MAYDAYS AND MURPHIES: A THEORETICAL STUDY OF ORGANIZATIONAL PERFORMANCE UNDER STRESS

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ABSTRACT

How should organizations of intelligent agents be designed so that they exhibit high performance even during periods of stress? We present a formal model of organizational performance given a distributed decision making environment in which agents encounter a radar detection task. Using this model, we examine the performance of organizations with various organizational designs and task environment characteristics subject to various stresses. We distinguish two types of stress — external stress (such as hostile events that we call maydays) and internal stress (such as communication channel breakdown that we call murphies). This formal analysis suggests that: (1) regardless of stress, performance is enhanced if there is a match between the complexity of organizational design and task environment; (2) task environment characteristics and maydays (external stress) have more effect on performance than murphies (internal stress) and organizational design; (3) the effects of murphies (internal stress) can be combated by training, but only to a limited extent; and (4) technology induced stress typically is more debilitating than personnel induced stress.

INTRODUCTION

It was July 3, 1988, the Persian Gulf. On board the most advanced Aegis warship, U.S.S. Vincennes, a group of operators was working intensively in front of the radar defense system. Suddenly, they detected a signal of attack by an "enemy F-14 fighter". The warning signal was immediately sent to Captain Will Rogers III, who without hesitation, gave the order to fire. Several minutes later, an Iranian civilian aircraft with nearly 300 passengers was shot down, no-one survived (Cooper 1988)[1].

This tragedy prompted many to wonder: what went wrong? Investigations following the incident suggested many possible causes for the tragic mistake. One criticism was that the Navy lacked training in real fighting, but had experience only with computer games and "canned exercises". Consequently, some crew members were unprepared and misinterpreted the data from the radar system when facing a real and highly stressful situation such as the Persian Gulf (Cohen 1988). Another criticism was that the Navy was not properly trained for low intensity conflict, but only for superpower confrontation, and their personnel as well as war machines were not suitable for the Persian Gulf situation (Duffy et al. 1988). Others forwarded the criticism that the Navy used biased judgments in dealing with the Gulf situation (Watson et al. 1988). Adm. William J. Crowe Jr., then Chairman of the Joint Chiefs of Staff, commented: "The rules of engagement are not neutral. They're biased in favor of saving American lives". Others pointed out that incorrect information received by the radar system regarding whether the aircraft was civilian or military caused the tragedy (U.S. Congress 1988). Still others challenged the commanding hierarchical structure of the Navy warship and argued that the mistake was caused because the error was passed to the captain without sufficient cross-checking (Watson et al. 1988).

The above incident demonstrates that organizational performance is subject to the nature and type of stress, but the effect of stress is mediated by a variety of organizational factors, such as organizational structure, resource access structure, and training (which we call organizational design), and the problems came upon the organization (which we call task environment). Despite the often tacit acknowledgment that stress, organizational design, and task environment are intimately related, few studies have systematically and simultaneously explored the impact of these factors on organizational performance. Such a study should provide insight into interactions between these factors. In this paper, we examine using computer simulation the decision making performance of organizations (as stated by Simon (1947) decision making is the true heart of administration) under conditions where there are either or both external and internal stress. We observe organizational performance under stress under different organizational designs and task environments. The organizations we examine are engaged in a radar detection task, which though stylized, resembles that faced by the Vincennes.

BACKGROUND

Stress

Organizations often face stress. This stress can take the form of "a potential crisis", a situation that is perhaps novel, may be essentially inevitable (Perrow 1984), and have potentially crisis level consequences. We refer to these potential crises as maydays. Examples include the citing of possibly hostile aircraft and natural disasters such as Hurricane Andrew. Or the stress can be more routine (March and Simon 1958; March and Olsen 1976) and take forms such as turnover (Carley 1992; Tushman et al. 1989), and communication breakdowns (Carley 1991). We refer to these routine stress as murphies. A feature that separates maydays and murphies is that maydays derive in part from the task or problem environment; that is, we can think of different problems in the environment as maydays. Whereas, murphies can occur independently of the problem environment.

Clearly, maydays and murphies are often interrelated. Maydays may cause murphies, and murphies may aggravate the mayday situation. For instance, response organizations must respond to various disasters. Hurricane Andrew was a mayday, a catastrophic external event to which organizations need to respond. It caused numerous murphies such as communication being cut off due to downed power lines and people being dislocated. Such murphies, in turn, made the situation more critical and disastrous (Carley and Harrald 1992). In examining organizational performance it is important to consider both sources of stress and to conceptually separate the two types of stress. Maydays are important to consider because they may be inevitable (Perrow 1984) and the consequences of the organization's decision so universally important. Murphies are important to consider because they are so pervasive (Cohen and Mach 1974) and yet potentially capable of being reduced, if not prevented.

Maydays stress the organization because they force individuals in the organization to face situations for which there are potential severe consequences. The effect of maydays also depends on how the organization is designed. Maydays can be crises if the organization is not prepared for them, but the impact of maydays can also be reduced if the organization has the right design. Murphies stress the organization because they cause ambiguities and uncertainties and force individuals in the organization to make decisions under suboptimal conditions. The effect of murphies may also depend on the design of organizations. The nature of maydays and murphies also suggests that their effects on organizational performance are different.

How can organizations cope with stress. Two strategies that have dominated the literature are "better technology" and "better trained". The better technology strategy (Neuhauser 1971) is an engineering approach, and centers on the idea *if we can just design the procedure (and/or the associated equipment) right, then crises can be avoided.* But if Perrow (1984) is right, better technology may reduce stress but it will not completely eliminate it. The better trained strategy (Dunbar and Stumpf 1989; Green 1989) is a personnel approach and centers on the idea *if we can just train people then they will respond more quickly and accurately during crises thus minimizing the impact of crises.* But the value of training is indeterminate (Ganster et al. 1991; Hammond 1973). A third strategy, which has received less attention is "better design". The better design approach (Burton and Obel 1984; Carley 1990,1991,1992; Malone 1978) is a structural approach, and centers on the idea *if we can just design the organization right, the impact of crises can be mitigated.* Contingency theorists have suggested that the right design is highly situationally specific and so little general guidance or simple theory of design can exist (Galbraith 1973, 1977; Lawrence and Lorsch 1967). However, as Scott (1987) points out "such a quest not only overlooks the vast diversity of existing organizational forms, but also fails to recognize the great variety of tasks undertaken by organizations" and also "fails to search for any underlying principles to guide their designs". Efforts at forging contingency theory and an understanding of tasks into a theory of design have gone the route of creating expert systems replying on highly situation specific knowledge (Baligh et al. 1990, 1992).

In this research, we focus on the third approach, the design approach, and consider training as the part of design that adapts to the task environment. We believe there is systematicity underlying the relationship among stress, organizational design, and task environment. Through an examination of multiple organizational designs, the expected relations between design and performance under stress will be deduced. The focus of our analysis is on the relative performance of various designs given different types of stress. This is in contrast to that work on organizational design that given a set of constraints tries to locate the optimal design. This analysis will make it possible to systematically determine whether effects such as Staw et al.'s (1981) threat-rigidity effect will occur universally or only under certain conditions.

Organizational Design and Stress

Organizations must deal with, and are generally created for dealing with, problems, i.e., a task environment (Thompson 1967). However, unlike the task environment, which is exogenous to the organization, organizational design is more (or less) under the control of the organization and is thus relatively adjustable or adaptive to the task environment (Baligh and Burton 1992; Lawrence and Lorsch 1969; Woodward 1965). For this study, we follow the suggestion of Thompson (1967) and Mackenzie (1978) and conceptually separate organizational design from task environment, and focus on their respective features and the connections between them.

The interest in design largely is due to the fact that organizations can alter their design. To the extent to which performance is related to design organizations can improve their performance by altering their design. In general there is the assumption, albeit often implicit, that organizational performance (or efficiency) is tied intimately to the organizational design. However, the literature is replete with contradictions. For example, Mackenzie (1978) argues that the degree of hierarchy is linked directly to the organization's efficiency. Roberts (1989) suggests that "hierarchical structures should increase the reliability of performance". In contrast, other people claim that hierarchies may exhibit lower performance due to information loss through the process of condensation (Jablin et al. 1986) or inability to absorb uncertainty under internal stresses (March and Simon 1958). Davis and Lawrence (1977) suggested that a matrix will exhibit high performance only if the task environment is complex. However, Houskisson and Galbraith

(1985) showed that matrix organizations improved their performance even when the task environment was simple.

Organizational design can affect the impact of stress on organizational performance. Organizational design has been viewed from a variety of perspectives. Organizational design has been characterized in a number of ways: the formal structure and task decomposition structure (Burton and Obel 1984; Mintzburgh 1983); the degree of hierarchy (Mackenzie 1978); the structure of the informal network (Krackhardt 1989); the process of coordination in the organization (Pfeffer 1978); the procedures for combining information or making decisions (Panning 1986; Radner 1987); and the information processing characteristics or cost of the organization (Carley 1990; Galbraith 1973, 1977; Malone 1986; March and Simon 1958). Despite the numerous approaches there are still aspects of design that are frequently neglected; e.g., the skill or expertise level of the employees.

Design is expected to affect the organization's performance under both optimal and stress conditions. Staw et al.' suggest that organizations become rigid in the face of stress and stated that "whether a threat-rigidity effect is functional may rest on the nature of the threat itself." Specifically, rigidity would be functional when the organization faced a simple or well known environment; but, it would not be functional when the organization faced a complex or radically changing environment. For Staw et al., rigidity is "restriction in information processing and constriction of control". Taken to its limit, a rigid structure would be a simple organizational structure such as a team with a manager. Thus simple structures should perform poorly under stress if the environment is complex. Similarly, Krackhardt and Stern (1988) suggest that "adaptation to crisis requires increased coordination", and that more complex structures will help organizational performance under maydays or murphies. Another aspect of design, training, is also expected to affect performance under stress. Though the common wisdom is that training (an aspect of design) helps organizational performance and prevents degradation of performance under stress, other research (Perrow 1984; Roberts 1989; Shrivastava 1987), Ganster et al. (1991) and Hammond et al. (1973) suggests that training may have an adverse effect on performance under certain situations.

In large part, the relation between organizational design and performance is expected to hold because organizations are composed of intelligent agents who can, and do, learn from experience (Carley 1991, 1992; Carley et al, 1992; March and Simon 1958). Thus the organization's performance depends on the performance of its members (Hastie 1986). However, the agents' performance is affected by the organization's design which places constraints on the agents.

In this paper, organizational design is viewed as a combination of organizational structure, resource access structure, and procedures (such as training). As pointed out by Thompson (1967) and Mackenzie (1978), organizational design and task environment are in many situations closely related and the task environment can impact the organizational design. In order to clarify the impact of task environment on organizational performance we find it useful to conceptually separate the organizational structure from the resource access structure. Such a separation enables us to make a distinction between the connections between people (organizational structure) and the connections of people to direct information and resources regarding the task (resource access structure). In our model, part of the linkage between organizational design and task environment is through the resource access structure (or as Mackenzie called it — task process structure)[2].

Task Environment and Stress

Open system theory (Scott 1987) and population ecology (Hannan and Freeman 1977) have refocused attention on the environment as a set of problems that are externally posed for the organization. Research in artificial intelligence, and of particular interest to organizational theorists, research in distributed artificial intelligence (Bond and Gasser 1988; Carley et al. 1992, Dreznick 1986), use a similar notion of task environment and have clearly demonstrated the importance of task environments. Such research demonstrates that features of task environments serve as constraints on what organizations are most effective, and even possible (Demael and Levis 1991; Levis 1988). We take this view of the environment as posing a set of problems for the organization and note that the task environment can limit the organization's performance; i.e., some tasks are easier than are others. Despite the agreement that the task environment constrains organizational action there is little agreement as to what are the salient features or dimensions of task environment.

Task environments vary on a large number of dimensions besides number of components, not the least of which is complexity. There have been numerous studies of the effect of task or environmental complexity on organizational performance (Wood et al. 1990). These studies demonstrate that increases in complexity correspond to decreases in performance. In addition, Carley (1990) using a model similar to that in this paper, found that organizational performance tended to degrade with the complexity of the task environment. Some experiments also show that when task environment is simple, centralized organizations (such as hierarchy) make fewer errors than decentralized organizations (such as team with voting) (Cohen 1962; Shaw 1981), but when task environment is complex, the opposite is true (Shaw 1981). However, there are multiple factors which may affect the complexity of the task environment; e.g., decomposability and bias.

Decomposability has received extensive attention. The common wisdom is "divide and conquer" (Babbage 1832; Massie 1965; Tausky 1970). Decomposability is related highly to the interdependence of the task environment components (Roberts 1989, 1990). Problems of coordination can occur if organizational design does not take the decomposability of the task environment into consideration. Bias, another factor affecting the complexity of the task environment has received less attention. Bias can be thought of as operation within a niche. The niche defines what types of problems the organization sees. Some organizations operate within a highly specialized niche (Hannan and Freeman 1977) and are therefore expected to perform well in a specialized environment. Other organizations operate within a more generalized niche and are therefore expected to perform well in a coarse-grained environment. From the perspective taken in this paper, organizations within a specialized niche are coping with a biased task environment; i.e., they have a tendency to see only one aspect of a more general problem. Organizations facing unbiased task environments see all aspects of the general problem and therefore are in a more generalized niche.

MODEL

Stylized Radar Task

We use a stylized radar detection task similar to that used by Ilgen, Hollenbeck and Sego (1991). There is a physical air space that is being scanned by the agents. Within this airspace, during any specific time period, there is a single aircraft. This aircraft may be friendly (1), neutral (2), or hostile (3). Each aircraft has nine characteristics such as speed and direction (see Figure 1). For an aircraft each characteristic takes on one of three values, e.g., the speed may be low, medium, or high. The indication of a specific characteristic may not reflect the true state of the whole aircraft. For example, while the aircraft may have weapons, and so on the characteristic Radar Emission Type may appear hostile, the aircraft when all characteristics are considered may actually be friendly. The number of possible unique aircraft or problems is 19683 (3^9).

