

# **ACTS THEORY: Extending the Model of Bounded Rationality**

Kathleen M. Carley  
Social and Decision Sciences  
Carnegie Mellon University  
Pittsburgh, PA 15213

Michael J. Prietula  
Center for the Management of Technology  
Graduate School of Industrial Administration  
Carnegie Mellon University  
Pittsburgh, PA 15213

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## **ABSTRACT**

In this paper we propose an extension to the traditional model of bounded rationality and incorporate the extended model into a theory of organizational behavior. We argue that organizations are collections of tasks and intelligent agents engaged in performing those tasks, both situated within an organizational setting. Organizational behavior is an emergent property of such collections and is constrained by the agent, the task, and the situation. We propose that a unified theory of organizational behavior is possible, but only if agents, tasks, and situations are specified at a sufficient level of detail, and only if that specification embodies both the agents' mental models of the task and social-situation and the task and social-situation. Inattention to relevant details of the agent, task, or situation (and their interactions) may produce misleading results. We describe a candidate theory, ACTS theory, that integrates Agents who are Cognitively-restricted, Task-oriented, and Socially-situated in an interlinked set of representational systems. We suggest that the complexity of the theory warrants its realization and testing in a computational form, and that there exist candidate computational theories of cognitive agents and organizational situations. We illustrate the importance of attending to task and the benefits of multi-point focus on agent cognition, task, and situation using two computational models that take the ACTS perspective, yet are currently only partially sufficient as models that embody a full ACTS theory.

## **ACTS THEORY: EXTENDING THE MODEL OF BOUNDED RATIONALITY**

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 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 and Cooper, 1963; Cyert and March, 1956, 1963; Glazer, Steckel and Winer, 1992; Huber, 1990; Lord and Maher, 1990; March, 1978; March and Shapira, 1987; Radner, 1975; Sims, Gioia and Associates, 1986; Simon, 1976; 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. In this paper, we propose such an extension, and illustrate its value for studies of organizational behavior.

The motivation initially underlying bounded rationality was to replace the fundamental model of the agent on which theories of economics and organizations were based with one 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. At the time, however, various forms of behaviorism were still dominant and, to these psychologists, behavior resulted from learning, and learning was based on mediated, conditioned associations, without theoretical reference to mentalistic constructs such as thinking, understanding, goals, ideas, and intentions. However, Simon proceeded to propose a model of restricted individual deliberation that was distinctly non-behavioralistic (1955, 1956).<sup>1</sup> One part of this model was that the agent itself was boundedly rational (1955). Another part of this argument was that the environment, and the interrelations between the environment and the agent, set bounds on, and therefore constrains the agent (1956). As Simon noted (1956, p. 130) 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.”

In this paper, we extend the original model of bounded rationality along the lines of its initial intent and incorporate the extended model within a 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 agent and environmental constraints. The extension occurs by: (1) replacing the general principles of the boundedly rational agent with a full model of the cognitive agent that exhibits general intelligence; and (2) replacing general notions of environmental constraints with detailed models of two environmental components — the task and the organizational social-situation within which the task and agent are situated.

The main theme of this paper is that organization theory should take a balanced multi-point focus on the agent, the task, and the situation in which both the agent's mental models of the task and situation and the reality of such situations are considered. Such a multi-point focus places us

squarely in the realm of what are now called meso-theories.<sup>2</sup> Meso-theories (or mid-level theories) link the macro to the micro, or in our case the "physical and social" to the "cognitive." Because we take this multi-point focus, this meso-perspective, we are in effect combining the *sociology* of organizations and the *psychology* of organizations into a single perspective.<sup>3</sup>

We will present the assumptions of ACTS theory axiomatically. We will also illustrate the importance of the multi-point focus on the agents' internal representation of this world (agent-cognition) and the physical and social world (task and social-situation) to a unified theory of organizations by examining two partially sufficient computational-models of organizations based on the ACTS perspective — Plural-Soar (Carley, Kjaer-Hansen, Newell, and Prietula 1992) and an organizational Experiential Learning Model (hereafter ELM, Carley 1990, 1991b, 1992). We demonstrate the power of the ACTS perspective by examining new results drawn from these two computational models. First, however, we wish to briefly describe the implications of failing to taking this multi-point focus, and the methodological consequence of taking this focus by extending the model of bounded rationality.

Organizational studies are replete with examples where there was a failure to take a multi-point focus. For example, despite the initial emphasis on task by organizational theorists (Fayol 1949; Taylor 1947), current organizational theories are for the most part task-less. Task-based analyses are central to operations research, engineering, cognitive science, artificial intelligence, and business (e.g., case-based research and teaching), but not to most main-line organizational research. While the task-less nature of much organizational theory may not be surprising when a macro-perspective is taken, it is surprising in micro-perspectives (such as Cohen, March and Olsen, 1972; Padgett, 1980).

Virtually all micro-perspectives lack both a detailed model of the task and a detailed model of the generally intelligent agent. Moreover, some even lack a detailed model of the situation. Consider the Garbage Can Model proposed by Cohen, March, and Olsen (1972). In this model of organized anarchy, the agents (characterized only by position and energy level) work on tasks (characterized in part by the energy needed to complete the task). A given task can constrain action by preventing an agent from solving it in a single attempt by requiring energy levels beyond that of a single agent. Consequently, the Garbage Can Model allows conclusions to be drawn such as the agents should "work harder." However, most of the issues that arise due to task-based constraints on agents (such as, how to partition the task across agents, what should be communicated, which agent has the necessary skill or expertise for this task, the impact of new technology on the task) cannot be addressed when the task is "underdefined." With neither a detailed task nor agent model, communication becomes featureless, actions become uniform, and agents become skill-less. In consequence, many essentially task and cognition constrained organizational phenomena such as negotiation, scheduling, design, and coordination cannot be studied in detail. As a further consequence, with task-less cognition-less models it becomes difficult to generate policy implications of sufficient detail to help the manager. We argue that it is important to examine the salient aspects of tasks, rather than overly general and ill-specified task features, and to examine generally intelligent agents with specific knowledge, rather than knowledge-less agents, in order to determine the interaction between the task, organizational situation, and the agents' cognition. This interaction is often not addressed by those who take a purely structural or network approach and by those who take a purely psychological approach to organizational issues such as power struggles, negotiation, and enculturation.

Knowledge-less, task-less, and situation-less organizational studies can be misleading. All three components are equally important and can be highly inter-related. For example, without

details on both what knowledge is available to the agents and what limits exist on their processing capabilities, additional information on the task is of little use in predicting and explaining organizational behavior.

