MANUFACTURING & SERVICE OPERATIONS MANAGEMENT
Vol. 10, No. 4, Fall 2008, pp. 676–691
ISSN 1523-4614 | EISSN 1526-5498 | 08 | 1004 | 0676

informs®
DOI 10.1287/msom.1070.0205

Toward a Theory of Behavioral Operations

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Human beings are critical to the functioning of the vast majority of operating systems, influencing both the way these systems work and how they perform. Yet most formal analytical models of operations assume that the people who participate in operating systems are fully rational or at least can be induced to behave rationally. Many other disciplines, including economics, finance, and marketing, have successfully incorporated departures from this rationality assumption into their models and theories. In this paper, we argue that operations management scholars should do the same. We explore the theoretical and practical implications of incorporating behavioral and cognitive factors into models of operations management and suggest fruitful avenues for research in *behavioral operations*.

Key words: behavioral operations; decision making; beer game; system dynamics; cognitive biases
History: Received: March 21, 2006; accepted: December 1, 2007. Published online in *Articles in Advance* March 11, 2008.

1. Introduction

The field of operations dates back to Frederick Taylor's time-motion studies in the early 20th century. Since then, much has changed in the environment (e.g., technology, globalization), the nature of operations themselves (e.g., network structures, information systems, lean manufacturing), and the repertoire of tools available (e.g., capacity planning, inventory models, forecasting methodologies, project management methods). Yet one thing has not changed: in the vast majority of operations—from manufacturing and services to supply chains and R&D—people are a critical component of the system. As Hayes et al. (1988) state:

> Superior performance is ultimately based on the people in an organization. The right management principles, systems, and procedures play an essential role, but the capabilities that create a competitive advantage come from people—their skill, discipline, motivation, ability to solve problems, and their capacity for learning. (p. 242)

The enduring importance of human behavior in operations suggests that people may significantly influence how operating systems work, perform, and respond to management interventions.

Most formal analytical models in operations management (OM) assume that the agents who participate in operating systems or processes—as decision makers, problem solvers, implementers, workers, or customers—are either fully rational or can be induced to behave rationally. More specifically, these models assume that people can distinguish signals from noise, that they react to relevant information and discard irrelevant information, that their preferences are consistent, and that their decision-making process incorporates all relevant alternatives and variables and is unhampered by cognitive biases or emotions. According to the traditional OM literature, one way to achieve rational behavior is to increase monetary incentives; any irrationality, it is argued, is simply a matter of insufficient or misaligned incentives. This solution, however, does not take into consideration the findings of behavioral decision research, such as the results of studies on overconfidence (e.g., Oskamp 1962, 1965) or anchoring (e.g., Tversky and Kahneman 1974). Although advances in the understanding of human behavior and cognition have begun to influence the fields of economics, finance, accounting, law, marketing, and—more recently—strategy, a "behavioral perspective" has largely been absent in the field of operations.

This has started to change with a growing number of experimental studies within OM, the majority of which has explored the behavioral underpinnings of the bullwhip effect (Croson and Donohue 2002, 2006; Sterman 1989a, b) or investigated issues at the interface between operations and human resource management (for a thorough review, see Boudreau et al. 2003). Related work from a system dynamics perspective has begun to shed light on how behavioral factors impede improvement in operations (see, for instance, Repenning and Sterman 2002; Ford and Sterman 1998, 2003a, b).

Part of this research was probably stimulated by the paper by Boudreau et al. (2003), which emphasizes the importance of incorporating behavioral factors into OM work. In their article, Boudreau et al. highlight the relevance of considering both technical and human aspects when investigating operating systems and their performance and provide an organizing framework that includes both human resource management and OM factors. Building on the work of Boudreau et al. (2003), a comprehensive review by Bendoly et al. (2006) provides a framework that can be used to identify behavioral assumptions commonly used in OM analytical models. This framework is very helpful for identifying OM problems that could be better explained or investigated through a behavioral lens.

In this paper, we build on this earlier work to explore the theoretical and practical implications of incorporating behavioral and cognitive factors into OM models. We argue that differences between firms' and other organizations' operational performance cannot be explained by existing OM models: only a careful examination of behavioral and cognitive factors can shed light on differences in operational performance such as productivity, efficiency, and flexibility.

We have structured the paper as follows. The next section describes the issues investigated by traditional OM scholars and highlights the relevance of the human factor across these issues. In §3, we define a behavioral perspective on operations. In §4, we identify fruitful avenues for future research by examining how specific findings from the behavioral decision research literature might apply to various OM settings. Section 5 concludes by discussing the implications of adopting a behavioral perspective to study OM problems and delineating potential areas for future work.

Our goal is not to provide a comprehensive review of prior research that has used a behavioral perspective to investigate OM phenomena. For this, we refer interested readers to both Boudreau et al. (2003) and Bendoly et al. (2006). Our goal, instead, is to provide a precise definition for behavioral operations, to highlight the limitations of current OM models in predicting outcomes in operations settings, and to identify fruitful venues for future research. With this aim in mind, we describe both the intellectual terrain of OM and behavioral decision research. We also describe areas in OM research that would benefit from an investigation using a behavioral perspective. With this paper, we hope to help OM researchers identify areas where behavioral factors can help explain or predict differences in operations performance. At the same time, we hope to educate behavioral decision researchers about OM settings that could be fruitful contexts in which to study judgment and decision making.

2. Intellectual Terrain of OM

OM is a multidisciplinary field that investigates the *design, management*, and *improvement* of processes aimed at the development, production, delivery, and distribution of products and services (Weiss and Gershon 1989). Research in OM focuses on explaining differences in operating performance across organizations (e.g., productivity, quality, product development lead times) and, as a normative field, identifying the implications for processes, structures, and systems. Historically OM focused mainly on manufacturing environments, but the field today also covers issues pertinent to R&D, services, supply chains (logistics and distribution), and retailing.

