researchers (Gore & Riley, 2005; Klein & Militello, 2005; Peterson, Stine, & Darken, 2005). According to Klein (2005), cognitive task analysis is a set of methods and tools for gaining access to the cognitive processes that organize and give meaning to observable behaviour. It "is a generic label for a variety of methods that attempt to identify how experts perform complex cognitive tasks" (Montgomery et al., 2005, p. 8). Chipman et al. (2000) pointed out the potential significance of this methodology by stating that "sometimes it is difficult to draw a distinction between a basic research investigation and a cognitive task analysis. If nothing like it has been done before, a cognitive task analysis may become, de facto, a basic research investigation" (p. 17). In a review of naturalistic decision making methodologies, Montgomery et al. (2005) concluded and recommended the following: "(a) methodologies are focused primarily on solving problems and secondarily on testing or developing general theories; (b) methodologies must be relatively simple and possess visible face validity; (c) methodologies still lack general accepted criteria of rigour; and (d) the issue of producing general and testable models remains looms as large today as it did a decade ago" (p. 8).

Research issues related to decision making processes in team-based and naturalistic environments have implications for management education and learning. Schön (1992) argued that traditional didactic teaching in professional development programs is strongly rooted in the positivist philosophy of education. In this philosophy, professions such as medicine, law, engineering and business are considered to be essentially technical disciplines. Their "rigour depends on the use of describable, testable, replicable techniques derived from scientific research, based on knowledge that is objective, consensual, cumulative, and convergent" (p. 54), and does not correspond to real-world situations. Hmelo and Evensen (2000) stated that the 21st century professional not only has to have extensive and up-to-date domain knowledge but also the skills to solve new problems in collaboration with others. According to these authors, problem-based learning (PBL) is an effective pedagogy to educate these new age professionals, a pedagogy that combines theory (or reflection) with practice. Barrows (1986) pioneered and popularized the concept of PBL in the medical school environment during the late 1960s and, according to Hmelo and Evensen, defined PBL as model in which "a rich problem is used that affords free inquiry by students, and learning is student-centered" (p. 2).

According to Williams (1992), case-based learning is a form of problem-based learning. The case-based method has been used in professional education to help students become proficient about their domain. For example, medical students working in small teams use the process of research and reasoning to diagnose problems created using actual patient records or case studies. Ashley (1992) found that case-based reasoning in the legal profession was useful in interpreting rules, and supporting knowledge acquisition and learning. Aleven (2003), on the other hand, noted a constraint with the case-based method: "More often than not, when comparing a problem and a past case, one sees similarities as well as differences. The significance of similarities and differences depends on context and should be interpreted in accordance with the specific domain" (p. 186). There is general agreement, however, that case-based reasoning is the preferred method for problem solving and decision making in complex and dynamic (i.e., naturalistic) situations (Deng 1996). Researchers have further argued that case-based reasoning (or practitioner stories) can be considered as a rich form of cognitive task analysis (Jonassen, Tessmer, & Hannum, 1999) and have described how such "stories can be used as a task analysis tool and as an instructional aid in the form of case-based teaching" (Jonassen & Hernandez-Serrano, 2002, p. 76).

Business Case Study Analysis

According to Erskine, Leenders, and Mauffette-Leenders (1982), case-based instruction is the most popular pedagogical method in business schools and it is considered as one of the most effective way of training managers in naturalistic decision making. They stated that "a case is a description of actual administrative situation, commonly involving a decision or problem. It is normally written from the viewpoint of the decision maker involved and allows the student to step figuratively into the shoes of the decision maker or problem solver" (p. 10). The case study method is based on the premise that by exercising managerial decision making in the classroom, students can prepare for real-world business challenges. This method was introduced, promoted, and popularized by the Harvard Business School (Barnes, Christensen, & Hansen, 1994). According to the school's website (retrieved January 15, 2009, from www.hbs.edu/learning), the "case study is a description of an actual administrative situation involving a decision to be made or a problem to be solved. It can be a real situation that actually happened just as described, or portions have been disguised for reasons of privacy. Most case studies are written in such a way that the reader takes the place of the manager whose responsibility is to make decisions to help solve the problem.

In almost all case studies, a decision must be made, although that decision might be to leave the situation as it is and do nothing."

The Harvard Case Study Handbook (Ellet, 2007) stated that "a business case imitates or simulates a real situation. Cases are verbal representations of reality that put the reader in the role of a participant in the situation" (p. 13). The case places its readers in a position from which decisions are to be made (Erskine et al., 1981). Most importantly, "the case method focuses on the executive's analysis of a typical situation. Thus it capitalizes on his or her opinion, problem solving, and real-world expertise" (Berger, 1983, p. 332). The structured process of case study analysis is considered to provide the necessary skills and practice for better decision making and has claimed to shorten the time to achieving decision making expertise (Barnes et al., 1994; Ellet, 2007; Erskine et al., 1981).

Ellet (2007) stated that "cases involving an explicit decision are a staple of management education" (p. 61). In case analysis, a decision is the judgment made and position taken by the decision maker, usually after some consideration of the information from the case study. The decision itself can be defined at two levels. At a higher level, the decision maker has to decide whether to opt for change, which often requires action, or to maintain status quo, which often does not require any action. The *Business Dictionary* defines this higher-level decision as a "go/no-go decision" (retrieved June 5, 2009, from www.businessdictionary.com/definition). An example of a go/no-go decision is either a yes or no response to the question: Should the business launch a new product? According to Ali and Seider (2003), the go/no-go decision is a "commitment to pursuing a business opportunity long before the outcome of that decision is known" (p. 77). They suggested that a decision maker should "ask whether she is making a mistake by pursuing an opportunity with poor potential ('sinking the boat' error) … [or] if she is making the mistake of forsaking a good chance ('missing the boat' error)" (p. 77).

Table 3 illustrates the go/no-go decisions in terms of elementary bad/good outcomes.

Table 3
Go/No-go Decisions

Decision	Outcome/Performance	
	Bad	Good
Go	Type I or "sinking the boat" error	Right decision
No-go	Right decision	Type II or "missing the boat" error

At a more detailed level there is a strategic decision, which refers to the decision about the strategy of an organization. According to *The Economist*, as cited in Eisenhardt (1999), strategy answers two basic questions: "Where do you want to go?" and "how are you going to get there?" (p. 65). In addition to the go/no-go decision, a strategic decision includes a high-level reference to the plan of action needed to execute the decision. Using the product launch question above, for example, a strategic decision could be: Launch a limited offering of the product to a niche market. Ellet (2007) stated that "a decision requires concrete options [alternatives]; otherwise there is no decision to be made" (p. 61), and that "a rational decision cannot be made without criteria" (p. 63). The process of generating alternatives and assessing them against criteria is known as decision analysis (Raiffa, 1997). Ellet defined the objective of decision analysis "is to recommend the best choice among the available options [alternatives]" (p. 65). He added the recommended decision is then followed with a detailed action plan and "the purpose of the action plan is to implement the decision as effectively as possible" (p. 65).

Ellet (2007) has outlined a comprehensive and structured process for analyzing cases. He suggested two basic but contrasting approaches to decision analysis. The prove-and-state approach orders the decision analysis in the following six steps:

1. Decision options [alternatives]
2. Decision criteria
3. Proof of recommended option [alternative]
4. Critique of options [alternatives]
5. Recommended decision
6. Action plan

In this order, the decision maker first considers all available alternatives, determines the decision criteria and then conducts analyses to come up with the recommended decision and action plan. Given the data-driven nature of this approach, prove-and-state is analogous to forward reasoning. A second approach, state-and-prove, changes the order of the activities in the following manner (Ellet, 2007):

1. Recommended decision
2. Decision options [alternatives]
3. Decision criteria
4. Proof of recommended option [alternative]
5. Critique of options [alternatives]
6. Action plan

Here the decision is stated first and then the analyses are conducted to support or critique the decision. Given its hypothesis-driven nature, the state-and-prove approach is analogous to backward reasoning.

The purpose of these templates is to provide a form of discipline and structure in the case analysis and decision making process. Mackay, Barr, and Kletke (1991) conducted a study that used protocol analysis to investigate the impact of a specific decision aid (structured analysis) on problem solving processes in a case study-based problem. Results indicated that decision aids influence the problem solving processes of decision makers. Ge and Land (2003) found that question prompts (regarding concepts and issues in a case study) had significantly positive effects on student problem solving performance. According to Lajoie (2003), "the transition from student to expert professional can be accelerated when a trajectory for change is plotted and made visible to learners" (p. 21). She suggested that, by identifying trajectories and transitions, especially where instruction could help, a roadmap for expertise could be planned and implemented.

Issues in Practice and Education

Management as a profession has a well documented history and its practice has extended beyond business enterprises where it originated in the late 19th century (Drucker, 1998). According to Mintzberg (1975), "no job is more vital to our society than that of the manager. It is the manager who determines whether our social institutions serve us well or whether they squander our talents and resources" (p. 61). Recently, however, critics have pointed out specific issues related to the practice and education of management. For example, unlike medical professionals, business managers are not required to have formal education or training (Mintzberg, 2004) to assume managerial positions. According to Khurana et al. (2005), the criteria for calling an occupation a bona fide profession are as follows: “A common body of knowledge resting on a well-developed, widely accepted theoretical base; a system for certifying that individuals possess such knowledge before being licensed or otherwise allowed to practice; a commitment to use specialized knowledge for the public good, and a renunciation of the goal of profit maximization, in return for professional autonomy and monopoly power; a code of ethics, with provisions for monitoring individual compliance with the code and a system of sanctions for enforcing it” (p. 44-45). Certainly along these criteria management does not compare well with the more traditional professions of law and medicine. Given the lack of professional formality, it is also challenging to determine the nature of expertise in management. When it comes to attributes such as management experience, organizational position, and management education, there are successful expert managers who possess some or all combinations of these attributes. For example, there are managers who have more than ten years of experience and hold a senior management position in their organizations yet do not have any formal management education. On one hand, Livingston (1971) stated that “how effectively a manager will perform on the job cannot be predicted by the number of degrees he holds, the grades he receives in school, or the formal management education programs he attends” (p. 316). On the other hand, Ericsson and Smith (1991) found that the number of years of experience by itself does not correlate with expertise in any domain.

Mintzberg (2004) has stated that conventional management programs “are specialized training in the functions of business, not general educating in the practice of managing" (p. 5). Most recently, Bennis and O'Toole (2005) argued that business schools have overly focused on "scientific" research and have hired and promoted professors of management "who have never set foot inside a real business, except as customers" (p. 5). The case for studying managerial decision making in academia has never been stronger. Management research needs to regain relevance by recognizing how organizations really work and how managers make decisions in authentic settings. Academics need to engage in studying expert managers to better understand how decisions are made in the real business world. Results from such a study would provide a new basis for future research in managerial decision making. These results will inform management educators on what effective reasoning approaches are so that they can be taught in business schools. Results from this study should also make practicing managers aware of their own thinking and motivate them to consider alternative approaches when making decisions. Most importantly, a better understanding of these reasoning approaches should provide insights to both academics and practitioners on the processes underlying decision making and decision outcomes.

Purpose of Study and Research Questions

The purpose of this study is to examine the effect of forward and backward reasoning on managerial decision making. The need for studying reasoning and decision making in management is important and relevant to both business and academia. Managers are regularly required to make important decisions under complex and uncertain conditions but often do not have the formal knowledge of problem solving and decision making techniques. The review of literature shows that although previous research has examined how managers make decisions in different problem situations, there has not been a study that has systematically compared different reasoning strategies. By conducting a controlled experiment, this study provides evidence on whether or not there is a difference between forward and backward reasoning on managerial decision making.

This study proposed three research questions:

1. What effects do managerial expertise and reasoning strategy have on reasoning preference?
2. What effects do reasoning strategy, managerial expertise, and reasoning preference have on the go/no-go decision?
3. What effects do reasoning strategy, managerial expertise, and reasoning preference have on the strategic decision, alternatives, criteria, and action plans?

Method

A two-group experiment was conducted on four occasions where expert managers were given a business case study and asked to use forward or backward reasoning templates to write down their decision along with alternatives, criteria and action plans. The type and quality of the decisions as well as the number of alternatives, criteria and action plans were compared between the two groups to determine if there were any significant differences.

Participants

A total of 120 experienced managers were recruited from four executive education programs at a Canadian university school of business. The participants were from a diverse set of backgrounds, representing middle- to senior-level positions in mid- to large-sized organizations, mostly from the private sector. The sessions took place during the year 2008 on April 9, April 30, June 16, and October 22. The April and October sessions included participants from different offerings of the same program (a three-week “general management” executive education program) and the June session included participants from a one-week “strategy” executive education program. These two types of programs were chosen because they draw the most similar as well as the most experienced managers to the business school.

The managers were recruited through a fifteen-minute verbal presentation made to all prospective participants at the end of a scheduled class session by the author of this thesis. Participants were informed of the objective of the study, the time (one hour) required to complete the study, the location of the study (the same classroom), the materials used (consent forms, questionnaire, case study, templates) during the study, and, most importantly, that participation was voluntary and opting out (before, during or after the study) would not result in any negative consequences or retribution.

This study involved the participation of human subjects and was required to comply with the McGill University Faculty of Education Ethics Review Board and a Certificate of Ethical Acceptability for Funded and Non Funded Research involving Humans was obtained from the Board (Appendix A). Because this study involved participants attending a program at another university, it was also required to receive approval from Queen's University's General Research Ethics Board (Appendix B). Participants were not compensated for taking part in the study.

Design

The main purpose of this study was to compare two different reasoning strategies and their effects on decision making outcomes. Specifically, the study attempted to determine whether the use of forward or backward reasoning strategies had any significant effects on the type and quality of the decisions made, and the number of relevant alternatives generated, criteria considered, and action plans developed by the participants. An experimental design was used that involved random assignment of participants to two treatments (Group A: Forward Reasoning; Group B: Backward Reasoning). This treatment was operationalized with two sets of envelopes, each containing documents relevant to one of the reasoning approaches. The envelopes were given to the participants in a random fashion so that each participant had an equal chance of being assigned to each group. The random assignment was used to increase the likelihood that the two groups were equivalent prior to treatment.