The final comment, before presenting ACTS theory, is that ACTS theory (indeed any organizational theory that attends to cognition, task, and situation at the level of ACTS theory) is potentially so complex in its representational demands that instantiations may often take computational (i.e., computer based) forms. As such approaches are now fundamental to understanding human intelligence (Simon, 1981b), it is only natural that the added complexity of interpreting computational models be handled computationally. Moreover, such a computational theory requires bringing together both a model of the agent (complete with the agent's mental models and other knowledge of the task and social/organizational situation) and models of the physical and social world in which the agent operates. Advances both in cognitive science and in social/organizational theory make possible the search for, and articulation of, a unified, computational theory of organizations predicated on a computational theory of the agent and its environment. Research on individual cognition has generated models of general intelligence and learning that extend beyond task-specific models of performance, such as Soar (Laird, Newell and Rosenbloom, 1987), ACT\* (Anderson, 1983), and classification systems (Holland, Holyoak, Nisbett, and Thaygard, 1986). Such models can potentially serve as the more precise model of general cognition. Similarly, research on positions, roles and networks has generated characterizations beyond specific organizations to general features of organizational design (Burton and Obel, 1984; Galbraith, 1973,1976; MacKenzie, 1978; Malone, 1986; Mintzbergh, 1983; Krackhardt, 1989) and the social and organizational constraints on agent action within particular organizational designs (see, for example, Carley, 1990,1992; Cohen March and Olsen, 1972; Harrison and Carroll, 1991; Masuch and LaPotin, 1989).

## **ACTS THEORY**

ACTS theory is a meso-level 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 non-task characteristics of the organizational environment in which the agents are situated (the social-situation). The individual'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 are highly volatile and so are immutable only in the short term (Cohen, March and Olsen, 1972; March and Romelaer, 1976). The volatility creates further constraints on, and opportunities for, action (Carley, 1986; Cohen, March and Olsen, 1972). In addition, this volatility encourages the use of actions whose only value is symbolic (Feldman and March, 1981; Pfeffer, 1981). ACTS theory seeks to explain organizational behaviors and performance by employing a set of computational models interlinked through an organizational design.<sup>4</sup> This set includes a model of the cognitive agent (including knowledge), a model of task, and a model of the social-situation. Manipulating the organizational design manipulates the knowledge, task-based and social-situation based constraints on agent actions.

At the micro-level 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 macro-level 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.

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. ACTS theory is explicitly multi-focus, thus individual cognition (and hence agents' representation of the task and social-situation which includes other agents) is as key to ACTS theory as is 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 (Simon and Baylor, 1966; Simon, 1976, March and Simon, 1958), but adds precision, prediction and testability through the specification of the component models.

The general stance taken in this paper vis-a-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 architecture 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 is 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(s)<sup>5</sup> that are currently interrupting the organization's "normal," or perhaps ideal, operating conditions. 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 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 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 phenomena* in a dynamic and often volatile organizational setting. All constraints and opportunities are a function of the agent's knowledge and mental models of self, of other agents, the task, and the social situation and how the dynamic events unfold.

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 presumably true (or, perhaps, untestable but reasonable) 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 inter-relation between these constructs.

**Agent Axioms:**

- Axiom 1: Organizations are composed of goal-directed, intelligent agents (decision makers) who can learn, communicate, and take action in pursuit of goals.
- 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.
- Axiom 3: The Problem Space Computational Model of Newell (Newell, et. al., 1990; Yost and Newell, 1989) sufficiently describes 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.

**Task Axiom:**

- 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.

**Social Axiom:**

- 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.

**Interlink Axioms:**

- Axiom 6: The agent's current task and social-situation define a limited set of knowledge, opportunities, and consequent constraints on action and learning. Individual deliberation and choice are restricted by the constraints of architecture and knowledge (the latter of which is affected by personal history, current task, and current social-situation).
- Axiom 7: An organizational agent will select goals and actions enabled by the current task and social-situation as perceived (and represented) by the agent.
- Axiom 8: Organizations are faced with dynamic environments that can alter the characteristics of the task or social-situation temporarily or permanently. Difficulties can and frequently do arise upsetting the normal or standard operating conditions in the organization. These difficulties can be with the agents (e.g., lack of experience or poor motivation), the tasks (e.g., change in design specifications), or the social-situation (e.g., turnover level or broken communication channels).
- Axiom 9: The social-situation is continually constructed as individuals engage in concurrent actions (Carley, 1991a). The existence of socially-situated positions and all their attendant characteristics (opportunities for interaction and mobility, relative power, links with other positions, status, associated procedures, and so forth) are the result of previous interactions among individuals and their decisions and actions. Further interaction and decision making by individuals will alter the social-situation and these positions.

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 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 agents and that the problem space computational model is sufficient for modeling such agents. Computational models, by their very nature, move beyond the principles of bounded rationality to specific details of the cognitive architecture. An example of a computational model that embodies the problem space computational model is Soar (Laird, Newell and Rosenbloom, 1987). Soar has been argued to be a general model of intelligence (Rosenbloom, Laird, Newell and McCarl, 1991) and to embody a unified theory of human cognition consistent with, and going beyond, the principles of bounded rationality (Newell, 1990). Computational models of human decision making, such as Soar, specify the constraints due to human architecture (e.g., role of, and limits on knowledge and goals that move us from the boundedly-rational agent to the cognitive agent). ACTS theory seeks to use this characterization of the intelligent agent and to further explicate the specific additional sets of task and social constraints and opportunities that surround the agent and which contribute to less-than-optimal choice by affecting the agent's mental models.