Design encompasses the specification of the various processes, policies, and strategies that constitute the overall operating system. Setting inventory policy, determining plant size and location, specifying a product development process, deciding which information technology (IT) system to deploy, and creating incentive plans are just a few examples of common operating system design issues. *Management* refers to the decisions and actions that take place within the constraints imposed by the design of the operating system. It involves activities such as implementing policies, procedures, and strategies; making contingent decisions; coordinating processes; identifying and solving problems; responding to uncertainty and unforeseen problems; and motivating people. *Improving* the system refers to experimentation and learning activities geared toward enhancing operating performance over time.

Research on the design, management, and improvement of operating systems and processes is carried out through multiple methodological approaches, such as mathematical modeling, computer simulations, large sample empirical research, and field-based case studies. In addition to many methodologies, OM also pulls from many reference disciplines, including applied mathematics, economics, computer science, engineering, and sociology.

Given its receptivity to many disciplines, it is somewhat surprising that explicit behavioral decision theories and studies are still relatively rare within OM.[1] Over the past decade, the study of human behavior has taken root in many fields, such as economics (with the rise of behavioral economics), finance (behavioral finance), and marketing (with an increasing focus on the psychology of consumer behavior).[2] Scholars in these fields have started to realize that relying exclusively on normative models and theories of individual behavior led to systematic errors in describing or predicting outcomes (Thaler 1980). These systematic and predictable errors are due to the fact that, when facing decisions (especially if such decisions are complex), people behave in ways that are inconsistent with available theories. Indeed, although normative theories generally assume that people are rational, actual behavior provides evidence for what Simon called *bounded rationality* (Simon 1957, p. 198):

> The capacity of the human mind for formulating and solving complex problems is very small compared with the size of the problems whose solution is required for objectively rational behavior in the real world—or even for a reasonable approximation to such objective rationality.

We explain how the idea of bounded rationality has affected research in economics, finance, and marketing next.

2.1. Closer Look at Human Behavior in Other Fields

For many years, economists built their models on the assumption that individuals are rational. In particular, most economists assumed that individuals act as if their economic choices and decisions are rational. This perspective reached full bloom with the rational expectations revolution of the 1970s (see, for example, Lucas 1972). The work of Simon (1956, 1957) and Tversky and Kahneman (1974) instead argued that human beings are limited in their capacities to learn, think, and act, and that these limits have important implications for economic theory. In particular, research has found that human beings are limited in their ability to process information (Simon 1976). As evidence, various researchers have identified a large number of biases and heuristics over the past 30 years. Biases, which result from cognitive limitations, are systematic errors that affect people's decisions or judgments; heuristics are rules of thumb that people commonly employ to navigate the ocean of information available to them in their decision-making process. Because of this evidence, in the past 20 years, economists have begun to accept that psychology plays an important role in describing and explaining people's behavior.[3] Many economics models have incorporated deviations from pure rationality to explain and predict behavior (e.g., hyperbolic discounting as an explanation for self-control problems and limited attention or fairness concerns as an explanation for menu pricing).

[1] In this paper, we use the term *behavioral research* broadly; in our definition, it includes both behavioral decision research (BDR), judgment and decision-making research (JDM), and some areas of experimental and behavioral economics.

[2] *Behavioral economics* encompasses research that combines psychology and economics to explore the effects and implications of individual shortcomings in market settings. Research in behavioral economics has identified the ways behavior differs from the traditional rational model and has demonstrated how such behavior matters in economics settings. *Behavioral finance* refers to research that drops the traditional assumption of rational and utility-maximizer investors in efficient markets. As a result, behavioral finance models agents as not fully rational and investigates the impact of their behavior in financial markets. Finally, *behavioral marketing* encompasses research that drops the traditional assumptions of rational choice and assumes that consumers have imperfect and inconsistent preferences.

[3] For an overview of behavioral economics, see Camerer (1999) and Thaler (1980, 2000).

In the case of finance, the theoretical foundation challenged by behavioral research has been the "efficient market hypothesis," which asserts that prices on traded assets in financial markets reflect all known information (including the collective beliefs of all investors about future prospects) and are therefore accurate. A growing field of research—behavioral finance—studies how cognitive or emotional biases create anomalies in market prices and returns that may be inexplicable via the efficient market hypothesis alone (e.g., Shefrin 2000).[4] Several studies have shown under what conditions and in what directions investors deviate from rationality. For instance, investors often fall prey to herding behaviors, making decisions based on what others have chosen (e.g., Shiller 1984, Olsen 1996). Investors are overconfident and, as a result, often trade much more than they should (e.g., Odean 1998, 1999).

Finally, in the field of marketing, long-held assumptions about rational choice and, in particular, consumer preferences have been challenged. Three assumptions about preferences underlie the rational theory of choice: preferences are complete (i.e., the consumer is able to rank any two goods);[5] preferences are transitive (i.e., the consumer makes choices that are consistent with each other);[6] and the consumer prefers more choices to fewer choices (because having more choices increases the likelihood of a match between the consumers' preferences and the item, without added costs). However, actual consumer behavior, like that of investors, often does not conform to theory. For instance, both experimental and field studies show that extensive choice may hinder people's motivation to buy and decrease their subsequent satisfaction with purchased goods, even if the purchase is initially appealing (e.g., Iyengar and Lepper 2000, Botti and Iyengar 2004). In addition, marketing research has shown that consumption levels are influenced by the perceived variety of an assortment (Kahn and Wansink 2004) and that consumers believe variety leads to more favorable and interesting consumption memory (Ratner et al. 1999, Ratner and Kahn 2002).

In contrast to economics, finance, and marketing, OM is multitheoretical.[7] An analysis of more than 40 years of project management research, for example, found no clear "theory of project management" (Kloppenborg and Opfer 2000). OM may not offer a unified body of theory into which behavioral regularities can be incorporated, but it does offer many prescriptions to practitioners. Yet to the extent that these prescriptions rest on models with ungrounded behavioral assumptions, their usefulness in practice might be limited. We argue that an explicit perspective that is cognitively and behaviorally accurate is crucial for the future of the OM field. Behavioral operations is aimed at filling this gap. By investigating the human factor, behavioral operations attempts to explain differences in operations processes and performance across firms that existing OM models fail to explain.