The design of the study and sequence of information in the envelopes was as follows:

Table 4

Study Design

	Group A (Forward Reasoning)	Group B (Backward Reasoning)
1.	Pre-test Participants were asked to complete the Background Information Form.	Pre-test Participants were asked to complete the Background Information Form.
2.	*Treatment 1* Participants were asked to read the case study and provide their responses on the Decision Making Forms in a forward reasoning manner: A. Alternatives and Criteria B. Decision and Action Plan	*Treatment 2* Participants were asked to read the case study and provide their responses on the Decision Making Forms in a backward reasoning manner: A. Decision and Action Plan B. Alternatives and Criteria
3.	Post-test Participants were asked to make a selection on the Reasoning Preference Form	Post-test Participants were asked to make a selection on the Reasoning Preference Form

Materials

There were two sets of materials. The first set of materials were prepared for the participants and provided to them in an envelope at the beginning of the study. Each envelope contained six documents:

1. Two Consent Forms
2. Background Information Form
3. Case Study
4. Decision Making Form A

5. Decision Making Form B
6. Reasoning Preference Form

The two one-page Consent Forms (Appendices C and D) were for the participants to read and sign. The one-page Background Information Form (Appendix E) contained questions asking the participants to provide their total work experience, management experience, organizational position, industry familiarity, and educational background. A five-page Case Study (Appendix F) titled *Holding Fast* (Gourville, 2006a) described a new product introduction in the medical device industry, a business domain presumed unfamiliar to most participants. The reason for selecting an unfamiliar industry was to ensure that the situation was unknown to all managers, thus creating more of a level playing field. This case study featured a company called *Crescordia* (a disguised company name) whose chief executive officer must decide whether to launch an eagerly anticipated, but still flawed, new technology-based product line called *resorbables*, a polymer-based medical fixation device that can be used instead of metal plates to treat bone fractures. The case described Crescordia as a leader in metal-based fixation devices that is now facing a competitive threat from a company specializing in resorbables. Unlike metal fixation devices, resorbables are biodegradable and supposed to dissolve in a patient's body harmlessly, thus requiring no follow-up surgery. The case study provided an overview of the company, its customers and competitor, and the opinions of company's senior managers. The case concluded with the question: "Should Crescordia launch a resorbables offering?" (Gourville, 2006a, p. 39).

There were two versions of Decision Making Form A. For Group A (Forward Reasoning), the Decision Making Form A (Appendix G) contained two sections:

Alternatives and Criteria. These two sections were adapted from the Prove-and-State Template. For Group B (Backward Reasoning), the Decision Making Form A (Appendix H) contained two different sections: Decision and Actions. These two sections were adapted from the State-and-Prove Template. Similarly, there were two versions of Decision Making Form B. For Group A, the Decision Making Form B (Appendix I) contained two sections: Decision and Actions, which were adapted from the Prove-and-State Template. For Group B, the Decision Making Form B (Appendix J) contained the other two sections: Alternatives and Criteria, which were adapted from the State-and-Prove template. The Reasoning Preference Form (Appendix K) contained brief definitions of forward and backward reasoning and asked participants to select their preferred mode of reasoning on a five-point Likert-scale.

The second set of materials was prepared for independent coders who were asked to read, interpret, and code the participant responses. This set consisted of three documents:

1. Case Commentaries
2. Coding Template
3. Coding Instructions

The Case Commentaries (Appendix L) included detailed analyses and decisions from four subject-matter experts (Gourville, 2006b). These commentaries were published in the same business management journal as the case study. These experts were described by the journal as knowledgeable about the specific industry or new product innovation. Expertise related to business innovation, which includes new venture management and new product/service development, is said to be generalizable across industries. For example, studies of venture capitalists or VCs (experts who provide funding and advice to new ventures) have suggested that experienced VCs develop a more general form of venture and product/service development expertise that can be applied to a variety of other industries (Busenitz et al., 2004; Zacharakis & Meyer, 1998). As such, the expert case commentaries were used to prepare a general outline of the coding template. The specific fields in the coding template were developed using results from a pilot study conducted on October 17, 2007. The pilot study found statistically significant differences between the forward and backward reasoning groups, and showed that backward reasoning resulted in decisions that were closer to the decisions made by subject-matter experts. Note the pilot study data were not included in this study. The Coding Instructions and Template (Appendix M) contained detailed instructions on how to interpret and code responses from the participants (i.e., Decision Making Forms A and B).

Procedure

The participants were randomly assigned to one of two groups and were part of a blind study. Group A participants received an unmarked envelope containing documents for the forward reasoning treatment and Group B participants received an unmarked envelope containing documents for the backward reasoning treatment. All participants were asked to complete and return the Consent Forms. After agreeing to voluntarily participate in the study – i.e., by signing and returning the Consent Forms – all participants (from both groups) were instructed to follow five specific steps in exactly the same order:

1. Fill out the one-page Background Information Form. The purpose of this form was to determine the extent of their management experience, organizational position, and education to establish the level of their managerial expertise;
2. Read the five-page business case study. They were advised not to take any notes (write, underline, highlight, etc.) when reading the case study;
3. Fill out Decision Making Form A, which contained the Alternatives and Criteria sections for Group A, and Decision and Actions sections for Group B;
4. Fill out Decision Making Form B, which contained the Decision and Actions sections for Group A, and Alternatives and Criteria for Group B; and
5. Read the Reasoning Preference Form and select a Likert-scale number to indicate their preference.

Data Coding

The Decision Making Response Forms (A and B) for each participant were photocopied and given unique number identifier. This identifier was assigned such that the coders would not know to which group (forward or backward reasoning) the forms belonged. The forms were then given to the two independent coders, who were asked to read, interpret, and code the participant responses using the Coding Instructions (Appendix M). These instructions contained specific information on how to code every variable on the coding template in order to ensure a high level of consistency between the two codes. A third independent coder was then given the coded responses and asked to resolve any discrepancies.

The data were coded using 13 variables. Table 5 lists the variables with brief descriptions. Three of these variables, managerial expertise, go/no-go decision, and strategic decision are described in more detail after the table.

Table 5

List of Variables

No.	Variable	Description
1	Reasoning strategy[a]	Grouping variable: Forward (1) or Backward (2).
2	Work experience[b]	Number of years of total work experience. This was asked in the study to ensure participants would not confuse management experience with total work experience. This variable was not used in the subsequent analysis.
3	Management experience[b]	Number of years of managerial experience. Must be less than work experience (see above). This variable was used in determining the managerial expertise variable.
4	Management education[a]	Level of university-based education: No university-based business education (1), university-based non-degree executive education (2), university-based degree executive education (3). Used in determining managerial expertise.
5	Organizational position[a]	Managerial position within the organization: Supervisor (1), Manager (2), Director (3), Vice-President (4), and Senior Executive (5). Used in determining managerial expertise.
6	Industry[c]	Medical Device (3), Healthcare (2), Other (1). Responses indicating Medical Device were to be removed from the sample, due to their domain expertise.
7	Managerial expertise[a]	Middle manager (0) or Senior manager (1). Calculated using the condition: Senior manager if Managerial experience >= 10 and Organizational position >= 3 and Management education >=2.
8	Reasoning preference[b]	All Forward (1), Mostly Forward (2), Mixed (3),

		Mostly Backward (4), and All Backward (5).
9	Go/no-go decision[a]	No-go (0) or Go (1).
10	Strategic decision[b]	Stop R&D (1), Maintain Status Quo (2), Conduct Field Test (3), Partially Launch Product (4), Fully Launch Product (5).
11	Alternatives[b]	Number of alternatives (1 to 5).
12	Criteria[b]	Number of criteria (1 to 5).
13	Action plans[b]	Number of actions (1 to 5).

[a]Categorical variable

[b]Interval variable

Four out of the 120 participant responses were incomplete and removed from the sample. Also, two other responses were from participants who held a non-managerial position in their organization. These responses were also removed from the sample, leaving the final sample size at 114. All remaining participants in the sample were considered expert managers as they held a management position and had significant work experience (ten or more years). There were, however, significant differences among the participants in terms of years of management experience, organizational position level, and management education.

The expert managers were further classified into two groups: Middle managers and senior managers. Using three independent variables – management experience, organizational position, and management education – an additional binary variable called managerial expertise was created. The two levels of managerial expertise (middle or senior) were determined by using a synthesis of the following definitions: Chase and Simon's (1973) ten year rule, Kotter's (1982) definition of a general managers as someone holding upper-level position in an organization, and Kharuna et al.'s (2005) finding that most managers do not have formal business management education, which was interpreted as a university-based degree program. Although this managerial expertise classification is somewhat arbitrary in terms of how it was determined, it is based on a combination of logical factors. For example, a senior manager was deemed as someone who had ten or more years of management experience, held a director/vice-president/senior-executive level organizational position, and had attended at least one non-degree university-based management program in the past. All other managers in the sample were classified as middle managers.

The business case study used for the study ended with the question: "Should Crescordia launch a resorbables offering?" (Gourville, 2006a, p. 39). As mentioned in the literature review section, there are two high-level responses to this question: yes or no. A decision response that indicated launching the product (yes) was coded as go and all other responses were coded as no-go. The strategic decision variable was coded on a five-point scale: Stop R&D (1), Maintain Status Quo (2), Conduct Field Test (3), Partially Launch Product (4), Fully Launch Product (5). The alternatives, criteria, and action plans variables were coded by interpreting and counting the number of items listed for each variable.

The Cohen's kappa for inter-coder reliability between the two independent coders for the categorical variable go/no-go decision was 0.824. The Pearson's correlation for inter-coder reliability between the two independent coders for the interval variables strategic decision was 0.856, alternatives was 0.830, criteria was 0.840, and action plans was 0.976. As mentioned earlier, a third independent coder was used to resolve the discrepancies between the two original coders.

Data Analysis

Data were analyzed using statistical techniques and tests that were appropriate given the classification of the variables and the nature of research questions. Descriptive statistics were generated to present a single but comprehensive listing of the means, standard deviations, and frequencies of the variables.

Research question #1 asked about the relationship that categorical variables managerial expertise and reasoning strategy have with the interval variable reasoning preference. A two-way analysis of variance (ANOVA) was used with categorical variables as independent variables and the interval variable as the dependent variable.

Research question #2 asked about the relationship that categorical variables reasoning strategy and managerial expertise, and interval variable reasoning preference have with the categorical variable go/no-go decision. A binary logistic regression analysis was used to evaluate the effects of two categorical variables and one interval variable as predictors on the categorical variable as the dependent variable.

Research question #3 asked about the relationship that categorical variables reasoning strategy and managerial expertise, and interval variable reasoning preference have with the interval variables strategic decision, alternatives, criteria, and action plans. A 2 x 2 between-subjects multivariate analysis of covariance (MANCOVA) was used with categorical variables as independent variables, the interval variable as the covariate, and the four interval variables as dependent variables. This was followed with an analysis of covariance (ANCOVA) to determine the effect of the covariate, the individual independent variables, and the interaction of the independent variables on the dependent variables. Finally, a discriminant analysis was performed using the four dependent variables as predictors to determine their contribution towards group membership.

Results

Table 6 lists the descriptive statistics by reasoning strategy and Table 7 lists the descriptive statistics by managerial expertise. Results of the statistical analyses are presented following this table as responses to each of the three research questions.

Table 6

Descriptive Statistics by Reasoning Strategy

Variables	Reasoning Strategy					
	Forward N = 59		Backward N = 55		All N = 114	
	Mean	SD	Mean	SD	Mean	SD
Management experience	14.49	5.42	14.29	5.58	14.39	5.48
Organizational position	3.39	1.10	3.40	0.87	3.39	0.99
Management education	1.66	0.78	1.75	0.78	1.70	0.78
Managerial expertise (N)	Middle = 46 Senior = 13		Middle = 42 Senior = 13		Middle = 88 Senior = 26	
Reasoning preference	2.85	1.17	3.27	1.15	3.05	1.17
Strategic decision	3.15	1.10	3.73	1.16	3.43	1.16
Go/no-go decision (N)	No-go=38 Go=21		No-go=23 Go=32		No-go=61 Go=53	
Alternatives	2.66	0.86	3.18	0.70	2.91	0.82
Criteria	3.29	0.83	2.64	0.95	2.97	0.94
Action plans	1.46	0.65	2.02	0.89	1.73	0.82

Table 7

Descriptive Statistics by Managerial Expertise

Variables	Managerial Expertise: Middle manager N = 88		Managerial Expertise: Senior manager N = 26		All N = 114	
	Mean	SD	Mean	SD	Mean	SD
Management experience	13.85	5.72	16.23	4.09	14.39	5.48
Organizational position	3.14	0.96	4.27	0.62	3.39	0.99
Management education	1.48	0.69	2.46	0.57	1.70	0.78
Reasoning preference	2.90	1.22	3.58	0.85	3.05	1.17
Strategic decision	3.34	1.14	3.73	1.21	3.43	1.16
Go/No-go decision (N)	No-go=49 Go=39		No-go=12 Go=14		No-go=61 Go=53	
Alternatives	2.90	0.83	2.96	0.81	2.91	0.82
Criteria	2.94	0.93	3.08	1.02	2.97	0.94
Action plans	1.62	0.85	1.89	0.72	1.73	0.82

Research question 1: What effects do managerial expertise and reasoning strategy have on reasoning preference?

An analysis of variance (ANOVA) was used with managerial expertise and reasoning strategy as independent variables and reasoning preference as the dependent variable. Table 8 shows the descriptive statistics of dependent variable reasoning preference by managerial expertise and reasoning strategy group. The Levene's test confirms the equality of variance between the two reasoning strategy groups.