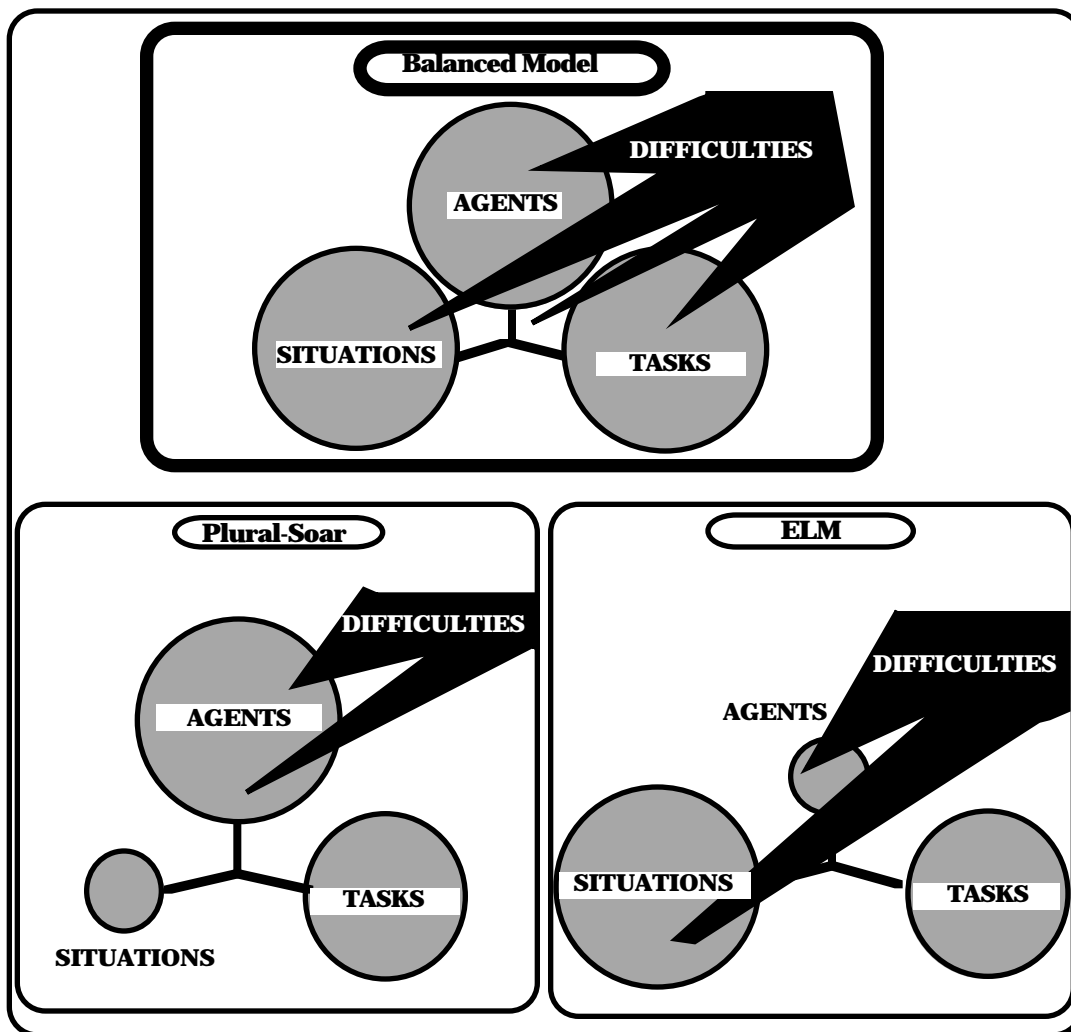
The nature of the organizational agent is central to ACTS theory and should figure prominently in the computational model. Yet, the task and social-situation are as key to ACTS theory as individual cognition, for it is through an examination of the interaction between the physical and social world and the cognitive world that we can begin to craft an accurate theory of how decisions are made in organizations. 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. 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. In Table 1, some typical individual and organizational behaviors explainable with a detailed model of cognition, task, or social-situation are listed.

While ACTS theory, like open system 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 "partially sufficient" computational models: Plural-Soar and ELM. Figure 1 shows the inter-relation of these three components and the position of Plural-Soar and ELM in this trinity.



**Table 1: Examples of Agent Types and Their Organizational Beha**

|                | <u>Agents who are:</u>   |  |   |
|----------------|--|--|---|
|                | Cognitively Restrictive  | Task Oriented  | Socially Situated   |
| <u>ACTIONS</u> | reasoning<br>adaptation<br>planning<br>error<br>compulsiveness | scheduling<br>coordination<br>negotiation<br>performance | norms<br>coordination<br>organizational culture<br>communication<br>standard operating procedures |



**FIGURE 1: ACTS THEORY**

Plural-Soar and ELM are only partially sufficient from an ACTS point of view as neither completely embodies the multi-point focus on the cognition, task and social-situation. 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 weak model of social-situation with a strong 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, Soar. Using Plural-Soar the performance of organizations with essentially uncoordinated agents can be examined. In contrast, ELM couples a strong model of social-situation with a minimal model of the intelligent agent. Within ELM organizational performance is examined for organizations facing a 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 three-fold: (1) demonstrate the importance of considering real tasks, (2) demonstrate the power of a multi-point focus, and (3) indicate the type of minimally sufficient model of the task world, social world, and the cognitive world necessary to an ACTS approach. We see Plural-Soar as the prototype for the agent model, ELM as the prototype for the social-situation model, and both the warehouse and binary-choice task as minimally sufficient task models. The strengths and weaknesses of Plural-Soar and ELM relative to the axioms of ACTS theory are summarized in Table 2.

**Table 2: Degree to Which Plural-Soar and ELM Fulfill Axioms of ACTS Theory.**

| <u>AXIOM</u>     | <u>Plural-Soar</u> | <u>ELM</u> |
|------------------|--------------------|------------|
| Agent Axioms     |                    |            |
| 1                | met                | met        |
| 2                | met                | met        |
| 3                | met                | not met    |
| Task Axiom       |                    |            |
| 4                | not met            | not met    |
| Social Axiom     |                    |            |
| 5                | minimal            | mostly met |
| Interlink Axioms |                    |            |
| 6                | met                | met        |
| 7                | met                | met        |
| 8                | minimal            | met        |
| 9                | not met            | minimal    |

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

Plural-Soar is an exploratory computational model used to examine how a set of agents, predicated on a sophisticated computational model of a generally intelligent agent, can be combined into a functioning organization (Carley, Kjaer-Hansen, Newell, and Prietula, 1992; Prietula and 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 disfunctionality. Each Plural-Soar agent runs on a separate machine and all machines 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) and each agent acts on a problem (fills the order) when the agent is ready. By specifying the social-situation (number of agents and the communication scheme) and each agent's knowledge and set of available actions (including preference and available standard operating procedures) a unique type of organizational design is identified (e.g., a five-person team with no communication capabilities). The performance of this type of organization can then be simulated. The system is non-stochastic, so each organizational type need only be simulated once to determine its performance (see Carley, Kjaer-Hansen, Newell, and Prietula, 1992). Plural-Soar is consistent with the axioms of ACTS theory, although it meets only minimally, if at all, the more social aspects of axioms 4, 5, 8 and 9.

### **Agents: Cognitive Restrictions on Generally Intelligent Agents**

Plural-Soar is a collection of Soar agents interlinked into an organizational design and working collectively to perform a warehouse task. Each Plural-Soar agent has an equivalent cognitive architecture (Soar), so all agents have the same set of architectural capabilities and constraints. Initially, all agents have equivalent task-knowledge and task-preferences, social-knowledge and social-preferences. The goal for the agents is quite simple — fill orders. In order to meet this goal the agent must select an order from the order stack, locate the items listed on the order (through either personal search or by asking others), and move the items necessary to fill the order, once located, to the conveyor belt.

Each agent occupies a specific social (but completely undifferentiated) position in an organization. Agents differ initially only in the physical order in which they are standing in front of the order-stack as the simulation begins. As the task unfolds, differential experiences with the environment (i.e., orders and warehouse locations) permit agents to accumulate different knowledge. Over time, different agents' will evolve different mental models. Further, an agent's mental model of task and situation, though based on task and situation will differ from "reality" due both to cognitive limitations and to task and social opportunities for gathering knowledge. Consequently, agents' capabilities may ultimately appear to be different.