3. Behavioral Operations: A Definition

Behavioral operations is an emerging approach to the study of operations that explicitly incorporates social and cognitive psychological theory. We define behavioral operations as *the study of human behavior and cognition and their impacts on operating systems and processes*.

Behavioral operations and traditional OM share the same intellectual goal (the design, management, and improvement of operating systems and processes), but their research focus is different. In the OM literature, human behavior traditionally has been either ignored or, at best, treated as a second-order effect. For instance, normative models developed in operations research (e.g., inventory theory, forecasting, and scheduling models) typically assume that decisions

[4] For a comprehensive introduction to behavioral finance, see Shleifer (2000).

[5] For goods A and B, for example, the consumer can state her preferences according to one of the following possibilities: she prefers good A to good B; she prefers good B to good A; or she is indifferent between, or equally happy with, goods A and B.

[6] Suppose that a consumer says that she prefers good A to good B and good B to good E. We can then expect her to prefer good A to good E.

[7] For instance, production thinking throughout the 20th century was dominated by three main theories: the transformation view (e.g., Starr 1966), the flow view (first proposed by Gilbreth and Gilbreth 1922 and first translated into practice by Ford 1926), and the value generation view of production (initiated by Shewhart 1931).

are carried out by an idealized decision maker who is unfailing rational (Swamidass 1991). In contrast, behavioral operations treats human behavior as a core part of the functioning and performance of operating systems—that is, as a first-order effect. Specifically, behavioral operations focuses on how cognitive and behavioral factors shape the way operating systems and processes work and perform and on the normative implications for the design, management, and improvement of these systems and processes. In behavioral operations, the performance impacts of any given management intervention (e.g., a new tool or a new process) cannot be predicted or explained without explicit reference to the underlying behavioral and cognitive factors at work in the operating system. At its core, behavioral operations explores the intersection of behavioral decision research, which is focused on human behavior, and OM, which is focused on system behavior. OM contexts are complex organizational settings where, very likely, individual biases interact and various decision makers use heuristics at different stages of the decision-making process. Operating problems, by their very nature, engage groups of people with various skills and organizational responsibilities and involve processes that are ongoing and dynamic, in the sense that the conditions and decisions made at one point in time affect the conditions experienced, the skills and resources available, and the actions that can be taken at a later point.

Another element adds complexity to this picture. In operations, two categories of inquiry need to be considered: (1) the properties of individuals, or the study of how cognition affects operations, and (2) the properties of groups and organizations, or the study of how social norms and systems affect operations. These properties are considered according to the areas of psychology most relevant to behavioral operations, namely cognitive psychology and social psychology.

Cognitive psychology studies the mental processes that underlie behavior, including thinking, deciding, reasoning, and, to some extent, motivation and emotion. These topics cover a broad range of research domains, examining questions about the workings of memory, attention, perception, knowledge representation, reasoning, creativity, and problem solving. Of particular relevance for OM are issues related to bounded rationality (e.g., Simon 1956, 1957; Kahneman 2003) and findings from studies on judgment and decision making (e.g., Bazerman 2005, Gilovich et al. 2002).

Social psychology is the study of the nature and causes of human social behavior, with an emphasis on how people think about and relate to each other (Aronson et al. 2004). Social psychology attempts to understand the relationship between minds, groups, and behaviors in three primary ways. First, it examines how the actual, imagined, or implied presence of one or more people influences the thoughts, feelings, and behaviors of individuals. Topics within this area include social perception, social interaction, and the many types of social influence, including trust, power, and persuasion.[8] Second, social psychology examines the influence that individual perceptions, beliefs, and behaviors have on the behavior of groups; this area has led to research on group productivity in the workplace and group decision making. Finally, social psychology tries to understand groups as behavioral entities, as well as the relationships and influences of one group on another group. Of particular relevance for OM are issues related to equity and fairness, trust and reciprocity, and attributions.

In addition to research on small groups, of particular importance to behavioral operation research is work on organizational behavior (for an overview of the field and research contributions, see Thompson 2003, and Shapira 1997). Indeed, operations often take place in the context of large organizations. Issues such as organizational culture, organizational design and structure, and organizational communication and learning are of crucial importance.

The findings of these areas of psychology have not yet made their way into the OM field. Indeed, the overwhelming majority of research articles published in OM utilizes analytical frameworks that assume a high degree of rational decision making. Moreover, many practice-oriented frameworks of OM, although somewhat more flexible, still ignore (or minimize) the impact of human behavior and, consequently, the systematic biases that affect it. Yet it is possible

[8] The research in these areas focuses on the influences that individuals have on the beliefs, attitudes, and behaviors of other individuals, as well as the influence that groups have on individuals.

to identify OM research that has adopted a behavioral perspective (for comprehensive reviews, see Boudreau et al. 2003, Bendoly et al. 2006). We believe this is an important and fruitful area of research.

3.1. Prior Research in Behavioral Operations

It is probably premature to discuss behavioral operations as if it were an existing field, yet behavioral considerations have been prominent in a number of OM investigations. The earliest of these, in fact, are almost as old as the OM discipline itself. Research conducted by Mayo, Roethlisberger, and Dickson in the 1920s and 1930s (see, for instance, Ross and Nisbett 1991, pp. 210–212) examined the physical and environmental influences of the workplace (e.g., brightness of lights or humidity) as well as the psychological aspects (e.g., breaks, group pressure, working hours, managerial leadership). The major finding of the study was that, almost regardless of the experimental manipulation employed, worker production seemed to improve, leading to the conclusion that the workers were pleased to receive the researchers' attention and interest.[9] Along with Frederick Taylor's work, this study gave rise to the field of industrial psychology but did not result in a new approach to the study of OM.