Table 8

Descriptive Statistics by Reasoning Preference

Managerial Expertise	Reasoning Strategy	Reasoning Preference		
		Mean	SD	N
	Forward	2.85	1.17	59
	Backward	3.27	1.15	55
	Total	3.05	1.17	114
Middle	Forward	2.63	1.18	46
Middle	Backward	3.19	1.13	42
	Total	2.90	1.22	88
Senior	Forward	3.62	0.77	13
Senior	Backward	3.54	0.88	13
	Total	3.58	0.81	26

The ANOVA results showed that managerial expertise had a significant effect on reasoning preference, $F(1, 112) = 7.026$, $p = 0.009$, partial $\eta^2 = 0.060$. Reasoning strategy or the interaction of managerial expertise and reasoning strategy did not have a significant effect on reasoning preference.

Table 9 includes the percentage breakdown of reasoning preference by managerial expertise.

Table 9

Reasoning Preference by Managerial Expertise

Managerial expertise	Reasoning Preference				
	All forward	Mostly forward	Mixed	Mostly backward	All backward
Senior managers (N = 26)	0.0%	15.4%	15.4%	65.4%	3.8%
Middle managers (N=88)	11.4%	35.2%	15.9%	27.3%	10.2%

Research question 2: What effects do reasoning strategy, managerial expertise, and reasoning preference have on the go/no-go decision?

Table 10 lists the go/no-go decision for launching the product by reasoning strategy group, and Table 11 lists the go/no-go decision by managerial expertise.

Table 10

Go/No-Go Decision by Reasoning Strategy

Launch New Product?	Forward Reasoning	Backward Reasoning
No-go	38	23
Go	21	32

Table 11

Go/No-Go Decision by Managerial Expertise

Launch New Product?	Managerial Expertise (Middle Managers)	Managerial Expertise (Senior Managers)
No-go	49	12
Go	39	14

A binary logistic regression analysis was used to simultaneously evaluate the effects of two categorical predictors, reasoning strategy and managerial expertise, and one interval predictor, reasoning preference, on go/no-go decision, a categorical dependent variable. A test of the model with only the reasoning strategy predictor was significant, $\chi^2(1, N = 114) = 5.886$, $p = 0.015$. The model was able to correctly specify 62% of no-go decisions, and 60% of go decisions, for an overall success rate of 61%. All other predictors did not have a significant effect on the dependent variable.

Table 12 shows the results of the analysis for each predictor in a backward stepwise format. The odds ratio for reasoning strategy indicated that when holding all other variables constant, a backward reasoning strategy is 2.5 times (1/0.397) more likely to make a go decision (to launch the new product) than a forward reasoning strategy.

Table 12

Logistic Regression Analysis

Step	Predictor	β	Wald χ^2	p	Exp(β)
1	Reasoning Strategy	-0.874	4.966	0.026*	0.417
	Managerial Expertise	-0.296	0.392	0.531	0.744
	Reasoning Preference	0.128	0.547	0.460	1.137
2	Reasoning Strategy	-0.865	4.886	0.027*	0.421
	Reasoning Preference	0.154	0.840	0.359	1.167
3	Reasoning Strategy	-0.923	5.374	0.017*	0.397

*p < .05.

Research question 3: What effects do reasoning strategy, managerial expertise, and reasoning preference have on the strategic decision, alternatives, criteria, and action plans?

Table 13 lists the percentage breakdown of strategic decision by reasoning strategy group.

Table 13
Strategic Decision by Reasoning Strategy

Reasoning Strategy	Strategic Decision				
	Stop R&D[a]	Status quo	Field test	Partial launch	Full launch
Forward reasoning (N = 59)	5.1%	23.7%	35.6%	22.0%	13.6%
Backward reasoning (N=55)	1.8%	16.4%	23.6%	23.6%	34.5%

[a]Research and development

A multivariate analysis of covariance (MANCOVA) was used with reasoning strategy and managerial expertise as independent variables, reasoning preference as a covariate, and strategic decision, alternatives, criteria, and action plans as dependent variables.

As shown in Table 14, reasoning strategy had a significant multivariate effect on the combined dependent variables (strategic decision, alternatives, criteria, and action plans), $F(4, 106) = 8.831$, $p < 0.001$, partial $\eta^2 = 0.250$. Managerial expertise and the interaction between reasoning strategy and managerial expertise did not have a significant multivariate effect. The covariate reasoning preference did not provide a significant adjustment to any of the dependent variables. Note the reasoning strategy variable was used as a covariate for two reasons. First, to determine if it influenced the result by confounding the relationship between the categorical independent and the interval dependent variables. Second, given reasoning strategy was an interval variable, it could only be included in this particular multivariate test as a covariate.

Table 14

Multivariate Analysis of Covariance

Effect	Value	F	df	p
Reasoning Preference	0.987	0.353	4	0.841
Reasoning Strategy	0.750	8.831	4	0.000***
Managerial Expertise	0.980	0.536	4	0.709
Reasoning Strategy * Managerial Expertise	0.988	0.324	4	0.861

***p < .001

Analysis of variance (ANCOVA) tests were used to determine the effect of the independent variables and covariate on each dependent variable. Given reasoning strategy was the only significant multivariate effect, only the results of this grouping variable were analyzed.

Reasoning strategy had a significant effect on strategic decision, $F(1, 108) = 4.631$, $p = 0.034$, partial $\eta^2 = 0.041$. Reasoning strategy had a significant effect on alternatives, $F(1, 108) = 5.806$, $p = 0.018$, partial $\eta^2 = 0.051$. Reasoning strategy had a significant effect on criteria, $F(1, 108) = 11.949$, $p = 0.001$, partial $\eta^2 = 0.099$. Reasoning strategy had a significant effect on action plans, $F(1, 108) = 7.654$, $p = 0.007$, partial $\eta^2 = 0.066$.

A discriminant analysis was performed using the four dependent variables – strategic decision, alternatives, criteria, and action plans – as predictors of membership in the two reasoning strategy groups.

Table 15 shows the raw correlations, including significant ones between strategic decision and action plans, and between alternatives and action plans.

Table 15

Correlations (Raw)

	Alternatives	Criteria	Action Plans
Strategic Decision	0.049	-0.014	0.429**
Alternatives		0.156	0.342**
Criteria			0.092

**p < .01 (2-tailed).

Given there were only two reasoning strategy groups, one discriminant function was calculated with a $\chi^2(4) = 46.620$, $p < 0.001$, with this discriminant function accounting for 35% (canonical correlation = 0.588) of the between-group variability.

All four predictors made significant contributions in distinguishing between the two groups. Criteria had a loading of -0.508, action plans a loading of 0.501, alternatives a loading of 0.459, and strategic decision a loading of 0.354.

The discriminant dimension was negatively weighted by criteria (-0.911), positively weighted by alternatives (0.756), action plans (0.561), and strategic decision (0.241).

Finally, the classification results shown in Table 16 indicate that 75% of the original grouped cases were correctly classified.

Table 16

Classification Results

	Reasoning Strategy	Predicted Group Membership		
		Forward	Backward	Total
Original Count	Forward	45	14	59
	Backward	14	41	55
Percentage	Forward	76.5	23.7	100.0
	Backward	25.5	74.5	100.0

Discussion

Decision making is arguably the most important job of a manager. Yet the construct of reasoning, the cognitive process used in decision making, has not been extensively or methodically studied in management research. This study is the first attempt to systematically examine the effect of forward reasoning (where a decision is made after analyzing information) and backward reasoning (where the information is analyzed after making the decision) on managerial decision making. The purpose of this study was to determine if managerial expertise and reasoning strategy have an effect on reasoning preference, and if these three reasoning characteristics, in turn, have an effect on the four key factors of decision making and analysis: decision outcome, alternatives, criteria, and action plans. Management research has found that expert managers tend to use experienced-based intuition in familiar decision making situations and analytically-driven reasoning in unfamiliar situations, however, it is unclear which reasoning strategy, forward or backward, they use in unfamiliar situations and if these contrasting reasoning strategies result in different decision outcomes. Cognitive science studies in physics and medicine have found that experts use forward reasoning when solving familiar problems but use backward or mixed reasoning when faced with complex or unfamiliar problems (Arocha et al., 2005; Larkin et al., 1980; Simon & Simon, 1978). A review of literature conducted for this study concluded that the cognitive process of reasoning has not been sufficiently researched in the management domain or rigorously tested in a controlled decision making situation. For this study, findings from research in cognitive science are used as a basis to understand the relationships among expertise, reasoning, and decision making. This understanding was also used to formulate the research questions and to set the expectations for the results of this study. Prior to collecting and analyzing the data, it was expected that:

1. Managerial expertise would effect reasoning preference but that reasoning strategy would not effect reasoning preference;
2. Managerial expertise, reasoning strategy, and reasoning preference would not effect the go/no-go decision outcome. Expert managers would make the same decision regardless of which reasoning they prefer or strategy they use; and
3. Managerial expertise, reasoning strategy, and reasoning preference would not effect decision making and analysis factors such as strategic decision, alternatives, criteria, and action plans.

To examine these effects, a two-group experiment was conducted in a naturalistic-like setting (experienced managers making a decision using a business case study) and data were collected using a cognitive task-oriented process (structured templates that prompted either forward or backward reasoning). The results of this study show that:

1. Reasoning strategy, as expected, did not effect reasoning preference and although managerial expertise had an effect on reasoning preference, the nature of the effect was somewhat unexpected. When analyzed by level of expertise, the preference was not consistent among all expert managers. Senior managers preferred backward reasoning and middle managers were divided between forward and backward reasoning.
2. Managerial expertise or reasoning preference, as expected, did not have an effect on the go/no-go decision outcome, but reasoning strategy had an unexpected effect. Forward reasoning and backward reasoning strategies resulted in different

decision outcomes. Importantly, backward reasoning resulted in a superior decision outcome.

3. Managerial expertise and reasoning preference, as expected, did not have an effect on the strategic decision and the number of alternatives, criteria, and action plans, but reasoning strategy had an unexpected effect on these decision making and analysis factors. Also, criteria and alternatives were found to be strongly related to the strategic decision.

The next section provides a detailed discussion of these findings as responses to each of the three research questions. The subsequent sections include a summary of contributions as a critical analysis of the findings in terms of the theoretical and practical implications, the limitations of the study, and suggested directions for future research.

Findings

Research question 1: What effects do managerial expertise and reasoning strategy have on reasoning preference?

Participants in this study were randomly assigned to two reasoning strategy groups to ensure a priori equivalence between the two groups. A total of 114 participant responses were included and analyzed in this study. There were 59 participants in the forward reasoning group and 55 in the backward reasoning group. All participants in this study were considered to be expert managers as they had significant amount of work experience and held upper-level organizational positions. However, there were differences among the participants in terms of their management experience, organizational position, and management education. As such they were further categorized into two levels of experts: Senior managers and middle managers. In the forward reasoning group there were 13 senior managers and 46 middle managers, and in the backward reasoning group there were 13 senior managers and 42 middle managers. Managers in both reasoning strategy groups were given a brief description of forward and backward reasoning, and asked to provide their preference on a five-point Likert scale. The results show that, as expected, reasoning strategy did not have a significant effect on reasoning preference. A pre-experiment concern was that the grouping by reasoning strategy could bias reasoning preference. For instance, participants in the forward reasoning group could be influenced by the sequence of the reasoning (analysis first, decision second) and would report a preference for forward reasoning. This phenomenon is often referred to as the Hawthorne effect, which is a significant observation that has no causal basis but it is due to participants changing their behaviour in response to the fact that they are being studied (Adair, 2001). The lack of this effect in this study further strengthens the nature of equivalence between the two groups.

The important finding here is that, as expected, managerial expertise had an effect on reasoning preference, but the nature of the effect was unexpected. Senior managers preferred mostly backward reasoning and middle managers were divided between mostly forward and mostly backward reasoning. Specifically, more than two-thirds of senior managers (69.2%) and only a little more than one-third of middle managers (37.5%) preferred mostly backward or almost all backward reasoning. But nearly half of middle managers (46.6%) preferred mostly forward or almost all forward reasoning. This difference can be explained through a re-examination of system 1 and system 2 processes of decision making, and the interaction of these systems in forward and backward reasoning. Research in management has identified two basic systems of decision making.

System 1 is intuition-based and effortless as it relies on mental shortcuts or heuristics. system 2 is reasoning-based and effortful as it uses deliberative, rule-based processes (Stanovich & West, 2002). In familiar situations, expert managers routinely rely on system 1 decision making (Gigerenzer & Selten, 2001; Klein, 1997), but in unfamiliar or complex situations, expert managers make an effort to use system 2 decision making (Kahneman, 2003b). Cognitive science research has further identified two contrasting strategies of reasoning. In the forward reasoning strategy, one reasons from data to hypothesis (i.e., solution or decision), and in the backward reasoning strategy, one reasons from hypothesis to data (Patel et al., 2005). Although system 1 and system 2 are defined as competing thinking processes (intuition versus reasoning), they often interact with each other. Isenberg (1984) found that senior managers "rely heavily on a mix intuition and analysis in their decision making" (p. 1) and often bypass analysis to come up with quick solutions. For instance, in a problem situation, system 1 can quickly and automatically propose an intuitive decision to the decision maker, but system 2 can then be engaged by the decision maker to evaluate the situation slowly and deliberately and if convinced that the intuition is wrong can correct or override the initial decision. (Sanfey & Chang, 2008). This is, in essence, an example of backward reasoning. Similarly, the inverse interaction, system 2 followed by system 1, is an example of forward reasoning. Hall (2002) stated that "intuition and uncertainty are inescapable conditions of many instances of clinical decision making" and that "physicians and students are generally unaware of these influences" (p. 1).

Research in decision making has found that the proportion of managers with a preference for intuition is likely to increase with seniority (Sadler-Smith & Shefy, 2004).

