CHPT. 4

Computational Organization Theory

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ACTS Theory: Extending the Model of Bounded Rationality

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The model of bounded rationality asserts that agents in an organization may be rational in intent, but less than rational in execution because functional limits on cognition severely restrict their ability to achieve optimality in the pursuit of their goals (Simon, 1976). The original purpose of the model was to characterize the effects of a restricted rational agent on the assumptions (and conclusions) of economic and administrative (i.e., organization) theory (Simon, 1979). This model and its variants have significantly influenced, directly and indirectly, theories of organizations, as well as explanations of organizational behavior, to include restrictions on rationality and optimal choice (e.g., Charnes & Cooper, 1963; Cyert & March, 1956, 1963; Glazer, Steckel & Winer, 1992; Huber, 1990; Lord & Maher, 1990; March, 1978; March & Shapira, 1987; Radner, 1975; Simon, 1976; Sims, Gioia, & Associates, 1986; Stinchcombe, 1990; Williamson, 1975). We suggest that advances in organizational theory can be achieved by extending the model of bounded rationality by moving beyond general principles to specific detailed models realized as computer programs. In this chapter, we propose such an extension, and illustrate its role in defining and interpreting two computational theories of organizational behavior.

Bounded rationality was to replace the fundamental model of the agent on which theories of economics and organizations were based with a model that better approximated the actual capacities, and therefore the behavior, of a human decision maker. The natural source of such a "more human model" would be those models proposed by psychology. One part of bounded rationality was that the agent itself was boundedly rational (Simon, 1955),
whereas another part was that the environment, and the interrelations between the environment and the agent, set bounds on and therefore constrained the agent (Simon, 1956). As Simon noted (1956), the agent's mental models that enable decisions to be made employ simplifications of reality that "may depend not only on the characteristics—sensory, neural, and other—of the organism, but equally upon the structure of the environment" (p. 130).

In this chapter, we extend the original model of bounded rationality and incorporate the extended model within a general process theory of organizations. We refer to the theory as ACTS theory—organizations are viewed as collections of intelligent agents who are cognitively restricted, task oriented, and socially situated. ACTS theory embodies the two fundamental foci of the original model of bounded rationality: the limited deliberative power of the agent and the constraints of the environment. The extension occurs by (a) replacing the general principles of the boundedly rational agent with a broader, more encompassing perspective of a cognitive agent, and (b) replacing general notions of environmental constraints with two specific environmental perspectives, the task and the organizational social situation within which the task and agent are situated.

The main theme of this chapter is that organization theory may benefit by taking balanced, multiple perspectives of the agent, the task, and the (social) situation in which both the agent's perspective of the task and situation and the reality of such situations are jointly considered. Such a multiple perspective is an instance of what are now called meso-theories, where the term meso describes midlevel theories that link microlevel mechanisms to macrolevel phenomena—in our case the physical and social to the cognitive. Because we take this meso-theoretical approach, we are in effect combining the sociology of organizations and the psychology of organizations into a single perspective (cf. Daft, 1989).

In this chapter we present the assumptions of ACTS theory axiomatically. We also illustrate the role of the multiple perspective on the agents' internal representation of this world (agent cognition) and the physical and social world (task and social situation) with a slightly more unified theory of organizations by examining two computational models of organizations—Plural-Soar (Carley, Kjaer-Hansen, Newell, & Prietula, 1992) and an organizational Experiential Learning Model (ELM; Carley, 1990, 1991b, 1992). We demonstrate the use of the ACTS perspective by comparing the extent to which both computational models satisfy the underlying axioms, and examine the results of simulation experiments from these two computational models.

**ACTS THEORY**

ACTS theory is a theory of constraints and opportunities. Within ACTS, the actions of agents (the composite of which are organizational acts) are
constrained by the immutable aspects of the human cognitive architecture, the characteristics of the task, and the nontask characteristics of the organizational environment in which the agents are situated (the social situation). The agent's knowledge, which is continually changing, mediates the effect of the task and social situation on individual and organizational behaviors and performance (Simon, 1976). The task and social situation can be highly volatile and may be immutable only in the short term (Cohen, March, & Olsen, 1972; March & Romelaer, 1976). The volatility creates further constraints on, and opportunities for, action (Carley, 1986; Cohen et al., 1972). Furthermore, this volatility encourages the use of actions whose only value is symbolic (Feldman & March, 1981). ACTS theory seeks to explain such organizational behaviors and performance by supporting the development of a set of computational models interlinked through an organizational design. This set would include a model of the cognitive agent (including knowledge), a model of the task, and a model of the social situation.

At the microlevel, ACTS theory focuses on explicating how a given organizational design will affect the behavior and performance of individual agents as they communicate and reason within a social situation while trying to accomplish a task. At the macrolevel, ACTS theory focuses on explicating the behavior and performance of groups and organizations with different organizational designs, given that the group or organization is comprised of intelligent agents who are socially situated and task oriented. Thus, ACTS theory addresses those research questions in which individual and group decision making play a key role; therefore, what an agent knows and to whom an agent communicates are important components of ACTS theory. As ACTS theory jointly considers multiple (level) perspectives, individual cognition (and hence agents' representation of the task and social situation, which includes other agents) is as key to ACTS theory as are the task and the social situation. The task and social situation constrain behavior by limiting opportunities for action and by setting limits on what the agent knows, does, and therefore can know. ACTS theory is consistent with the tenets of bounded rationality (March & Simon, 1958; Simon, 1976; Simon & Baylor, 1966), but adds precision, prediction, and testability through the specification of the component models.

The general stance taken in this chapter vis-à-vis the actions and decisions of intelligent agents follows from that suggested by Carley and Newell (1990). An agent's actions are a function of the agent's cognitive architec-

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1 We view organizational design as including the set of rules of operations or procedures, institutional norms, databases, task decomposition scheme, and the formal and informal organizational structure (Lin & Carley, 1992). Thus, organizational design is present in and affects agents (through their knowledge bases), tasks (through their decomposition), and situations.
ture and knowledge. The cognitive architecture is immutable over time and constant across agents. The mechanisms by which an agent processes information, makes decisions, and learns are a function of the agent's cognitive architecture. The agent's knowledge changes over time as the agent learns (and perhaps forgets). This knowledge is a function of the agent's position within the organization (which is defined from a socio-cultural-historical standpoint), the task in which the agent is engaged (and the associated goals), and the problem or problems that are currently interrupting the organization's "normal," or perhaps ideal, operating conditions.\textsuperscript{2} The information processed, the decisions made, and the knowledge learned are all heavily influenced by (a) the knowledge that is currently salient, (b) the knowledge available to the agent by virtue of the agent's social position, (c) the task in which the agent is engaged, and (d) knowledge limitations due to the current difficulties besetting the organization.