Place Figure 1 about here

We choose this stylized task for the following reasons: First, it is a real world problem. The task has been widely examined in military and civilian (e.g., air-traffic control) contexts. Second, it is a very general task, not a specific or narrowly defined task. Although we think of this task as radar control, in reality it is a trinary choice task, and any task where the agents can choose between three options has features in common with this task. Third, because the true decision can be known, feedback can be provided and so issues of training can be addressed. Fourth, it is ideal for a distributed environment as the task is sufficiently complex that multiple agents can be used to work on different aspects of the task. Fifth, the task itself has a limited number of cases ($19683=3^9$) and so numerical enumeration techniques can be used to evaluate performance. Sixth, this task can also be thought as a trinary version of the binary choice task used by Carley (1990,1991,1992), so admits replication and extension of this earlier work. While binary choice tasks have received a great deal of attention (Tang, Pattipati, and Kleinman 1992), trinary choice tasks have received less attention. Thus, this study will extend our understanding of organizational performance on choice tasks. And finally, this task is sufficiently interesting that it can be expanded later with relative ease to include many other factors, such as communication of different types of information or different process rules or learning rules or training orientations. This makes possible a wide variety of studies using the same task and so enhances the prospect of cumulative research in this area.

Each time period, the organization must scan the air space and make a decision as to the nature of the aircraft in that airspace. The organization goes through this process 19683 times, once for each unique aircraft.[3] Some of the organizational agents (the radar operators) access information on the aircraft, develop a recommendation (their opinion as to whether they think the aircraft is friendly (=1), neutral (=2), or hostile (=3)), and communicate this recommendation. How these recommendations are processed or combined by the organization depends on the organizational structure. This will be discussed in the next section. Regardless of the organizational structure, the processed (or combined) recommendations form the organization's final decision on that aircraft (the organization's decision that the aircraft is friendly (=1), neutral (=2), or hostile (=3).

The aircraft really exists, and is therefore "truly" friendly (=1), neutral (=2), or hostile (=3). The organization is not omniscient and the true state of the world is not known a priori. Rather, it must be determined by the organization by examining the radar characteristics of the aircraft. Given that organizations have only history and their understanding of their current technology to guide them the organization as a whole has only a vague understanding of the true state of the world. The organization's understanding resides both in the agents and in the pattern of relationships among the agents (Carley 1992). The agents' understanding of the true state of the world depends on how they were trained. Each agent is assumed to be intelligent; i.e.. each agent makes a recommendation or decision on the basis of all the task-based information available to the agent. What information is available to the agent depends both on what the current problem is and on how the agent was trained.

Stress

We examine two types of stress — maydays and murphies.

Maydays

Maydays represent crises to the organization. As noted earlier they are stresses external to the organization (such as hostile events). This is similar to the definition of "stress" provided by Staw et al. (1981). In this analysis, those aircraft that given a particular task definition are hostile are considered maydays.

Murphies

Murphies represent stresses or crises internal to the organization. As noted earlier they are internal stress (such as communication channel breakdown). Murphies are expected to create internal ambiguity within the organization (March and Simon 1958). In this paper we examine 5 different types of murphies — missing information, incorrect information, agent unavailability, agent turnover, and communication channel breakdown. These types of murphies were chosen because they are prevalent in real organizations and the vary in terms of whether the represent technology based ambiguity (missing information and incorrect information) or agent based ambiguity (agent unavailability and agent turnover) or ambiguity due to some technology-agent interlink (communication channel breakdown).

In addition, we vary the degree of severity of such murphies. We examine three levels of severity — low (1 murphy occurs), medium (2 murphies occur), and high (3 murphies occur). In reality, during most crises multiple murphies of different types occur. In this paper, in order to examine the differential impact of different types of murphies, only a single type is examined at a time. Thus, even when there are multiple murphies they are all of the same type.

For each organization, the location of the one or more murphies is chosen randomly before each decision cycle. Thus, a technology based murphy is equally likely to occur for each of the 9 task characteristics. And an agent based murphy (or the communication breakdown) is equally likely to occur for each radar operator.

Missing Information

Missing information is defined as occurring when one or more of pieces of the incoming information for a particular problem is not available. For example, the altitude of the aircraft may not be detected because certain surveillance equipment is broken.[4]

Incorrect Information

Incorrect information is defined as occurring when incoming information is erroneous, e.g. when the radar system reports an aircraft as being very fast when indeed it is moving slow. This can happen, for example, when some surveillance equipment does not work properly.[5]

Agent Unavailability

Agent unavailability is defined as occurring when one or more radar operators is not available to help the organization solve the problem and so does not report his or her decision to his or her manager. Agent unavailability frequently results in erroneous organizational decisions. For example, this can happen when certain operators are sick and unable to be on duty.[6]

Communication Channel Breakdown

A communication channel breakdown is defined as occurring when one or more radar operators are unable to report to a superior because the communication channel is unavailable. This can be thought of as a failure in the communication technology, or, as ignorance of the necessity of communication. For example, this can happen when some operators do not report their observations to their superiors.[7]

Agent Turnover

Agent turnover is defined as occurring when one or more radar operators leave the organization and are replaced by a new radar operator. In this study, new radar operators in experientially-trained[8] organization are untrained, and do not learn, and so proceed simply by guessing. Turnover, may be very debilitating. This can happen, for example, when some radar operators are transferred to other places or become a casualty of war, and new operators take over. [9]

Organizational Design

In this paper, organizational design is characterized by three factors — the organizational structure, the resource access structure, and the organizational procedures (herein limited to procedures for providing training, feedback, communicating recommendations, and combining these to create an organizational decision). By considering all three factors, design elements of structural theory, resource dependency theory, and instutuional theory are combined in a single formal framework.

Organizational Structure

We examine four structures: team with voting, team with a manager, hierarchy, and matrix[10] (see Figure 2). Each structure consists of nine baseline radar operators. In addition, some structures also employ middle and/or top-level managers.

Place Figure 2 about here

These structures are examined because they represent stylized version of real organizations. Each type of structure has been analyzed by various research traditions, but rarely has their performance been contrasted[11]. Each structure has features which have been touted as enabling it to perform well under some circumstance. The team with a manager, or "wheel" structure as called by Mackenzie (1978), for example, is virtually a flat hierarchy such that while each radar operator examines information and makes a recommendation, the ultimate organizational decision is made by the manager (or team leader). Such teams are common in settings such as software design projects. They are the simplest of centralized structures and arguably are good at simpler task environments. The team with voting, or "all channel" structure as called by Mackenzie (1978), is a collection of equals, not subject to any supervisor, who together make the final organizational decision by majority vote[12]. Such teams are common in settings such as congress and judiciary systems. They are the simplest of the decentralized structures, and arguably are quick to learn new information but are rarely resilient in the face of various forms of stress such as turnover (Carley 1991, 1992). The hierarchy, which is the most common structure in organizations, is multi-leveled and designed such that each radar operator examines information and makes a recommendation to his or her immediate supervisor who in turn makes a recommendation to the top-level manager who makes the ultimate organizational decision. Hierarchies have been extensively studied (Malone 1987; Simon 1973), and are expected to absorb uncertainty (Simon 1973). The matrix, like the hierarchy, is multi-leveled, but unlike the hierarchy has cross-links between the divisions in the organization. Thus the matrix has "redundant" communication links such that radar operators report to multiple managers. Matrix organizations are supposed to be good at complex task environments and to sustain more uncertainty.

In the foregoing discussion, we tried to illustrate that these are unique organizational structures with different properties. Moreover, even the most cursory examination of the literature demonstrates that each of these structures is expected to have very different performance profiles. By examining these typical, albeit stylized, organizational structures we will gain insight into the impact of organizational structures on organizational performance.

Resource access structure(Access)

The resource access structure[13] determines the distribution of raw (unfiltered) information to members of the organization. It is the part of the organization connecting to the task environment. In our model, what this means is that the resource access structure determines which radar operator has access to which type of radar or surveillance equipment. Each type of equipment allows that radar operator to garner information on a particular (or a particular set of) characteristics. We examine four resource access structures (see Figure 3). They are: segregated, overlapped, blocked, and distributed[14].

Place Figure 3 about here

As with the organizational structures, these schemes were chosen as they represent unique, albeit stylized, patterns of distributing the task information across radar operators. These schemes represent a range of ways in which task based information can be differently accessed by members of the organizational structures. In choosing these resource access structures we varied two features — how much information overlap exists and where the overlap occurs. The segregated resource access structure essentially is employing the divide and conquer scheme. It has been studied by Cohen et al. (1972) who found that the segregated resource access structure is fragile under stress. Cohen et al. suggested that information overlap makes the organization less reliant on the whims of a particular employee and enables the organization to better deal with stresses such as communication breakdowns. While the overlapped, blocked, and distributed all have information overlap they differ in how that overlap affects the overall distribution of information across the organization. The blocked resource access structure provides complete redundancy within a division and none across divisions. Whereas, the overlapped resource access structure provides for some information being shared between divisions, and the distributed resource access structure guarantees that all information is available to all divisions. The teams of course, do not have divisions, so the impact of these different resource access structures may be less. By considering these variations we are able to see how different resource access structures impact organizational performance.

Organizational Procedures

The artificial organizations we examine have procedures for feedback, communicating recommendations, combining recommendations to create an organizational decision, and training. In all organizations agents during their training phase received accurate and immediate feedback as to what was the correct organizational decision. In all organizations agents could communicate their decision only to their immediate supervisor(s). In the team with voting, a majority rule combination procedures was used. In all other organizational structures the procedure for combining subordinates' recommendations was determined by the supervisor. Training procedures were systematically varied across all organizations. We consider the effect of 3 training procedures — no training, experiential training, and training in standard operating procedures (SOPs). As with the organizational structures and the resource access structures these training scenarios are stylized but they do reflect types of training prevalent in real organizations. These training conditions help us illuminate the effect of training on organizational performance.

At this point it is important to re-iterate that when we measure organizational performance we are dealing with organizations composed of fully-trained agents (other than under certain types of stressed conditions). In all cases we will be examining the performance of organizations after the training process has been completed. The agents are not going through a training process. Rather, the agents, already have as much training as they are going to get. Nevertheless, in order to fully appreciate why the organizations behave as they do it is necessary to understand the type of training the agents received, as well as the exact decision procedure followed by the agents. It is also important to point out that within an organization all agents are either untrained, experientially-trained, or procedurally-trained (other than under certain types of stressed conditions where untrained agents become mixed with either experiential training or procedural training).

No Training Procedure

In the untrained condition, the agents have no historical information or standard operating procedure on which to base their recommendation so they simply guess. This condition is interesting as it represents a baseline against which to compare all other organizational behavior. That is, given this baseline we can address the question *to what extent does training improve performance over and above guessing*.

Agent's Knowledge

The agent's knowledge consists only of current information For example, only the speed, direction, and altitude of the aircraft.

Training Procedure

There is no training procedure. The agent has never seen any of the problems before. The agent has been given no guidance on how to proceed.

Decision Procedure

Given a problem, the agent simply makes a random guess. This procedure is followed whether the agent has complete information or incomplete information. The agent proceeds as though simply following hunches. Returning to the radar scenario, this corresponds to a situation where all the agents are simply placed in front of a series of surveillance systems, with no prior experience and told *OK tell me is that aircraft out there friendly, neutral or hostile*. The untrained agents in this situation will simply throw up their hands and guess or toss a three-sided coin.

Experientially-Trained Procedure

In the experiential condition, the agents have historical information on which they base their recommendation. The experientially trained agents are fully-trained agent in the sense that they have previously encountered all possible aircraft and have received feedback on each aircraft. The experientially trained agents follow the decision procedure identified below but they no longer alter their memory. Thus, their expectations remain fixed.

This condition is interesting as it represents agents who are empowered to act on the basis of their own assessment of the situation. Agents proceed as though they are following a historical dominance rule. That is, the agent after having classified an aircraft will make the decision that has been the historically dominant (most often correct in the past). This corresponds to a situation where all the agents placed in front of a series of surveillance systems have extensive prior experience and are told *OK tell me is that* *aircraft out there friendly, neutral or hostile*. Unlike the untrained agents, who in this situation will simply throw up their hands and guess, the experientially-trained agent will say *well, in my experience, when this particular pattern appeared on my equipment, the aircraft out there was typically ...*

Agent's Knowledge

In this scenario, each agent's memory contains a record of the types of aircraft seen during the training period and the number of aircraft of each type that were truly friendly, neutral, or hostile. Aircraft types are defined by the pattern of observed characteristics. For example, for one agent, a type of aircraft might be high speed, long range, and radar emission of type weapons. The number of types of aircraft that an agent who can observe three pieces of information is 3^N, such that N is the number of pieces of information that the agent has access to when working on the sub-task.

Training Procedure

During training, each agent sees each of the 19683 possible aircraft, is asked to provide a recommendation, and is given feedback. The decision procedure followed during training is the same as that followed after training, what differs is the information that informs that procedure. The feedback provided to the agent is the true state of the aircraft (based on the objective definition). This feedback is the same for all agents in the organization regardless of their position and does not depend on what the agent has done or should have done.

Let us consider how the agent learns. The agent begins knowing nothing, and like the untrained agent previously described will start out by just guessing. As the agent sees each of the possible types of aircraft, his or her memory of the frequency with which that set of problem characteristics is associated with that true outcome is augmented. By the end of training each agent has seen all possible aircraft and has a memory of the frequency with which aircraft of a particular type are friendly, neutral, or hostile. Since different agents observe different characteristics, their memories will be slightly different. This is the same procedure followed in the experiential learning model employed by, and described in detail by, Carley (1990, 1991, 1992).

Decision Procedure

Each agent makes decisions only on the basis of his or her historical experience. The decision procedure varies slightly depending on whether the agent has complete or incomplete information.

Complete Information

When the agent has complete information, the agent first classifies the aircraft on the basis of the characteristics he or she observes. The agent looks up in his or her historical record, how often for that type the true decision was a friendly, neutral or hostile. Let us call, the number of times that, for a particular type, the true decision was "x", the expectation of "x". The decision procedure is described as follows:

If the expectation of a friendly aircraft is greater than the expectation of either a neutral or a hostile aircraft given that sub-task, the agent reports that the aircraft is friendly.

If the expectation of a neutral aircraft is greater than the expectation of either a friendly or a hostile aircraft given that sub-task, the agent reports that the aircraft is neutral.

If the expectation of a hostile aircraft is greater than the expectation of either a friendly or a neutral aircraft given that sub-task, the agent reports that the aircraft is hostile.

If neutral and hostile aircraft are equally likely and both greater than friendly aircraft, then the agent randomly chooses either neutral or hostile aircraft.

If friendly and hostile aircraft are equally likely and both greater than friendly aircraft, then the agent randomly chooses either friendly or hostile aircraft.

If neutral and hostile aircraft are equally likely and both greater than friendly aircraft, then the agent randomly chooses either neutral or hostile aircraft.