In management practice, business instinct is often touted as an important factor in singling out successful performers and that intuition is needed increasingly as people climb the corporate ladder (Hayashi, 2001). Managers in this study were asked to select their reasoning preference on a five-point Likert scale. Forward reasoning was described to them as, when faced with a problem, “people first carefully analyze a situation and then make a decision.” Backward reasoning was described as “people first quickly scan the situation and make an initial decision, and then they analyze the situation to either support or change their initial decision.” Einhorn and Hogarth (1986) have suggested that forward thinking depends on formulation and backward thinking is driven by intuition. Considering their predisposition to use intuition in making the initial decision, senior managers would have preferred backward reasoning. Middle managers, although experts in their own right, are not as experienced or highly-positioned as their senior counterparts and are in the midst of developing their intuitive decision making skills. This would explain their divided preference between forward and backward reasoning, with a slight preference for forward reasoning. The variation between middle and senior managers found in this study can be interpreted as following: The higher the level of managerial expertise the stronger the preference for backward reasoning.

But this interpretation, that senior manager (i.e., higher level of experts) prefer backward reasoning, does not seem to support research from other domains. For example, research in medicine has found that expert clinicians reported using forward reasoning when making a diagnosis in familiar problem situations, but both expert and novice clinicians reported using backward reasoning in unfamiliar or complex situations (Patel et al., 1994; Patel & Groen, 1986, 1991). Studies from medicine and other domains have in fact “identified that forward reasoning, from data to solution, as a hallmark of expertise” (Norman & Schmidt, 2000, p. 723). An explanation for this discrepancy could be that expert managers in this study were simply surveyed for their reasoning preference whereas the reasoning of expert clinicians was actually observed while they were solving problems. A comparison of reasoning preference with reported reasoning would not be valid. Unfortunately, the literature search did not yield studies from any domain that surveyed reasoning preferences of experts. But some researchers have questioned the validity of the forward reasoning orientation of medical experts. For example, in a comprehensive review of clinical reasoning, Norman (2005) stated “one thing is clear. There is no such thing as [a preferred mode of] clinical reasoning; there is no one best way through a problem” (p. 426). Even the earlier proponents of forward reasoning in clinical experts have since noted that although there is general agreement that there are two basic modes or types (forward and backward) of reasoning, “real-world” reasoning “does not appear to fit neatly into these basic types” (Patel et al., 2005, p. 730).

Based on the review of expertise literature, it was assumed at the outset of this study that expert managers are similar to experts in general. Ericsson et al. (2007) noted that expert performance “is the product of years of deliberate practice and coaching” (p. 114) and this process-based outcome also applies to the practice of management. The literature also emphasized that “both in the laboratory and in practice, expert intuition and expert analysis combine to produce expert performance” (Prietula & Simon, 1989, p. 122), and proposed that “thinking backwards [backward reasoning] is largely intuitive and suggestive; it tends to be diagnostic and requires judgment” (Einhorn & Hogarth, 1987, p. 66). Overall, research has shown that in unfamiliar problem situations experts actually use backward reasoning (Patel et al., 1994; Patel & Groen, 1986, 1991) and do not follow the rational model of forward reasoning (Isenberg, 1984, 1986). In such situations, lack of previous knowledge does not allow expert managers to use strong methods (forward reasoning) and requires them to using weak methods (backward reasoning). The finding from this study that higher level of expert managers prefer backward reasoning is a confirmation of these streams of research.

Research question 2: What effects do reasoning strategy, managerial expertise, and reasoning preference have on the go/no-go decision?

The results show that, as expected, managerial expertise and reasoning preference did not have an effect, but reasoning strategy had an unexpected and significant effect on the go/no-go decision, which was to launch the new product (go) or to not launch the product (no-go). Majority of the managers in the backward reasoning group (58%) decided to launch the new product, while only a minority of managers in the forward reasoning group (36%) decided to launch. In business situations, go/no-go decisions are usually major investment choices with only two alternatives, and are typically the responsibility of upper-level management. According to Jacobson (1987), the two most basic factors in business investment decisions are risk and return, and managers expect higher returns for higher risk decisions. Decision making researchers have found that managers will take additional risks to avoid a decrease in performance but will try to minimize or even avoid risks to improve performance (Kahneman & Tversky, 1979). Although launching a new product (a go decision) can improve the performance of a business organization (Cooper, 1984), it can also be considered a riskier and costlier option (Di Benedetto, 1999), and in such a situation managers will try to minimize the associated risk and costs (Huchzermeier & Loch, 2001). According to Davis (2002), product development and launch decisions can be categorized as a function of market and product risk and expected return, and a newly defined product using new technology is considered to pose the highest market and product risk. By making a decision not to launch, managers in the forward reasoning group made a decision that exhibited risk avoidance, confirming previous research. But those in the backward reasoning group made the decision to launch, a risk taking decision. Given the only difference between the two groups was the mode of reasoning, this finding can be interpreted as follows: Forward reasoning results in a risk-averse decision while backward reasoning results in a risk-taking decision. Evidence that reasoning strategy can result in greatly different decisions (go versus no-go) is a significant finding and requires further explanation.

Tversky and Kahneman (1991) suggested that in most domains where sizes of losses and gains can be measured, people value moderate losses roughly twice as much as equal-sized gains. This tendency is called loss aversion and it strongly favours the avoidance or minimization of risks. Loss aversion could explain why managers in the forward reasoning group were risk-averse. Managers in this group were required to list alternatives and criteria before stating their decision. All alternatives inherently have associated consequences or disadvantages and advantages (Cyert, Simon, & Trow, 1956) and loss aversion could have caused managers to over-value the disadvantages associated with the alternatives, and inclined them to favour inaction and status-quo (i.e., the risk-averse decision to not launch the new product). However, the premise of loss aversion did not seem to apply to managers in the backward reasoning group. Here the explanation could be that these managers were asked to state their decision upfront without considering other alternatives. They would have not had the same opportunity as the managers in the forward reasoning group to generate and evaluate other alternatives. They might have intuitively selected their initial decision, their first and only alternative, as it would have had the least amount of perceived disadvantages (Klein, 2003), thus favouring action and change (i.e., the risk-taking decision to launch the new product) over inaction and status quo.

Managers in decision making situations are also vulnerable to biases that can alter their risk taking propensity. Kahneman and Lovallo (1993) found that "decision makers are excessively prone to treat problems as unique" (p. 17), a condition they termed isolation error, and as a result susceptible to two specific biases: scenario anchoring and risk pooling. Decision makers either anchor on future success scenarios rather than past results and become overly optimistic, or they consider only the risk associated with a single situation and become overly timid. Managers in the backward reasoning group, with no past knowledge of the industry in the case study, could have been biased by scenario anchoring. Asked to state their decision upfront, they might have considered only on the most positive outcome scenario and made a decision that was overly optimistic. On the other hand, managers in the forward reasoning group, who also did not have any industry knowledge, had the opportunity to consider additional alternatives and even evaluate those alternatives against criteria to determine the consequence of each alternative. This additional analysis could have biased them to focus mostly on the risks associated with this single problem situation and led them to make a decision that was overly timid.

Given the only difference between the two groups was the ordering of the templates, the finding that reasoning strategy has an effect on the go/no-go decision is significant. As mentioned earlier in the methods section, case commentaries from four subject-matter experts were used to prepare the coding templates. All four experts favoured launching the new product (three unconditionally and one conditionally), which was also the decision favoured by majority of participants in the backward reasoning group. A similar result was also noted in the pilot experiment preceding this study. Patel et al. (2005) found “data-driven [forward reasoning] is successful only in constrained situations in which one’s knowledge of a problem can result in a complete chain of inferences from the initial problem statement to the problem solution” (p. 732), but that forward reasoning breaks down when case complexity or uncertainty is introduced. All participants in this study were unfamiliar with the problem situation and it would have been counterintuitive for the managers in the forward reasoning group to follow the templates in the order they were presented. Gigerenzer (2007) has argued “proof that expected-utility calculations are the best form of clinical reasoning does not exist, and there are even reports that they do not always lead to better decisions” (p. 168). He proposed that decision procedure based on simple heuristics often yields better results than a decision procedure based on logical calculation. A considerable amount of management research has suggested that intuitive decision making is inferior to rational decision making (Kahneman, Slovic, & Tversky, 1982; Schoemaker & Russo, 1993), but a growing amount of research has also suggested that for certain people in certain situations, intuitive decision making may be superior to rational decision making (Blattberg & Hoch, 1990; Dane & Pratt, 2007; Khatri & Ng, 2000). Similar findings have been reported in cognitive science research, where in a variety of problem situations intuitive judgment outperformed analytical reasoning (Ambady & Rosenthal, 1992; Berry & Broadbent, 1988; Schooler & Melcher, 1995; Wilson & Schooler, 1991). As mentioned earlier, relative to forward reasoning, backward reasoning is more heuristic- and intuition-driven (Einhorn & Hogarth, 1987). Although participants in both reasoning strategy groups were asked to consider the same case study and respond to the same questions, it was the direction of the reasoning that made the difference in their decision outcome. If the decision of launching the product in this case study, favoured unanimously by four subject-matter experts, can be considered as the superior or better outcome, then participants who reasoned backwards made a superior decision than participants who reasoned forwards. In other words, in an unfamiliar problem situation, backward reasoning results in better decision making. This finding supports previous educational psychology research, which found that in unfamiliar problems situations, expert physicians make better diagnoses using backward reasoning (Patel et al., 1990).

Research question 3: What effects do reasoning strategy, managerial expertise, and reasoning preference have on the strategic decision, alternatives, criteria, and action plans?

The results indicate that there is a relationship between reasoning strategy and strategic decision, alternatives, criteria, and action plans. These findings were unexpected. In a competitive business environment, the purpose of strategy is to create a unique, valuable, and defensible position for the company (Porter, 1996). Managers make strategic decisions about customers, employees, resources, and products to enable the strategy of the company (Andrews, 1987). In new product development and launch situations, a strategic decision involves selecting a target market, defining product features, and establishing organizational competence (Eisenhardt, 1999). For this study, the participant responses were coded using these three attributes of strategy (target market, product scope, and organizational structure) resulting in a strategic decision that was measured on a five point scale (stop R&D, status quo, field test, partial launch, and full launch), in increasing level of risk. According to Bonabeau, Bodick, and Armstrong (2008), in the pharmaceutical industry early stages of new product development (e.g., laboratory or field testing) contain less risk than later stages (e.g., partial or full launch). Launching a new product based on a new technology is considered a riskier and costlier option (Davis, 2002; Di Benedetto, 1999) than laboratory or field testing, and a full (a broad line of product to mass target market) launch is riskier as it requires higher development, marketing and distribution costs than a partial (a limited line of product to a niche target market) launch. Compared to the go/no-go decision, the level of detail in a strategic decision provides deeper insight into how reasoning effects the decision outcome. Of the 58% managers in the backward reasoning group who favoured a go-decision, about two-thirds (19 out of 32) decided on a full launch, the riskiest of decisions on the five-point scale. Of the 36% managers in the forward reasoning group who favoured a go-decision, about two-thirds (13 out of 21) decided on a partial launch, a relatively less risky decision. Forward reasoning led to fewer product launch decisions and the majority of the launch decisions were lower risk. Backward reasoning led to more product launch decisions and the majority of those decisions were higher risk. This finding can be interpreted as follows: Reasoning strategy not only has an effect on the decision to launch a product (i.e., go/no-go decision) but also on the decision of how and where to launch the product (i.e., strategic decision). This is an insightful finding as it provides evidence that reasoning has a much deeper effect on the decision outcome including the plan of action needed to execute the decision.

Compared to the forward reasoning group, managers in the backward reasoning group generated more alternatives, considered less criteria, and made more action plans. Managers in the forward reasoning group were required to list alternatives and criteria prior to stating their decision. The upfront generation of alternatives could have influenced these managers to make a decision that might have been different if none or fewer alternatives were listed. Redermeier and Shafir (1995) found that “adding new options can increase the probability of choosing a previously available alternative or, in particular, of maintaining the status quo” (p. 304). Majority of the managers in the forward reasoning group preferred a decision that was closer to status quo (to not launch the product). Managers in the backward decision group were required to state the decision first and then list the alternatives and criteria, but were not given an opportunity to change their initial decision afterwards. Rollier and Turner (1994) found that in a planning task, significantly more ideas were generated in the retrospective thinking (backward reasoning) mode than in the prospective (forward reasoning) mode. On average, managers in the backward reasoning group generated significantly more alternatives (3.18) than managers in the forward reasoning group (2.66). An influential management study found that managers in a high velocity (new technologies-based) industry who made superior decisions developed relatively more alternatives (Eisenhardt, 1989). As noted earlier, a majority of the managers in the backward reasoning group preferred a decision that was considered superior. But the findings from the literature are contradictory: It is not clear if additional alternatives hinder (Redermeier & Shafir) or help (Eisenhardt) decision making. Even though results from this study support certain aspects of the literature, it is not possible to explain the difference between the two reasoning groups based solely on the number of alternatives.