The architecture of the Plural-Soar agents can be characterized in terms of their problem spaces, operators, and associated preferences as shown in Table 3. The sophistication of the agent can be altered by manipulating components of the agent model. When at a location, an agent can directly perceive the number of items in the stack at that location, whether there are other agents present at that location, and the items held in the stack. An agent proceeds to a location following the walkway. There are no physical constraints for an agent in 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, an agent at an adjacent location can move items to this stack.

**Table 3: Problem Spaces, Operators, Preferences in Plural-Soar**

| <u>PROBLEM SPAC</u> | <u>OPERATORS*</u> | <u>PREFERENCES*</u>   |
|---------------------|-------------------|---|
| Top                 | Define Warehouse  |   |
| Warehouse           | Go-To-Location    | Agent is socially indifferent   |
|                     | Take-Order        | Agent trusts self most  |
|                     | Manipulate-Stacks |   |
|                     | Wait              |   |
|                     | Remember-Item     |   |
|                     | Ask-Question      |   |
|                     | Answer-Question   |   |
| Agent Movement      | Move-Agent        | Agent is Lazy   |
|                     | Move-Agent-Right  | Asking is better than searching   |
|                     | Move-Agent-Left   | Recalling is better than searching                                      |
|                     |                   | Near locations better than far<br>Moving items is better than moving se |
| Order Acquisition   | Take-Order        |   |
| Stack Manipulations | ReMove-Item       |   |
|                     | Move-Item         |   |
|                     | Move-Item-Right   | Left is better than Right   |
|                     | Move-Item-Left    |   |

\* These are only illustrative preferences and operators (instantiations are not show).

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.

### **Tasks: Processing Orders in a Warehouse**

A graphic illustration of the warehouse task is shown in Figure 2. On the floor of the warehouse is a two-dimensional row of locations or stacks. Each location is uniquely identified. At each location (except for the order-stack) there are stacks of one or more items. These stacks

can be viewed as a stack of boxes with a label on the outside of each box identifying the contents. In the warehouse there is also a set of posted orders (the order-stack). Each order contains a list of items requested by a customer, but no information about where the requested items are in the warehouse. In front of the stacks is a walkway along which agents can move, and across the walkway is a conveyor belt onto which selected orders must be placed by the agents.

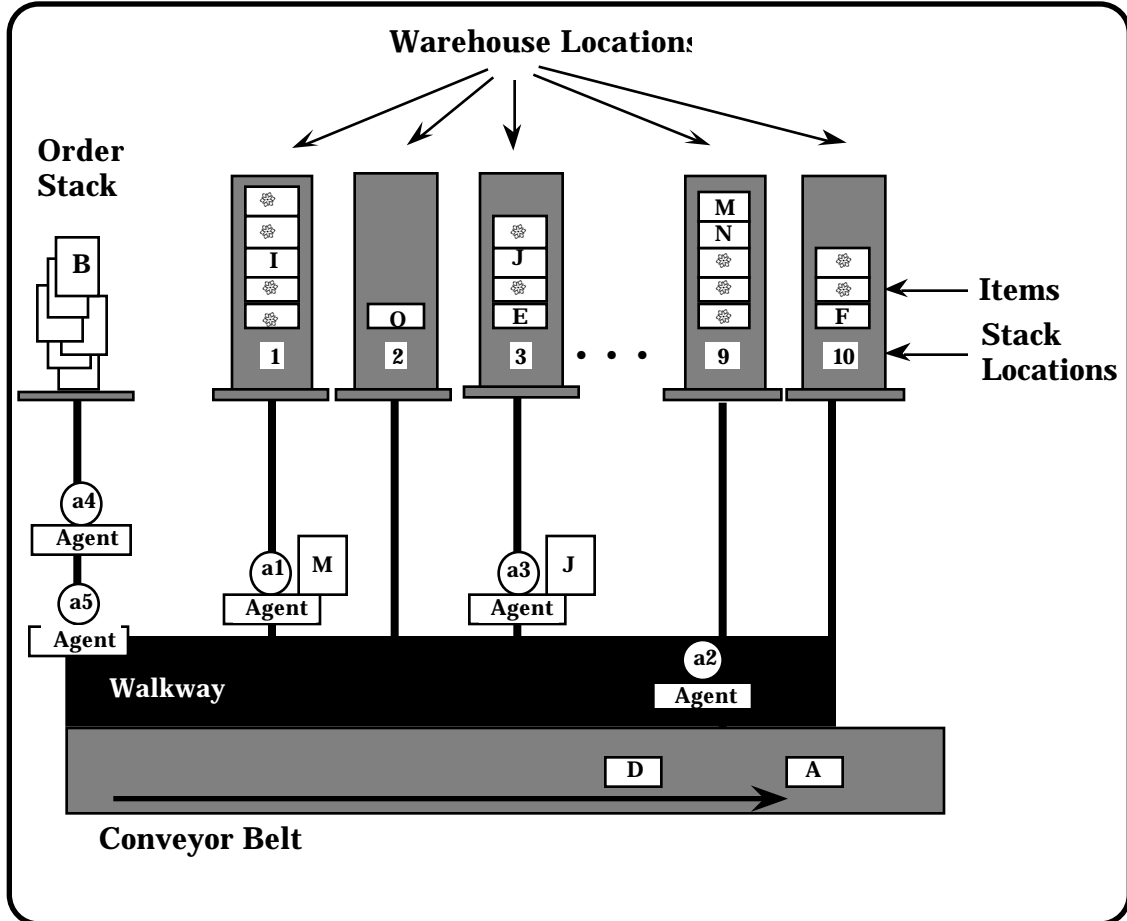


Figure 2: Possible Warehouse Configuration

Recall that the task to be accomplished by agents is to fill all orders in the order-stack from the items distributed throughout the warehouse. To process an order, each item listed on it must be located in one of the stacks, made accessible (i.e., removal of any item on top of the target item), selected from the stack and delivered to the conveyor. An item is made accessible by moving the items placed on top of it onto adjacent stacks (either left or right). Within the warehouse each agent takes orders and fills them.

**Situations: Historically Determined**

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 whom they provide information to. 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. 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' history.

### **Difficulties: Preresolved by Preferences or Ability to Search**

In one sense, Plural-Soar deals only with ideal 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 the item they desire is at the bottom of the stack. In this case, predefined preferences make these difficulties non—problems by providing a solution.

### **ACTS Axioms and the Capabilities and Limitations of 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 goal 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 the fifth axiom, as previously noted, the Plural-Soar agents occupy positions that are undifferentiated (at least initially). Axiom 8 is met in part 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. However, there are relatively few items and few stacks so such difficulties, though inevitable, are minimal. Future work would need to consider conditions under which the difficulties were more likely. 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 while 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.