If friendly, neutral, and hostile aircraft are equally likely, then the agent randomly chooses either friendly, or neutral, or hostile.

By following this procedure the agent is acting as though it has perfect recall.[15] As the agent has no way to determine the "correctness" of the information, this procedure is followed whether or not the information acquired by the agent is correct. Since the agent can not discriminate between correct and incorrect information, if the information is incorrect then the agent will simply misclassify the aircraft. For example, the agent might think it is looking at an aircraft of type "a" when it in reality is looking at an aircraft of type "b". As a result, the agent recalls the expectations for aircraft of type "a" and not "b", and acts on these.

Incomplete Information

Incomplete information might occur because the radar detection system does not function well, or an radar operator is off-line, or a communication channel is broken. When information is incomplete, the agent can not uniquely classify an aircraft. Instead, the agent matches only that information available (partial pattern matching). This may result in the selection of 3 or more types. Then, for each selected type, the agent sums up the expectations of friendly in all types, neutral in all types, and hostile in all types and acts on the basis of the combined expectations following the procedure previously dictated.

Procedurally-Trained Scenario

In the procedural condition, the agents have standard operating procedures (SOPs) on which they base their recommendation. Agents are considered fully-trained as they have perfect knowledge of the SOP and employ it without error.

This condition is interesting as it represents agents who are expected to mechanically follow accepted procedure. The SOP chosen is such that the agent acting purely on the basis of the criticality of his or her local current information. History, has no effect. The SOP decision procedure is such that agents proceed as though they were following a local dominance rule; i.e., they make the decision that appears most correct given just the agent's current knowledge. This corresponds to a situation where all of the agents are placed in front of a series of surveillance systems, and told *OK report whether that aircraft out* *there friendly, neutral or hostile*. Unlike either the untrained agent or the experientially-trained agent, the procedurally trained agent will say *well, let's plug this data in to the SOP and the answer will pop out*. The agents in this case are following orders blindly, with no apparent concern for the consequences.

Agent's Knowledge

The agent's knowledge consists of current information and the standard operating procedure.

Training Procedure

All agents in the organization are told the standard operating procedure which they perfectly memorize. They then follow the procedure automatically.

Decision Procedure

The standard operating procedure is:

1) Sum up the information available to you on the current aircraft.

2) Categorize this sum. The categorization procedure followed is such that the total number of cases is equally divided into three parts. For example, for three pieces of information, the sum of information available to the agent ranges from 3 to 9. If the sum is between 3 and 5 the agent is to classify the aircraft as friendly, if 6 as neutral, and if between 7 and 9 it is to be classified as hostile.

3) Make as your recommendation/decision the category into which the sum falls.

In practice, this operating procedure appears slightly different if the agent has complete or incomplete information.

Complete Information

The agent, given information on an aircraft, simply adds the values of all the information, and reports the category into which the sum falls.

Incomplete Information

When information is not complete — due to either missing information, or other agent's unavailability, or communication channel break down — the agent adds the remaining known information and reports the modified category that the sum value falls in. The category is modified by taking the total number of cases of the remaining information and dividing it equally into three parts. When there is no information known, the agent simply guesses (in this case, the possible decisions 1, 2, and 3 are equally likely).

Task Environment Characteristics

The true state of the world is a feature of the task environment that is external to the organization, and that is not manipulatable by the organization, at least in the short run. Such true states are often a product of the technology. For example, within the radar environment aircraft that are moving very fast, are within the corridor, are carrying weapons, and have an unknown identification typically are hostile. We can manipulate the "true state of the world" in order to examine different types of task environments, all within the radar scenario. By altering the "reality" faced by our organizations we are altering the definition of what constitutes a truly friendly, neutral, or hostile aircraft. Two such manipulations are particularly interesting, given the previous review of the literature, decomposability and bias.

A task environment is decomposable if there are no complex interactions among components that need to be understood in order to solve a problem. In a decomposable task environment each component has a separable, identifiable and additive effect in determining the problem solution. Each piece of information contributes equally to the final decision. No agent has greater "power" simply by virtue of having access to a more powerful or more important piece of information. In contrast, when the task environment is non-decomposable then the pieces of information do not contribute equally to the final decision, and portions of the information interact to determine the true nature of the aircraft. In this case, some agents may have greater "power" simply by virtue of having access to more powerful or more important information. Decomposable task environments are less complex than non-decomposable task environments due to the absence of complex interactions.

A task environment is biased if the possible outcomes are not equally likely. Biased environments are quite common. For example, during war time one might see many more hostile than friendly aircraft. In an unbiased environment approximately one third of the 19683 aircraft (6568) are hostile and one third of the aircraft are friendly. This environment can be thought of as an uncertain environment because the chance of all three outcomes are almost identical. In contrast, biased environments are more certain simply because the most common aircraft is hostile. Biased task environments thus are less complex than unbiased task environments due to the preponderance of a particular solution.

Based on these two manipulations, we examine four different "realities" or environmental situations.[16] These four environments are described in Figure 2. Given a particular reality, the 19683 problems can be classified as being "truly" friendly, neutral, or hostile. This classification involves first calculating a sum of the values of all nine characteristics and then categorizing the aircraft as either friendly, neutral, or hostile depending on the value of the sum. As can be seen in Figure 2 when the task environment is decomposable the sum is based on an unweighted linear combination of the characteristics; whereas, the non-decomposable task environment uses a weighted sum. Further, when the task environment is unbiased the three possible outcomes are equally likely; whereas, when the task environment is biased one outcome (hostility) is more likely. Thus, as shown in Figure 4, the number of aircraft that are "truly" friendly, neutral, or hostile depends on the environmental situation.

Place Figure 4[17] about here

Performance Measures

There are many indicators of organizational performance, with little agreement as to which is the best indicator of all. In this paper, we use a single indicator and define organizational performance as the percentage of correct decisions made by the organization given a set of problems presented to the organization. Recall that an organization's decision is considered correct if the final decision made by the organization as to whether the observed aircraft was friendly, neutral, and hostile matches the true nature of that aircraft. We examine performance relative to two sets of problems — all aircraft and only those aircraft that are maydays. All aircraft — performance is measured as the percentage of correct decisions made by the organization given all 19683 cases. This measure provides an indicator of the overall organizational performance. Maydays — performance is measured as the percentage of correct decisions made by the organization given all hostile aircraft (recall the number of hostile cases depends on the task environment). This measure provides an indicator of organizational performance under external stress. Mistakes under this condition have severe repercussions (e.g., the team might lose the war).

EXPERIMENTAL DESIGN

An illustration of the relationship among the factors described seriously such as stress, organizational design, and task environment is shown in Figure 5. All organizations are modeled as open systems, with links to the task environment, and subject to external and internal stress. A series of simulation experiments are run. The experimental design is shown in Table 1. We examine 192 types of organizations across 20 different conditions. The 192 types of organizations are obtained by varying organizational structures (4), resource access structures (4), training scenario (3), and type of task environment (4). The performance of each organizational type was calculated under both optimal operating conditions (no murphies) and under each of the suboptimal internal stress conditions (one or more murphies). The 20 conditions are obtained by varying the levels of severity (4, including "no" murphies), and the type of murphies (5). The combination of 192 organizational types by 20 operating conditions results in a total of 3840 cases.

Place Figure 5 about here

Place Table 1 about here

This experiment is for the most part an exercise in numerical estimation. We consider all possible problem scenarios (all aircraft) in each case. However, the location of each murphy is randomly chosen each time period using standard Monte Carlo approaches.

PROPERTIES OF THE MODEL

Bias Toward the Hostile Extreme

When the organization is experientially trained in a biased task environment, each agent's memory contains more information about hostile situations than friendly or neutral situations. Consequently, agents have a conservative bias, i.e., a tendency to think of borderline aircraft as being hostile. This results in the organization exhibiting higher performance under maydays than under non-maydays (Table 2).

In an unbiased task environment, the number of friendly, neutral, and hostile problems is approximately the same (33.33%). Consequently, the agents are not automatically biased by the task itself.

However, the agents, particularly the middle level managers can exhibit a conservative bias if the analysts face a non-segregated resource access structure. The conservatism of the middle managers, results in the organization exhibiting higher performance under maydays than under non-maydays (Table 2). The factors leading to this result will be explained by considering the decomposable unbiased task environment in a hierarchy faced with a distributed resource access structure. In an unbiased task environment, all analysts become majority classifiers and basically denote that an aircraft is, in their opinion, hostile/neutral/friendly if the majority of the incoming data is 3/2/1. Given some overlap among analysts due to the resource access structure, a neutral decision by one analyst often masks a truly overall hostile aircraft. If the structure is non-segregated, as it is in the distributed case, and if all analysts under one manager report that the aircraft appears to be neutral (or hostile), then the manager, whose decision is based on experience, has actually learned not to respond that the plane is neutral but that it is hostile (see Table 3). This is because the chance of the sum of the remaining features of the aircraft being close enough for the plane to be called hostile is slightly higher than the chance for the sum to be low enough for the plane to be labeled friendly. In a non-segregated resource access structure, such as overlapped, blocked, or distributed, the distribution of information makes it appear as though the chance of the "whole" aircraft being hostile are higher than the chance of it being friendly or neutral. The middle managers develop a "conservative" bias — "better safe than sorry". If the true state of the aircraft were not determined by a sum, but symbolically, this might not happen. Further, this bias of the middle managers is also present in the biased task environments, but for that environment the bias of the task environment itself outweighs this consideration. Any partial redundancy at the analyst level results in bias at the next level up in the hierarchy. This result is an argument for either extreme specialization or complete generalizism. Either extreme may eliminate the conservatism or bias in the middle level managers. Future research might further investigate this "conservatism of the middle".

Place Table 2 about here

Place Table 3 about here

Baseline

We use as a baseline the case when all agents are untrained (and so act only on their hunches) and are faced with optimal operating conditions (no murphies). Under this circumstance, all organizations under all conditions make the correct decision 33.33% of the time[18]. When an agent guesses he or she is equally likely to decide that the aircraft is friendly, neutral or hostile. Thus, the chance of the agent making a correct decision is 1/3. In the team with voting, for example, the probability that the overall vote will be correct is 1/3, because a) majority rule is used, b) there are 9 radar operators voting, c) probability of each one giving the correct answer is 1/3, and d) all agents are independent. In all other organizations, there is a CEO. For the CEO the input of untrained subordinates to untrained supervisors is irrelevant as the untrained CEO no matter what he or she is told will simply guess. For the untrained organizations stress does not affect performance.

RESULTS

The Effect of Stress

Organizational performance is expected to degrade with stress, particularly if the stress is mayday in nature. However, training, particularly training for the extremely stressful environment, is expected to mitigate the impact of stress.

Proposition 1: Maydays degrade organizational performance if organizations are not designed for maydays (Perrow 1984; Shrivastava 1987).

Our results show that organizations generally perform better under maydays than they do on average (across all external conditions) regardless of the type of training (see Table 4). This shows that, if the organization is operating in the environment in which the agents were trained maydays may not degrade performance. Organizations, where personnel are trained to deal with maydays (experientially trained, facing biased task environments) do better when faced with maydays than on average. General training procedures, the organizational structure and resource access structure can work together so that performance is actually better under maydays than on average. Studies have also shown that organizations can maintain high performance even during crisis situations (Dynes and Quarantelli 1977). This is good news for managers, as it suggests that when it really matters organizations will benefit from the effort they have expended on training. This supports Proposition 1.

Place Table 4 about here

Internal stress produces ambiguities. Organizations facing such sub-optimal conditions should exhibit degraded performance.

Proposition 2: Murphies degrade organizational performance (March and Olsen 1976; March and Simon 1958).

On average (across all external conditions), as the number of simultaneous murphies increases organizational performance degrades (see Figure 6[19]). For experientially trained organizations, murphies on average degrade performance (optimal conditions mean = 62.18, stderr=0.96, n=320 and sub-optimal conditions mean = 59.18, stderr=0.55, n=960). This difference is significant ($t = 2.71$, $df = 319$, $p < .005$). Similarly, for procedurally trained organizations, murphies degrade performance (optimal conditions mean=57.29, stderr=0.75, n=320 and sub-optimal conditions mean=53.66, stderr=0.33, n=960). This difference, too, is significant ($t = 4.43$, $df = 319$, $p < .0005$). When faced with maydays, murphies also degrade organizational performance (optimal conditions mean=96.63, stderr=0.43, n=320 and sub-optimal conditions mean=91.30, stderr=0.43, n=960). This difference is significant ($t = 9.10$, $df = 319$, $p < .0005$). Similarly, for procedurally trained organizations, murphies degrade performance (optimal conditions mean=72.92, stderr=0.98, n=320 and sub-optimal conditions mean=68.98, stderr=0.51, n=960).

This difference is significant ($t = 3.94$, $df = 319$, $p < .0005$). These results support Proposition 2.

Place Figure 6 about here

As an aside, the effect of murphies also depends on the type of the murphies. In general, misinformation related murphies (such as missing information and incorrect information) are more debilitating than personnel based murphies (such as agent unavailability, communication channel breakdown, and agent turnover) (see Figure 7[20]). However, if the organization is experientially trained then agent turnover, on average, degrades the performance most from performance under optimal conditions (mean=56.10, stderr=1.09, n=256). In procedurally trained organizations turnover has less effect and incorrect information degrades the performance most from performance under optimal conditions (mean=49.80, stderr=0.60, n=256). Under maydays, this pattern is similar.

Place Figure 7 about here

So far we have been talking about training as trained in a particular task environment. We have not been concerned with the way in which the agents were trained, but simply with whether they continue over time to operate in the same environment. What we found was that training matters. It is worth noting that the task environment also matters. Task environment, in fact, has a strong effect on performance. Further, the task environment moderates the degree to which murphy type affects organizational performance. The pattern of the impact of different murphy types, however, remains the same under different task environments (Figure 8).

Place Figure 8 about here

Let us now turn to the way in which the agents were trained. We considered two style — experiential and procedural. The effect of the training is highly debated in the literature:

Proposition 3: Training improves organizational performance and prevents degradation of performance during maydays and murphies (Perrow 1984; Roberts 1989; Shrivastava 1987).

Proposition 4: Training impedes organizational performance (Ganster et al. 1991; Hammond et al. 1973).