The agent's cognitive architecture defines what the agent can possibly do with that knowledge. The agent's position, task, and the current set of difficulties, by affecting what known information is salient and what new knowledge is available, constrain these possibilities and provide opportunities. ACTS theory is thus consistent with Simon's (1981) observation that the apparent complexity of human behavior lies not with the mechanisms of reasoning, but with the task environment. ACTS theory is also consistent with Carley and Newell's (1990) extension of Simon's argument, in which they argue that the vast complexity of the task and social situation is necessary for many characteristically human (social) behaviors to emerge.

Thus, ACTS theory refocuses the attention of the researcher interested in organizations on the details through which task and social environment (interaction and communication with other agents) influence agent and group adaptation (including socialization and enculturation) and performance.

ACTS theory focuses on articulating collective organizational constraints and opportunities—as defined by the individual agents, the task(s) being performed by the agents, and the specific social situation (and its ramifications) within which the agents are situated—and how these constraints and opportunities serve to restrict and enable individual and hence emergent collective (i.e., organizational) phenomena in a dynamic and often volatile organizational setting.

ACTS theory is an extensible, deductive theory, embodied in a fundamental set of propositions functioning as axioms and an expandable set of testable propositions functioning as theorems deduced from the axioms (Blalock, 1969). Ideally, the fundamental set of axioms should serve as the

\textsuperscript{2}These problems may be part of the general difficulties faced by the organization that make organizational life anarchical at times (Cohen et al., 1972) or they may be more catastrophic in nature, like those occurring when high-risk technology is employed (Perrow, 1984).
presumably true (or, perhaps, untestable but plausible) propositions from which a set of theorems can be deduced to explain and predict observed phenomena. These axioms reflect the primary components and sources of constraints and opportunities in ACTS theory. They reflect the agent, task, and social situation, and the interrelation between these constructs, and are shown in Tables 4.1 and 4.2.

Collectively, these axioms provide an image of organizations as both dynamic and historically bound, constrained by and constraining human action, purposive and reactionary, restricted by and capable of generating organizational culture. From this perspective, organizations are collections of tasks and situated intelligent agents engaged in performing tasks. The agents are generally intelligent agents that cooperate and coordinate (to varying degrees) with each other, from socially situated positions within organizational structures (which embody previous interactions and decisions and are continually reconstructed) through the exchange of information and resources, in order to perform tasks (which accomplish goals that are more or less articulated) despite the obstacles or problems that make organizational life less than predictively certain.

These axioms assert that organizational agents are generally intelligent

<table>
<thead>
<tr>
<th>TABLE 4.1</th>
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<tr>
<td>Agent, Task, and Social Situation Axioms of ACTS Theory</td>
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<tr>
<th>Agent Axioms:</th>
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<tbody>
<tr>
<td>Axiom 1. Organizations are composed of goal-directed, intelligent agents (decision makers) who can learn, communicate, and take action in pursuit of goals.</td>
</tr>
<tr>
<td>Axiom 2. All goal-directed cognitive deliberation, perception, and communication by agents occurs within a physical symbol system architecture that is functionally constrained by natural physical laws.</td>
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<tr>
<td>Axiom 3. Symbolic cognitive architectures and their derivative forms, such as Soar and the Problem Space Computational Models of Newell (Newell et al., 1990; Yost &amp; Newell, 1989), sufficiently describe the mechanisms by which a goal-directed agent exhibits intelligence, communication, and learning within the constraints of Axiom 2. Such goals need not be articulated or be articulable by the agent. Further, the goals can be automatically generated or selected by the agent as deliberation ensues.</td>
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<tr>
<th>Task Axiom:</th>
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<tr>
<td>Axiom 4. An organizational agent performs one or more tasks in an organization in order to achieve specific personal, task, and/or social (group and organizational) goals, several of which may simultaneously arise and, perhaps, conflict with each other.</td>
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<tr>
<th>Social Axiom:</th>
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<tbody>
<tr>
<td>Axiom 5. An organizational agent occupies a position (formal and informal) in the organization that is a socio-cultural-historical artifact involving one (or more) socially situated roles.</td>
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agents and that computational models, such as the problem space computational model articulated by Newell, Yost, Laird, Rosenbloom, and Altman (1990), are sufficient (if properly specified) for modeling such agents. The problem space computational model is one articulation based on a symbolic architecture of cognition, which, in general, has the potential for having the necessary and sufficient conditions for intelligent behavior (Newell & Simon, 1976; Newell, 1990). The particular selection in Axiom 4 was chosen as there exists a well-defined instantiation of the symbolic cognitive architecture in the form of a computer program, Soar (Newell, Rosenbloom, & Laird, 1989), that would enable a firm theoretical infrastructure for simulations (i.e., computational organizational models) requiring strong models of individual intelligence and cognition.

Computational models, by their very nature, move beyond the principles of bounded rationality to specific details of the cognitive architecture. The nature of the organizational agent is central to ACTS theory and should figure prominently in the computational model. Within ACTS theory, the more generally intelligent the agents, the more capable they are of learning, the greater the number of organizational behaviors that will be explainable with the same formal model (other things being equal), given the constraints imposed by the task and social situation. Similarly, the more complex the
socio-cultural-historical situation, the more detailed the organizational designs and the tasks being engaged in, the greater the number of organizational behaviors that will be explainable with the same formal model. Yet, the task and social situation are as key to ACTS theory as individual cognition, for it is through an examination of the interaction between the physical and social world and the cognitive world that we can begin to craft an accurate theory of how decisions are made in organizations. In fact, the complexity of a computational model required to represent the critical decision-making properties of an organizational agent may be much less than the general capability of an intelligent agent, if the task, knowledge, and organizational situation collectively restrict and constrain the optional behaviors, knowledge, goals, and communication of the agents. Thus, a specific organizational situation may so attenuate the degrees of intellectual freedom brought to bear on a task that far simpler agent models may effectively achieve the level of sophistication required for a computational organizational model. In Table 4.3, some typical individual and organizational behaviors explainable with a detailed model of cognition, task, or social situation are listed.

Although ACTS theory, like open systems theory (Scott, 1987), recognizes that the environment is dynamic, it suggests that there may be immutable and fundamental principles on which a theory of organizations can be developed, but that such principles can only be observed by examining human reasoning and interaction under both optimal and less than optimal conditions. Further, to the extent to which there are such immutable principles, they will arise from the physical constraints inherent in the human cognitive architecture, the properties of the task, and the design of the organization. Accordingly, we illustrate each of the three components (agent cognition, task, and social situation), using two computational models: Plural-Soar and ELM. Figure 4.1 shows the interaction of these three components and the position of Plural-Soar and ELM in this trinity.