Soar, has been characterized as a generally intelligent agent capable of learning (Newell, 1990). The Soar model is perhaps the most elaborate and *psychologically* valid cognitive simulation 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 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 section 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. Since 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 limitations on knowledge due to the agents role in the organization. The coordination between agents in performing the task is a function of the physical constraints on 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. When exhaustive search does not provide an answer (a location), the agent eventually ceases to function. This fragility of the agents' mental models is part of what contributes to the decreasing returns to scale as the number of agents increases. The further implications of this fragility in terms of agent action and organizational performance are being explored.

## **Results**

One might expect with the warehouse task that allowing agents to communicate should improve organizational performance. That is, 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. Asking other agents involves upgrading the asker's mental model of the task and social-situation on the basis of others' mental models of the task and social-situation. The basic idea then is that transferring knowledge between agents (updating each agent's model of the task) should decrease the need to physically manipulate self and/or the environment. To examine this proposition within Plural-Soar, organizations of three, four and five Plural-Soar agents were simulated under four conditions. These conditions varied the task — either fifteen orders of one item each or five orders of three items each — and whether or not the agents could communicate with each other. These are manipulations of the physical and social world.

The results are shown in Figure 3. The first item of note is that the expectation does not hold. Communication does not always decrease effort. Agent's who are able to alter their mental models of the task and social-situation on the basis of others' mental models may not decrease their physical effort. In part, this is because there is a minimum amount of physical effort to do the task. And, in part, this is because the agents' mental models do not match the physical reality. The agent may get another's best information on where item  $x$  is, only to get to that location and find that the item may have been moved by yet another agent. These two 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 five 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 multi-point focus on the cognition, task, and social-situation.

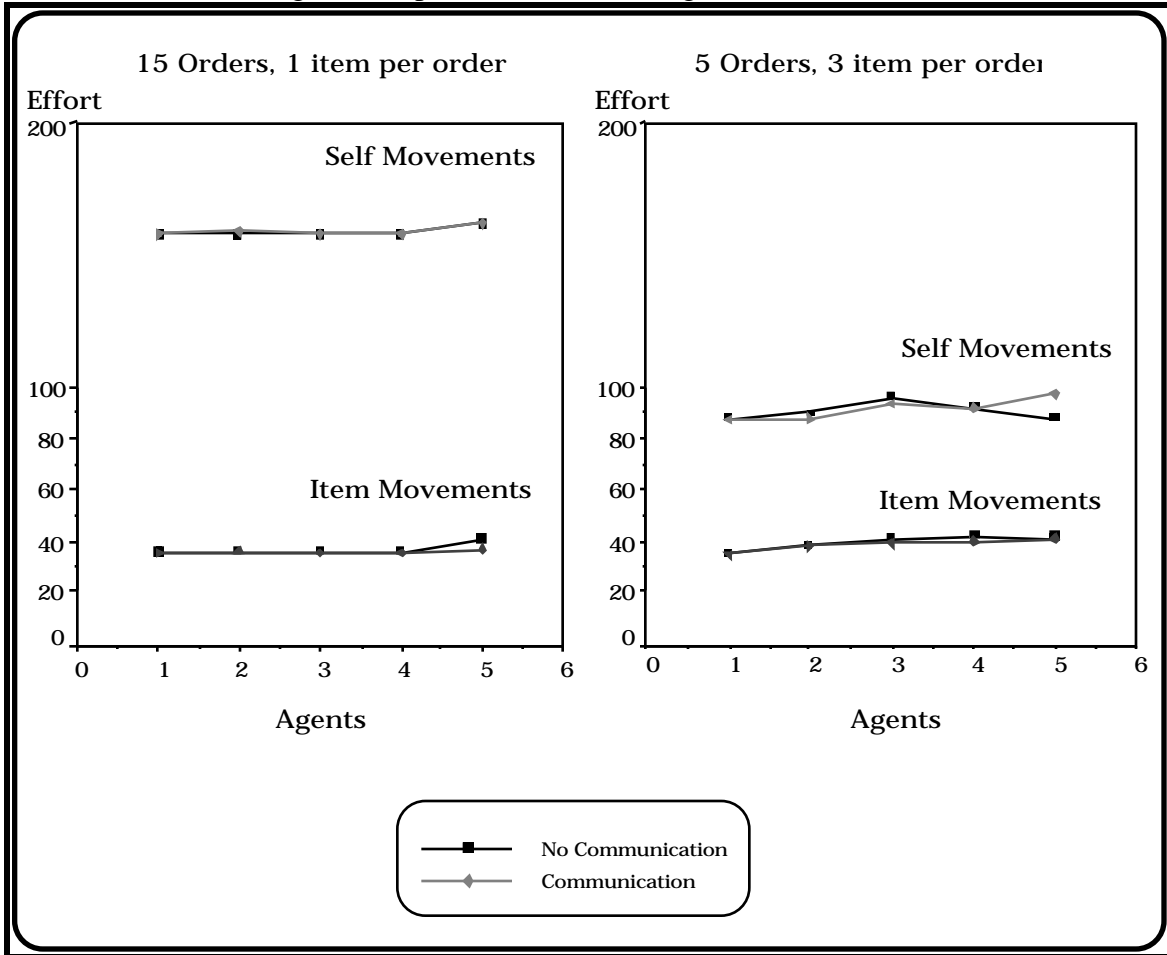


Figure 3: Illustrative PLURAL-Soar Result

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 human rationality is bounded, nor was it the specific architecture of human cognition (as embodied by Soar). Rather, it was the way in which rationality was bounded and the knowledge on which the architecture operated that effected certain outcomes. In other words, while the agent's cognition (Soar) allowed it to do the task, the agent's preferences 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. Future research is needed 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, replacing generic task description with specific task models, enable analysis at this level.

### **ELM: A STRONG SOCIAL-SITUATION MODEL**

The organizational experiential learning model (ELM) is a simulation testbed that has been used to examine the relative performance of organizations that vary in their design and in which the agents act on the basis of their personal experience. Previous studies using this model 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 (Carley, 1991b). ELM employs a simple situated-cognition model of individual action in which agents learn from their personal 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 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 each time-period the organization is faced with a new binary 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 1's than 0's (e.g., 1101101). Each time-period each agent acquires new information on some subtask (a portion of the word), makes a decision (the agent's opinion based on the subtask as to whether there are more 1's than 0's in the full task), and communicates this decision (not the information used to make the decision). Agents may differ in their mental model of the specific task as they are seeing different subtasks (or aspects of the full task). By specifying a particular organizational design a unique organizational type can be identified (e.g., a hierarchy with low turnover and a completely segregated task decomposition scheme). The particular organizational design affects the agents' mental model of the task as it affects what information they have access to. Each agent in making its decision brings all of the knowledge (new data and historical experience) that it has to bear. Thus each agent's decision is based not only on its representation of the current task but its historical knowledge garnered by working on previous tasks.