This literature, however, often does not discriminate between different styles of training. Although, Scott (1987, pp. 247) suggests that it is a critical issue in organizational design as to whether agents should be professional (and so follow experience) or trained to follow procedures. We do discriminate between these different training styles and find that in general, experiential or procedural training improves performance compared with the performance of untrained (or baseline) organizations, which is at 33.33% (see Table 1).[21] The effect of training, however, depends on the style of training. Overall, organizations employing experientially trained agents tend to outperform those employing agents trained to follow SOPs. This generally holds. The average performance of all organizations with experiential training (59.93), regardless of the operating conditions is significantly higher than the average performance of organizations with procedural training (54.56) ($t=9.4$, $df = 1279$, $p < .001$). Both are significantly higher than the baseline. This supports Proposition 3, but not Proposition 4.

As a final note on training, we find that when the type of the task environment is considered, experientially trained organizations outperform procedurally trained organizations for biased task environments; whereas procedurally trained organizations do better under unbiased task environments (Figure 9). Agent experience serves them best when the preponderance of their experience is in the same area (in this case hostile task environments). In other words, not unexpectedly, there is an interaction between training style and task environment.

Place Figure 9 about here

Organizational Design

The question remains how should organizations be designed to obtain high performance. There are not consistent expectations as to which organizational designs will exhibit high performance. This can be shown through the following assertions.

Proposition 5: Organizations with a high degree of hierarchy will perform better than organizations with a low degree of hierarchy (Mackenzie 1978; Roberts 1989).

Proposition 6: A high level of hierarchy will degrade organizational performance (Jablin et al. 1986).

Proposition 7: Organizations with hierarchical structure may perform poorer than organizations with non-hierarchical structure when under murphies (March and Simon 1958).

Proposition 8: Matrix type organizations perform better than purely hierarchical organizations (Houskisson and Galbraith 1985).

Proposition 9: Complex structures (with more communication ties, such as matrix) perform better under maydays or murphies (Krackhardt and Stern 1988).

We find, that on average, the top performing experientially trained organization is the team with voting, with a segregated resource access structure (mean=66.76, stderr=1.79, n=80), and the bottom performing organization is the team with manager with an overlapped resource access structure (mean=54.69, stderr=2.10, n=80). On average, the top performing procedurally trained organization is the hierarchy with a distributed resource access structure (mean=56.28, stderr=1.05, n=80), and the bottom performing organization is the hierarchy with a segregated resource access structure (mean=52.16, stderr=1.20, n=80) (Figure 10). But organizational form has a limited effect on procedurally trained organizations compared with experientially trained organizations. Proposition 5, 6, and 7 receive mixed support when organizations are procedurally trained. On average, Propositions 8 and 9 do not receive support.

Under maydays, however, the performance of all organizational forms is generally higher than on average. Among experientially trained organizations, hierarchy with an overlapped resource access structure has the highest performance (mean=98.30, stderr=0.43, n=80), while team with a manager with segregated resource access structure becomes the worst performer (mean=83.28, stderr=1.88, n=80). Again, organizational form does not have a critical effect on the performance of procedurally trained organizations, in which matrix with distributed resource access structure performs the best (mean=76.24, stderr=1.65, n=80), and hierarchy with segregated resource access structure performs the worst (mean=64.21, stderr=1.64, n=80). Thus, under maydays, Proposition 3 is conditionally supported when organizations are experientially trained, while Propositions 6, 7, 8, and 9 are supported when organizations are procedurally trained.

Place Figure 10[22] about here

The Role of Organizational Design and Task Environment

Let us now consider how organizations with different designs perform under different stress situations and different task environments. Contingency theorists argue that there is a relationship among organizational form, task environment, and performance. One such argument is about the matrix organizational form and task environment. Unlike Proposition 6 by Houskisson and Galbraith (1985), the following proposition suggests that whether a matrix form is functional depends on task environment.

Proposition 10: Matrix organizations only perform well under complex task environments (Davis and Lawrence 1977).

We first consider experientially trained organizations under different levels of stress (Figures 11, 12). When there is no stress (no maydays or murphies), under biased decomposable task environment, which is a simple one, team with voting structure with segregated resource access structure, and matrix structure with distributed resource access structure outperform other organizational forms. But when under the unbiased decomposable task environment, team with voting structure becomes the sole best performer. When facing non-decomposable task environments, which are more complex, blocked resource access structure helps organizations to achieve highest performance.

When there are only murphies, the pattern is similar to that of stress free situation, except that the performance is on average lower. When there are only maydays, organizational performance has improved to the point where the exact structure and resource access structure chosen are less critical. In fact, in the simplest task environment, the biased decomposable task environment, all organizations do perfectly. Otherwise, organizational designs with more redundancy, either in structure or resource access structure, tend to be slightly better performers. We see that while such redundancy may be a hindrance on average it helps in the critical cases. Such redundancy reduces performance on average due to the collapse in information in the more hierarchical structures and due to the potentially greater disagreement in opinions in the more redundant resource access structures. When faced with maydays, however, the incoming information is in a sense more consistent. Thus, there is less difference in information to get collapsed away by the structure and less possibility of disagreement in opinions particularly when the resource access structure is more redundant. Where redundancy works against the organization on average it works for it in the case of external crises.

When there are both maydays and murphies, the performance is similar to the under maydays only situation, except that the performance is slightly lower on average. Murphies degrade performance whether or not they occur concurrently with maydays.

As an aside, we can also see in Figures 11 and 12 that on average, the team with voting structure generally exhibits the highest level of performance, particularly when the task environment is unbiased. But, when task environments are biased there is much less difference of performance due to structure. When the task environment is non-decomposable, organizations with more complex resource access structures outperform organizations with less complex resource access structures. This suggests that when the task environment requires integration of information redundancy in information access helps. In this sense, individuals are better than the organization at integrating information.

Place Figures 11 and 12 about here

Now let us consider the procedurally trained organization under the same conditions (Figures 13, 14). When there is no stress, the performance across organizational forms is relatively flat, except when under unbiased decomposable task environment, in which team with voting structure with segregated resource access structure is the best performer.

When there are only murphies, the pattern is similar to that of when there is stress free, except that the performance is constantly lower. When there are only maydays, the performance is relatively high, regardless of task environment. Further, more complex forms such as matrix structure with distributed resource access structure, helps organizational performance, though not much. When there are both maydays and murphies, the performance pattern is similar to that of procedurally trained organizations when there is only maydays, except that the performance is lower.

As an aside, we can also see in Figures 13 and 14 that on average and under unbiased decomposable task environments, the team with voting is still one of the better performing organizations. Overall, however, more complex organizational designs help organizational performance. Further, as can be seen by contrasting experientially trained and procedurally trained organizations, the performance in procedurally trained organizations is lower. Procedural training tends to decrease differences due to organizational structure and resource access structure. Training personnel to follow SOPs thus reduces the reliance of the organization on its structure and resource access structure. This is particularly important for organizations that might expect to have rapidly changing designs such as might occur in response to rapid turnover. If such an organization follows SOPs then switching design may cause less damage in performance than if the organization allows the agents to follow their own historical information.

Place Figures 13 and 14 about here

The above analyses support propositions 1, 2, and 3. The results also support Propositions 8 and 9 when organizations are procedurally trained. However, Proposition 10 is only supported when under maydays or on average.

When now look into the results to see which organizational form performs the best under which task environment. As seen from the previous results, the organization with a team with voting structure and a segregated resource access structure outperforms other organizational forms in general. But when faced with maydays or when procedurally trained, organizations with matrix structure and distributed resource access structure generally perform better. Under optimal operating conditions (no murphies) teams with voting outperform other structures as long as the task environment is unbiased and decomposable, which suggest such organizational structure may be better to balance all the factors and make less biased decisions. This supports the result reported by Carley (1991,1992). Further, this is true whether the organization is employing decision makers who make decisions following their own experience (Table 5) or SOPs (Table 6). However, as can be seen in Tables 5 and 6, teams with voting are not better in all circumstances. In fact, in what one might consider the most common real world situation, a biased non-decomposable task environment, teams with voting exhibit the worst performance. As a final point in examining Tables 5 and 6, it appears that under maydays organizations that exhibit high performance require slightly more management and a more complex task decomposition structures unless the task environment is one of the simpler task environments — the unbiased decomposable task environment. For this task environment the simplest organizational form teams with voting, with segregated resource access structure appear to be the best performer. These findings suggest that there may be a relationship between complexity and performance.

Place Tables 5 and 6 about here

Complexity Matching

Contingency theorists argue that organizations should design for task environment. We now examine whether matching the complexity of the organizational form and the task environment actually improves performance.

Proposition 11: Overall, more centralized organizations (in this paper they are hierarchy and matrix) perform better than decentralized organizations (in this paper they are team with voting and team with a manager) when facing simple task environment, but perform worse than decentralized organizations when facing complex task environment (Cohen 1962; Shaw 1981).

Proposition 12: Under stress, rigidity (in terms of less communication links) helps organizations when facing simple task environments but not complex task environments (Staw et al. 1981).

Given the organizational structure and the resource access structure, we can define a measure of organizational complexity. This measure is useful as it will allow us to examine whether more complex organizations are needed to deal with more complex task environments. We define organizational complexity as: (a) simple organization — an organization with either a team with voting or a team with a manager structure and a segregated or an overlapped resource access structure; (b) complex organization — an organization with either a hierarchical or a matrix structure and a blocked or a distributed resource access structure; (c) moderate organization — all other organizations.

Task environment complexity is defined by its decomposability and biasness. A biased task environment is simpler than an unbiased one and a decomposable task environment is simpler than a non-decomposable one. Thus, we also have three levels of complexity for task environment: (a) simple task environment — a biased decomposable task environment; (b) complex task environment — an unbiased non-decomposable task environment; (c) moderate task environment — all other task environments.

Using these measures, we can determine whether there is a match between the organizational complexity and task environment complexity. A poor match (match=1) occurs if an organization is complex and a task environment is simple, or vise versa; a perfect match (match=3) occurs if the level of complexity is the same in both organizational form and task environment; a moderate match occurs in all other cases.

The average performance at each level of match is shown in Table 7. The result indicates that overall, the better the match the better the performance. Regardless of training scenario, complex organizations facing a complex task environment and simple organizations facing simple task environments exhibit higher performance. There is one exception, the procedurally trained organization facing maydays. In this case, redundancy in structure improves organizational performance under hostile external conditions, even when it degrades the match. These results support Proposition 12 but not Proposition 11.

Place Table 7 about here

In summary, we observe several general patterns (see Table 8): (1) Organizations with training perform better under maydays (Proposition 1, supported). External stress can be largely overcome with appropriate training. (2) Murphies degrade organizational performance (Proposition 2, supported). In addition, our results demonstrate that different types of murphies have different effects on performance, with mis-information based murphies being the most debilitating on average. Although, agent turnover has a bigger impact on organizational performance when organizations are experientially trained. (3) Hierarchical, and matrix organizations perform better when organizations are procedurally trained (Proposition 5 and 8, partially supported). However, on average and when organizations are faced with an unbiased task environment, the team with voting performs better (Proposition 6, 7, and 10, conditional support). However, we also find that the resource access structures has a major impact on performance, a factor not fully captured by any of the propositions. (4) Training improves performance (Proposition 3, supported; Proposition 4, not supported). Further, we also find that experientially trained organizations perform better than procedurally trained organizations on average. (5) Experientially trained organization, which are more discretionary, fit better in a biased task environment (or a narrow niche) than in an unbiased task environment (or a generalized setting). The opposite is the case for procedurally trained organizations, which are more rigid. (6) Matching the complexity of the organizational form to the task environment generally improves performance for experientially trained organizations under stress, but for procedurally trained organizations, such complexity matching improves performance only on average and under non-mayday situations (Proposition 12, conditional support; Proposition 11, not supported).

Place Table 8 about here

DISCUSSION

In this paper we have used the ELM framework with a trinary choice task to examine the interrelations among organizational design, task environment and stress in affecting organizational performance. In doing this analysis we have found it necessary to generalize the nature of stress by treating it as two types of stress (internal or murphies and external or maydays). The result of these extensions is a more comprehensive study of organizational performance. Using this framework we were able to examine a wide range of propositions extant in the literature and determine whether they were internally consistent. We found a set of 9 propositions that all followed (sometimes with qualifications) from our model of organizational performance. In addition, using this model we found important qualifications and extensions to these propositions.

This work extends Carley's (1991, 1992) work using organizations composed of ELM agents with a binary choice task. This analysis enables us to determine the extent to which the earlier results were a product of the specific task environment characteristics. To review our conclusions, we find that many of our results are consistent with those found by Carley. The consistency of results, despite moving from a binary to a trinary task environment, suggests that the results are a function of organizational design and stress rather than the number of choices available to the decision makers. The greater comprehensiveness of this study demonstrates that Carley's results are a special case because of the task environment examined, not because of the number of choices available to the agents. We have also demonstrated that the relationship between stress, organizational design, and task environment may be so strong that different designs are most cost effective for different task environment-stress combinations.

We suggest that there is a systematicity to when what design is most effective, that there are underlying principles that guide design. By broadening the concept of organizational design to include aspects of task environment, and training, in addition to structure, and by examining performance under stress from a combined stress, organizational design, and task environment perspective, it is possible to develop a theory of design that suggests strategies for mitigating stress consistent with the organizational goals. Or as Carley (1990) suggests although the right design may be to an extent situationally specific, there is an underlying systematicity to what works when. Thus, although organizations with different designs perform differently given different task environments and subject to different stresses, there are systematic shifts in performance as these factors change. Consequently, organizations can choose that design which admits the highest performance given the type of stress and task environment they expect to encounter most frequently or for which, when encountered, has the most costly consequences.

In this analysis we have focused on performance under hostile external conditions when under maydays, as we treat type I and type II errors as being equally important. Under friendly external conditions (biased toward friendliness), organizational performance would tend to have a complementary pattern as hostile external conditions. In this sense, friendly and hostile conditions are mirror conditions in our model.

We have only focused on two dimensions of task environments: biasness and decomposability, with number of task environment components fixed. This may limit the complexity of task environment because number of components in many cases can a major part of complexity. Also, in biasness of task environment, we only limit ourselves to the one type of biasness, to the critical ones, and also by the task environment and training. In many cases, such bias can also be caused by different risk assessments of decision choices, which can be incorporated into the model given the probabilities of potential risks and losses.