Plural-Soar and ELM may be considered as partially sufficient from an

<table>
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<tr>
<th>TABLE 4.3</th>
<th>Agent Model Components and Associated Individual/Organizational Actions</th>
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<tbody>
<tr>
<td>Agent Component of Actions</td>
<td>Cognitively Restricted</td>
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<td></td>
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<tr>
<td>Reasoning</td>
<td>Scheduling</td>
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<tr>
<td>Adaptation</td>
<td>Coordination</td>
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<td>Planning</td>
<td>Negotiation</td>
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<tr>
<td>Error</td>
<td>Performance</td>
</tr>
<tr>
<td>Compulsiveness</td>
<td>Goal specification</td>
</tr>
<tr>
<td>Choice/judgment</td>
<td>Goal selection</td>
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</tbody>
</table>
FIG. 4.1. Relative sophistication of ACTS components realized in Plural-Soar and ELM.

ACTS point of view, as neither completely embodies the full multiple perspectives of agent cognition, task, and social situation. However, the point must again be made regarding the distinction between the individual complexity of an agent model qua agent, and the actual complexity required (or permitted) as afforded by the multiple perspectives considered jointly. Thus, the collective perspectives may coconstrain each other such that most of the variance in behavior (individual or collective) is accounted for by a disproportionate subset of either the task, situation, or agent. For example, a highly constrained task and social situation may afford a highly constrained (and restricted) cognitive agent, where differences in organizational (i.e., collective) behavior are accounted for by variations in task parameters, and not by differences in agent cognition (e.g., knowledge, learning, richness of the model). On the other hand, unconstrained task situations may have much of the variance accounted for by differences in agent parameters (e.g., agents with more knowledge make better choices, agents that can learn reduce collective errors, agents that can communicate reduce
collective effort). Consequently, stronger (i.e., more detailed) models (of a perspective) may be traded off against weaker models, depending on the particular setting. But that setting is strictly determined by the specification of the three components (i.e., task, agent, situation) and how they coconstrain each other.

Both Plural-Soar and ELM have strong task models. Plural-Soar focuses on the cognitive world at the expense of the social; ELM focuses on the social at the expense of the cognitive. Plural-Soar couples a weaker model of social situation with a stronger model of cognition to examine organizational performance for organizations facing a task that requires filling customer orders from stocks in a warehouse. Plural-Soar employs a model of distributed organizational decision making and action in which each agent is modeled using a general model of intelligence. Using Plural-Soar, the performance of organizations with essentially uncoordinated agents can be examined.

In contrast, ELM couples a stronger model of a social situation with a weaker model of an agent. Within ELM, organizational performance is examined for organizations facing a simple binary choice task. ELM employs a model of distributed organizational decision making and action in which each agent is modeled as being boundedly rational and learning through individual experience. The performance of multiple organizations (within which the agents can be placed in a large number of different social situations) can be contrasted.

Our purpose in presenting Plural-Soar and ELM is twofold: (a) to illustrate the relationship between ACTS theory axioms and actual computational organizational models, and (b) to suggest the type of minimally sufficient models of the task, social, and cognitive perspectives necessary to formulate an instantiation of ACTS theory. We advance Plural-Soar as a candidate for a strong agent model, ELM as an example of a social situation model, and both the warehouse and binary-choice tasks as examples of minimally sufficient task models.

ACTS theory, as articulated by the axioms in prior Tables 4.1 and 4.2, serves as a common reference permitting multiple models of organizations to be compared to each other. The extent to which a given computational model directly addresses (or should address) an axiom depends on the extent to which the constructs under investigation are salient to the axiom. This, in turn, determines the nature of the inferences that can be made from the computational model. How Plural-Soar and ELM relate to the axioms of ACTS theory is summarized in Table 4.4.

**PLURAL-SOAR: A STRONG AGENT MODEL**

Plural-Soar is an exploratory computational organizational model used to examine how a set of agents, predicated on a strong model of a generally
<table>
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<th>Axioms</th>
<th>Plural-Soar</th>
<th>ELM</th>
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<tr>
<td>Agent:</td>
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<td>1</td>
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<td>2</td>
<td>met</td>
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<td>3</td>
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<tr>
<td>Task:</td>
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<td>4</td>
<td>not met</td>
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<tr>
<td>Social:</td>
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<tr>
<td>5</td>
<td>minimal</td>
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<td>Interlink:</td>
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<td>6</td>
<td>met</td>
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<td>7</td>
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<td>8</td>
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<tr>
<td>9</td>
<td>not met</td>
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Intelligent agent, can be combined into a functioning organization (Carley et al., 1992; Prietula & Carley, 1992). The Plural-Soar system can be used to address questions regarding the impact of individual learning, rationality, norm violation, and knowledge differences on organizational performance and dysfunctionality. Plural-Soar is a collection of agents interlinked into an organizational design and working collectively to perform a task, each Plural-Soar agent runs on a separate workstation, and all workstations are interconnected. Plural-Soar is designed to operate in effective real time; that is, there is a set of problems available (orders to be filled in a warehouse), and each agent acts on a problem (searches the warehouse to fill the order). By specifying the social situation (the number of agents and the communication scheme) and each agent's knowledge and set of available actions (including preferences for particular actions and task standard operating procedures), a unique type of organizational design is identified (e.g., a five-person warehouse team with no communication capabilities). The system is nonstochastic, so each organizational type need only be simulated once to determine its performance (see Carley et al., 1992).

Each Plural-Soar agent has an equivalent cognitive architecture, Soar, so all agents have the same set of architectural capabilities and constraints. Soar (Laird, Newell, & Rosenbloom, 1987) is a symbolic cognitive architecture capable of exhibiting general learning and intelligence through goal-oriented, flexible behavior. Initially, all agents have equivalent task knowledge (e.g., where to pick up orders to fill), task preferences (e.g., preferring to search the warehouse in a particular fashion), social knowledge (e.g., other agents may have information relevant for the search), and social preferences (e.g., preferring to ask other agents for information rather than perform an uninformed search). Furthermore, each agent
constructs a mental model of the task and updates it based on experience as the task unfolds. An agent only has access to its personal knowledge and mental model (interagent communication is one of the social properties manipulated).