In fact, only recently have OM scholars begun to pay attention to insights from psychology. Prior studies that examined OM problems (e.g., the bullwhip effect) through a behavioral lens are reviewed by Bendoly et al. (2006). Taken together, the findings of this body of research suggest that taking behavioral and cognitive factors into account can lead to fundamentally different predictions about the performance of given operating systems under specific conditions. By focusing on the interaction and feedback among technical, organizational, and behavioral features of OM systems (Ford and Sterman 2003a), prior research has identified a different root cause of many operating performance problems and thus suggests different managerial interventions.

Although the review by Bendoly et al. (2006) and the paper by Boudreau et al. (2003) both do an excellent job of providing an organizing framework for prior research on behavioral operations, many questions regarding how common biases studied in behavioral decision research affect operating systems and processes remain unanswered. In an attempt to close this gap, the next section provides examples of open questions that behavioral operations studies could explore in future research. Specifically, we describe some fruitful avenues for future research in behavioral operations.

4. Opportunities for Behavioral Research in OM

Research in the OM field tends to be normative and focused on prescribing how operating systems and processes should work. The main concern is the identification of the appropriate principles, processes, and structures needed to make the system work in the optimal (that is, most efficient and most effective) way. As a result, OM theories provide normative prescriptions and models that, if followed, should assure an optimal functioning of the systems and processes in the areas of design, management, and improvement. Yet these models are often not considered useful by those who are supposed to use them. For instance, the decision-theoretic models proposed to deal with R&D portfolio decisions are highly complex and, as a result, have not been commonly used in management practice (Loch and Kavadias 2002). We suggest that practitioners recognize what OM researchers have largely ignored: Real operating systems like factories, supply chains, and product development organizations are complex social systems where human behavior is a central driver; thus the usefulness of tools, methods, and frameworks that ignore the realities and limitations of human behavior is limited.

OM as taught and practiced today rests on models and theories that can be enriched by descriptions of how operating systems and processes do work. Behavioral operations starts with grounded assumptions from cognitive and social psychology; it recognizes that people have cognitive limits and, as a consequence, their decisions might be hampered by systematic biases. Only after taking these limits and characteristics into account does behavioral operations consider how to design, manage, and improve operating systems and processes. We suggest that a

[9] After this series of studies, *the Hawthorne effect* is a label used to refer to an increase in worker productivity produced by the psychological stimulus of being singled out and made to feel important.

deep understanding of how operating systems and processes actually work is needed to provide a basis for building tools and models for designing, managing, and improving them. This understanding will not only incorporate more realistic assumptions into OM models, but also generate more useful prescriptions and implications for both research and management practice.

We propose two main approaches in which behavioral considerations can be included in OM models and research. The first approach is prescriptive and suggests that, as mentioned above, behavioral factors should be integrated into OM models. The second approach is instead descriptive and highlights the relevance of understanding the effects of individuals' shortcomings on decision-making processes and problem-solving activities within OM contexts. A clear understanding of the effects of individuals' biases will indeed help OM scholars design effective interventions. We believe these two approaches to be complimentary. Yet one approach might be more appropriate than the other in certain situations. For instance, the prescriptive approach is especially important when a decision maker's biases can be corrected via feedback and training. This might happen when the decision maker is an employee in the same organization as the analyst. In this case, the results of a normative analysis (which ignores the decision maker's biases) could be compared with the results of a descriptive analysis (which include the biases). Observed differences in the results of the two analyses could provide useful feedback and ideas for training for the decision maker. Conversely, in cases in which a decision maker cannot be de-biased, then the descriptive approach is more appropriate. An example of this type of situation arises in service operations during interactions with customers. A firm, indeed, cannot (or may not wish to) train its customers to behave more "rationally."[10]

4.1. Rationale for Behavioral Operations

The rationale for a behavioral approach to operations should be improved insight into and understanding of problems. In finance and economics, for example, behavioral theories began to gain traction because they offered explanations for empirical regularities that were considered anomalies when viewed through existing theoretical lenses. Anomalies provide a useful starting point for the construction of a new theory. A behavioral theory of operations must do a better job than existing theories of explaining how operating systems work and how they can be improved. If not, there is no intellectual motive for an alternative approach.

The bullwhip effect in supply chains is an example of one such anomaly that was better explained through a behavioral lens. Building on findings from the behavioral decision research literature, several studies explored behavioral causes of the bullwhip effect and found that they can better explain such anomalies than operational causes. In a similar vein, we suggest that several biases investigated in the behavioral decision research literature could be at the root of well-known OM anomalies, such as the tendency of projects to run late and over budget or the tendency of organizations to over commit their R&D resources. These biases are often the results of "shortcuts" people use to simplify decision-making processes. Indeed, people use heuristics that, although valid in some circumstances, can lead to systematic errors with serious implications (Bazerman 2005). We explore some of these heuristics and biases studied in the behavioral decision making literature, and we describe their potential implications for OM settings.

4.2. Impact of Heuristics and Biases on Operating Systems and Processes

The source of problems or anomalies in OM settings can be linked to systematic errors people make in their judgments and decisions. A variety of biases and their potential implications for OM settings is presented in Table 1. As the table shows, the OM settings where biases might affect behavior include product development and R&D, project management, supply chains, forecasting, inventory management, services, and management of IT. There is a common factor across this diverse set of contexts and research areas: activities in each identified setting involve the acquisition, processing, and interpretation of information from different sources (e.g., market, competitors, testing, experimentation, prior experience).

[10] We thank the editors for suggesting these examples.