While we have begun to examine the effect of training we have limited ourselves to training that was largely "helpful". That is, agents were trained in the same type of organization for which their performance was measured and the SOPs were generally of the "right" type. Nevertheless, this model does indicate that organizations where agents received the wrong training may actually perform worse than totally untrained organizations. For example, organizations trained for a biased task environment when faced with friendly aircraft can do better by just guessing. This suggests, for example, that radar groups trained during peacetime, on predominantly civilian aircraft, when put in a combat situation may actually do worse than a group who never trained. This suggests that training does not transfer to novel situations. We can apply this result to the Iranian airline incident, where the group was trained in an environment where most events, albeit hypothetical, were hostile. They were trained for war. But they were faced with a non-mayday. Our model would predict they are likely to make a mistake — which they apparently did. To investigate this issue of the extent to which training transfers between situations a more realistic model of human problem solving and memory may be needed.

Another caveat is that this study proceeded by using a stylized radar task, numerical enumeration, and computer simulation. Computer simulation technique has been used in many areas such as military training, business administration, and theory developing. Computer simulation can grasp the fundamental nature of human information processing behavior (Simon 1981). Compared with experiments using human subjects, computer simulations are easier to control, more flexible, more objective, with less noise, and thus can examine more factors within less time. As pointed out by Ostrom (1988), computer simulation offers a third symbol system in studying social science, besides natural language and mathematics, because "computer simulation offers a substantial advantage to social psychologists attempting to develop formal theories of complex and interdependent social phenomena". Computer simulations are limited by the simplified assumptions, as well as the computer technologies. Such simulations do not always capture difference due to individual cognition. Thus, when facing a task environment requiring more subjective judgments, our model may need to be modified. Nevertheless, these simulation experiments provide a series of hypotheses which we can test both with human experiments and by using real organizational data. Since human experiments are costly to run, and it is often improbable to obtain sufficient large quantities of data on real organizations, these simulation experiments help us develop organizational theory and determine which parameters are most important to explore in other settings.

Finally, there are several interesting issues that are suggested by our analyses that are not addressed in this paper. First, different training orientations such as training for friendly environments may affect performance. Thus, it would be important to develop a better understanding of how training in situation "x" affects performance in situation "y". Second, it is often suggested that organizations when faced with external crises or maydays, should restructure themselves. This study does suggest that the structure that is best under maydays may not be the best in general; however, it does not provide insight into whether the process of shifting structures would degrade organizational performance. Further studies should examine whether this restructuring is beneficial given that personnel were trained on the old (non-mayday) structure. Third, it is often shown that under time pressure, performance degrades. In this study the aircraft examined were effectively holding still and so time pressure was not an issue. Further studies should examine how time pressure will affect the performance of organizations given the presence of murphies and maydays. Finally, many measures of organizational design have been proposed which are expected to be able to predict organizational performance (e.g., Mackenzie 1978; Krackhardt 1989). Rarely have they been tested and contrasted. The formal framework we used in this paper provides a testbed for doing this. We are engaged currently in a study using this framework to examine how well these measures are able to predict performance (Lin forthcoming).

CONCLUSION

We have considered the inter-relationship between stress, organizational design, and task environment relative to organizational performance. These results confirm those found by Carley (1991, 1992): training improves performance, the greater the severity of the internal crisis (more murphies) the lower the performance, turnover degrades performance, mis-information leads to lower performance than communication breakdowns, and teams outperform hierarchies. Such replication indicates that such results are a product of the organizational design and environment and not the number of choices available to the agents when making decisions. However, our results do more than just replicate these earlier studies. They also place these earlier results in a broader context and show limitations to these findings. Let us consider two of these — that turnover degrades performance and that teams outperform hierarchies.

Turnover degrades performance, but the effect may be minimal and even appear non-existent when agents are trained to follow SOPs. In experientially trained organizations, turnover can be even more debilitating than technological murphies. However, in an procedurally trained organization turnover matters less. Thus, organizations which can not rely on SOPs should expand more effort to retain personnel, and to hire trained personnel. Organizations that employ SOPs need to worry less about personnel relations.

As to the second point, teams outperform hierarchies — but they do so predominantly when the task environment is unbiased decomposable. In a biased task environment, when one outcome is more likely than others, or a non-decomposable task environment, when the interrelationship between information is complex, more complex organizational structures outperform teams. We found that, in general, when facing complex task environments, complex organizations tend to help performance, but when facing simple task environments, simple organization tend to help performance instead, regardless of external stress and training scenarios. However, when the organizations face maydays the opposite seems to be the case. These results suggest that task environment complexity and external situation are stronger determinants of performance than either organizational design or murphies. Thus, the organization should first expend effort determining what task environments and external situations they are likely to face before settling on a particular organizational design or expending effort to minimize murphies.

A number of other policy implications can be drawn from these results. Let us consider a few of these. While turnover, and other murphies, can degrade organizational performance, the effect depends on the type of training received by organizational members. In general, technological murphies are more debilitating than agent based murphies, which means most organizations with limited budget should spend resources to get the information right in the first place. As the number of simultaneous murphies increases, organizational performance decreases, unless organizational members are trained to follow SOPs and are facing a biased task environment. This result suggests that more information does not necessarily help organizational performance, in fact, under certain conditions, organizations can benefit from less information. For biased task environments, experientially trained organization exhibit higher performance than procedurally trained organizations overall, and the opposite for unbiased task environments overall. Thus, in general, organizations that are unsure of the environment (i.e., don't know if it is biased or unbiased) should not use SOPs, but should experientially train their employees as this admits maximum adaptation. If the organization knows the environment, then an appropriate SOP is generally better. But, if the organization expects and needs high reliability during maydays, then SOPs generally are less risky as an incorrect experiential training may severely hurt organizational performance.

This study addresses many important policy issues. First, this study shows that it is important to evaluate the procedure and purpose of training. Training may be a waste of time or even hurt organizational performance without being properly guided. Second, this study demonstrates that more information does not always result in better decisions. Rather, decision making performance depends on the training procedure, the location of communication links, and the task environment characteristics. Thus, organizations should be very careful expanding or altering their organizational or task decomposition structures during crisis situations. Third, this study suggests that there is a strong relationship between stress and organizational design. Organizations should determine what type of stress most affects their performance before spending money to alleviate stress, as many types of stress will have little impact. Fourth, this study indicates that task environment is extremely critical in the determinants of organizational decision making performance, and that for different task environments, organizations should be designed accordingly to be most effective.

Our results support the idea that the best design is contingent. However, we have also demonstrated that by using a framework containing elements of open system theory, structuralism, resource dependency, and institutionalism we can begin to place limits on when what type of design is most effective. We find that the environment places limits on performance that no design can overcome and that major performance improvements can often be achieved only by changing the nature of the environment in which the organization operates.

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[1]Though there has been other version of the incident recently, we still use this version to illustrate the point to be addressed in this paper.

[2]In this paper, the task environments we study all have only nine task components as will be described later. The changes of task environments are limited to the relationships among task components.

[3] One could relax this assumption to make it a non-uniform distribution by assuming that certain problems appear more than others. Adding bias in that fashion would not change the results but it would affect the rate of learning with which we are not concerned in this study.

[4] Missing information is a problem for many organizations. For example, in China, lack of information on the date and amount of rain in the 1991 season left the land unprepared. The countryside was devastated by the unexpected flood.

[5] Incorrect information frequently results in costly mistakes. For example, the failure of the Nazi Germans on D-day was due, at least in part, to their "information" that Caray was the place the Allies would invade instead of Normandy. Incorrect information detected by the allied troops is also, at least partially, why friendly fire resulted in the cause of the one in four casualties during the Gulf war.

[6] For example, the Americans were unprepared when the Japanese attacked Pearl Harbor, in part, because some officers were on leave.

[7]Prior to the Challenger accident (Rogers at al., 1989) there was communication breakdown between the contractor Thiokol and NASA management, resulting in information about the O_ring failing to be communicated. Communication breakdowns are also quite common in war-time when military units must remain radio silent in order to preserve their secrecy.

[8]Experientially-trained organizations are also more discretionary.

[9] For example, in the chemical explosion disaster in Flixborough, Britain in 1974 (Lagadec, 1981) a new technician, who had little experience dealing with chemicals, was virtually unable to handle the situation and his lack of experience accelerated the disaster.

[10]We have also examined an alternative matrix structure, in which only six of the nine baseline analysts report to two managers, while the 3 remaining analysts report to a single manager. The performance of organizations with this structure is between that reported for the hierarchy and matrix.

[11]Malone (1986) and Carley (1991) contrasted the performance of various organizations.

[12]In dealing with trinary choices, the simple majority rule has to be slightly modified.

[13]The task decomposition scheme has also been referred to as the information access structure (e.g. Carley, 1991a, 1992). We use the term task decomposition scheme to (1) emphasize the role of task in

organizational performance, and (2) to clearly differentiate ties between people and data (the task decomposition scheme) and ties between people and people (the organizational structure).

[14]We also examined two other task decomposition schemes, segregated-2 and overlapped-2, The segregated-2 case differed from the segregated structure shown only in which analyst saw which specific characteristic. Examining this scheme enabled us to determine whether the exact pattern of which analyst sees which piece of information matters. The results, however, are close to the segregated scheme examined in this paper and so suggest that the exact order of information is not highly critical. In the overlapped-2 case, each analyst has access to three pieces of information, such that two pieces of information are shared (overlapped) with the next analyst. The result for this scheme are similar to the simple overlap pattern examined in this paper.

[15] As a further exploration, we also tried a probabilistic approach in the simulation of experientially trained organizations. The probabilistic approach differs in that the agent does not simply report the choice with the highest frequency, but can report any of the three choices but with a probability equal to the frequency of their occurrence. For example, if the distribution of decisions as truly "friendly", "neutral", and "hostile" is 10, 30, and 20, then the agent reports "friendly" 10/60 of the time, "neutral" 30/60 of the time, and "hostile" 20/60 of the time. The results showed that the performance of experientially trained organizations using this probabilistic approach was lower than that when the agents used perfect recall, and slightly lower than when they used SOPs. The particular performance of organizations with different structures and task decomposition schemes was essentially just scaled down.

[16]We also examined a non-decomposable rule where Sum = F1*F2*F3+F3+F4*F5*F6+F6+F7*F8*F9+F9. This rule generates results similar to that of the non-decomposable rule described. The fact that the results are similar suggests that decomposability in general is more of a problem than the specific type of decomposability.

[17]For the unbiased decomposable task the categorization scheme shown in Figure 4 is only an approximation. We further categorized those problems whose sum equals 17, such that some are friendly, and others are neutral. Similarly, for those problems whose sum is 19, we categorize them such that some are hostile and others are neutral. This categorization enabled the number of problems in each category to be more close to one third of the total problems.

[18]Had there been only two choices, as in the experimental learning model examined by Carley (1990, 1991, 1992), the baseline performance would have been 50.00%. When the organization must choose between a set of options, the minimum acceptable performance is simply 1 over the number of options. Any performance, if less than this baseline of 33.33%, is unacceptable as organizational performance could be improved by simply guessing.

[19]This degradation is non-linear. Also, when the organization is procedurally trained and the task

environment is biased then the occurrence of a single murphy may actually improve performance. For detailed data see the Appendix. Figure 6 is based on Table A1.

[20]For detailed data see Tables A2, A3, A4, A5,A6, and A7 in Appendix for corresponding data on which this and latter figures are based.

[21]We also examined the case where organizational members are trained experientially on a task where most events are friendly and then are faced with a series of maydays. The results demonstrated that training can degrade performance below guessing. An organizations whose members were trained in this way can perform even worse than an organization of untrained agents.

[22]For detailed data see Table A8 in Appendix.

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APPENDIX

Table A1: Organizational Performance by Number of Murphies

Training Type	External Condition	Murphy Number=0	Murphy Number=1	Murphy Number=2	Murphy Number=3
Experientially Trained	Overall	62.18(0.96)	60.47(0.93)	59.27(0.94)	57.79(0.97)
	Maydays	85.67(0.67)	83.39(0.66)	80.83(0.70)	77.40(0.77)
Procedurally Trained	Overall	57.29(0.75)	55.29(0.56)	53.79(0.55)	51.89(0.56)
	Maydays	74.91(2.18)	71.64(2.13)	69.53(2.12)	67.27(2.10)

Note: n=320 in each cell. Standard errors are in parentheses.

Table A2: Organizational Performance by Murphy Type

Murphy Type	Training Type			
	Experientially Trained		Procedurally trained	
	Overall	Maydays	Overall	Maydays
Missing Information	60.65(0.79)	95.06(0.61)	53.59(0.57)	68.16(0.82)
Incorrect Information	59.30(0.72)	92.75(0.90)	49.80(0.80)	63.21(1.09)
Agent Unavailability	61.83(0.85)	96.38(0.64)	55.94(0.42)	72.59(0.59)
Communication Breakdown	61.76(0.86)	96.42(0.64)	56.20(0.41)	72.94(0.59)
Agent Turnover	56.10(1.36)	82.53(2.18)	57.29(0.54)	72.92(0.63)

Note: There are 256 types of organizations in each cell. Standard errors are in parentheses.

Table A3: Organizational Performance by Task Environment

Task Environment	External Condition	Organizational Training Type: Experiential	Organizational Training Type: Procedural
Biased Decomposable	Overall	61.23(0.36)	47.80(0.18)
	Maydays	99.56(0.12)	69.62(0.74)
Unbiased Decomposable	Overall	53.48(1.85)	77.81(1.02)
	Maydays	91.51(1.29)	92.97(0.46)
Biased Non-Decomposable	Overall	85.39(0.19)	47.33(0.44)
	Maydays	99.98(0.01)	47.71(0.56)
Unbiased Non-Decomposable	Overall	48.61(1.15)	56.22(0.28)
	Maydays	95.45(0.83)	81.37(0.50)

Note: In each cell, n = 80 types of organizations. Standard errors are in parentheses.

Table A4: Performance of Experientially Trained Organizations across all External Conditions by Task Environment and Murphy Type

Task Environment	Missing Information	Incorrect Information	Agent Unavailability	Communication Breakdown	Agent Turnover
Biased Decomposable	61.04(0.38)	60.84(0.33)	61.81(0.50)	61.64(0.50)	55.49(1.04)
Unbiased Decomposable	50.79(1.47)	47.38(1.36)	52.16(1.53)	52.13(1.54)	48.93(1.64)
Biased Non-decomposable	85.04(0.14)	84.67(0.15)	85.39(0.21)	85.39(0.21)	78.06(1.44)
Unbiased Non-decomposable	45.74(1.17)	44.31(1.04)	47.97(1.16)	47.86(1.18)	41.90(1.31)

Note: There are 64 types of organizations in each cell. Standard errors are in parentheses.