There was also a significant difference in the average number of criteria between the two reasoning groups. Managers in the forward reasoning group considered more criteria (3.29) than managers in the backward reasoning group (2.64). Studies have found that effective decision makers not only generate multiple alternatives, they also compare the alternatives simultaneously (Eisenhardt, 1989, 1999) and such a process is related to a more effective decision outcome (Dean & Sharfman, 1996). But the number of criteria in an evaluation can also be detrimental to the decision making process. According to Saaty (1987), "a complex decision based on a number of criteria requires trade-offs among the criteria to derive the best alternative of choice. … Sometimes people make decisions by satisfying criteria one at a time. They focus on alternatives that satisfy the most important criterion and eliminate the remaining alternatives. … [which] may not lead to the best alternative" (p. 157). Required to consider alternatives and criteria prior to making the decision, managers in the forward reasoning group could have been overwhelmed by the higher number of tradeoffs and might have settled for an alternative that would have satisfied their most important and overriding criterion. About 60% of the managers in the forward reasoning group listed brand as a criterion. A critical issue in the business case study was that the proposed new product is inferior in quality and can hurt the company's brand recognition. According to Quelch and Kenney (1994), "most managers will extend a line [an existing product brand] than before they will invest the time or assume the career risk to launch a new brand" (p. 156). If brand was the overriding criterion, it makes sense why most managers in the forward reasoning group decided not to launch the new product. According to Klein (1993), intuitive decision makers rely on their experience and can identify a viable solution or make a feasible decision without comparing the relative benefits and costs of multiple alternatives. Managers in the backward reasoning group were required to state their decision and then list alternatives and criteria. As such they would not have had the opportunity to explicitly evaluate their initial decision and additional alternatives against a set of criteria. Even if they did conduct an implicit evaluation, it is interesting to note that only 40% of the managers in the backward reasoning group listed brand as a criterion. Using the overriding criterion argument, it makes sense that most of these managers decided to launch the new product. Therefore, the evaluation of the alternatives against the criteria is a more persuasive explanation for the difference in the strategic decision between the two reasoning groups.

Finally, there was a significant difference in the average number of action plans between the forward reasoning (1.46) and backward reasoning (2.02) groups. A majority of the managers in the forward reasoning group made a strategic decision that was closer to status quo, which by nature requires less action planning. On the other hand, majority of the managers in the backward reasoning group made a strategic decision that was less status quo and more action oriented thus requiring more action planning. The smaller number of actions in either group was a concern, however, as Isenberg (1986) found managers came up with action plans while making decisions, and Mintzberg (1975) noted that managers in general have an orientation for taking early action and linking action to decisions. A review of the coded data found that although most participants wrote at least three action plan items, there was some overlap among those items, which reduced the overall number of mutually exclusive action plan items. The resulting action plans were significantly correlated with the strategic decision and alternatives for both reasoning groups confirming the strong link between decision and action. All four of the decision making and analysis factors – strategic decision, alternatives, criteria, and action plans – emerged as independent determinants of reasoning strategy, suggesting that reasoning strategy can be predicted by these four interrelated factors. It is worth noting that in terms of predicting the reasoning group strategy, criteria had the most weight and that alternatives and criteria accounted for two-thirds of the weighting. These findings provide additional insights into the relationship between reasoning strategy and decision making, and into the relationship among decision analysis factors. The findings can be interpreted as follows: Reasoning strategy effects alternatives and criteria, and interaction of alternatives and criteria that, in turn, effects the strategic decision, which then effects the action plans. This chain of inference is an important finding as it provides evidence on how reasoning strategy modifies the decision outcome.

This study has essentially affirmed that the nature of expertise in management is similar to expertise found in other domains. Although management does not formally qualify as a profession, expert managers exhibit characteristics similar to experts in recognized professions. Expert managers' preference for backward reasoning in unfamiliar situations indicates their reliance on well-established declarative and procedural knowledge, and the influence of reasoning strategies on decision outcomes indicates their vulnerability to lack of domain- and situation-specific declarative and procedural knowledge. Greeno (1978) stated "the processes used to generate concepts and procedures in novel situations probably correspond to general problem-solving skills, and individuals who have those skills in a strong way are probably very strong problem solvers" (p. 266). This implies that strong skills for solving well-defined transformation problems would require understanding of general problem solving procedures that could be applied in a domain with minimal knowledge of that particular domain. The findings of this study suggest that this implication can be extended to ill-defined problem situations, such as business problems. Put another way, when expert managers lack domain-specific knowledge they use general problem solving strategies to fill in their knowledge gap. This study has confirmed that expert performance in management is dependent on the process of reasoning, just as it is in other domains. As stated earlier, decision making is arguably the most important job of a manager. This study has shown that it can also be the easiest one to get wrong. It is therefore critical to continue the study of reasoning and its effect on managerial decision making.

Summary of Contributions

This study contributes to knowledge in management and educational psychology research. Specifically, this study has provided evidence that:

1. Expertise is related to reasoning preference. In areas of unfamiliar knowledge, senior managers, who have a higher level of expertise than middle managers, prefer backward reasoning to make decisions. Middle managers do not have a strong preference for either mode of reasoning. This confirms previous management research that senior managers prefer an intuitive-driven decision making process, but it challenges educational psychology research that forward reasoning is the defining characteristic of expertise in general.

2. Reasoning strategy can modify the decision outcome. In an unfamiliar problem situation, forward and backward reasoning strategies result in different decision outcomes. Forward reasoning results in a risk-averse decision and backward reasoning results in a risk taking decision. In such situations, backward reasoning also results in a superior decision outcome. This confirms management research that intuitive decision making in certain circumstances is superior to rational decision making. It also supports educational psychology research that, in unfamiliar problem situations, backward reasoning leads to better decision making.
3. Reasoning strategy modifies decision outcome via decision analysis. The amount of decision analysis (evaluation of alternatives against criteria) has an effect on decision outcome. Forward reasoning leads to increased decision analysis, which results in a risk-averse decision. Backward reasoning leads to decreased decision analysis resulting in a risk taking decision. This confirms management research that risk-oriented decision are influenced by the amount of decision analysis.
4. This study can also inform and improve the practice of managerial decision making. Unlike purely rational frameworks (i.e., forward reasoning) prescribed in the normative management literature, this study acknowledges the usage and importance of hypothesis-driven or intuitive-based approaches to decision making. Most importantly, the findings make a strong case for encouraging managers to consider backward reasoning as a framework for strategic decision making in uncertain problem situations.

Research in cognitive science has long studied the process of reasoning in a number of professionalized domains such as physics and medicine. Achieving expertise in these domains requires formal education and practice. By studying reasoning strategies in management, a domain where expertise is usually gained without formal education and through informal experience, this study has provided new insights into the nature of expertise and decision making.

By examining the effect of reasoning strategy on decision outcome, this study has added to the understanding how a decision analysis process can influence the decision making outcome. Research in educational psychology has mainly looked at how experts and novices reason in familiar and unfamiliar situations. To date, there has not been a study that has controlled the mode of reasoning in experts to see if the change in the decision process would have an effect on the decision outcome. The discovery that the reasoning process can actually be guided and that the directionality of the process can vary the outcome is a major finding and significant contribution to research in managerial decision making and expert problem solving. Most importantly, this study challenges the normative literature in managerial decision making. Research and education based on this literature prescribes forward reasoning strategies for decision making in all problem situations. By systematically studying reasoning strategies with expert managers, this study has concludes that, in unfamiliar and complex situations, it is in fact backward reasoning that results in more effective decision making.

Study Limitations

The strength of this study is in the areas of sample selection (representative participants) and grouping (random assignment), and the method of data collection (task-based). The subject selection was such that it gathered a strong pool of the target audience, i.e., expert managers from a diverse set of industries. The grouping of the participants in a random method ensured equivalence between the groups. The use of a short business case study and response templates, along with strict time limits, elicited the appropriate cognitive task-oriented data.

But there are also a number of limitations in this study. These limitations are due to weaknesses in both the theoretical and methodological aspects of this study. Specifically there are eight limitations that are worth noting:

1. Only two contrasting forms of reasoning, forward and backward, were examined. Research in medical reasoning has also found that experts often combine reasoning strategies during problem solving and decision making processes. A more comprehensive study would require that such combined forms of reasoning be examined alongside forward and backward reasoning.
2. Participants were given a disguised business case study and guided through the use of templates to follow either a forward or backward reasoning strategy. This format is not truly reflective of a naturalistic situation. Either a real-life problem situation and/or an unguided approach or at least a third, unguided group could have been included to find what reasoning approaches would have been naturally used (i.e., without the use of templates) by those participants, and if the decision outcomes would have been different.
3. The case study presented participants with an unfamiliar problem situation. An examination of reasoning in a familiar problem situation could have yielded additional insights into the decision making process of expert managers.

4. Participant responses in this study were elicited under strict time constraints, which is again not akin to naturalistic decision making. Given differences in reading comprehension abilities, it is unclear if all participants had an opportunity to properly review and understand the content of the case study, as well as had enough time to satisfactorily respond to the questions on the analysis and decision templates.
5. The coding template was prepared using comments provided by four subject-matter experts and the results from the pilot study. The analyses and decisions of four experts did not fully reconcile with each other and with the results from the pilot study. Thus, a certain amount of interpretation and judgment was used by the author of this study to finalize the coding template. It would have been ideal to use a research-tested coding template or rubric. Unfortunately, given the nature of this study such an instrument was not available.
6. Although the number of participants in each reasoning group was sufficient to conduct statistical analysis, the breakdown between senior managers and middle managers was unbalanced. There were only 13 senior managers in each group. A larger number of senior managers in the study would have further strengthened the reliability of the results.
7. This study examined decision making at the individual level only. The process leading up to the decision often involves discussion in a group or team-based setting. In these settings, there are added factors that need to be examined, such as group interaction, information sharing and social cognition.

8. Finally, this study included only expert managers (i.e., senior and middle managers). A study of novice managers (e.g., junior managers, graduate and undergraduate business students) making decisions using different reasoning strategies could have provided a helpful comparison as well as useful insights into the decision making processes.

Future Research

This study has established a platform for future research in reasoning strategies used in managerial decision making. The limitations, as noted above, should provide researchers with an opportunity to test the findings of this study under different problem situations and with different audiences. There are two avenues of research that can be pursued. The first is incremental as it is similar to the study undertaken in this thesis. The second is considerable as it is much larger in terms of scale and scope:

1. The effect of forward and backward reasoning should be examined in a variety of other problem situations, familiar and unfamiliar, to ascertain the robustness and reliability of the results of this study.
2. Reasoning strategies should be examined in true naturalistic settings. This means that managerial reasoning should be studied in authentic work environments where both novice and expert managers, individually and in groups, can be observed making actual decisions in real-life problem situations.

Conclusion

This study is the first attempt at examining the effect of forward and backward reasoning on managerial decision making. Reasoning is the cognitive process through which managers solve business problems and make management decisions. Research in management has identified two systems of decision making. System 1 is experience- and intuition-based and system 2 is analysis- or reasoning-based. These systems compete as well as interact with each other during decision making situations. When faced with a familiar problem situation, expert managers rely mainly on system 1, but in an unfamiliar situation they switch mostly to system 2. Intuition, or system 1 decision making, is considered important for managers especially at the more senior levels of management. Reasoning, or system 2 decision making, can be further divided into two modes. Studies in medicine have found that expert clinicians use forward reasoning when faced with familiar problem situations but both experts and novices use backward reasoning in unfamiliar or complex situations.

The purpose of this study was to examine the effect of reasoning on expert managers in an unfamiliar decision making situation. Expert managers were randomly assigned to one of two, forward and backward, reasoning groups. Based on their experience and education, the managers were also categorized into two levels of expertise: senior managers and middle managers. In addition to providing their background information, all managers were asked to read a business case study and write down their responses using either a forward reasoning template (alternatives, criteria, decision, action plans) or a backward reasoning template (decision, action plans, alternatives, criteria). Finally, all participants were asked to identify their reasoning preference. A coding template was prepared using responses from four subject matter experts as well as results from a previously conducted pilot study. Two independent coders were used to code the participants' responses and a third independent coder was used to resolve the discrepancies between the first two coders. A series of statistical techniques and tests were used to analyze the coded data.

The results of this study yielded three main findings. The first finding is that managerial expertise is related to reasoning preference. Senior managers reported a strong preference for backward reasoning while middle managers did not have clear preference. The second finding is that reasoning strategy is related to decision outcome. Managers in the forward reasoning group made a risk-averse decision while managers in the backward reasoning group made a risk taking decision, and that backward reasoning resulted in a superior decision outcome. The third and final finding is that reasoning strategy influences decision outcome through decision analysis. Forward reasoning resulted in fewer alternatives and more criteria, while backward reasoning resulted in more alternatives and fewer criteria. The evaluation of the alternatives against the criteria was a key factor in influencing the decision outcome. The four factors of decision analysis - strategic decision, alternatives, criteria, and action plans – were also predictors of reasoning strategy, with criteria and alternatives emerging as the most important predictors.

Unlike other domains, management spans several sub-domains or functions. Expert managers are required to have knowledge of each of these functions as well the ability to think cross-functionally. Also, management is not considered a formal profession and expert managers are not required to be formally trained and accredited.

Given the added complexities and differences, it is remarkable that these findings from management support cognitive science research in other domains. Previous research has shown that experts in familiar situations use forward reasoning but in unfamiliar situations revert to backward reasoning, which results in better outcomes. By finding such similarities, this study has provided further evidence that the common dimensions of expertise are generalizable and replicable in the domain of management.

Findings from this study are expected to provide a new basis for future research as well as practice in expertise, reasoning, and decision making. These findings should encourage educational psychology researchers to study the vast domain of management. Researchers could test existing theories in cognitive science and further develop the theory of expertise. These findings should also inform management educators on how effective reasoning approaches can be taught in business schools and management programs. Instead of relying on biased intuitions and flawed conventional wisdom, managers can be taught effective and scientifically proven modes of reasoning. It can change the way managers think. They can be made aware of both forward and backward reasoning strategies and asked to apply these modes of reasoning in both familiar and unfamiliar decision making situations. Such deliberate practice can help novice managers to build their expertise and can inspire expert managers to consider appropriate reasoning strategies to help them make even better decisions.

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Appendix A: Certificate of Ethical Acceptability of Research Involving Humans (McGill)

Appendix B: Letter of Approval of Thesis Proposal (Queen's)

Appendix C: Informed Consent to Participate in Research (McGill)

Principal Investigator: (Main Study)	Salman Mufti, Queen's School of Business smufti@business.queensu.ca 613.533.3158
Faculty Supervisor:	Susanne Lajoie, McGill Faculty of Education susanne.lajoie@mcgill.ca 514.398.4242

Dear Participant,

This consent form should give you a basic idea of what this study is about and what your participation will involve. If you would like more details about something mentioned here, or information not included here, please feel free to ask or contact me by e-mail (smufti@business.queensu.ca).