Table 1 Impact of Heuristics and Biases on Operating Systems and Processes

<table>
<tr><th rowspan="2">Stages of the decision-making and problem-solving processes</th><th rowspan="2">Bias/Heuristic</th><th rowspan="2">Description</th><th colspan="6">OM settings/research areas</th></tr>
<tr><th>Product development and R&D/Project management</th><th>Supply chain (logistics and distribution)</th><th>Forecasting</th><th>Inventory management</th><th>Management of information technology</th><th>Services</th></tr>
<tr><td>Acquisition of information</td><td>Information avoidance</td><td>People's tendency to avoid information that might cause mental discomfort or dissonance</td><td colspan="6">• Because in the short term people experience stronger regret for actions taken than for those not taken, because of information avoidance managers might keep (a) investing in failing projects, (b) using the same suppliers the company worked with in the past—even when the company is not satisfied with them (e.g., because of delays in delivering materials or products), (c) using well-known IT tools even when better options are available, or (d) addressing the same market even when there are opportunities for investing in new markets or offering new services.</td></tr>
<tr><td></td><td>Confirmation bias</td><td>People's tendency to seek information consistent with their own views or hypotheses</td><td colspan="6">• Confirmation bias might lead management to discount information about the potential failure of products or projects for which they have high expectations of success.
• In forecasting, the confirmation bias might lead managers to make biased estimates of future sales based on market information that is consistent with their own perspective.
• In service operations, the confirmation bias might lead a company to judge the quality of its services by focusing selectively on the feedback from satisfied customers.</td></tr>
<tr><td></td><td>Availability heuristic</td><td>People's tendency to judge an event as likely or frequent depending on the ease of recalling or imagining it</td><td colspan="6">• The use of the availability heuristic might reduce the accuracy of risk perceptions that take place in product development settings, inventory management, and forecasting.</td></tr>
<tr><td></td><td>Salient information</td><td>People's tendency to weigh more vivid information (e.g., based on prior experience/incidents) than abstract information (e.g., statistical base rates)</td><td colspan="6">• Because of salient information, managers might decide not to implement new IT based on the failing experience in implementation of a single competitor. The information about the competitor's experience might thus be more heavily weighed than available or more valid statistical information (e.g., industry average for successful implementation of this IT).
• Because of salient information, when developing a new product, the positive or negative experience of a single product manager might be weighed more heavily than statistics available for the product category are.</td></tr>
<tr><td></td><td>Illusory correlation</td><td>People's tendency to believe that two variables covary when they do not</td><td colspan="6">• Illusory correlation might lead managers to select an inappropriate variable when making forecasts or ordering decisions.
• Illusory correlation might lead project managers to use inappropriate variables to judge the success or failure of development products or projects.</td></tr>
<tr><td></td><td>Procrastination</td><td>People's tendency to defer actions or tasks to a later time</td><td colspan="6">• Procrastination might lead inventory manager to fail to update an inventory policy resulting in too many stock-outs.
• Procrastination might lead project managers to keep investing in projects when clear signals of failure are available.</td></tr>
<tr><td>Processing of information</td><td>Anchoring and adjustment heuristic</td><td>People's tendency to rely too heavily, or "anchor," on one trait or piece of information when making decisions</td><td colspan="6">• The anchoring and adjustment heuristic has been used to explain deviations from optimal behavior in inventory ordering decisions.
• The anchoring and adjustment heuristic might influence forecasting (e.g., managers might anchor on last year's sales and adjust insufficiently).</td></tr>
<tr><td></td><td>Representativeness heuristic</td><td>People's tendency to assume commonality between objects of similar appearance</td><td colspan="6">• The representativeness heuristic might lead managers in service operations to use stereotypes when dealing with customers (e.g., think that a customer is a doctor because she exhibits characteristics of a doctor). This might lead them to offer inappropriate services, i.e., services that do not meet the customers' requirements or needs.</td></tr>
</table>

Table 1 (cont'd.)

Stages of the decision-making and problem-solving processes	Bias/Heuristic	Description	OM settings/research areas: Product development and R&D/Project management	Supply chain (logistics and distribution)	Forecasting	Inventory management	Management of information technology	Services
			• The representative heuristic might play an important role in product or project management. When selecting projects, managers might make mistakes in deciding which projects to terminate and which to continue by assuming signs of failure or success apply to projects within the same category.					
	Law of small numbers	People's tendency to consider small samples as representative of the populations from which they are drawn	• In OM settings, the law of small numbers might lead to inaccurate decisions because of a mistaken interpretation of available data (from testing, market research, previous forecasts, etc.).					
	Sunk costs fallacy	People's tendency to pay attention to information about costs that have already been incurred and that cannot be recovered to any significant degree when making current decisions	• The sunk cost fallacy might lead companies to keep outsourcing even when it is not producing the desired benefits. • The sunk cost fallacy might lead managers to keep investing in development products or new IT tools in the face of clear signs of failure.					
	Planning fallacy	People's tendency to underestimate task-completion times	• Planning is an important component of OM. Research on the planning fallacy has shown that planners tend to focus on the project and underestimate time for meetings and other "overhead" tasks. The planning fallacy might thus affect planning activities in product development, IT implementation, distribution, and forecasting.					
	Inconsistency	People's inability to use a consistent judgment strategy across a repetitive set of cases or events	• The inconsistency bias might lead project managers to make suboptimal and inconsistent selection decisions between the projects in their portfolio. • Similarly, this bias might lead managers in supply chain settings to make inconsistent decisions when choosing suppliers. • In inventory management settings, because of the inconsistency bias, managers might use different inventory policies or rules when facing subsequent but identical ordering decisions.					
	Conservativism	People's failure to update their opinions or beliefs when they receive new information (update is not consistent with Bayes' theorem)	• The conservativism bias might lead managers to make inaccurate forecasts (e.g., for future sales). • The conservativism bias might also lead product developers to launch products that consumers won't like or need as initially expected—in cases in which preliminary consumers' evaluations are conducted through market research.					
	Overconfidence	People's tendency to be more confident in their own behaviors, opinions, attributes, and physical characteristics than they ought to be	• Overconfidence might lead project managers to select too many projects for the company to work on. • Overconfidence might lead managers in service operations to believe they are offering services that are better than their competitors'. • Overconfidence might lead companies to implement new IT tools based on the belief that employees will easily learn how to use them, even when evidence shows employees have difficulty in implementation and learning.					