The organization makes an organizational decision, either through the actions of the CEO (a top-level decision-making agent that integrates information across agents) or by the voting of all agents (as in the team structure). For each task (i.e., each time-period) there is a true (or correct) decision based on the actual features of the task. Performance can be measured by examining whether the organization's decision is the true decision. Finally each time-period every agent receives feedback (new knowledge on what was the right organizational response in this situation — the true decision). Monte-Carlo simulation is used to estimate average performance across a large number of tasks.

#### **Agents: Cognitively Limited**

All agents, regardless of their position in the organization, are boundedly—rational and make decisions 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 effectively learns rules for how to respond to a specific situation.

### **Tasks: Binary—Choice Classification**

A classification task is used that requires the organization to determine whether there are more 1's than 0's in a binary word of length  $N$ . A problem is a word of length  $2^N$ . Each analyst sees only a subtask, a portion of this word. The organization is presented with a particular problem and must classify it as a word that has "more 1's" or as a word that has "more 0's".

### **Situations: Limiting Action and Access**

The social-situation is defined by the organization's design, which includes the following features: the composite organizational structure, task-decomposition scheme, associated order of processing, rules for processing information and communication, and procedures for training, hiring, personnel movement, and so forth. 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.

### **Organizational Structures**

Using ELM, a variety of organizational structures can be examined, such as, the centralized hierarchy, the dual-command hierarchy, and the team (see Figure 3). 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 Figure 4, analysts are represented as lightly shaded circles, AEOs as darkly shaded circles, and the CEO as a black circle. For the organizational structures shown only the analysts have access to the "raw data" associated with the task and the task decomposition scheme is a blocked structure. In all organizations each analyst sees only a portion of the task, that is, a subtask (as defined by the task-decomposition scheme). In the hierarchies, institutional memory is centralized in the upper-management, albeit in a reduced-information form. In the team institutional memory is completely distributed. The presence of such upper-level management, by mediating the decisions made by lower-level agents (analysts), can reduce the impact of various debilitations, such as turnover or unavailability, thus affecting the level of information redundancy needed for equivalent performance (Carley, 1992, 1990). Information loss is higher the more complex the task faced by the agents and the greater the number of levels in the organization.

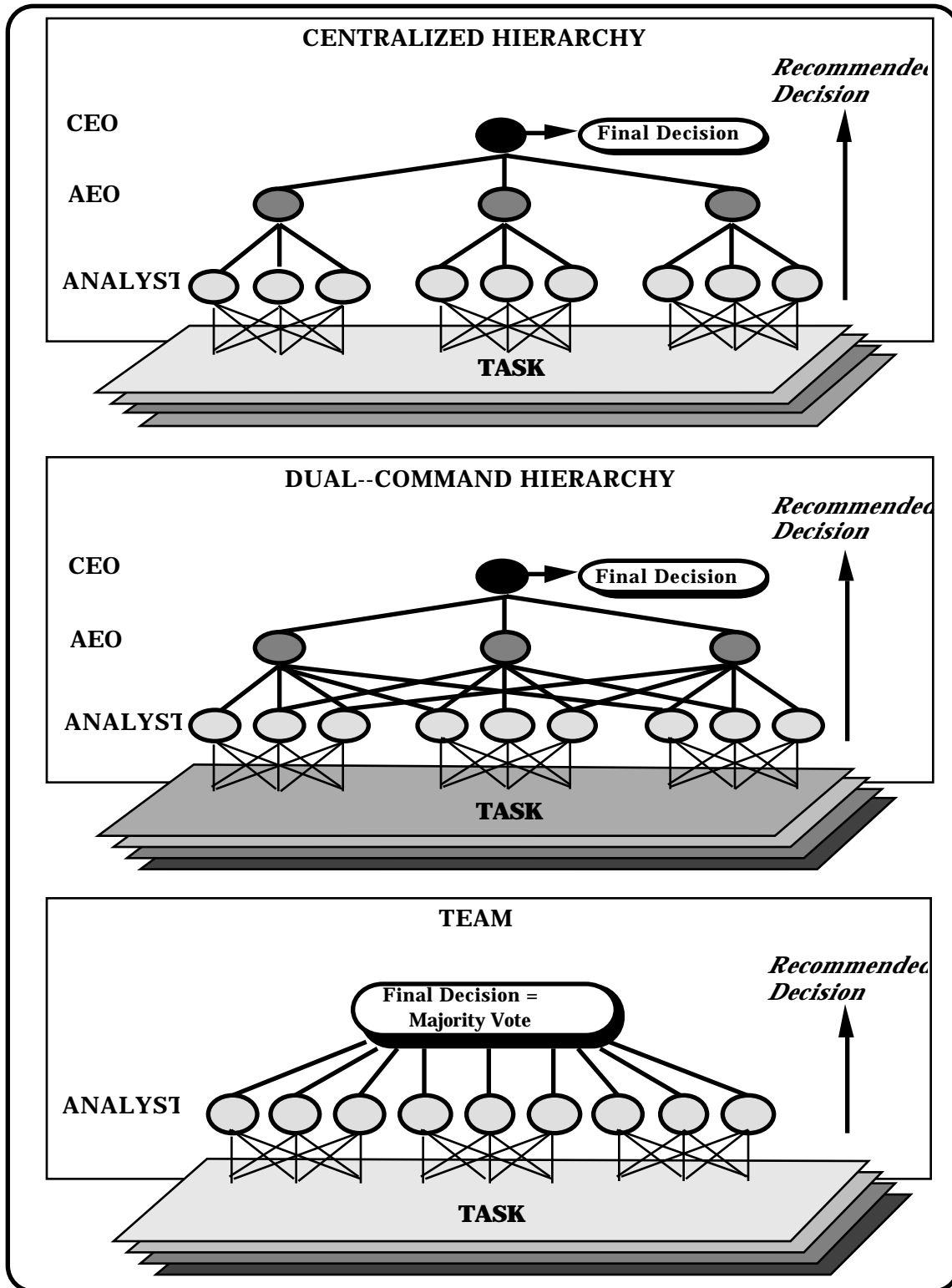


Figure 4: Typical Organizational Structures

### Task-Decomposition Scheme

The distribution of subtasks (i.e., which agent receives which subset of bits), and hence the level of redundancy at this primary level, is defined by the task-decomposition scheme (also referred to as the information access structure). Figure 5 illustrates some of the task-decomposition schemes that have been examined using the ELM testbed. In Figure 5 the squares represent the bit of information. 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. When the redundancy level equals the number of analysts, we have a situation in which all analysts have access to all information that corresponds to the case of complete information/complete overlap discussed in other studies (Carley, 1986; Cohen, March, and Olsen, 1972). As the level of redundancy increases relative to the number of analysts the complexity of the subtasks faced by the analysts increases.