Table A5: Performance of Procedurally Trained Organizations across All External Conditions by Task Environment and Murphy Type

Task Environment	Missing Information	Incorrect Information	Agent Unavailability	Communication Breakdown	Agent Turnover
Biased Decomposable	47.45(0.18)	45.03(0.35)	48.33(0.15)	48.52(0.15)	47.80(0.20)
Unbiased Decomposable	68.15(1.05)	60.49(1.51)	71.34(0.83)	71.93(0.78)	77.81(1.14)
Biased Non-decomposable	46.84(0.47)	46.23(0.47)	48.59(0.37)	48.60(0.37)	47.33(0.49)
Unbiased Non-decomposable	51.93(0.57)	47.43(0.85)	55.50(0.34)	55.75(0.35)	56.22(0.31)

Note: There are 64 types of organizations in each cell. Standard errors are in parentheses.

Table A6: Performance of Experientially Trained Organizations by Task Environment and Murphy Type When Faced with Maydays

Task Environment	Missing Information	Incorrect Information	Agent Unavailability	Communication Breakdown	Agent Turnover
Biased Decomposable	99.44(0.12)	98.69(0.26)	99.17(0.32)	99.23(0.33)	81.54(2.47)
Unbiased Decomposable	85.62(1.50)	82.59(1.77)	91.83(1.06)	91.99(1.07)	78.15(2.31)
Biased Non-decomposable	99.99(0.01)	99.48(0.17)	99.98(0.01)	99.98(0.01)	90.86(1.87)
Unbiased Non-decomposable	95.19(0.92)	90.25(1.39)	94.52(1.15)	94.47(1.16)	79.58(2.08)

Note: There are 64 types of organizations in each cell. Standard errors are in parentheses.

Table A7: Performance of Procedurally Trained Organizations by Task Environment and Murphy Type When Faced with Maydays

Task Environment	Missing Information	Incorrect Information	Agent Unavailability	Communication Breakdown	Agent Turnover
Biased Decomposable	65.80(0.85)	61.17(1.00)	70.49(0.66)	70.91(0.67)	69.62(0.83)
Unbiased Decomposable	83.61(1.01)	75.20(1.57)	89.67(0.64)	90.25(0.61)	92.97(0.51)
Biased Non-decomposable	47.10(0.61)	46.57(0.61)	49.37(0.48)	49.36(0.48)	47.71(0.62)
Unbiased Non-decomposable	76.12(0.82)	69.91(1.17)	80.81(0.56)	81.24(0.58)	81.37(0.56)

Note: There are 64 types of organizations in each cell. Standard errors are in parentheses.

Table A8: Average Performance by Organizational Structure and Resource Access Structure

Structure	Resource Access Structure	Training Type: Experientially trained Overall	Experientially trained Maydays	Procedurally trained Overall	Procedurally trained Maydays
Team with Voting	Segregated	66.760(1.794)	92.741(1.236)	54.658(1.947)	65.326(2.086)
	Overlapped	65.918(1.309)	91.274(1.145)	54.258(1.254)	68.780(1.838)
	Blocked	66.790(1.352)	86.267(1.681)	53.653(1.202)	67.457(1.742)
	Distributed	66.444(1.346)	97.029(0.555)	55.795(1.139)	73.080(1.796)
Team with a Manager	Segregated	55.214(2.066)	83.275(1.877)	54.658(1.947)	65.326(2.086)
	Overlapped	54.650(2.096)	85.196(1.961)	54.258(1.254)	68.780(1.838)
	Blocked	59.269(1.932)	90.297(2.022)	53.653(1.202)	67.457(1.742)
	Distributed	57.614(1.928)	90.849(1.491)	55.795(1.139)	73.080(1.796)
Hierarchy	Segregated	56.601(1.980	95.583(0.914)	52.160(1.196)	64.208(1.636)
	Overlapped	57.010(2.000)	98.299(0.426)	53.106(1.072)	67.248(1.642)
	Blocked	60.247(1.912)	94.968(0.997)	53.678(1.339)	66.094(1.758)
	Distributed	60.150(1.929)	95.949(0.796)	56.277(1.053)	74.943(1.769)
Matrix	Segregated	55.986(1.988)	95.235(0.923)	54.196(0.894)	71.718(1.600)
	Overlapped	54.932(2.129)	97.245(0.758)	55.942(0.902)	74.989(1.674)
	Blocked	60.899(1.876)	91.828(1.785)	54.856(0.804)	74.698(1.531)
	Distributed	60.372(1.881)	96.029(0.834)	56.071(0.839)	76.238(1.653)

Note: There are 80 organizational types in each cell. Standard errors are in parentheses.