Table 1 (cont'd.)

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<tr><td>Outcome</td><td>Wishful thinking</td><td>People's tendency to assume that because one wishes something to be true or false then it is actually true or false</td><td colspan="6">• Wishful thinking might lead people to assess the probability of outcomes they desire (e.g., a large number of satisfied customers, a 90% probability of success for the products the company is working on, a 90% probability that the orders will be fulfilled by the deadline) higher than their state of knowledge or amount of available information justifies.</td></tr>
<tr><td></td><td>Illusion of control</td><td>People's tendency to believe they can control, or at least influence, outcomes that they demonstrably have no influence over</td><td colspan="6">• In inventory decisions, the illusion of control might lead managers to believe they have control over environmental factors (e.g., demand).
• In supply chain settings, the illusion of control might lead managers to believe they have control over suppliers' decisions or over the choices and actions of other parties who are part of the supply chain.</td></tr>
<tr><td>Information received through feedback</td><td>Fundamental attribution error (FAE)</td><td>People's tendency to overemphasize dispositional or personality-based explanations for behaviors observed in others while underemphasizing situational explanations</td><td colspan="6">• Managers are often faced with the task of interpreting customers' behavior, competitors' behavior, suppliers' behavior, or employees' behavior before planning or making decisions about inventory, IT implementation, or project selection. The FAE is likely to affect such evaluations.</td></tr>
<tr><td></td><td>Hindsight bias</td><td>People's tendency to think of events that have occurred as more predictable than they in fact were before they took place</td><td colspan="6">• The hindsight bias might affect learning across various OM settings as well as planning activities. Indeed, managers might not reflect on the real causes of certain outcomes (e.g., failure to deliver a product on time, failure to implement new IT tools within the firm) that, in retrospect, are seen as not surprising and completely predictable.
• For instance, in product development, the hindsight bias might lead managers to overlook the reasons for the failure of a newly developed product. As a result, the company might repeat the same errors in prototyping or product development in the future.</td></tr>
<tr><td></td><td>Misperception of feedback</td><td>People's tendency to misperceive dynamic environments that include multiple interacting feedback loops, time delays, and nonlinearities</td><td colspan="6">• Misperceptions of feedback have been shown to affect supply chain settings, as well as inventory decisions.
• Misperception of feedback might also play an important role in service operations when the company receives feedback from its customers, as well as experimentation in product development when managers or scientists receive feedback on the status of their projects.</td></tr>
</table>

Notes. The list of heuristics and biases or the list of OM settings reported in the table cannot claim to be comprehensive. We hope it provides a starting point for researchers looking for behavioral operations questions.

We identify heuristics and biases that might be relevant in OM settings at each stage of the decision-making process. The table also includes a description of the potential implications of the listed biases for OM. The list of heuristics and biases as well as the list of OM settings presented in the Table 1 cannot claim to be comprehensive, but we hope that this description will provide ideas and stimulate research in behavioral operations. As examples of such research, in the next subsections we discuss in more detail a few of the heuristics and biases included in Table 1 and their potential implications for OM settings.

4.3. Anchoring and Adjustment

The anchoring and adjustment heuristic influences the way people intuitively assess probabilities. According to this heuristic, people start with an implicitly suggested reference point (the "anchor") and make adjustments to it to reach their estimate. Since its discovery (Tversky and Kahneman 1974), this bias has been shown to occur in situations as diverse as general knowledge issues, probability estimates, legal judgments, medical judgments, pricing decisions, and negotiation (Mussweiler and Strack 2001).

4.3.1. Product Development and Project Management. Product development and project management both require managers to make estimates about the length of the development process and its various stages for each product or project under development. Often, these estimates are made while evaluating past performance or information about competitors' development efforts. Both elements could serve as anchors and lead to inaccurate estimates. For instance, Aranda and Easterbrook (2005) showed that the anchoring and adjustment heuristic takes place in software estimation processes; when estimators are given a high anchor, their estimates are significantly higher than when they are given a low anchor or no anchor at all.

4.3.2. Inventory Management. In a newsvendor setting, Schweitzer and Cachon (2000) manipulated the relative level of holding and backorder costs and found that people consistently order quantities that are weighted averages of the optimal order and the expected level of demand. As a result, subjects order too much when holding costs are above backorder costs (so that the optimal order is well below expected demand) and too little when backorder costs are above holding costs (so that the optimal order is well below expected demand). In these studies, participants appear to treat expected demand as a starting point and make insufficient adjustments toward the optimal solution. This bias persists after extended experience and when the newsvendor can choose only among a few ordering options (Bolton and Katok 2008).

4.3.3. Forecasting. Future research might explore the role of this bias in forecasting. It could well be that sales forecasts are anchored to previous years' sales, with just a small, insufficient adjustment—thus resulting in systematically inaccurate predictions. Similarly, sales forecasts might be anchored to an estimate generated by a rational quantitative model and managers might adjust too little when making revisions to their initial forecasts.

4.3.4. Supply Chain Negotiation. Future research could also investigate the implications of the anchoring and adjustment heuristic in negotiation decisions with parties within the supply chain. When writing supply chain contracts, managers have to come to an agreement with their suppliers, for instance over the prices of the materials or services the company will receive from them. The prices mentioned in the contract might vary, depending on who suggested the price first, on what the suggested price was, or on prices parties had used in previous years.

4.3.5. Resource Allocation. Finally, the anchoring and adjustment heuristic might also play a role in discussions about the allocation of resources across products or teams that regularly take place in product development settings. Similarly, this heuristic might explain the budget firms decide to allocate to IT implementation and management. In both cases, managers might rely heavily in the industry average for R&D or IT expenses, without adjusting the amount based on the specific needs of the company or the situation.