The overall task goal for each agent is quite simple—fill available orders. The general components of the task are shown in Figure 4.2. To achieve the goal, an agent must proceed to, and select an order from, a particular location (the order stack), locate the locations in the warehouse (item stacks) of the item(s) listed on the order (either through search or by asking other other agents), and move the item(s) necessary to fill the order (once located) to a specific location (conveyor belt). Each order contains a list of items requested by a customer, but no information about where the requested items are in the warehouse.

Each agent occupies a specific social (but completely undifferentiated) position in an organization. Agents differ initially only in the physical order (queue) in which they are standing in front of the order stack at the beginning of the simulation. As the agents perform the task, different experiences with the environment (i.e., orders, warehouse locations, other agents) cause agents to accumulate different knowledge. Over time, different agents will evolve different mental models of the task and social situation. Further, a

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**FIG. 4.2.** Figural representation of warehouse components and agents.
given agent's mental model of task and social situation may differ from reality due to cognitive limitations (i.e., restricted perception of other agents' behaviors) as well as task and social opportunities for gathering knowledge (e.g., by restricting agent communication). The capabilities of an agent can be altered by manipulating components of the agent model.

An agent can directly perceive the items at an order stack only when the agent is situated at the particular stack location. Agents proceed to locations along the walkway, but there are no physical constraints for agents moving along the walkway, which means that agents can "pass each other" on the walkway and proceed to the same location. However, two or more agents at the same location cannot manipulate items or orders at the same time. When agents are at the same location they form a first-in, first-out queue, allowing the first arriving agent to manipulate the stack. Although agents at the same location cannot manipulate a stack at the same time (i.e., remove items on top of the desired item), an agent at an immediately adjacent location can move items to this stack and vice versa (i.e., placing removed interfering items out of the way).

An agent can locate a specified item in the warehouse by conducting an exhaustive search (i.e., moving to each stack and examining the contents), retrieving the item-location association from its memory (only if the agent has previously perceived the item at some location), or by asking other agents. Agents are inherently "lazy" and prefer to use either information in memory or information gathered by asking others, avoiding exhaustive search. Agents also trust themselves more than others and prefer to use information from their own memory rather than information gathered by asking others. Agents will respond to questions (of item locations) only if they have encountered the questioned item in a stack. All agents operate on an effectively one-to-many broadcast form of communication.

There are no hierarchical authority relations among these agents—all have equal rights to select and process an order. Nor are there any implicit social status relations—all agents are indifferent between which other agents they ask for information or to whom they provide information. The only authority structure is task-opportunism—the particular job an agent attempts to carry out is simply the next available order on the order stack. Furthermore, one agent cannot usurp or stop a job from another agent. Thus, assignments (of jobs to agents) are not planned, but emerge opportunistically as collective problem solving ensues. Apparent social differences are a consequence of the agents' and the organizations' task history.

**ACTS Axioms and Plural-Soar**

Plural-Soar automatically meets Axioms 1, 2, 3, 6, and 7, as it uses Soar agents. Plural-Soar does not meet Axiom 4, as personal, task, and
organizational goals are largely equivalent. To meet this axiom the agents would need to be extended so that they had models of other agents and could consider the differential benefits of filling their own orders versus helping others so that the organization as a whole filled all orders more effectively. In terms of Axiom 5, as previously noted, the Plural-Soar agents occupy positions that are undifferentiated (at least initially).

Axiom 8 is only minimally met, as the orders do get filled, thus leading to a redistribution of items in the stacks, and the items do get moved from the locations in which they are expected. In one sense, Plural-Soar deals only with stable situations; that is, all orders are available, all agents are available, no external crises are occurring that distract agents from the task at hand, and there is no time pressure. In this sense, it does not meet the spirit of Axiom 8. Problems could be easily added to the situation within this framework. In another sense, for those things that can go wrong, the agent already has procedures or answers. Agents clearly do not have complete information, but they have the ability to ask questions and search. Agents may be unable to perform their assigned task because another agent is in front of them, or because the item they desire is at the bottom of the stack. In this case, predefined preferences make these difficulties nonproblems by providing a solution. However, there are relatively few items and few stacks so such difficulties, although inevitable, are not catastrophic.

Finally, Axiom 9 is not met. The agents do not alter their position within the organization on the basis of previous interactions. Developing agents with such social construction abilities would require the agents to have models of other agents. This, however, is not a restriction on Plural-Soar, but simply a limit on this particular agent model defined in Plural-Soar.

It is important to differentiate between the fundamental adequacy of Soar as a plausible model of a generally intelligent agent and Plural-Soar as a model of an intelligent agent situated within a particular organizational context. The former addresses the extent to which Soar is psychologically valid as a theory of cognition, whereas the latter addresses the extent to which an agent modeled in Soar possesses the necessary and sufficient mechanisms to model the form and substance of reasoning within a particular organizational context.

The Soar model is one of the most elaborate cognitive simulations in existence. Plural-Soar is simply the first tentative step in placing Soar agents in an organizational setting and so determining the extent to which it makes possible a socially valid organizational simulation. With Plural-Soar, explorations can begin to examine how much context knowledge is necessary given Soar to sufficiently model the social agent. This first step, however, begins to reveal both the adequacies and inadequacies of Soar. SOAR is adequate in the sense that behavioral (i.e., knowledge-based) differences across agents can be represented. Plural-Soar agents were given
preferences, such as, prefer to ask rather than search. These preferences serve, in a way, as an encoding of organizational norms and behavioral (perhaps even emotional) traits. Agents with different characteristics can thus be easily modeled by giving them not only different knowledge, but also different preferences. Plural-Soar is seen as sufficient to generate some important expected organizational behaviors—for example, economies of scale and individual rationality resulting in social dysfunctionality (and organizational suboptimality).

The architecture presented in this chapter permits models of an autonomous agent performing self-contained tasks. This allows a team of agents to be defined, where each agent is performing a subtask of processing orders in the warehouse. This is accomplished without adding any further control knowledge to the “team” (individually or collectively) apart from what is already present in the individual agents. Because the tasks are self-contained, little cooperation or coordination between agents is required to do the task. Cooperation among the agents (in the form of communication) affects the efficiency with which tasks are done.

Thus the team is made up of a set of agents with totally distributed decision making. Each agent decides at any time what to try to do. There is no overarching organizational structure and, consequently, no particular limitations on knowledge due to the agent’s role in the organization. The coordination between agents in performing the task is a function of the physical constraints on, and capabilities of, the agents. No negotiation, planning, or communication related to coordinating the task takes place. Therefore, despite a sophisticated model of the agent, Plural-SoAR is not adequate to model organizations in general due to the lack of social situations and the subsequent constraints and opportunities they afford to the agents who occupy the associated positions. No coordination, negotiation, planning, or mobility takes place and no organizational design issues can be addressed (such as power exchanges and turnover).