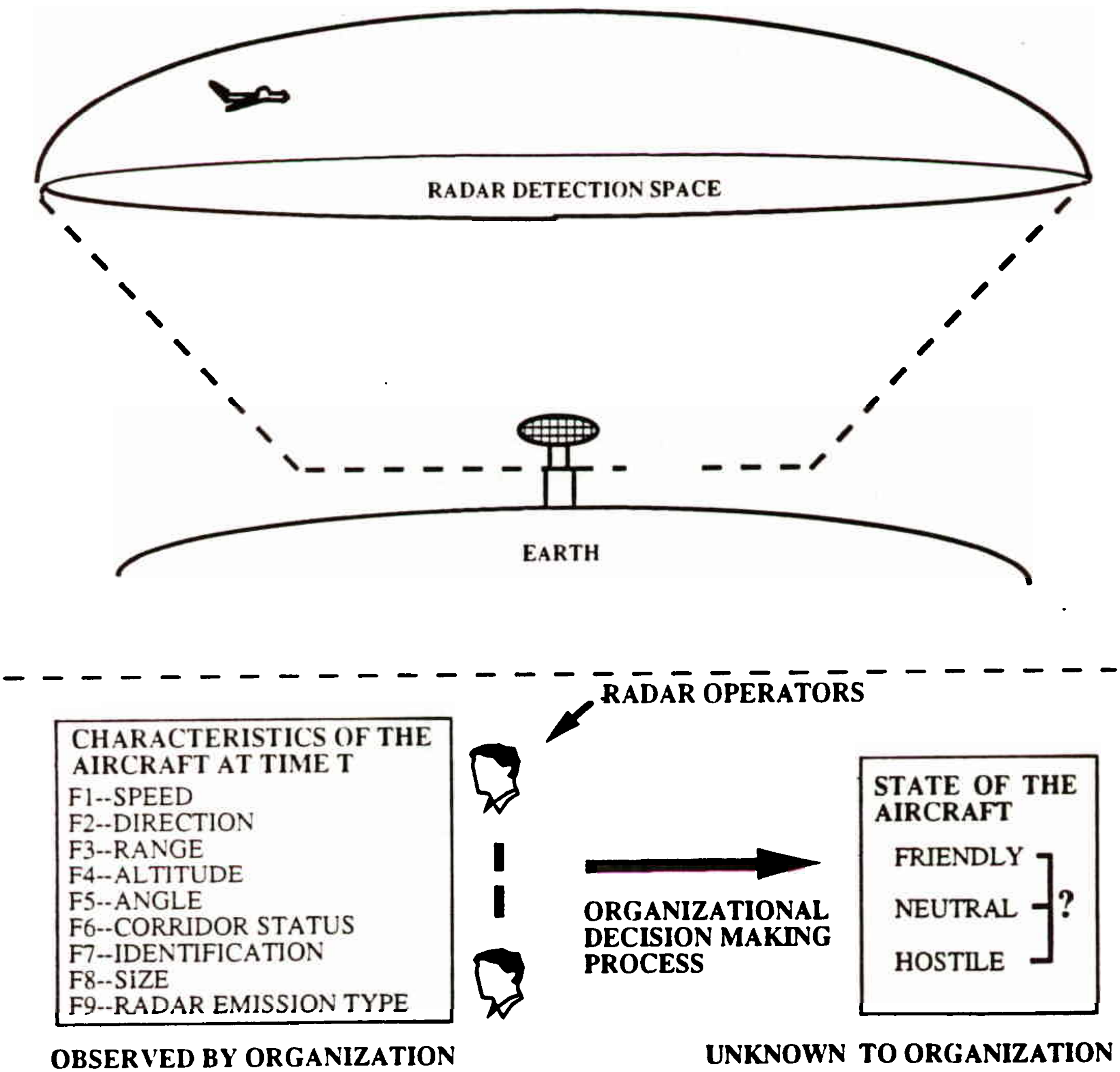


Figure 1. Stylized Radar Task

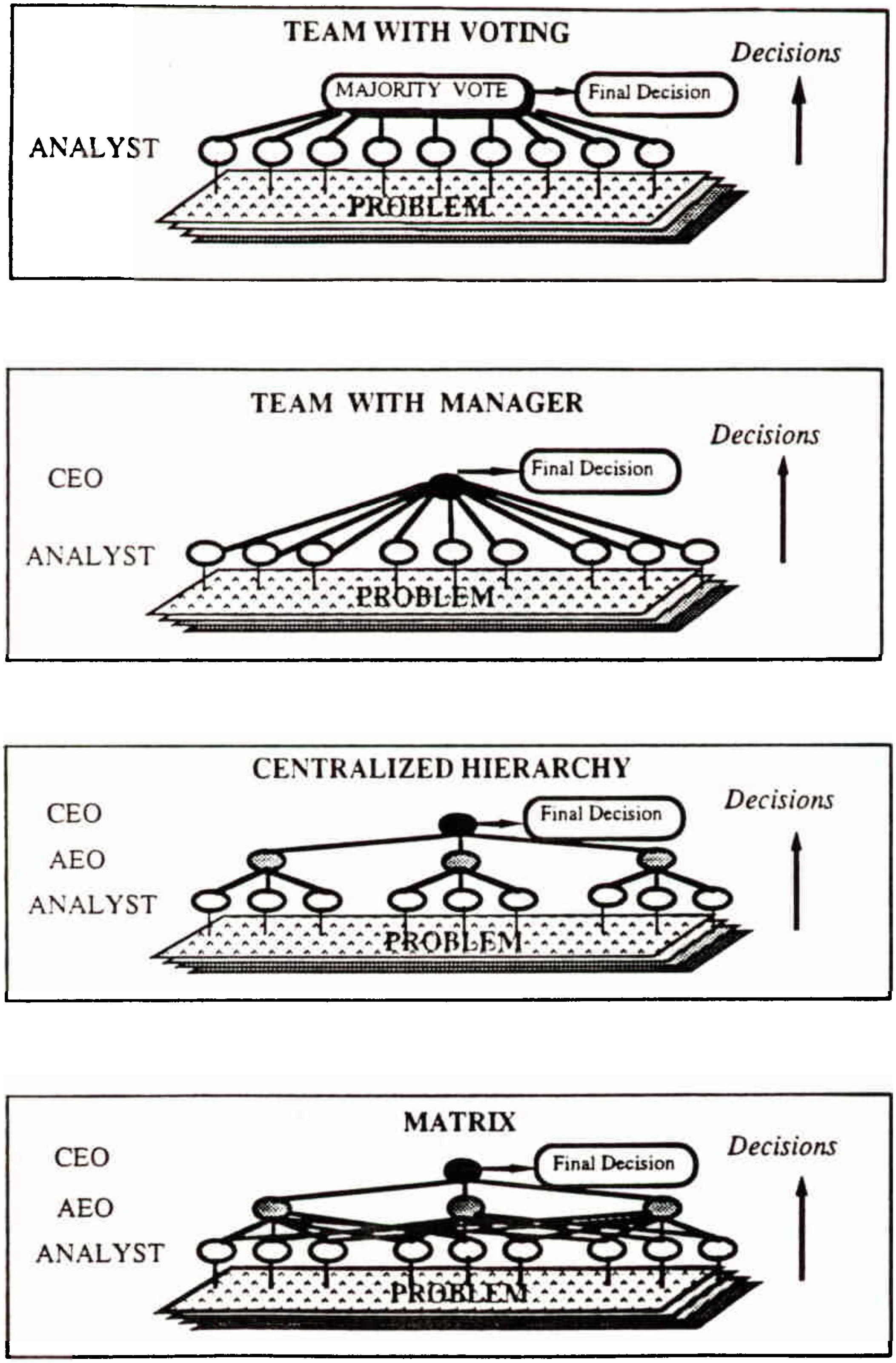


Figure 2. Organizational Structures

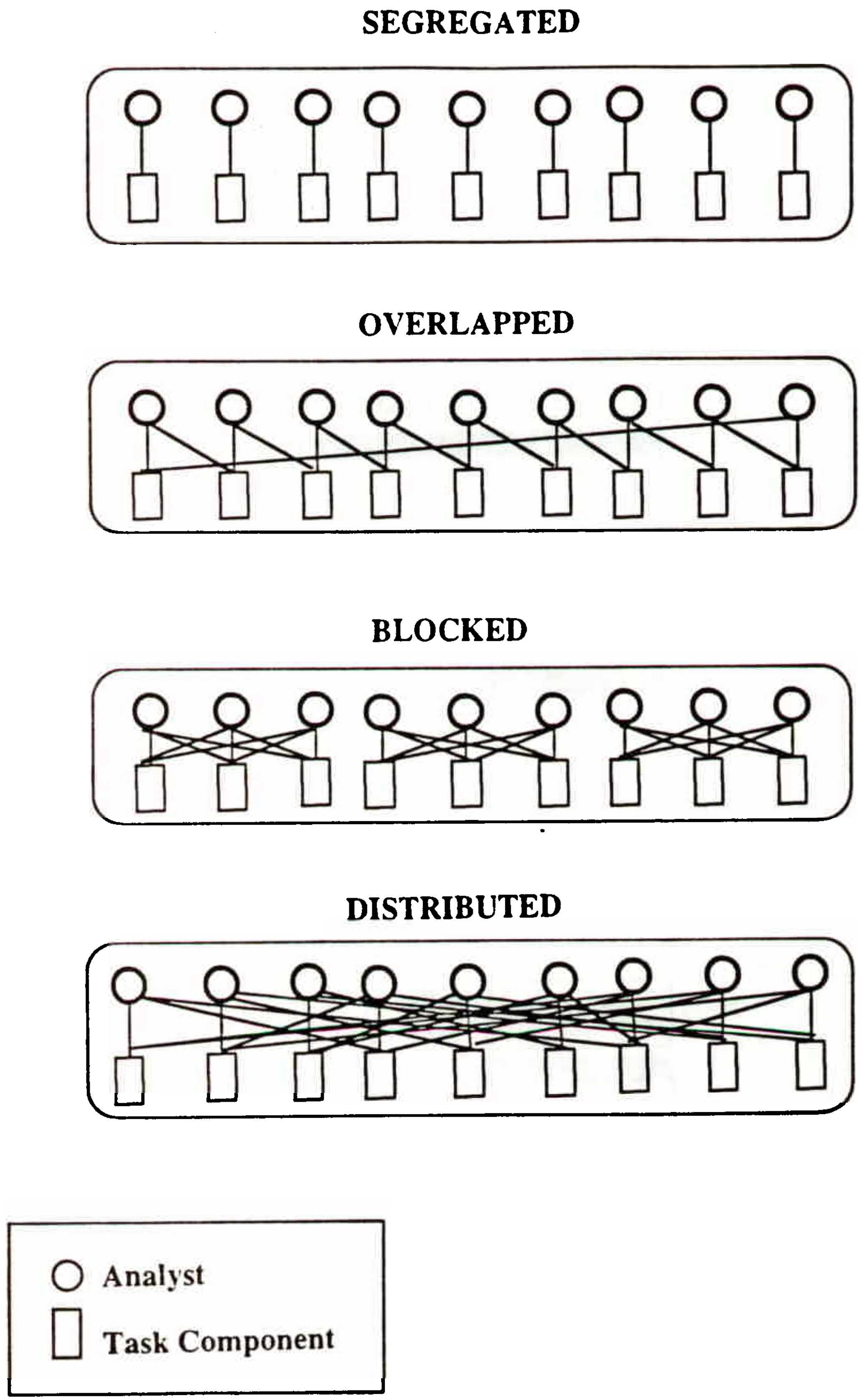


Figure 3. Resource Access Structures

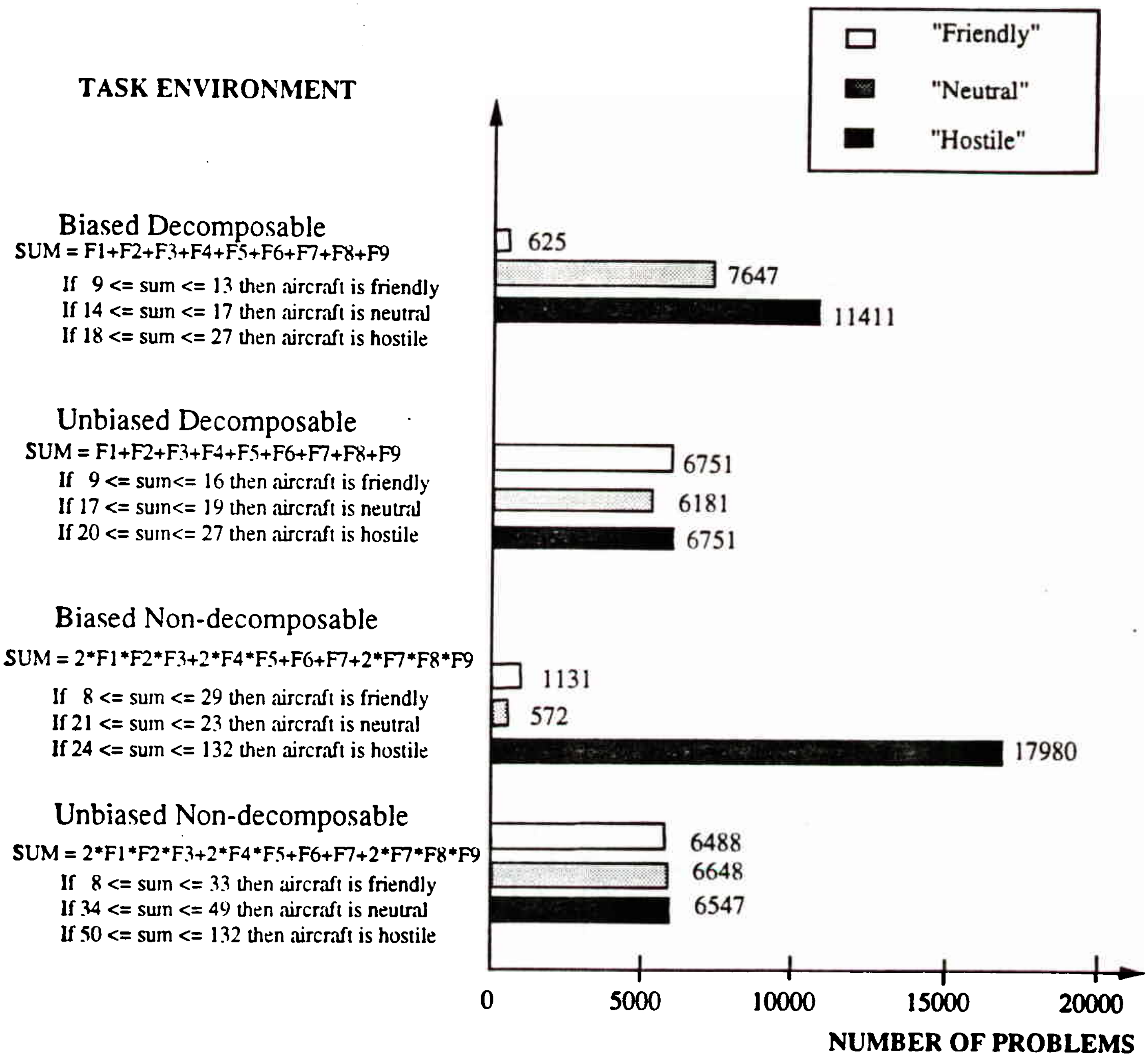


Figure 4. Task Environments

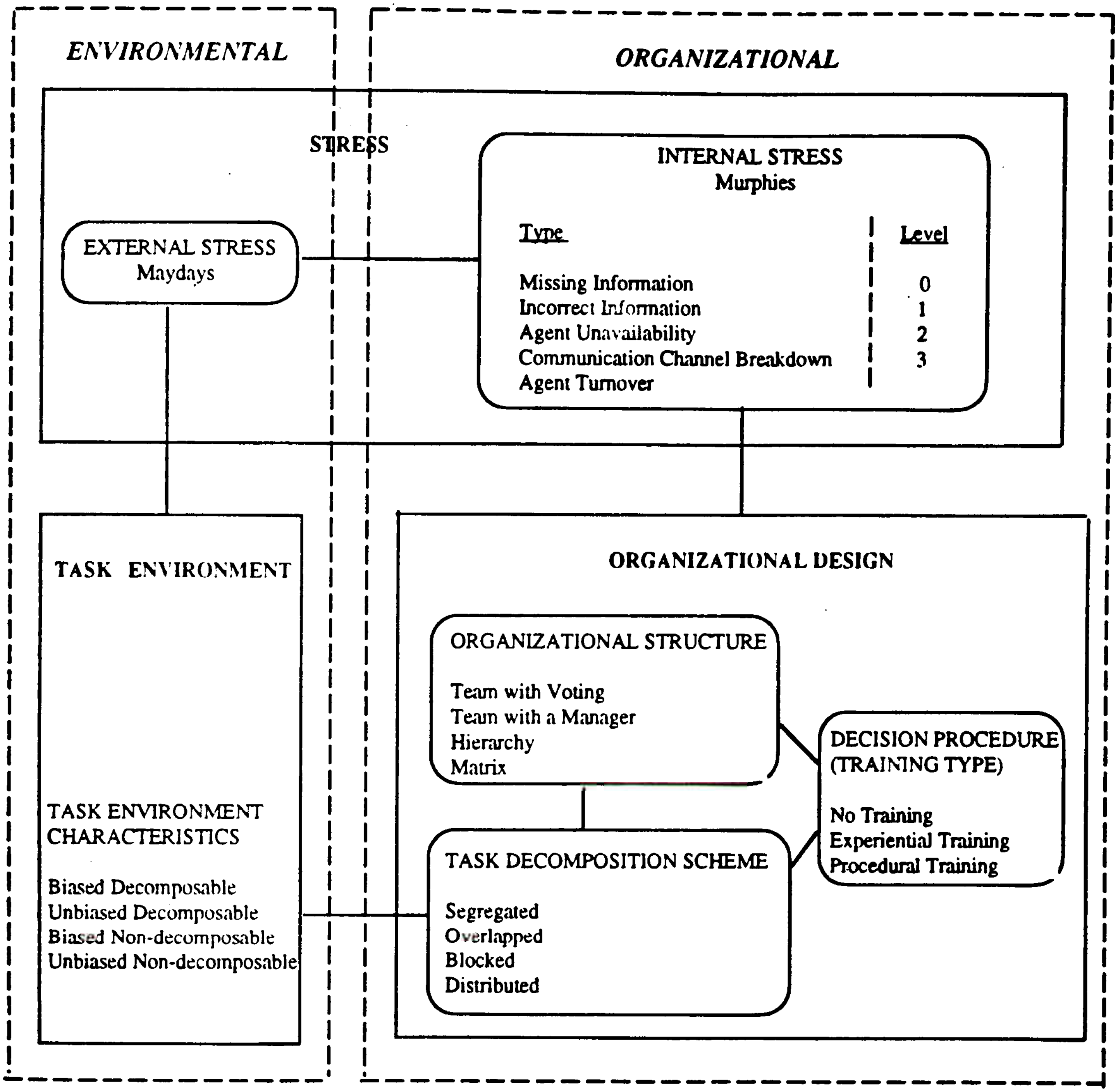


Figure 5. An Open System View of the Model

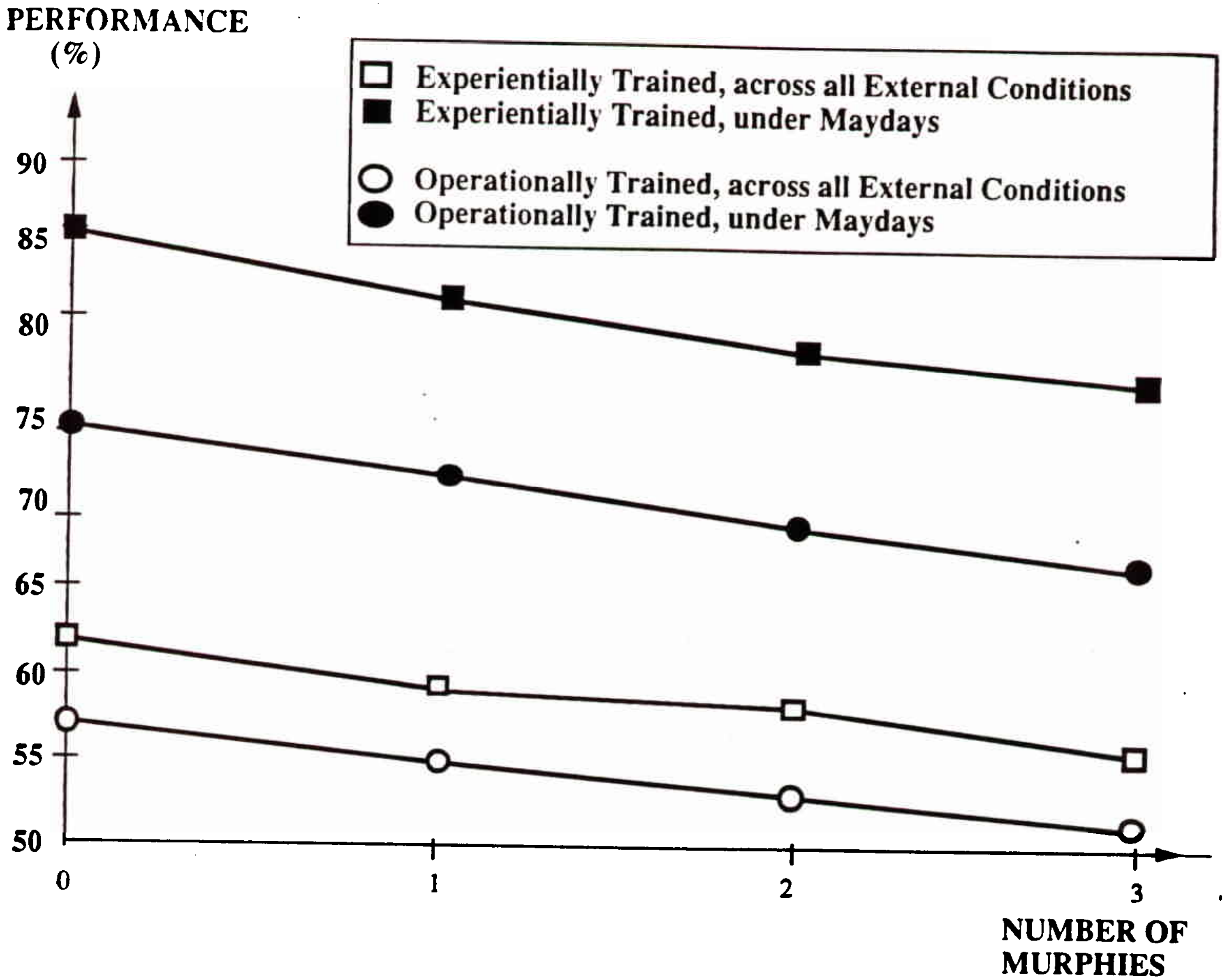


Figure 6. Organizational Performance by Number of Murphies

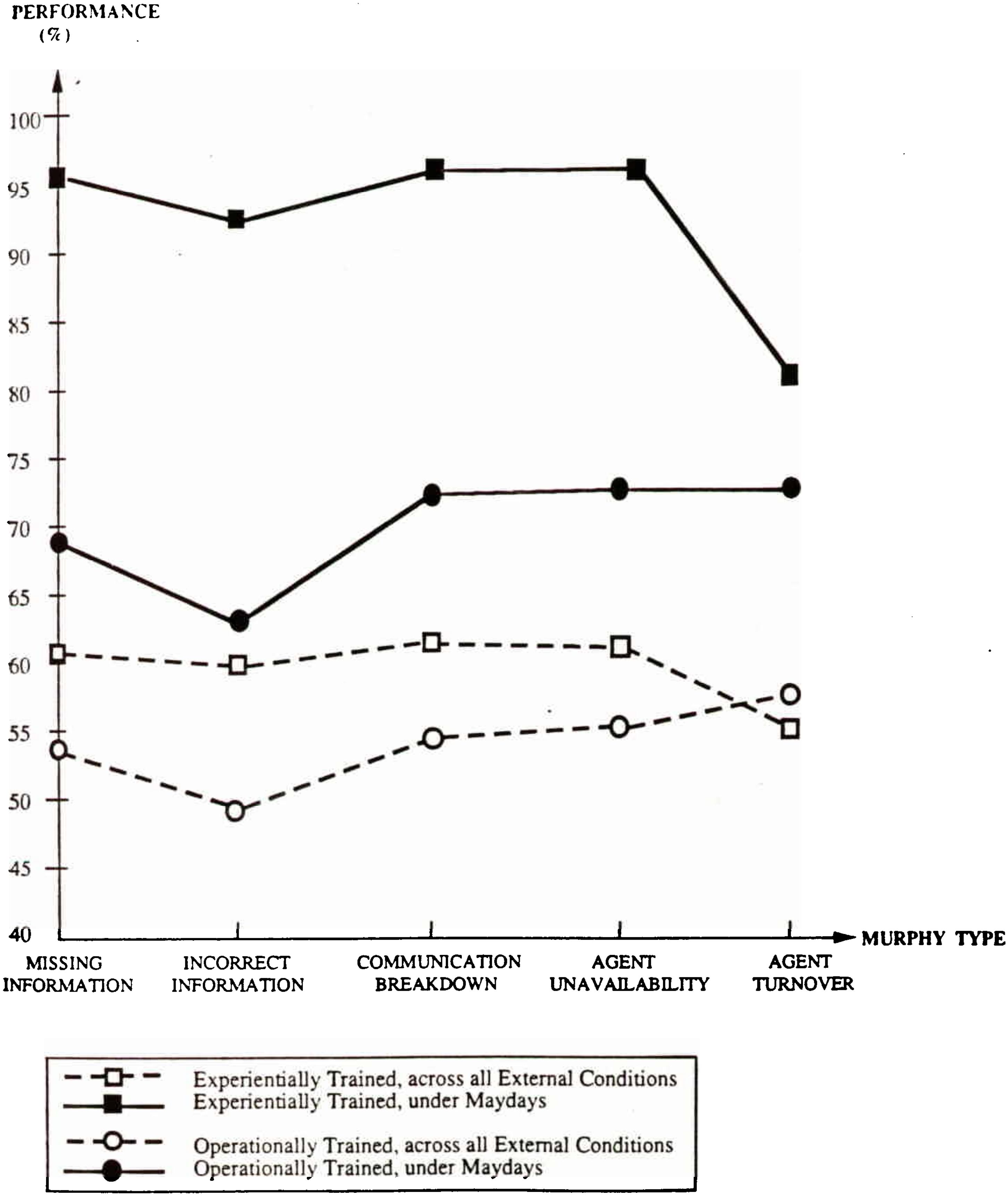