4.4. Overconfidence

The overconfidence bias refers to individuals' tendency to overestimate the accuracy of their estimates or forecasts. For instance, research in decision making has shown that people engage in a biased evaluation of their own skills but not of others', and thereby find themselves superior to others. Specifically, people rate themselves as better than average on many subjective and socially desirable dimensions (e.g., decision-making or bargaining skills). Overconfidence about one's relative ability has been suggested as an explanation for the high rate of new business failures (Camerer and Lovallo 1999) and for excessive job market search and unemployment (Dubra 2004).

4.4.1. Inventory Management. The majority of OM settings are characterized by uncertainty, and accurate estimates about future probabilities and quantities are essential for choosing appropriate policies. This is true, for instance, for inventory management policies. Managers have to make estimates of future demand. Evidence from the behavioral decision research literature suggests that overconfidence affects such estimates. Watson and Zheng (2007) incorporated the overconfidence bias in their formal models of inventory replenishment. Specifically, they investigated the effects of managers' overestimation of demand levels on the behavior and performance of inventory systems.

4.4.2. Project Management and Development. Overconfidence might also play an important role in project management and product development. In both settings, managers need to make selection decisions based on preliminary evidence of the potential success or failure of projects in the pipeline. They need to make accurate estimates of the probability of success and failure for each project. They also need to evaluate the risks associated with each project. Overconfident managers might underestimate the risk of failures and overestimate success, and thus fail to undertake appropriate risk-reducing activities and expenditures, such as killing projects. Overconfidence might also lead project managers to select too many projects for the company to work on.

4.4.3. Service Operations. Overconfidence might also have interesting implications for service operations. In this setting, overconfidence might lead to biased self-assessment of competence in offering services to customers. For instance, managers in service operations might believe their services are better than the competitors' when they are not. This bias might induce too few investments in monitoring and process improvement and thus have a negative impact on sales and customers' satisfaction.

4.4.4. Employee Learning. Finally, managers might be too confident in their estimates about the ability of employees to learn how to use new tools or technologies. For instance, overconfidence might lead companies to implement new IT tools based on the belief that employees will easily learn how to use them, even when evidence shows difficulty in implementation and learning.

4.5. Confirmation Bias

As a last example of research in behavioral operations, consider the confirmation bias and its potential implications for OM settings. This bias refers to individuals' tendency to search selectively for information that confirms their beliefs or expectations. For instance, we all enjoy and spend time listening to politicians, reading books, or watching TV programs that are consistent with our beliefs about the world.

4.5.1. Product Development. Product development requires managers to develop new products and collect information on their likelihood of success in the marketplace through testing, experimentation, and prototyping. All these activities involve information collection at different stages of the product development process. Product development managers often describe the products they are working on as "their babies," and they are hopeful that their products will be successful. Data from testing and experimentation are evaluated by the same managers who are working on the development of the products. Given their desire to see their product succeed, the confirmation bias might lead them to seek confirmatory information and avoid disconfirmatory evidence.

4.5.2. Supply Chain Management. As part of their supply chain management decisions, companies have to decide which suppliers to order from and which partners to involve in the chain. Such decisions are made based on the information collected about the potential suppliers and partners. Managers involved in such selection decisions often have set their mind on specific parties, based on their personal experience in working with them in the past. If managers view some of the parties as particularly suitable for the job, they might collect information from other companies that have worked with them to confirm their beliefs.

The confirmation bias might thus lead them to fail to account for information inconsistent with their view.

4.5.3. Forecasting. Future research might also explore the role of the confirmation bias in forecasting. Data and information that is relevant to managers who need to make accurate forecasts is usually stored in various places: records of past forecasts, market research information, results of testing, databases with information about the company's past performance, and market demand. The confirmation bias might lead managers to search through those records and databases in a biased way; based on their initial hypotheses or preconceptions, managers might seek confirmatory data and avoid disconfirmatory evidence. This biased search would lead to biased forecasts.

4.6. Beyond Demonstration

We believe that one task of behavioral operations is to demonstrate the existence and the effects on operating performance of the biases studied in behavioral decision research. But a further goal is to explore potential interventions that address these biases. In traditional OM, researchers develop models or tools based on the assumption that decision makers are fully rational. If used properly, it is argued, such models will improve operating performance. Behavioral operations, instead, starts with the assumption that decision makers are boundedly rational and their decision-making processes are affected by systematic errors. Based on this assumption, behavioral operations researchers develop models or tools that take human cognitive limitations into account and thus create interventions and institutions that help correct or counteract the effects of biases. Human psychology cannot be changed, but operating systems can be designed in such a way that systematic errors are eliminated, or at least their negative consequences reduced.

5. Conclusions and Future Research

Research in psychology over the past several decades teaches us that behavioral biases and cognitive limits are not just noise; they systematically affect (and often distort) people's judgment and decision making. Yet the implications of these forces for the design, management, and improvement of operating systems is barely understood. We believe there are two main areas for intellectual value added by behavioral operations.

First, a behavioral approach to OM can lead to a better understanding of underlying drivers of operating system performance and also to a better understanding of puzzling "pathologies" (e.g., excess inventory, late product development projects, overcommitment to R&D projects, etc.). Second, a behavioral perspective can lead to a better identification of appropriate management interventions. For instance, the knowledge that behavioral issues have caused a company to carry too much inventory precludes the search for a better optimization algorithm. Thus, to overcome the psychological distortions at the root of many OM problems, behavioral operations should consider ways to create "cognitive repairs" (Heath et al. 1998) or organizational practices that may solve the cognitive shortcomings of individuals within the organization.

5.1. Future Paths for Research

We suggest that five types of research in behavioral operations can and should be pursued: replication studies, theory-testing studies, theory-generating studies, adaptation studies, and OM-specific studies.