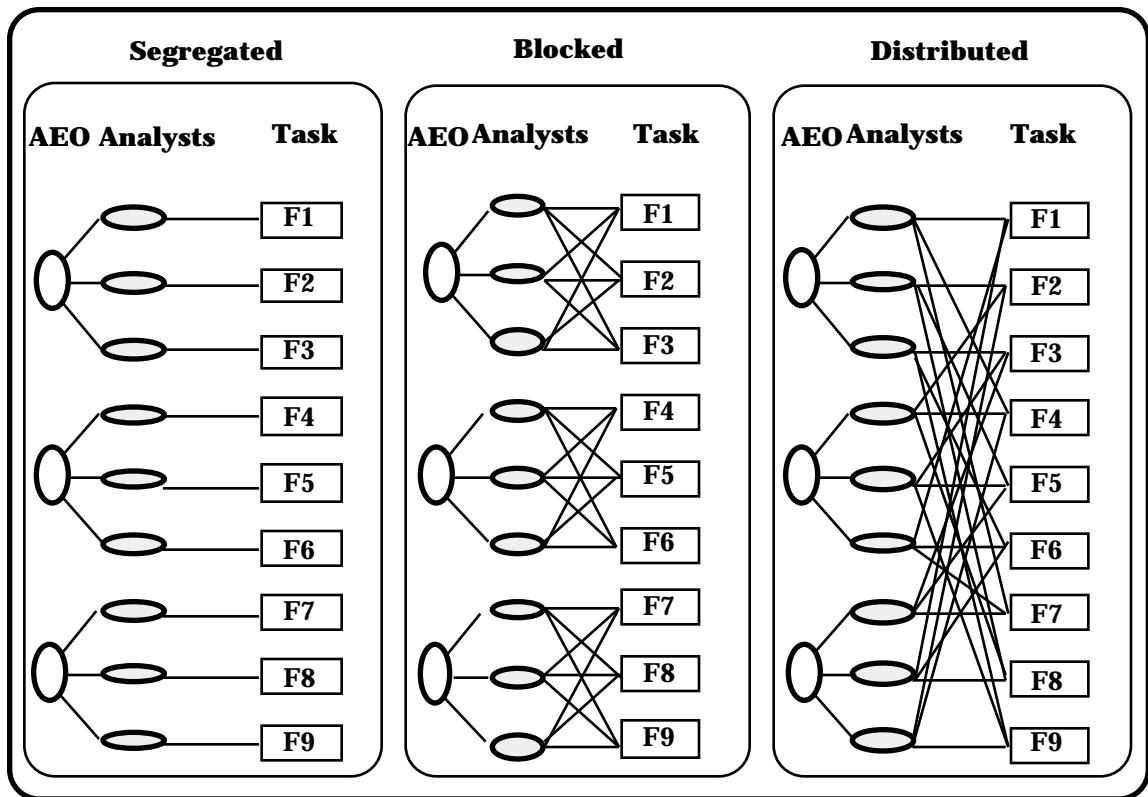


Figure 5: Typical Task Decomposition Schemes

### **Difficulties: Limiting Information and Communication**

Within ELM the organization's performance can be examined both under normal operating conditions and under sub-standard 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 impact of a various difficulties on organizational performance

have been examined: turnover (Carley, 1992, 1990), incorrect information, communication breakdowns and agent unavailability (Carley, 1991). Crises are often characterized by disruptions such as incorrect information, communication breakdowns and agent unavailability (Carley, 1991). Thus this framework can be used to examine organizational performance under both standard/optimal and substandard/crisis conditions.

### **ACTS Axioms and the Capabilities and Limitations of 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 either under standard and 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 vantage of ACTS the importance of ELM is that it specifies the minimum model of the social-situation, and it specifies that the organizations design can be characterized by detailing the network of relations between personnel, 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. 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, not 3. They do not have a general capability to learn but rather can only learn information about pre-defined categories given a 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 pre-defined categories (their pre-defined 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 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 allowing them to change positions in the organization would. To more fully approximate axiom 9 ELM agents would need to have mental models of the situation and the task.

### **Results**

The set of organizational structures in Figure 4 and the set of task decomposition schemes in Figure 5 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. 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 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 1,2, or 3), and duration (10, 20 or 50 time-periods).

The results are shown in Figure 6. Here we are not concerned with the 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.