The knowledge held by each agent is very episodic and task specific. To the extent that the environment is volatile (i.e., the composition of the warehouse changes rapidly with respect to memory), the agents’ knowledge of the warehouse structure is fragile. In the current system, an agent simply ignores environmental changes unless they prevent the agent from doing the task.

**Exploring Agent, Task, and Organizational Properties**

To illustrate how Plural-Soar is used to investigate organizational issues, we examined the effects of agent communication, organizational size, and task arrangement on organizational performance. One might expect with the warehouse task that allowing agents to communicate should improve
organizational performance—agents should be able to decrease their search of the stacks (and hence physical agent movements) by simply asking other agents for the location of the needed item. When an agent makes decisions based on answers from other agents, it upgrades its knowledge (mental model) of the task and social situation on the basis of the other agents' knowledge of the task and social situation. Transferring knowledge between agents (updating each agent's model of the task) should decrease the need to move or physically manipulate the environment. Similarly, increasing the size of the organization (i.e., the number of agents) should result in decreasing organizational effort, as more knowledge is distributed and therefore sharable.

To examine this question within Plural-Soar, organizations comprised of one to five Plural-Soar agents were simulated under four conditions. The four conditions consisted of crossing two levels of order size (15 orders with one item per order, or 5 orders with three items per order) with two levels of communication (whether or not all agents could communicate with each other). The results are shown in Fig. 4.3.

Communication does not always decrease effort. Specifically, agents that are able to alter their knowledge of the task and social situation on the basis of others' knowledge may not decrease their physical effort. This is in part,
because there is a minimum amount of physical effort to do the task and in part because the agents' mental models do not match the physical reality. An agent may get information from another agent on the location of an item, only to discover that the item has been moved. These two causal factors result in an interaction between task and communication. With 15 orders and one item per order, communication decreases effort and so improves organizational performance, not because it decreases the agents' physical movements (which remain almost constant) but because it decreases the number of times agents move items. In contrast, communication may increase, decrease, or have no effect on agent movements when there are 5 orders and three items per order. The ability to examine the subtleties of the interaction between task and communication is a direct result of having a multiple perspective on the cognition, task, and social situation.

A second important point about the Plural-Soar investigation is that it demonstrated that, at least for this version of the warehouse task, the major determinant of the organizational outcome was neither the fact that human rationality is bounded, nor the specific architecture of human cognition (as embodied by Soar). Rather, it was the way in which rationality was bounded in terms of the specific knowledge on which the architecture operated that effected certain outcomes. In other words, although the agent's cognition (Soar) allowed it to do the task, the agent's preferences (as knowledge) controlled how it did that task. For example, the agents had a preference to move items that were stacked on top of an item they were seeking onto an adjacent stack to their left rather than onto a stack to their right. Agents also preferred to ask other agents where items were located, rather than perform an uninformed search. When organizational agents are presented with a task, it is necessary to explicate when the immutable aspects of agent cognition (the architecture) and not the knowledge/preferences dictate the organizational outcome. Replacing principles of bounded rationality with specific cognitive models and replacing generic task descriptions with specific task models enable analysis at this level.

**ELM: A STRONG SOCIAL SITUATION MODEL**

The organizational experiential learning model (ELM) is a simulation tested that has been used to examine the relative performance of organizations that vary in their design and where agents act on the basis of their personal (organizational) experience. Previous studies using ELM have examined the impact of personnel turnover on organizational performance for different organizational coordination schemes (Carley, 1992), the relationship between information redundancy and personnel turnover (Carley, 1990), and the impact of various crises on organizational performance.
ELM employs a simple situated-cognition model of individual action in which agents learn from their individual experience. What information agents have access to, what they know, and what actions they can take are dependent on their social situation in the organization and the specific task assigned to them. In ELM, the social situation is defined by the agent's position in the particular organizational design.

Unlike Plural-Soar, where the agents operate in real time and so may be doing different tasks in parallel, in ELM the agents are forced to act in parallel doing exactly the same type of task. The testbed is designed so that in each time period the organization is faced with a new task, similar, but not identical, to previous tasks. The task the organization must accomplish is to determine whether a given binary "word" of length $n$ has more ones than zeroes (e.g., 1101101). The organizational problem is a word of length $2^n$. Each time period, every agent acquires new information on some portion of the task (i.e., a subset of the binary word, such as 1101 of the prior example), decides whether there are more ones than zeroes in the full task (based on current data and the results of prior decisions), and communicates this decision (not the information used to make the decision) to the proper agent(s) in the particular organizational structure simulated.

Agents may differ in their mental model of the task (i.e., the likelihood of ones and zeroes) as they are seeing different subtasks or experiencing different aspects of the full task. By specifying a particular organizational design, a unique organizational type can be simulated (e.g., a hierarchy with low turnover and a completely segregated task decomposition scheme). The particular organizational design potentially affects the agents' mental model of the task, as it determines what information is available to the agents. In making its decision, each agent brings all of the knowledge that it has to bear, based on the new data and historical experience. Thus, each agent's decision reflects not only on its representation of the current task but its historical knowledge accumulated by working on previous organizational tasks.

Once all of the agents have made their decisions, the organization makes an organizational decision, either through the actions of the chief executive officer (CEO; a top-level decision-making agent in a hierarchical structure integrates information across agents) or through the voting of all agents (as in a team structure). For each task (i.e., each time period) there is a correct decision based on the actual features of the task. Organizational performance is measured by examining whether the organization's decision is the correct decision. Finally, every agent receives feedback on its decision—new knowledge on what was the correct organizational response in the situation. Monte Carlo simulation is used to estimate average performance across a large number of tasks.

All agents, regardless of their position in the organization, are boundedly
rational and make decisions solely on the basis of their personal experience. Each agent has a hierarchically organized knowledge base containing a cumulative record of the subtasks that it receives, its decisions, and the true decisions for the associated full tasks. As the agent encounters subtasks, it learns rules for how to respond to the specific situation. However, these agents are not constructed from detailed, general cognitive models; rather, they are specifically crafted for this type of task and thus represent a restricted cognitive, task-oriented model.

The social situation is defined by the organizational design, which includes the following features: the composite organizational structure, task-decomposition scheme, associated order of processing, and rules for processing information and communication. The organizational design is viewed as a tacit coordination scheme. Both the organizational structure and the task decomposition scheme can be defined in network terms.