The purpose of this study is to understand cognitive processes used by experienced managers as they attempt to analyze a complex business situation. If you agree, your participation will contribute to our knowledge of managerial decision-making. The preliminary results of this study will be presented next week in our Managerial Decision Making session here at Queen's University and the data and results will be used in my research at McGill University.

You will be asked to read a business case and respond in writing to specific questions. You will be requested to follow instructions as closely as possible. There are a few steps in the process and each step has an allotted time limit that will be announced during the study. The overall duration of this session is 60 minutes.

All individual data from this study will be kept confidential and only the aggregated data will be used for teaching and research. Your identity will remain anonymous in the data interpretation phase as well as in storage of data. Participation in this study entails no cost or foreseeable danger to you. You are free to refuse to participate in the study without fear of any negative consequences and are free to withdraw your consent and discontinue your involvement at any time, without any penalty.

I have read this form and understand what my participation involves.

______________________________	______________________________
Participant name (please print)	Signature and date

Appendix D: Informed Consent to Participate in Research (Queen's)

Principal Investigator: Salman Mufti, Queen's School of Business
smufti@business.queensu.ca 613.533.3158

Dear Participant,

The purpose of this study is to understand cognitive processes used by experienced managers as they attempt to analyze a complex business situation. If you agree, your participation will contribute to our knowledge of managerial decision-making. The preliminary results of this study will be presented next week in our Managerial Decision Making session here at Queen's University and the data and results will be used in my research at McGill University.

You will be asked to read a business case and respond in writing to specific questions. You will be requested to follow instructions as closely as possible. There are a few steps in the process and each step has an allotted time limit that will be announced during the study. The overall duration of this session is 60 minutes.

Participation in this study entails no cost or risk to you. Participation is voluntary and you are free to refuse to participate in the study or withdraw during the study, or have your information withdrawn after the study, without fear of any negative consequences. Your form will have a number written on the top right corner which matches the number on a separate card provided in the envelope. Please hold onto the card. Should you wish to have your submitted form withdrawn from the study at a later date, please contact me with the number and your submitted form will be removed and destroyed. You are not obliged to answer any questions that you find objectionable or which make you feel uncomfortable.

All individual data from this study will be kept confidential and only the principal investigator will have access to the data. Your identity will remain anonymous in the data interpretation phase as well as in storage of data. The aggregated data will be kept in an electronic format in a password-protected computer. Only the aggregated data will be used for teaching and research. The research may be published in academic (management and/or educational) journals.

If you have any questions, concerns or complaints about the research procedures feel free to contact me (smufti@business.queensu.ca), Kelley Packalen (kpackalen@business.queensu.ca), Chair of the Unit Research Ethics Board, or Steven Leighton (greb@post.queensu.ca), Coordinator, Queen's University General Ethics Board.

Should you wish to participate in this study please read the following statement and print your name, date and sign below. Note there are two copies of this form. Please return one copy and keep the other copy for your records.

I have read this Letter of Information and have had any questions answered to my satisfaction. My signature below is meant to confirm that I understand that my participation is voluntary and that I am free to withdraw at anytime. Also my signature below is meant to confirm that I understand the provisions around confidentiality and anonymity.

Name (please print): ______________________ Date: ______________________

Signature: ______________________

Appendix E: Background Information Form

Please provide answers to all five (5) questions:

1. How many years of total work experience do you have?	
2. How many years of management experience do you have?	
3. Which title best describes your current position in the organization? Check only one.	○ Senior Executive ○ Vice-President ○ Director ○ Manager ○ Supervisor
4. Have you worked in any of the following industries? Check all that apply.	○ Medical Device ○ Healthcare (other than Medical Device) ○ Manufacturing (other than Medical Device)
5. Prior to this program, did you attend any of the following university-based programs or courses? Check all that apply.	○ BComm or BBA ○ MBA or Executive MBA ○ Executive Education

Appendix F: Business Case Study (Page 1 of 5)

Crescordia's products are respected the world over. Now, rivals have launched a radical—albeit still buggy—new technology. Can the company afford to sit out the revolution?

HBR CASE STUDY

Holding Fast

by John T. Gourville

"Now remember, with every blow of the hammer, you've got to feel the femoral nail advancing through the bone. If you don't, then for heaven's sake, stop. It might be impinging on the cortex or it might be too large for the canal. Keep whacking, and you'll fracture the cortex." The trainer's calm, authoritative voice boomed out across the room as a dozen orthopedic surgeons toiled away on the cadaver limbs laid out before them. Pausing to observe the technique of one of the surgeons, he glanced up to see his boss, CEO Peter Walsh, crack open the door and squeeze through, trying his best to be unobtrusive. The trainer glanced at the clock. "Okay, let's save some of this fun for the afternoon," he called out. "We'll meet in the lobby in ten minutes and walk over to lunch."

In addition to making a range of products from artificial hips to scalpels, Crescordia was one of a handful of major companies that developed, manufactured, and sold the steel and titanium plates, nails, and screws—known as fixation devices—that surgeons used to repair broken bones. At least twice a month, Crescordia hosted training sessions like this one for orthopedic surgeons who used the company's products. Walsh joined the group for lunch as often as possible. It was a great opportunity to connect with the physicians and hear firsthand what they liked and didn't like about Crescordia's products. Besides, he just plain enjoyed their company. Trauma surgeons tended to be brilliant but down to earth. With their hammers, saws, and drills, they were as much carpenters as they were doctors. Maybe because so many of the cases they saw were the result of bad luck, they had a certain perspective on the world. They tended to joke a lot when they got together, and if you could tolerate some morbid humor you found yourself laughing along.

After the air-conditioned chill and formaldehyde odor of the lab, the heat of the summer

HBR's cases, which are fictional, present common managerial dilemmas.

Appendix F: Business Case Study (Page 2 of 5)

day was a welcome change. Strolling along the paved path to the cafeteria, one of the surgeons launched into an account of a difficult case he'd seen that week. "Get this: The guy's a conductor—you know, with a symphony orchestra—so he really needs that wrist action." The surgeon flicked an imaginary baton upward by way of illustration. "So, of course, what does he manage to break his very first time on Rollerblades?" Walsh winced in sympathy. "On top of that, it's the same wrist he fractured five years ago, falling off his podium—and it was fixed that time with a distal radius plate." The rest of the group made sympathetic noises; no one liked having to remove old plates to implant new ones. "But wait—it gets worse. He's from Europe, just came here last year. And his surgeon must have fancied himself on the leading edge, because that plate was resorbable. Or, shall we say, it was *supposed* to be."

Now a great groan went up from the group, to the clear satisfaction of the surgeon. Everyone had a mental image of what he must have encountered, and it wasn't pretty. The idea behind resorbable hardware was a good one. Like dissolving sutures, resorbable plates and screws were made of biodegradable polymers that held up long enough to do their job—to support a healing bone—then gradually disintegrated harmlessly into the patient's body. The first and second generations of the technology were far from perfect, though, as the surgeon's case and many like it made clear. After five years, there should have been nothing left of the plate in the conductor's wrist—the key words being "should have."

"Let me guess," another doctor chimed in. "It looked like the hull of the *Titanic* in there." He sighed and shook his head. "And who knows if the resorbables on the market today are any better?" Walsh stiffened slightly and cleared his throat, anticipating what would come next.

Sure enough, someone posed the question right away. "So, when is Crescordia going to make a resorbable fixation system? You guys would do it right. Finally, I'd have the confidence to use the darn things on a regular basis."

Everyone looked at Walsh, but his response was as noncommittal as ever. "I wish we could give it to you today. But believe me, the science just isn't there yet. There's a reason those products are so buggy. And we wouldn't waste your time selling them to you. Our reputation—and yours—means too much to us."

Walsh then adroitly shifted the topic to what Crescordia would introduce next, and the conversation moved on. He relaxed again when they arrived at the bustling cafeteria and he could play host, offering pointers on what the various stations had to offer. As the trainees reconvened at the dining tables, Walsh sized up his seating options. Taking care not to spill his soup, he squeezed past a table with a group debating World Series prospects and joined a couple of surgeons who were obviously talking shop. One of them was using his turkey roll-up to describe a femur fracture he'd recently fixed. "So right here's where the blade plate had to go in," he was saying as he pressed a plastic knife through the pita. The fellow beside him interrupted. "And we're in a lateral position, right?"

"Yeah, yeah. Need to get the posterior exposure for this one." The surgeon guided the blunt plastic point expertly past a layer of Havarti and flicked at some shredded lettuce. "And the question is, Are these fragments here going to take to lag-screw fixation? Because, if so, that'll save me a lot of work." He studied his subject intently for a moment, then shoved it into his mouth.

Walsh laughed. "So much for that case!" he said. He wished he could eat with these guys every day.

Fixated on Quality

Later, in his office, Walsh returned to the challenge of resorbables. There was no question they would be great if they were reliable—and indeed Crescordia, along with many of its competitors, had been working on that problem for years. But were they ready for prime time? During internal trials, they still tended to fail about 8% of the time—sometimes disintegrating before the bone had fully healed and sometimes not fully disintegrating at all. Not exactly Six Sigma.

Unfortunately, not every company was so fussy. Walsh remembered the day back in the 1990s when he was stunned to find out that Innostat, an upstart competitor, was ready to launch a line of resorbable plates and screws. Walsh was confident he had the best scientists and R&D facilities in the business; could some geniuses have beaten them to the punch? Soon enough, the truth became clear, though

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Appendix F: Business Case Study (Page 3 of 5)

"Believe me, there's a reason those products are so buggy. And we wouldn't waste your time selling them to you. Our reputation—and yours—means too much to us."

it was only a partial relief: The product was even worse than what Crescordia could have put on the market at the time. Walsh made a strategic decision not to enter the fray and instead channeled resources into developing next-generation steel and titanium hardware. As the resorbables failed to deliver on their promise, Crescordia's market share and reputation grew.

But orthopedic surgeons, who'd been hearing for years that resorbables were right around the corner, were eager to use them. Some especially looked forward to using resorbables on children, so the kids wouldn't have to undergo a second operation for removal of the hardware after the bones healed, a common procedure in pediatrics. In patients of all ages, old plates and screws could sometimes shift or come loose, causing painful protrusions. Just enough of the current generation of resorbables worked, it seemed, to keep Innostat in business and everyone else in the industry continuing their research. Even Walsh had to admit that, were he a surgeon, he might occasionally take the risk of using a resorbable.

But Walsh wasn't a surgeon. He was the CEO of a company whose products were respected throughout the industry. Thanks to decades of refusing to compromise on quality, there were orthopedic surgeons out there who used nothing but Crescordia hardware. The company simply could not afford to do something and not do it right.

Under Stress

Walsh arrived at his office the next morning to a typical flurry of meetings, conference calls, and paperwork. It was ten o'clock before he found a chance to pop down to see Gary Miskimen, his head of R&D. Miskimen was in the testing lab at the moment, his assistant told Walsh. She offered to page him.

"No, no," Walsh said. "I'm heading that way anyway." Soon after, he found Miskimen and one of his managers, both in pristine lab coats, looking on as a technician operated one of the company's servohydraulic fatigue testing machines. The technician clamped a long, slender, metal screw into place, picked up her strain gauge and started the test.

Miskimen filled Walsh in, murmuring, "The new cannulated screw versus the standard cortex screw." They stood staring, scarcely breathing, as the tension built and built more. Finally, the screw snapped. Miskimen's eyebrows rose. "Not bad," he said. The technician grinned.

Miskimen turned to Walsh and gave him a proper greeting. "And what brings you down to the lab on this fine day?"

"Actually, I was just curious to know if there was any news on the resorbables front," Walsh answered. "I know we're not due for a status update, but the subject came up yesterday."

Miskimen looked to the manager beside him. "We just finished some trials on the latest prototypes, didn't we?" The manager hurried off to get the data.

"Don't get your hopes up," Miskimen said, as he and Walsh followed at a more measured pace. "It's not perfection." They walked along in silence for a few moments. Then Walsh spoke up.

"I think it may be time to step up our efforts. Let's say we delay those new compression plates and put Wilkins on the case and maybe Sid Stratton…" Walsh glanced at Miskimen for a reaction.

Miskimen rubbed his close-cropped beard, then shook his head. "Peter, the truth is we've done as much as we can with resorbables in the lab. I know you don't want to hear this, but we're not going to know what we need to know to make the product better until we get it out in the field. We need to get it into the surgeons' hands."

"And into the patients' bodies," Walsh said with a sigh. Miskimen was right; it wasn't what Walsh wanted to hear. But Walsh knew enough about the science to know Miskimen wasn't just making excuses. Metal plates were relatively straightforward to test. They were inert, nonreactive with body tissue, so what you saw in the lab was what you'd get in the human body. The whole point of resorbables, on the other hand, was to be reactive—to interact with the body and dissolve over time. But every body was different and it wasn't possible to replicate every individual's physiology in the lab.

The Governing Body

A week later, as Walsh approached the boardroom door for the executive committee meeting, the atmosphere seemed charged. Everyone had a strong opinion on the main topic the committee would be discussing today.

Probably most excited to see resorbables back on the agenda was Jane LaMott, vice pres-

Appendix F: Business Case Study (Page 4 of 5)

"If there is one thing surgeons hate to do, it's to go back in on a kid to remove an implant. They get no credit if it goes right and a huge headache if it goes wrong."

ident of sales. Walsh noted how antsy she seemed during Miskimen's R&D update and, as soon as Miskimen finished, gave her the nod to lead off the discussion.