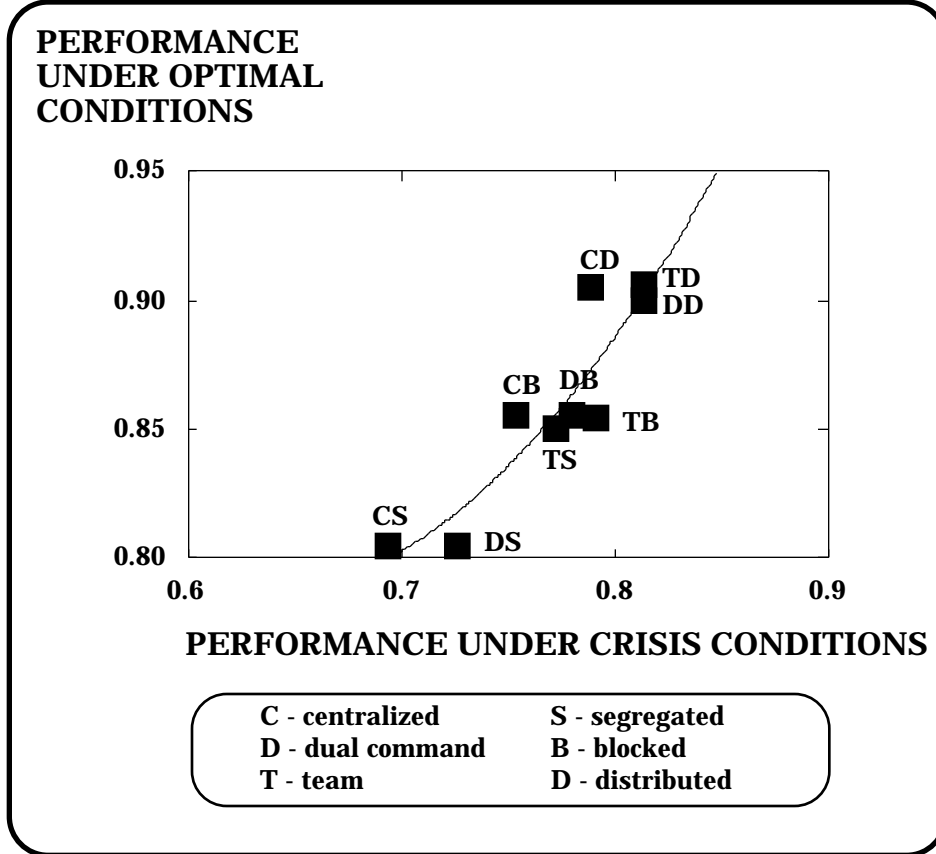


FIGURE 6: ILLUSTRATIVE ELM RESULT

Studies of organizational design often focus on the structure of the organization describing why some structures should out perform other structures. For example, hierarchies are expected to exhibit lower performance than teams due to uncertainty absorption (March and Simon, 1958), information condensation (Downs, 1967), and information distortion (Jablin, Putnam, Roberts and Porter, 1986). These arguments lead one to expect that dual-command structures should lie somewhere in 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 Figure 6 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, Cohen, March and Olsen, 1972; Anderson and Fischer, 1986). Unlike these earlier studies, this analysis suggests that whether teams outperform hierarchies depends on the extent to which the agents have different mental models of the task. In Figure 6 the line indicates that the relationship is quadratic 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, March and Olsen (1972) this study suggests that segregated task decomposition schemes (decision structure) leads to low performance. In addition we see that decomposing the task in a distributed fashion so that there is redundancy in who knows what, yet no two agents have identical information leads to the highest performance both under optimal and crisis conditions. For any particular type of organizational structure, in terms of performance, a segregated structure is worse than a blocked structure that is worse than a distributed structure regardless of whether the organization is operating under optimal or crisis conditions. These results suggest that the decomposition scheme has a more regular impact on performance than does the organizational structure.

However, 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, task and situation are clearly separated, thus agents mental models of task and 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

We have proposed a theory of organizations based on an extended model of bounded rationality. We have also argued that a unified theory of organizations (linking organizational/group phenomena with individual agent models) can be developed if we think of organizations as collections of tasks and intelligent agents engaged in performing those tasks, such that both agents and tasks are situated within an organizational structure, and that *organizational behavior emerges* as agents perform these tasks within an organizational context. Consistent with this argument are the following themes: the need to move organizational theory to the 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 principles of environmental constraints with specific characterizations of tasks and social-situations, and the corresponding need to move to broader and more encompassing computational theories of organizations. Our perspective suggests that if organizational studies do not account for an intelligent agent (one that is knowledge-based, adaptable, but cognitively restricted), the task, or the social-situation the quality of the results may be limited. In keeping with this argument we have proposed axioms that may serve as the foundation for a unified theory of organizations that exhibits this multi-point focus. We illustrated the potential of such a theory using two computational models, Plural-Soar and ELM, each of which is partially sufficient with respect to ACTS theory 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. Let us consider three of these: 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 a multi-point focus, and 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 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, the principles of bounded rationality. Such models also focus research attention on the mechanisms underlying behavior.

Since organizations are collections of tasks and intelligent agents it makes sense 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<sup>6</sup>, 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 (such as Soar). 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., Straw, 1991) and recent research on organizational design is moving in precisely this direction (Baligh, Burton and Obel, 1992; Carley, 1992; Lin and 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 which 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 and Weingart, 1991).

If models of individual cognition are sufficient models of an agent's social/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.<sup>7</sup> 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) have argued that they are very near to the social agent, limited mainly by a lack of attendance 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 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 and Zeithaml, 1989a, b; Chandler, 1990; Mintzberg, 1973, 1978; Snyder and Glueck, 1980; Donaldson and Lorsch, 1983) argues that much insight can be gained by systematically examining a cognitively predicated model of artificial organizations.



## **Research Implications of Multi-point Focus**

Constructing ACTS models requires addressing a number of issues that arise when a multi-point focus 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 and the organization and task as "perceived" by each agent. This will necessitate 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/non-work knowledge becomes salient in doing tasks within the organization. The deeper social issue is how do changes in the sociodemographic distribution of individuals in the 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 shared across individuals) but also 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 and Radner, 1986; Tang, Pattipati and Kleinman, 1991). Yet in real organizations there are many alternate information sources available for the agent to accomplish tasks, such as documents (static data), computer-based information systems (procedurally flexible), or other agents (intelligent).<sup>8</sup>

## **The Study of Tasks**

Both Plural-Soar and ELM employ simple models of real tasks. Admittedly both the warehouse task and the binary-choice task are rudimentary, nevertheless they contain many of the 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, 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, 1992). 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, domains. 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. 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 inter-relationship 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 paper to put forward a full theory of task influence or to define influential task dimensions from the multi-point focus on agent, task, and situation. Such a theory can be elaborated through multiple studies which examine real tasks in a systematic fashion. We do note, however, that a minimally adequate model of task must specify *actions* which can and cannot be taken in pursuit of the task, the *constraints* which denote task decomposability and component interrelatedness, and the *knowledge* needed to perform the task.

### **Final Comment**

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 difficulties that require continual adaptation by the agent (and subsequently the organization) to achieve their goals; (2) the cognitive world where the agents' mental model of their position, the task, and the extant difficulties determine what actions they take, what they learn, and what goals they pursue; and (3) the social world where agents and task are situated within and across specific organizational positions. ACTS theory encompasses these three foci.

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 and 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 propositions about organizational life that could not be generated with task-less 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. We have argued that the search for a unified theory 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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<sup>1</sup>The two papers of Simon (1955, 1956) are, as Simon puts it, “mathematizations” of chapters 4 and 5 of *Administrative Behavior*. McCorduck (1979) points out that, in fact, Simon included an appendix to the Behavioral Model of Rational Choice paper in which he demonstrates how the principles put forth in the article could be used to construct a chess machine. The appendix was never published.

<sup>2</sup>The term “meso” has been used to describe those theories or perspectives that lie between the micro- and the macro- and that link micro-level mechanisms to macro-level phenomena.

<sup>3</sup>This division is provided by Daft (1989) who observed that organization theory is “the sociology of organizations” while organizational behavior is “the psychology of organizations.”

<sup>4</sup>We view organizational design as including the set of rules of operations or procedures, institutional norms, data bases, task decomposition scheme, and the formal and informal organizational structure (Lin and Carley 1992). Thus, organizational design is present in and affects agents (through their knowledge bases), tasks (through their decomposition), and situations.

<sup>5</sup>These problems may be part of the general difficulties faced by the organization that makes organizational life anarchical at times (Cohen, March and Olsen 1972) or they may be more catastrophic in nature like those occurring when high-risk technology is employed (Perrow, 1984).

<sup>6</sup>The use of cognitive simulations as psychological models has been demonstrated in several domains — extensively in medicine (e.g., Clancey and 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 and Anderson 1981), and even scientific discovery (Langley, Simon, Bradshaw, and Zytkow 1987).

<sup>7</sup>For 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).

<sup>8</sup>For a perspective that considers both individual cognition and organizational design see Huber (1990).

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