Using ELM, a variety of organizational structures can be examined, such as, the centralized hierarchy, the dual-command hierarchy, and the team (see Figs. 4.4, 4.5, and 4.6). In these illustrative structures, three types of agent roles are defined: the analyst (A), the assistant executive officer (AEO), and the chief executive officer (CEO). In these figures, analysts are represented as circles, AEOs as lightly shaded circles, and a CEO as a black circle. For the organizational structures shown, only the analysts have access to the “raw data” (the ones and zeroes) of the task. The task decomposition scheme is a blocked structure; that is, in all organizations each analyst sees only a portion of the task (i.e., a subset of the full binary

![Diagram of centralized hierarchy structure used in ELM.](image)

**FIG. 4.4.** Centralized hierarchy structure used in ELM.
word) as defined by the particular task decomposition scheme. In hierarchies, institutional memory is centralized in the upper management, albeit in a reduced-information form. In team structures, institutional memory is completely distributed to the component agents. The presence of upper level management, by mediating the decisions made by lower level agents (analysts), can reduce the impact of various debilitating factors such as turnover or unavailability, thus affecting the level of information redundancy needed.
for equivalent performance (Carley, 1990, 1992). Information loss is higher the more complex the task faced by the agents and the greater the number of levels in the organizational structure.

The distribution of subtasks (i.e., which agent receives which subset of of the binary word) defines the amount of redundancy at the lowest level and is referred to as the task decomposition scheme. Figure 4.7 illustrates three task decomposition schemes that have been examined using ELM. In Fig. 4.7, each square at the bottom of the structure represents the bit of information (1 or 0), with the total (organizational) problem being comprised (in this case) of nine total bits (word length). To illustrate the potential interaction between the task decomposition scheme and the organizational structure, the analysts are shown as though they are reporting to an AEO. The level of information redundancy is defined as the average number of analysts who know each piece of information (indicated by links to specific bit positions in the word). When the redundancy level equals the number of analysts, we have a situation in which all analysts have access to all information, which corresponds to the case of complete information/complete overlap discussed in other studies (Carley, 1986; Cohen et al., 1972). As the level of redundancy increases relative to the number of analysts, the complexity of the subtasks faced by the analysts increases.

Within ELM the organization's performance can be examined both under normal operating conditions and under substandard operating conditions. Within this framework, difficulties are typically modeled as disruptions in what information is available to whom. Difficulties degrade organizational performance because they decrease the degree to which the agents' mental model of the task matches the task. The impacts of various difficulties on organizational performance have been examined: turnover (Carley, 1990, 1992), incorrect information, communication breakdowns, and agent unavailability (Carley, 1991a). Thus, this framework can be used to examine organizational performance under both standard/optimal and substandard/crisis conditions.

ACTS Axioms and ELM

The primary advantage of the ELM system is that it can be used as a generic testbed for examining the performance of a large number of organizational designs under either standard or substandard conditions (as when difficulties occur) for different classes of tasks. Using this testbed, insight into the effect of social situation on performance may be gained. In particular, this approach could be used to explore limits on performance due to structural properties. From the perspective of ACTS, the importance of ELM is that it specifies the minimum model of the social situation, and it specifies that
FIG. 4.7. Example task decomposition schemes used in ELM.
the organization's design can be characterized by detailing the network of relations between personnel and information, and the procedures for moving or altering personnel or information. It is in this sense that ELM better fulfills Axiom 5 than does Plural-Soar (see Table 4.2). Another advantage of ELM, from the ACTS perspective, is that it can be used to examine whether and to what extent organizational performance is affected as various difficulties and crises arise. In this way, Axiom 8 is fulfilled.

In contrast to Plural-Soar, the individual ELM agents are quite simple. Nevertheless, they do meet Axioms 1, 2, 6, and 7, but do not meet Axiom 3. These agents do not have a general capability to learn, but rather learn information about predefined categories given this type of binary task. Even though the ELM agents engage in one-trial learning (like the Plural-Soar agents), they may not perform correctly in subsequent trials as their predefined categories (their predefined way of representing the task) may prevent them from utilizing the information they have learned relative to a specific task. Further, like Plural-Soar, ELM does not meet the spirit of Axiom 4 as personal, task, and organizational goals are largely equivalent. Within the ELM system, issues such as negotiation and group-think cannot be addressed due to the inadequate model of the agent. In Plural-Soar, these issues cannot be addressed due to the inadequate model of the social situation. Some of the ELM agents, the managers, unlike Plural-Soar agents, do have (simple) models of other agents. These managers, within the constraint that they must remain managers, do adjust their interaction with other agents in a fashion consistent with that suggested in Axiom 9. To more fully approximate the intent of Axiom 9, all agents should be provided with models of other agents, and should be allowed to change positions in the organization. To more fully approximate Axiom 9, ELM agents would need to have specific mental models of the situation and the task.

Exploring Crises, Tasks, and Organizational Structures

The set of organizational structures in Figs. 4.4, 4.5, and 4.6 and the set of task decomposition schemes in Fig. 4.7 define nine types of organizational designs. Each of these types was simulated 200 times for 100,000 time periods. After 100,000 time periods a crisis occurred (explained later). In each case, there was no turnover. Thus, we can interpret these results as the expected behavior of organizations of highly trained agents. Performance is measured using ensemble averaging—the percentage of correct decisions made during 100 time periods as averaged across 200 simulation runs of organizations with that particular type of design. Each time period, the organization works on a different problem. Performance under optimal conditions was measured for the 100 time periods immediately preceding the crisis. Performance under crisis conditions was measured for the 100
time periods at the end of the crisis period. The crisis lasted for 300 time periods. Each crisis is characterized by type (the incoming information was incorrect, there was a communication breakdown, or an analyst was unavailable), strength (the number of simultaneous problems, one, two, or three), and duration (10, 20, or 50 time periods).

The results are shown in Fig. 4.8. In this discussion we are not concerned with the specific and differential effects of the different characteristics of crises. Thus, the performance during crisis shown is the average performance across all 27 crisis conditions for that organizational design.

Studies of organizational design often focus on the structure of the organization, describing why some structures should outperform other structures. For example, hierarchies are expected to exhibit lower performance than teams due to uncertainty absorption (March & Simon, 1958), information condensation (Downs, 1967), and information distortion (Janblin, Putnam, Roberts, & Porter, 1986). These arguments lead one to expect that dual-command structures should lie somewhere between hierarchies and teams in terms of performance. However, these arguments provide no guidance as to either the impact of crisis or the relationship between task decomposition scheme and performance.