"In the past few months, three of our top-tier accounts have placed substantial orders with Innostat," she said ominously. "And here's the kicker: They weren't just for resorbables. They included metal devices directly equivalent to ones that we sell." She went on to offer her analysis. These were surgeons who were doing some experimentation with resorbables, which they couldn't procure from Crescordia. "And once they turned to Innostat for resorbables—well, the camel's nose was under the tent."

Walsh leaned forward in his chair. "That's an important point, Jane. Having a resorbables option, even if limited, might prevent market share erosion in other areas."

Chief marketer Diane Robinson took her cue. "I couldn't disagree more," she said. "Our market share is a function of our reputation for quality. If we put out a product that isn't up to our standards, will people trust us with the rest of the product line?" She gave LaMott a conciliatory look. "Perhaps if we could move into this new technology in a very limited way—"

"Can't do it," Rob Bond piped up. As chief operating officer, he was acutely aware of the complexity of a new platform launch. "If we enter the market at all, we'll need to do it with the full set of implants—plates and screws in all relevant sizes—plus the hand and power tools to attach these implants." He nodded in LaMott's direction. "And you'll need an education offering to support them. And none of it has a chance of profitability if we can't scale production." That sent the group into a discussion of the retooling and inventory levels required, which quickly devolved into side debates.

"One conversation, folks," Walsh reminded them, then noticed that Miskimen was waiting patiently for the floor. He invited him to speak his mind.

"What about targeting just the pediatric market for a start?" Miskimen suggested. "It's a smaller range of sizes, and, from my perspective, it offers the greatest potential benefit to doctors and patients."

LaMott looked at Miskimen gratefully. "Not to mention the biggest source of demand," she said. "If there is one thing surgeons hate to do, it's to go back in on a kid to remove an implant. They get no credit if it goes right and a huge headache if it goes wrong. That's a terrific idea."

Up to this point, legal counsel Sam Maddox had hung back, observing the back-and-forth with an air of detachment. Now he made a face as though he were smelling sulfur. "Let me get this straight," he drawled. "We have a product that is probably substandard. We're expecting it to get better based on what we learn in the field. And our human guinea pigs are…children? Sounds like a field day for tort lawyers. Can't we try it out on old people or something?" He frowned thoughtfully. "Then again, I'm not sure I want my mother suing us, either."

What's In It for Us?

Walsh was glad he'd put the item on the agenda, even though the discussion was far from conclusive. The group tabled the resorbables debate until the next meeting, with various people promising to scare up relevant data.

The next day, however, Walsh had a morning of work scheduled with CFO Calvin Westbrook, and it struck him that Westbrook hadn't weighed in.

"I don't know, Peter," Westbrook admitted. "I'm no expert, but at this point I question the whole resorbables idea. Scientists have been promising us results for 20 years, and what do we have to show for it? It reminds me of that joke about Brazil: It's the country of the future—and always will be."

Walsh smiled. "But I think we're getting close. What if the market does materialize? It will be very fertile for whoever gets it right. I want Crescordia to be the one to make that happen."

"Well, there again, I'm not so sure," Westbrook said. "I was thinking about this last night. Let's assume the very best scenario—that we are the ones to get it right. Our resorbable implants succeed in the field and become the product of choice. Then, everyone responds and we see a gradual shift to the new technology. As I see it, we may be no better off."

"How's that?" Walsh asked.

"The margins will be only slightly better. But the retooling needed to make resorbables

Appendix F: Business Case Study (Page 5 of 5)

will be a huge capital expense." He sat for a few moments silently, letting Walsh ponder the point.

Walsh raised his head finally and stared at his colleague intently. "I get what you're saying," he said. "With the rest of the industry making no headway, why be in a hurry?"

"Exactly," said Westbrook. "Why usher out a golden era?"

Should Crescordia launch a resorbables offering?

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Appendix G: Decision Making Form A (Forward Reasoning)

Please respond to the following questions as briefly as possible. You have a maximum of 10 minutes to complete this page.

What decision alternatives are you considering? List two (minimum) to four (maximum):
1.
2.
3.
4.

What are your decision criteria? List two (minimum) to four (maximum):
1.
2.
3.
4.

Appendix H: Decision Making Form A (Backward Reasoning)

Please respond to the following questions as briefly as possible. You have a maximum of 10 minutes to complete this page.

What is your decision? State your decision and summarize the reason(s) for it. Be decisive!
Decision:
Reason(s):

What steps or actions are needed to implement your decision? State two (minimum) to four (maximum) steps without worrying about their order.
1.
2.
3.
4.

Appendix I: Decision Making Form B (Forward Reasoning)

<u>Please respond to the following questions as briefly as possible. You have a maximum of 10 minutes to complete this page.</u>

What is your <u>decision</u>? State your decision and summarize the reason(s) for it. Be decisive!
Decision:
Reason(s):

What steps or <u>actions</u> are needed to implement your decision? State two (minimum) to four (maximum) steps without worrying about their order.
1.
2.
3.
4.

Appendix J: Decision Making Form B (Backward Reasoning)

<u>Please respond to the following questions as briefly as possible. You have a maximum of 10 minutes to complete this page.</u>

What other decision <u>alternatives</u> could be considered? List two (minimum) to four (maximum):
1.
2.
3.
4.

What are the decision <u>criteria</u>? List two (minimum) to four (maximum):
1.
2.
3.
4.

Appendix K: Reasoning Preference Form

Please read the following and provide a response.

Reasoning is defined as a process through which people make decisions. There are two basic ways of reasoning:

- In the "forward reasoning" approach, people first carefully analyze a situation and then make a decision.
- In the "backward reasoning" approach, people first quickly scan the situation and make an initial decision, and then they analyze the situation to either support or change their initial decision.

On a scale of 1 to 5, which reasoning process best describes your decision making approach (please circle one number only):

1	2	3	4	5
Almost all forward reasoning	Mostly forward but some backward reasoning	A balanced mix of forward and backward reasoning	Mostly backward but some forward reasoning	Almost all backward reasoning

Appendix L: Business Case Study Commentaries (Page 1 of 4)

Case Commentary

by Robert A. Lutz

Should Crescordia launch a resorbables offering?

Certain aspects of Crescordia's dilemma feel all too familiar for those of us in the auto industry. First, there's the advice from legal counsel predicting "a field day for tort lawyers," words that cause senior executives everywhere to tremble. America's litigious culture has created a society in which a child's Batman cape carries a label that reads, "Warning: This does not enable the user to fly," and nobody seems surprised.

I'll put it as gently as I can: Contingency fee lawsuits and sky's-the-limit punitive damage awards are cancers eating away at society. Until there is considerable and meaningful tort reform in this country, true risk-taking innovation—the kind that moves a society forward in giant leaps—will suffer. The auto industry knows that as well as anybody else.

Another familiar enemy of innovation comes up at the very end: the all-powerful Voice of Finance. The CFO deftly pleads his case: Why make the huge capital expenditure necessary to innovate when we're already on top and the competition isn't making any headway?

That's a classic example of left-brained thinking shooting its pencil-sharp arrows straight into the heart of right-brained creativity. When all is said and done, more good ideas are snuffed out in the name of the bottom line than there are dollars saved in doing so. The best companies balance perspectives from both sides of the brain when making decisions. That way, the CEO has the greatest possible input before deciding whether to play it safe or leap into the fray. The creation of the Dodge Viper when I was at Chrysler is a good example.

The Viper wasn't new technology by any stretch. It was good, old-fashioned, American V-10 power. But it was a radical idea and certainly disruptive. There were those at Chrysler who, quite rationally, thought the budget could be spent more prudently. Let's face it: We weren't exactly printing money at that time. But those of us who looked at the idea from an emotional, right-brained perspective saw what the car could do for the company. Sure, we could've spent another $100 million on a glitzy ad campaign or on refurbishing our plants, but how would that set us apart from any other automaker? In the end, we decided to take the risk.

If I'd had any lingering doubts that we'd done the right thing (and I didn't), a Wall Street institutional-investor analyst put them to rest. In 1991, two years into the Viper program, he asked what we'd cut if things started going south, and I soberly replied, "Viper." "My God," he said. "You can't do that! This car's changing everyone's perception of the company. It's reestablishing confidence. It's the last thing you should cut!" And he was absolutely right.

Automotive hybrids are another good example of the need for careful balance. You have to weigh the questionable business case that hybrids present versus the reputational benefit of connecting emotionally with consumers and breaking new technological ground. The same applies to the fuel cell issue. Once a company like GM commits itself to hydrogen fuel cells as the future of automotive transportation, it will have to go at it the way we're doing it—full throttle, no excuses, large investment. We know exactly how Peter Walsh feels when he says the market "will be very fertile for whoever gets it right. I want Crescordia to be the one to make that happen."

Now, I'm not saying that all decisions should be based on right-brained thought. Risks need to be carefully calculated, not foolishly hazarded. But it takes instinct, common sense, creativity, and a risk-taking mind-set to know when to take the plunge—any plunge. The problems occur when the left-brainers wield too much power in senior management.

Robert A. Lutz is General Motors' vice chairman of global product development.

Appendix L: Business Case Study Commentaries (Page 2 of 4)

Case Commentary

by Clayton M. Christensen

Should Crescordia launch a resorbables offering?

Resorbable implants are a textbook example of a *disruptive technology*—my term for products that promise to render current technology obsolete but that aren't yet good enough to be used in mainstream applications. Therefore, Crescordia stands at the fork in the road that all established companies face when a disruption emerges in their industry. One possible direction to take is to commercialize the disruption as a sustaining technology that helps the company's mainstream customers do what they're already doing, only better. The other is to commercialize it as a disruption.

The sustaining direction entails keeping the technology in the lab and spending large amounts on R&D until the new product is better than the existing technology. This is the direction Walsh favors when he suggests that it's "time to step up our efforts" on the R&D front. He knows that his current customers—the ones looking for high quality and reliability—won't buy resorbables unless they are at least as good as metal implants on traditional metrics of performance and better on new metrics. Of course, as CFO Calvin Westbrook anticipates, the rewards and drawbacks for going down that path are mixed. Crescordia could spend millions to perfect the technology, only to watch it cannibalize the current product line and provide little growth beyond that. In many ways, then, this is a defensive strategy. The motivation is: "If the technology ever becomes good enough to start displacing our permanent implant technology, then, by gosh, we're going to be there."

Pursuing a disruptive strategy is harder. It requires competing against nonconsumption—finding applications where implants historically haven't been possible because of the complexity, cost, or unfavorable characteristics of permanent implants. From my reading of the case, it appears that the pediatric market may offer just such applications. If, as the vice president of sales notes, "one thing surgeons hate to do [is] to go back in on a kid to remove an implant," then it's probably true that many orthopedists opt not to use implants at all on young bones. The beauty of using resorbables in pediatrics is that, although they don't attain the same level of perfection as established offerings, surgeons will embrace them because they are much better than nothing. And the howling packs of tort lawyers will be held at bay for the same reasons.

If history is any guide, the technology will take root in these applications. And if Innostat or some other upstart seizes that turf first, it will be in position to make the products better and better and, ultimately, to invade Crescordia's original market—a very attractive endgame for the company.

The question for Crescordia isn't whether *it should follow a disruptive strategy. The question is* how.

So the question for Crescordia isn't *whether* it should follow a disruptive strategy. The question is *how*. Overwhelmingly, the evidence shows that the only way to address such a market is to create or acquire an autonomous business unit, including a new sales force that can target the new applications. This is what IBM did, with great success, when it entered the minicomputer and PC markets. Johnson & Johnson, similarly, has transformed itself repeatedly over the past few decades, always by setting up or acquiring new disruptive business units.

If Crescordia does not set up a resorbables business that is autonomous, the technology will be killed by a corporate sales force that is not motivated to seek new (and therefore small) applications. Instead, salespeople will try to sell that technology to existing customers in existing applications, because they think that's their path of least resistance. From Crescordia's perspective, that would constitute cramming a disruption down a sustaining path. And that amounts to a death march.

Clayton M. Christensen is the Robert and Jane Cizik Professor of Business Administration at Harvard Business School in Boston. He is the author of several books, including *The Innovator's Dilemma* (Harvard Business School Press, 1997). Most recently, he coauthored *Seeing What's Next* (Harvard Business School Press, 2004).

Appendix L: Business Case Study Commentaries (Page 3 of 4)

Case Commentary

by Jason Wittes

Should Crescordia launch a resorbables offering?

Medical devices companies often wait too long to put an emerging technology on the market. Clinical, intellectual-property, and industry trade-secret requirements often constrain them for years, and then they are forced to make a rushed, possibly irrational, decision on how to proceed.

In Crescordia's case, at least two considerations should be persuading Walsh to move sooner rather than later into the resorbables business. First, even though most of Crescordia's customers aren't ready to embrace the technology, it is capturing the interest of an influential subset made up of more experimental physicians. Second, Crescordia's investors assuredly expect the company to hedge its bets. In the face of a potentially disruptive competing technology, it must at least position itself to eventually capitalize on the opportunity.

An acquisition would give Crescordia a jump-start into the business of resorbables, with the added bonus of eliminating a competitor.

Interestingly, we don't see Crescordia's management team contemplating one of the most common moves in this kind of situation—simply acquiring Innostat. Acquisitions are, of course, the most expensive way to finance R&D. If you buy early, it's often unclear what you're paying for, and if you wait for the technology to mature, you've waited too long and will pay a significant premium. But the reality of the industry is that smaller private companies do have innovation advantages—such as more focused management and a better talent pool attracted to the potential rewards (cashing out at the IPO)—that typically can't be matched by larger, established companies. In this case, an acquisition would give Crescordia a jump-start into the business of resorbables, with the added bonus of eliminating a competitor. It's worth considering.

Unfortunately, whether it buys or builds the new venture, Crescordia will have to worry about Wall Street breathing down its neck. Publicly financed ventures are the worst settings for nascent disruptive technologies because the investment horizons are so short. In medical devices, the adoption curve for new technologies typically extends from three to five years. But investors aren't that patient. They want to see measurable revenue generation on investment within two years. Given the inherent risks, it would be naive to expect public investors to pay or wait for investments beyond this horizon—especially when the profitability outlook is not significantly better than in Crescordia's current markets.