Replication studies refer to research that attempts to replicate or test existing behavioral theories with data from OM contexts. This type of research uses behavioral decision-making theories and findings from the psychology literature as a starting point. Can those theories and findings be replicated in OM contexts, or will their nature change? For instance, one might consider the impact of sunk cost effects on product development choices. Economists argue that, if people are rational, they will not take sunk costs into account when making decisions. Yet several experimental studies on individual decision making have shown that people's economic behavior is often influenced by the sunk cost fallacy (Arkes and Blumer 1985, Garland 1990, Heath 1995, Thaler 1980). Do sunk cost effects influence project termination decisions? What is the impact of costly prototyping on decisions in product development? Explorations of these questions would constitute replication studies, replicating the impact of existing biases in new contexts.

Theory-testing studies aim at examining OM theories in a laboratory setting. Like experimental economics research, theory-testing studies should have three purposes: (a) normative, aimed at designing laboratory experiments mimicking settings where theories make predictions; (b) descriptive, or designed to test behavior and explain deviations caused by psychological forces; and (c) prescriptive, aimed at suggesting debiasing techniques that can be used to reduce or eliminate systematic errors observed in people's behavior. The stream of research on the bullwhip effect and on the use of experiment in OM belongs to this second category (for specific studies, see Bendoly et al. 2006). Many other OM theories could be tested as part of this type of behavioral operations.

The third type of research in behavioral operations consists of *theory-generating studies*. In 1963, Bowman investigated aggregate production and employment scheduling and offered a method of "starting with the managers' actual decisions and building on them to reach a better system" (Bowman 1963, p. 310). For several decades, however, this view has been almost completely ignored. Theory-generating studies would build on existing mathematical OM models, addressing the same problems but with changed assumptions formulated based on managers' actual decisions and biases. An example of this type of research comes from behavioral economics. Standard dynamic models of economics commonly assume that agents have exponential discount rates. But empirical evidence shows that people's preferences are not consistent over time (e.g., Loewenstein and Prelec 1992). To fit this psychological evidence, behavioral economists have started building their models with the assumption of hyperbolic discounting (e.g., Laibson 1997).

The fourth type of research in behavioral operations consists of *adaptation studies*. In this case, the research originates from OM problems, phenomena, or puzzles and focuses on potential behavioral explanations. The stream of research on system dynamics models applied to operational contexts belongs to this third category. Other OM phenomena that could be explored under this rubric include inventory record inaccuracy and discrepancies between inventory records and physical inventory—a major obstacle to improved operational performance (Kok and Shang 2006). Documented inventory inaccuracy might result from factors such as stock loss or shrinkage, transaction errors (in the inbound or outbound processes), and misplaced products (Piasecki 2003, DeHoratius and Raman forthcoming, Raman et al. 2001). But a behavioral perspective might reveal new insights into causes of inventory inaccuracy and misplacement. For instance, products might get displaced simply because employees assigned to the job procrastinate in dealing with their assignments.

Finally, *OM-specific studies* are a fifth opportunity for behavioral operations. These studies use mixed methodologies, such as lab experiments, field-based research, modeling, and empirical analyses to investigate important OM problems. Their main purpose is to uncover new behavioral or cognitive factors that tend to arise in OM contexts. An example of this type of research is given by Edmondson's work on psychological safety (Edmondson 1996, 1999), or "the shared belief held by members of a team that the team is safe for interpersonal risk-taking" (Edmondson 1996). Within a work team, psychological safety facilitates learning behavior because it reduces an individual's concern about others' reactions to actions that might be embarrassing or threatening (Edmondson 1999). This bias was uncovered in research in the operating context of medical errors, but it is an example of a newly identified bias that could affect OM settings more generally.

Ultimately, multiple approaches will be required to unlock our understanding of how operating systems work and, in particular, how the social, human, and physical components of these systems interact. This perspective represents a significant broadening of the research agenda in operations. There is perhaps no agenda for the field more important than a deeper understanding of the behavioral and cognitive forces shaping operating systems and processes and the implications for the design of appropriate management tools and practice.

5.2. How to Successfully Contribute to the Behavioral Operations Field

In the previous sections we discussed several types of research in behavioral operations that we believe are worth pursuing. We turn briefly to pragmatic issues of how behavioral decision research can be best incorporated in the OM field and strategies that can be used to accomplish this goal.

The first strategy is aimed at improving awareness within the OM field of the importance of behavioral and cognitive factors in operating performance. This strategy can be implemented through the usual methods of disciplinary cross-fertilization in academia, such as symposia that bring together researchers from both fields. A second strategy is collaborations between scholars in different fields (for instance, a "straight" OM person and a "straight" behavioral researcher) or scholars interested in behavioral operations and with a background in either OM or behavioral decision research. Finally, a third strategy is to train doctoral students who are part of OM or operations research programs in behavioral decision research.

Perhaps the biggest challenge for behavioral operations, like any emerging subfield, is to gain legitimacy. Such legitimacy can only be earned by shedding new light on important phenomena in operations. Behavioral operations cannot simply be an exercise in "intellectual arbitrage," porting well-known concepts from one field into another. There are many theoretical and experimental insights from behavioral research in other fields, but understanding the implications of those insights for designing, managing, and improving complex operating systems is no trivial task. We now have an impressive body of knowledge about biases like sunk costs, framing, and the planning fallacy, but how those affect the behavior and performance of operating systems is largely unexplored. This will require the development of novel conceptual insights. And this is a task that only researchers in operations management, who understand the complexities of actual operating environments and systems, can tackle.

Acknowledgments

The authors gratefully acknowledge financial support from the Harvard Business School Division of Faculty Research and Development. They thank participants at the MIT Sloan School OSG seminar for their insightful feedback on the ideas presented here. The authors are especially grateful to Amy Edmondson, Charles Fine, Robert Hayes, Richard Nelson, Andrew McAfee, Roy Shapiro, Noel Watson, and Steven Wheelwright for their insightful comments on earlier drafts. The authors also want to thank the reviewers for their excellent feedback and the editors for their patience and wise guidance during the revision process. Please address correspondence by e-mail to fgino@andrew.cmu.edu or gpisano@hbs.edu.

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