In Fig. 4.8 performance under optimal and crisis conditions is shown. Contrary to the expectations, dual-command structures do not exhibit performance between that of hierarchies and teams. Similar to several earlier simulation studies, unsegmented structures (such as teams) often outperform more centralized structures (such as hierarchies; see, for
example, Anderson & Fischer, 1986; Cohen et al., 1972). However, unlike these earlier studies, the analysis in this chapter suggests that whether teams outperform hierarchies depends on the extent to which the agents have different mental models of the task. In Fig. 4.8 the line indicates that the relationship is nonlinear, such that organizations with a blocked structure are the least affected by the stress of crisis (i.e., they show less of a drop in performance during crises than do other organizational designs). Similar to Cohen et al. (1972), this study suggests that segregated task decomposition schemes (decision structure) lead to lower performance. In addition, we see that decomposing the task in a distributed fashion such that there is redundancy, but not total equivalence or overlap in task information, leads to the highest performance both under optimal and crisis conditions. For any particular type of organizational structure, in terms of performance under either optimal or crises conditions, a segregated structure performs the worst and the distributed structure performs the best, with the blocked structure situated between the two performance extremes. These results suggest that the decomposition scheme has a more regular impact on performance than does the organizational structure.

These results are not directly comparable with much previous simulation research on organizational design, in large part because this study, unlike most others, uses a distributed task in which all agents must always be involved and in which different agents work on different parts of the task. Further, many other studies conflate the task decomposition scheme and the organizational structure, in large part because they do not look at specific tasks. Within ELM, the task and the social situation are clearly separated; thus, agents' mental models of task and social situation emerge as separate factors affecting organizational performance. Thus, this study addresses issues of how similar agents' mental models of the task need to be and how accurate the agents' mental models of the task need to be, and at the same time addresses issues of organizational design.

DISCUSSION

In this chapter we have proposed a general theory of organizational behavior based on an extended model of bounded rationality of the agents comprising an organization. We have also argued that a unified theory of organizations (linking organizational/group phenomena with individual agent models) might be developed if we consider organizations as collections of tasks and agents engaged in performing tasks, such that both agents and tasks are situated within a specific organizational structure. Organizational (i.e., collective) behavior is viewed as emergent behavior from groups
of deliberating agents interacting to perform these tasks within that organizational context. This theory embodies four important beliefs, which are critical for the evolution of a theory of organizations: the need to move organizational theory to a meso-level, the need to replace the principles of bounded rationality with extended and specific models of cognitive agents (which exist as computational theories), the need to replace general notions of environmental constraints with specific characterizations of tasks and social situations, and the corresponding need to move to broader and more encompassing theories of organizations expressed and tested as computational models to unify component organizational findings.

This view suggests that if organizational studies cannot account for a sufficient characterization of the critical properties of the participant agents (e.g., ones that are knowledge-based, adaptable, but cognitively restricted), the task, or the social situation and how they interact and coconstrain each other, the quality and generalizability of the results may be limited. The proposed ACTS theory may serve as the foundation for a theory of organizations that exhibits this multiple perspective. We illustrated the use of ACTS theory in comparing two computational models, Plural-Soar and ELM, each of which is partially sufficient with respect to ACTS axioms and each of which exhibits the level of detail needed to begin to make progress in models of this type. Moving toward such a theory will bring up new research concerns, such as the following:

- What can one expect from a computational theory of organizations predicated on a computational theory of agents?
- What are some of the research issues that arise when the researcher takes on a multiple-perspective agenda?
- What type of tasks should be considered?

**Expectations for a Computational Organization Theory**

Within cognitive science, the search for a general theory of cognition has led to the development of computational models that embody substantial cognitive theory. In essence, these computational models perform the task they seek to describe and become both the instrumentation of and the tool for developing the theory. Such models encompass, and extend (to greater and lesser degrees), the principles of bounded rationality and focus research attention on the fundamental mechanisms underlying behavior.

Because organizations are collections of tasks and intelligent agents, it is empirically consistent to construct organizational models by weaving into an organizational design models of individual agents, tasks, and social situations. Even as progress in cognitive science has been facilitated by
replacing the premises of bounded rationality with computational theories of cognition, progress in organizational science may be facilitated by replacing models of organizations as collections of boundedly rational agents with models of organizations as collections of cognitive agents, when the phenomena under investigation require it. This suggests that within organization science, the search for a general theory of organizations may also lead to the development of computational models that embody organizational theory. In fact, organizational theorists are attempting to reconcile macro-organizational activity with the behavior of individuals (e.g., Staw, 1991), and recent research on organizational design is moving in precisely this direction (Baligh, Burton, & Obel, 1992; Carley, 1992; Lin & Carley, 1992). If the analogy with cognitive science holds, such a movement to computational approaches within organization science should refocus the attention of researchers on the mechanisms underlying organizational behavior, a proposal that has not gone unnoticed by organization theorists (Stinchcombe, 1991). Computational research that examines the kinds of mechanisms that work together focuses on both process and product of behavior, enforces rigor and uniformity in descriptions of mechanism and process, and admits systematic testing of the theoretical components and their contribution to behavior (Prietula & Weingart, 1991).

If models of individual cognition are sufficient models of an agent's social and organizational behavior, then a computational model of an organization composed of a collection of such agent models, in addition to a model of the physical and social world, should account for the major forms of organizational goal-oriented deliberation that underlie organizational and group phenomena, such as organizational learning, group communication, group goal setting, negotiation, and group-think. Such a computational organization model should generate a robust characterization of group behavior and a strong theoretical basis for exploring substantive issues of organizational design, strategy and behavior. A major research question then is whether, in fact, these models of the cognitive agent are sufficient as a model of the social/organizational agent. Carley and Newell (1990) argued that they are very near to the social agent, limited mainly by a lack of attention to emotions. Consequently, there is still a question of whether a full ACTS model will be sufficient to characterize all relevant aspects of organizational life. Despite the insight that ACTS theory

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3The use of cognitive simulations as psychological models has been demonstrated in several domains—extensively in medicine (e.g., Chace & Shortliffe, 1986) and to a lesser extent in business (e.g., Bouwman, 1983), as well as in planning (Wilensky, 1983), particular models of skill acquisition (Neves & Anderson, 1981), and even scientific discovery (Langley, Simon, Bradshaw, & Zytkow, 1987).

4For an extended discussion of this point and an analysis of which organizational and social behaviors should be observable given such models, see Carley and Newell (1990).
may potentially provide, we may still find that there are organizational behaviors, particularly those that are intimately tied to emotions such as behavior under stress, that are not entirely articulable in an ACTS model. Elaboration of the theory would then be necessary.