The result of this conflict is that the successful, larger companies in the industry have become very good at sales and marketing and at product iterations in established markets where turnover is quick. But their track records in developing new, disruptive markets with slower turnover have proven abysmal.

The best solution for Crescordia is to shelter its investment in resorbables from Wall Street expectations. It can do this through a passive (less than 50%) investment in a new venture. That would give the venture itself significant autonomy—a benefit in attracting managerial and research talent—while still allowing Crescordia a measure of control. And Walsh can maintain Crescordia's focus on serving its core group of physicians instead of alienating them with experimental, possibly buggy, products. Meanwhile, the new entity can appropriately develop resorbable technologies and serve the more experimental physicians.

Ultimately, this new business could begin to significantly encroach on Crescordia's traditional business, but that is not a development to be feared. In fact, that is precisely when Crescordia should choose to exercise its option. Everyone would be well served at that point by bringing the resorbables venture into Crescordia's organization, because the technology would be ready for prime time. The company would then need to shift its focus from development to selling into an established market, bringing Crescordia's core competencies to the fore.

Jason Wittes (jasonw@leerink.com) is a New York–based senior equity analyst covering medical supplies and devices at Leerink Swann. In *Institutional Investor* magazine's most recent survey of the best of the boutiques, Leerink Swann was voted best in the following sectors: biotechnology, medical supplies and devices, pharmaceuticals/major, and pharmaceuticals/specialty.

Appendix L: Business Case Study Commentaries (Page 4 of 4)

Case Commentary

by Nick Galakatos

Should Crescordia launch a resorbables offering?

I would certainly not take the risk if the product threatened to lead to safety problems.

What's missing in this case is a clear sense of whether the resorbable products' shortcomings are only a question of efficacy or also of safety. If the product is safe in clinical trials, and if the efficacy potential is there but not fully proven, then I would take the risk of launching it. That's a fairly common approach in the pharmaceutical and biotech industries, given that (as it's phrased in the case) every body is different, and it isn't possible to replicate every individual's physiology in the lab. On the other hand, I would certainly *not* take the risk if the product threatened to lead to safety problems. If things went wrong on that front, it would be very tough to recover.

Consider the challenge that the entire gene therapy sector has faced for the past six years. Gene therapy is a disruptive technology that promises to revolutionize the practice of medicine. With this treatment, a patient would no longer take drugs to control symptoms of a genetic disorder; instead, the therapy would control the expression of the therapeutic gene in the patient's defective cells. But the several dozen companies pursuing that promise were dealt a stunning blow by the death of just one patient—a young man participating in a trial at the University of Pennsylvania in 1999. It seems that less-than-optimal clinical planning was to blame, but investors became extremely skeptical of the whole sector. Only now do we see the ill perceptions beginning to dissipate and some venture capitalists making contrarian bets.

Let's assume, however, that Crescordia's qualms are not fundamentally about safety and that the resorbables already on the market have produced no disastrous outcomes (beyond wasting surgeons' time). In that case, the company is proceeding too cautiously. I am reminded of the sad story of a Cambridge, Massachusetts–based company called Genesis Pharmaceuticals. In the early 1990s, Genesis was a pioneer in the brand-new field of combinatorial chemistry. At the time, this was another disruptive technology; instead of the conventional drug-discovery method of focusing on one molecule at a time, the technology introduced the now common procedure of creating many, many molecules in parallel and rapidly screening them for desirable properties. The potential for accelerating drug discovery made every big pharmaceutical company sit up and take notice. Genesis's missteps in bringing this new capability to market, however, cost its investors dearly. They netted less than $30 million when the company was ultimately acquired by Sphinx Pharmaceuticals (itself later acquired by Eli Lilly). The fact that Affymax—a Palo Alto, California, company that came up with the same concept a year later—was sold in 1995 to Glaxo Wellcome for more than $500 million gives a sense of the lost opportunity.

Today, of course, the big story in health care is genomics. Thanks to the study of the human genome, we now have a better understanding of human biology as an integrated system rather than a set of individual drug targets—and that is a profoundly disruptive shift. Surely companies that stand on the sidelines too long will suffer. They will see their business models overturned by the likes of Millennium Pharmaceuticals, probably the most aggressive player in the field. Since 1993, Millennium has completed large transactions with pharmaceutical companies and raised more than $2 billion to explore genomics. It has used the created value to buy companies like ChemGenics, LeukoSite, and COR Therapeutics and to accelerate its transition from a technology company to a product company. The strategy is paying off: In a business where it takes 12 to 14 years to go from concept to launch, Millennium already has two products on the market. It's a great example of how upstarts can turn into major players in a hurry. Walsh should take note.

Nick Galakatos (ngalakatos@mpmcapital.com) is a general partner of MPM Capital in Boston. He has extensive experience in building new life-sciences businesses both as an executive in major pharmaceutical companies and as an entrepreneur.

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Appendix M: Coding Instructions and Template (Page 1 of 5)

The participant responses are provided on four boxes on the Response Form (double-sided page). The format and content of the pages and boxes are as follows:

Page #B

Decision and Reason: Subjects were asked to state their decision and one to three reasons for the decision.
Action Plan: Subjects were asked to list two to four steps or actions that will be needed to implement their decision.

Page #A

Alternatives: Subjects were asked to list two to four other alternatives they had considered.
Criteria: Subjects were asked to list two to four decision criteria to support their decision.

The responses from each of the boxes are to be coded on the supplied Coding Spreadsheet, which has Response Form numbers listed as rows and coding categories as columns. First code Page #B and then Page #A. The coding is binary, which means the number 1 is coded in the appropriate column for the applicable row. A blank cell by default indicates a code of 0 (zero).

The next four pages provide instructions on how to interpret and code the responses. These instructions are to be followed as closely as possible. If any assumptions are made, they need to be noted in writing on the Response Form.

Appendix M: Coding Instructions and Template (Page 2 of 5)

Decision and Reason

The “Decision and Reason” should be coded based on what is mentioned in this box. If the response is unclear or incomplete then the “Action Plan” box can be consulted.

Overall Strategy Note: There are five categories but only one category can and must be coded	Code
Halt research or drop “resorbable” product line and/or focus only on “titanium” products	Stop = 1
Continue with existing laboratory research to improve “resorbables” but no mention of field/trial testing on humans or animals	Status = 1
Field or trial test “resorbables” on humans or animals, or a particular segment of humans (children, seniors, athletes, etc.) or animals	Field = 1
Launch the “resorbable” product into a niche market such as children, seniors, athletes, or animals, or launch a limited product line into a niche/mass market	Partial = 1
Launch “resorbables” into a mass market. No mention of niche market or limited product line can be considered as a mass market launch with a broad product line	Launch = 1
Target Market Note: There are three categories but only one can and must be coded	
If the decision is coded as “Stop” or “Status”	None = 1
If the decision is coded as “Field” or “Partial” a target market is mentioned explicitly or implicitly	Niche = 1
If the decision is coded as “Field” or “Partial” but no mention of a specific market explicitly or implicitly, or the decision is coded as “Launch”	Mass = 1
Organizational Structure Note: There are four categories but only one can and must be coded	
If the decision is coded as “Stop” or “Status”, or there is no mention of acquiring/partnering with a company or starting a new venture	Internal = 1
If the decision is coded as “Field”, “Partial” or “Launch” and there is mention of partnering with an existing or a new company	Partner = 1
If the decision is coded as “Field”, “Partial” or “Launch” and there is mention of acquiring a company, such as the competition (e.g., Innosat)	Acquire = 1
If the decision is coded as “Field”, “Partial” or “Launch” and there is mention of starting a new venture/company but no mention of acquiring or partnering	New = 1
Product Scope Note: There are three categories but only one can and must be coded	
If the decision is coded as “Stop” or “Status”	None = 1
If the decision is coded as “Field” or “Partial” a limited product line is mentioned explicitly or implicitly	Limited = 1
If the decision is coded as “Field” or “Partial” and there is no mention of a limited product explicitly or implicitly, or if the decision is coded as “Launch”	Broad = 1
No. of Reasons	
Consider any justification or reasons provided for the decision in both the Reason and Decision sub-boxes	Enter the number of reasons (0 to 4)

Appendix M: Coding Instructions and Template (Page 3 of 5)

Action Plan

The “Action Plan” should be coded based on what is mentioned in this box. If the response is unclear or incomplete then make a judgment but do not consult other boxes.

Business There are four categories and a minimum of one and a maximum of four should be coded	Code
If there is mention of financials, including cost, revenue, return on investment (ROI), profits, etc.	Financials = 1
If there is mention of marketing, advertising, sales, promotion, internal communications, external communication, public relations, etc.	Marketing = 1
If there is mention or operations, production, plant set up or re-tooling, distribution, logistics, etc.	Operations = 1
If there is mention of internal testing, field testing, trials, pilots studies, research etc.	Testing = 1
Resources There are four categories and a minimum of one and a maximum of four should be coded	
If there is mention of consulting, informing or working with patients directly or indirectly	Patients = 1
If there is mention of partnering, consulting, informing or working with physicians/surgeons or hospitals/clinics directly or indirectly	Doctors = 1
If there is mention of involving and/or communicating with employees, staff, managers, board of directors directly or indirectly	Employees = 1
If there is mention of consulting with lawyers, government, regulatory bodies or related persons or organizations	Lawyers = 1
Time There are three categories but only one can and must be coded	
If there is no mention of time or urgency explicitly or implicitly	None = 1
If there is a mention of time (explicitly or implicitly) but no sense of urgency, or the timeline mentioned is more than one year	Slow = 1
If there is an explicit mention of time and/or a sense of urgency, or the timeline mentioned is less than one year	Fast = 1
No. of Actions	
The number of action items	Enter the number of actions (0 to 5)

Appendix M: Coding Instructions and Template (Page 4 of 5)

Alternatives

Should be coded based on what is mentioned in this box as well as in the “Decision and Reason” box (if the Decision is not included in the “Alternatives” box)

Overall Strategy Note: There are five categories and a minimum of one to a maximum of five can be coded	Code
Halt research or drop “resorbable” product line and/or focus only on “titanium” products	Stop = 1
Continue with existing laboratory research to improve “resorbables” but no mention of field/trial testing on humans or animals	Status = 1
Field or trial test “resorbables” on humans or animals, or a particular segment of humans (children, seniors, athletes, etc.) or animals	Field = 1
Launch the “resorbable” product into a niche market such as children, seniors, athletes, or animals, or launch a limited product line into a niche/mass market	Partial = 1
Launch “resorbables” into a mass market. No mention of niche market or limited product line can be considered as a mass market launch with a broad product line	Launch = 1
Target Market Note: There are three categories and a minimum of one or a maximum of three can be coded	
If the decision is coded as “Stop” or “Status”	None = 1
If the decision is coded as “Field” or “Partial” a target market is mentioned explicitly or implicitly	Niche = 1
If the decision is coded as “Field” or “Partial” but no mention of a specific market explicitly or implicitly, or the decision is coded as “Launch”	Mass = 1
Organizational Structure Note: There are four categories and a minimum of one or a maximum of four can be coded	
If the decision is coded as “Stop” or “Status”, or there is no mention of acquiring/partnering with a company or starting a new venture	Internal = 1
If the decision is coded as “Field”, “Partial” or “Launch” and there is mention of partnering with an existing or a new company	Partner = 1
If the decision is coded as “Field”, “Partial” or “Launch” and there is mention of acquiring a company, such as the competition (e.g., Innosat)	Acquire = 1
If the decision is coded as “Field”, “Partial” or “Launch” and there is mention of starting a new venture/company but no mention of acquiring or partnering	New = 1
Product Scope Note: There are three categories and a minimum of one or a maximum of three can be coded	
If the decision is coded as “Stop” or “Status”	None = 1
If the decision is coded as “Field” or “Partial” a limited product line is mentioned explicitly or implicitly	Limited = 1
If the decision is coded as “Field” or “Partial” and there is no mention of a limited product explicitly or implicitly, or if the decision is coded as “Launch”	Broad = 1
No. of Alternatives	
The number of alternatives including the decision if the decision is not mentioned in the alternative box	Enter number of alternatives

Appendix M: Coding Instructions and Template (Page 5 of 5)

Criteria

The "Criteria" should be coded based on what is mentioned in this box. If the response is unclear or incomplete then make a judgment but do not consult other boxes.

Criteria There are eight categories and a minimum of one to a maximum of eight should be coded	Code
If there is an explicit (e.g., Innostat) or implicit reference to competition or the nature of the competitive market	Competition = 1
If there is an explicit or implicit mention of brand, reputation, corporate name or status, etc.	Brand = 1
If there is an explicit or implicit reference to product quality or safety, product effectiveness, etc.	Quality = 1
If there is an explicit or implicit mention of cost, revenue, return on investment, profit, etc.	ROI = 1
If there is an explicit or implicit reference to legal issues such as lawsuit including class-action, liability, or if there is an explicit or implicit mention of government regulation or standards, etc.	Liability = 1
If there is an explicit or implicit mention of human resources and/or technological resources, etc.	Resources = 1
If there is an explicit or implicit mention of moral/ethical issues or dilemmas, at the personal, managerial professional, or organizational level	Ethics = 1
If there are additional criteria (please highlight it on the Response Form) that are not included in the list above	Other = 1
No. of Criteria	
The number of criteria items	Enter the number of criteria (0 to 8)

Final Note: If there are responses in any of the four boxes that cannot be coded using the above categories, then please highlight that portion of the response on the Response Form and if possible make an assumption and assign it to a category. Be sure to also state the assumption on the Response Form.

Should you have any questions or concerns, please feel free to contact me (Salman Mufti, Associate Professor, Queen's School of Business) by telephone 613.533.3158 or via e-mail smufti@business.queensu.ca.