Nevertheless, even an "emotionally restricted" ACTS model, such as that achieved by combining Plural-Soar and ELM, could advance our understanding of organizations. Indeed, the growing body of research in human organizations suggesting that the psychological processes and strategies of managers (particularly CEOs) have profound organizational and even industry-level reverberations (e.g., Bateman & Zeithaml, 1989a, 1989b; Chandler, 1990; Donaldson & Lorsch, 1983; Mintzberg, 1973, 1978; Snyder & Glueck, 1980) argues that much insight can be gained by systematically examining a cognitively predicated model of artificial organizations.

**Research Implications of Engaging Multiple Perspectives**

Constructing ACTS models requires addressing a number of issues that arise when a multiple perspective is taken on the agent, task, and situation. For example, in modeling the organization it will be necessary to simultaneously model important components of the "real" organization and task, as well as the organization and task as "perceived" by each agent, necessitating a more precise model of enactment (Weick, 1969). A consequence is that it will be possible to examine issues of social cognition, such as the extent to which agents need to share their mental models of the task or the cognitive social structure (Krackhardt, 1987) in order to work effectively together. As another example, in modeling an organization it will often be necessary to model the implicit links to the external world based on the ties that the agents have outside of the organization. This goes beyond a simple enumeration of interaction-based ties. The deeper cognitive issue entails identifying what knowledge passes outside of the workplace that affects actions within the workplace and when external/nonwork knowledge becomes salient in doing tasks within the organization. The deeper social issue involves examining how changes in the sociodemographic distribution of individuals in society affect the perception of, and changes in, demographic-related culture and concerns within the organization.

The representation of organizations as collections of tasks and individuals performing those tasks brings to the forefront the issue of representing organizational as well as individual task-related knowledge. It will thus be necessary to represent not only the procedures (which can be thought of as heuristics and methods shared across individuals) but also the external sources of information and agents' knowledge about these sources. Even those models of organizations that consider the role of agents in making
organizational decisions rarely allow those agents to access sources beyond their own historical knowledge (see, for example, Marschak, 1955; McGuire & Radner, 1986; Tang, Pattipati, & Kleinman, 1991). Yet in real organizations there are many alternate information sources available for the agent to accomplish tasks, such as documents (static data), live data feeds (text, video), computer-based information systems (procedurally flexible), or other (intelligent) agents.5

The Study of Tasks

Both Plural-Soar and ELM employ abstracted models of real tasks. Both the warehouse task and the binary-choice task are rudimentary; nevertheless, they contain many of the properties and complexities generally attributable to distributed decision making tasks: Agents work cooperatively, agents may not be engaged in face-to-face discussion, each agent has its own task, the organizational goal requires all agents to perform their tasks, issues of effort allocation and distributed skills arise, the task is not solved by all agents reaching consensus, the task has several parameters that can be manipulated to adjust difficulty, and so forth. Using such tasks, questions can be addressed that center on economies of scale, and the impact of information sharing, task decomposition, and communication on organizational performance.

Meaningful research in coordination and communication requires surprisingly simple tasks (Weingart, 1989). Indeed, the simplicity of the task can be advantageous, because it clarifies the relationship between organizational and individual goals and problem-solving constraints. Both the warehouse and the binary-choice tasks can be expanded in ways that realistically represent manipulations in cognitive, as well as social and organizational, perspectives. In many disciplines, attention by multiple researchers to a small number of tasks that can be performed by humans, but also modeled computationally, has admitted the accumulation of scientific information. For example, “Drosophila tasks” are used in cognitive psychology (e.g., the Tower of Hanoi), as well as in political science (e.g., the Prisoner’s Dilemma). Perhaps organizational science can also benefit from the development of a small set of characteristic modelable tasks that, when held constant, can be used to investigate the implications of various theories. The warehouse task and binary-choice task are possible candidates.

By appreciating the influence of the task and social situation, organizational models will be able to address issues such as the interrelationship

5 For a perspective that considers both individual cognition and organizational design, see Huber (1990).
between organizational designs and tasks, the role that information sharing plays in organizational performance, and the interrelationship between norms and technology. It is beyond the scope of this chapter (or current knowledge) to put forward a full theory of task influence or to define influential task dimensions from the multiple perspective on agent, task, and situation. Such a theory can be elaborated through many studies that examine significant tasks in a systematic fashion. We do note, however, that a minimally adequate model of task must specify actions that can and cannot be taken in pursuit of the task, the constraints that denote task decomposability and component interrelatedness, and the knowledge needed to perform the task.

CONCLUSION

The search for a fundamental theory of organizations of any consequence or explanatory power requires going beyond a theory of the task or a theory of the organizational situation, but requires in addition a general theory of the intelligent agent that expands the model of bounded rationality. Such a theory must encompass:

1. The physical world where agents are engaged in specific tasks, and are barraged by both information and difficulties that require continual adaptation by the agent (and subsequently the organization) to achieve goals.
2. The cognitive world where the agents' knowledge of their self, their social situation, the task, and the extant difficulties determine what actions they take, what they learn, and what goals they pursue.
3. The social world where agents and task are situated within and across specific organizational positions.

ACTS theory is a first step toward the articulation of a theory that addresses these perspectives. ACTS models (as instantiations of theory) can, if sufficiently specified, provide a perspective on organizational behavior and performance that goes beyond the rhetoric of bounded rationality to the specific details of how constraints and opportunities afforded by cognition, task, and situation determine organizational behavior. ACTS models can provide a perspective on organizational design that goes beyond the rhetoric that effective organizational design is contingent on the task (Lawrence & Lorsch, 1967) and the environment by providing a detailed prescription as to what are the systematic relationships between performance, design, task, and environment. Detailed ACTS models can be used to generate a series of proposi-
tions about organizational life that could not be generated with taskless models and/or models of the organization as collections of boundedly rational agents. ACTS models can make it possible to address a variety of topics central to organizational theory, ranging from the impact of new technology to the evolution of organizational norms within a systemic framework in which the dynamic behavior of actual individuals and groups can be examined simultaneously. By combining models of the agent, task, and situation, ACTS models can provide an integrated theoretical platform with sufficient detail to facilitate simultaneous attention to both theory and policy issues. However, saying that such computational models can forward theoretical development is one thing—crafting and evaluating such models is quite another thing, for simulation in organizational science should be expected to be no less complex than in physical science. Small, incremental steps may be needed to understand the level of complexity in fluid, highly symbolic, social aggregations of intelligent agents. Ideally, an encompassing, unifying theoretical perspective may facilitate the search for answers. We have argued that the search for unifying theories of organizations is a realistic, plausible, albeit difficult, goal for organizational science. ACTS theory is an incremental step toward that goal.

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REFERENCES


4. ACTS THEORY