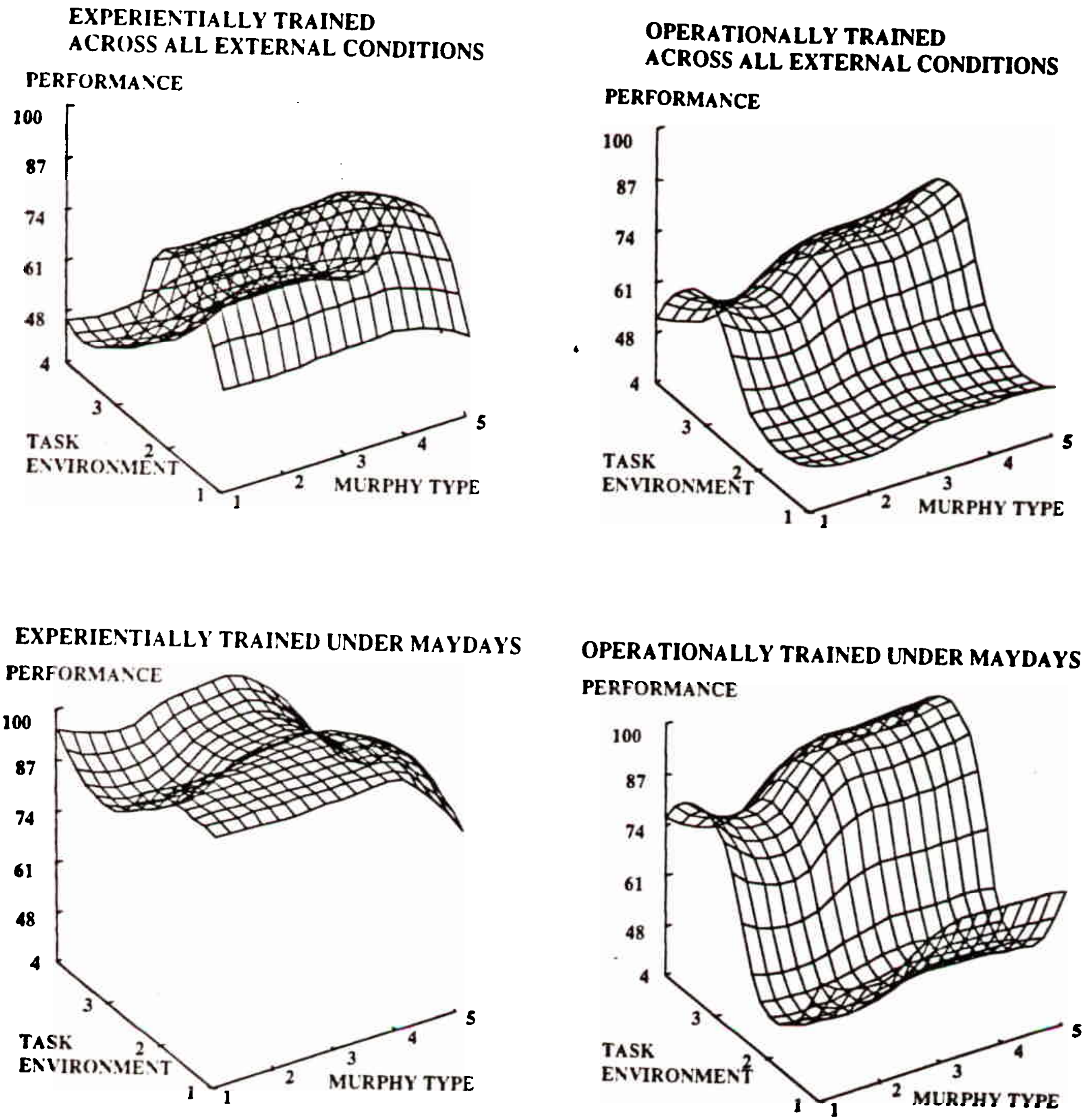


Figure 7. Organizational Performance by Murphy Type



TASK ENVIRONMENT	MURPHY TYPE
1--BIASED DECOMPOSABLE	1--MISSING INFORMATION
2--UNBIASED DECOMPOSABLE	2--INCORRECT INFORMATION
3--BIASED NON-DECOMPOSABLE	3--AGENT UNAVAILABLE
4--UNBIASED NON-DECOMPOSABLE	4--COMMUNICATION CHANNEL BREAKDOWN
	5--AGENT TURNOVER

Figure 8. Organizational Performance by Murphy Type and Task Environment

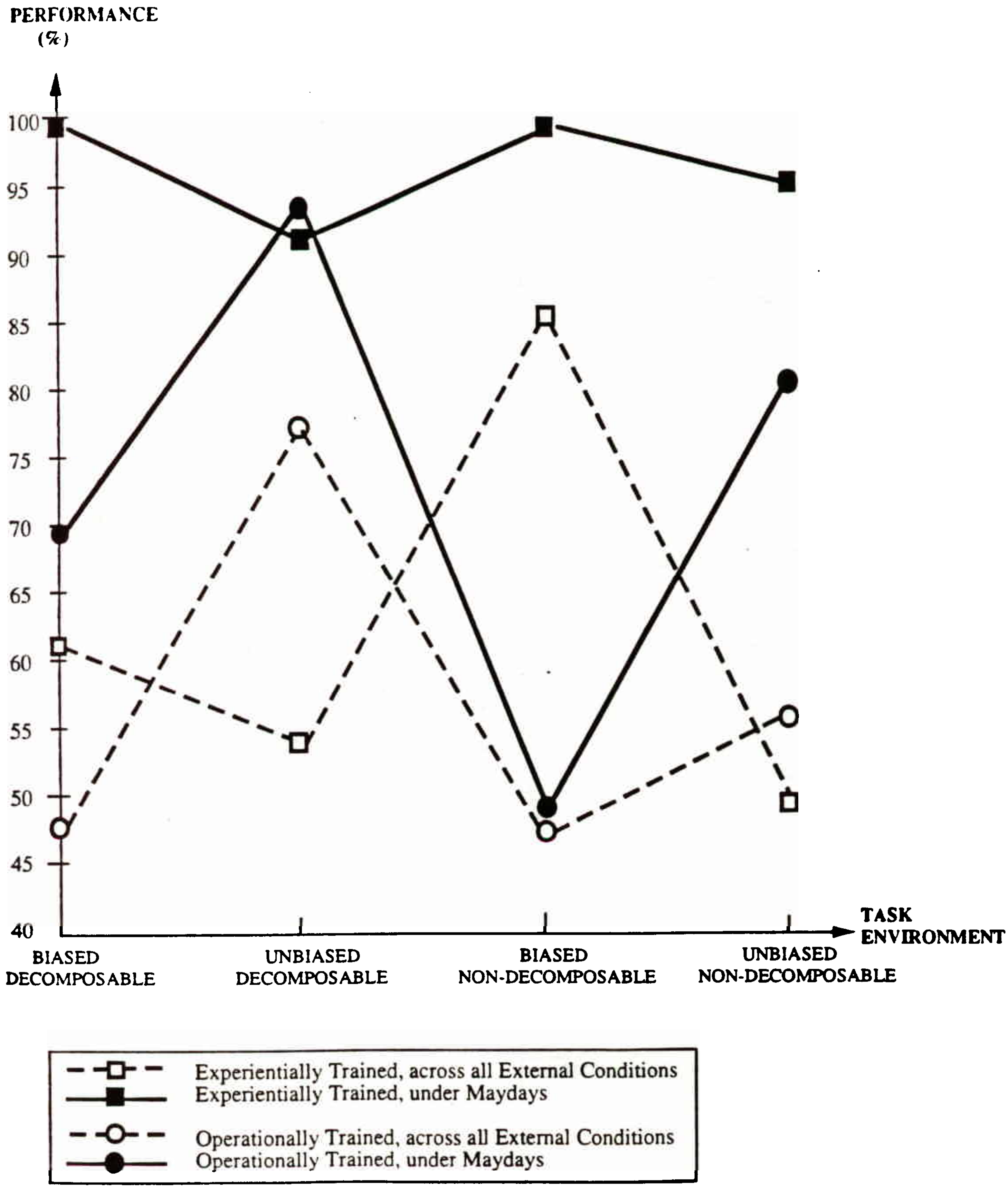


Figure 9. Organizational Performance by Task Environment

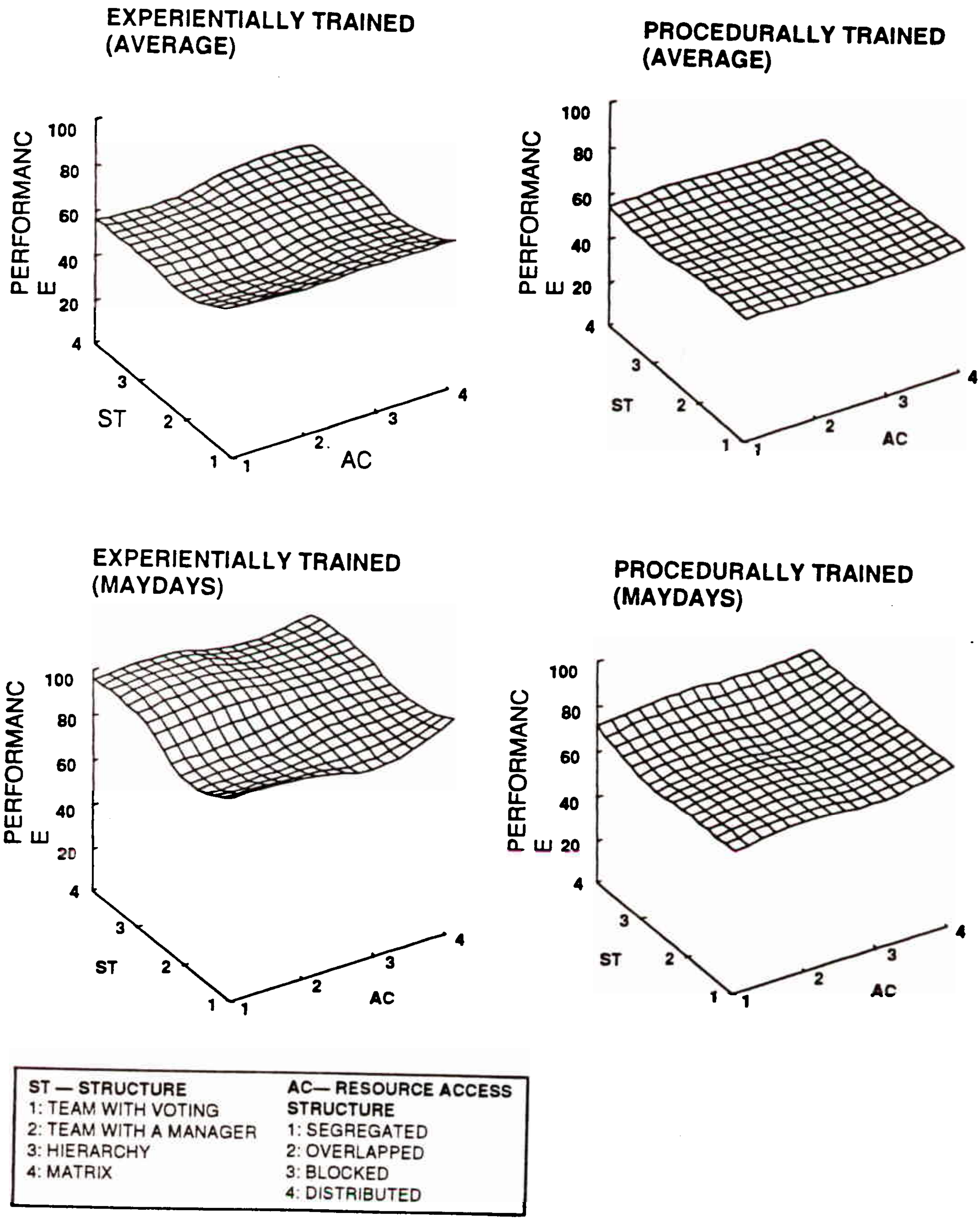
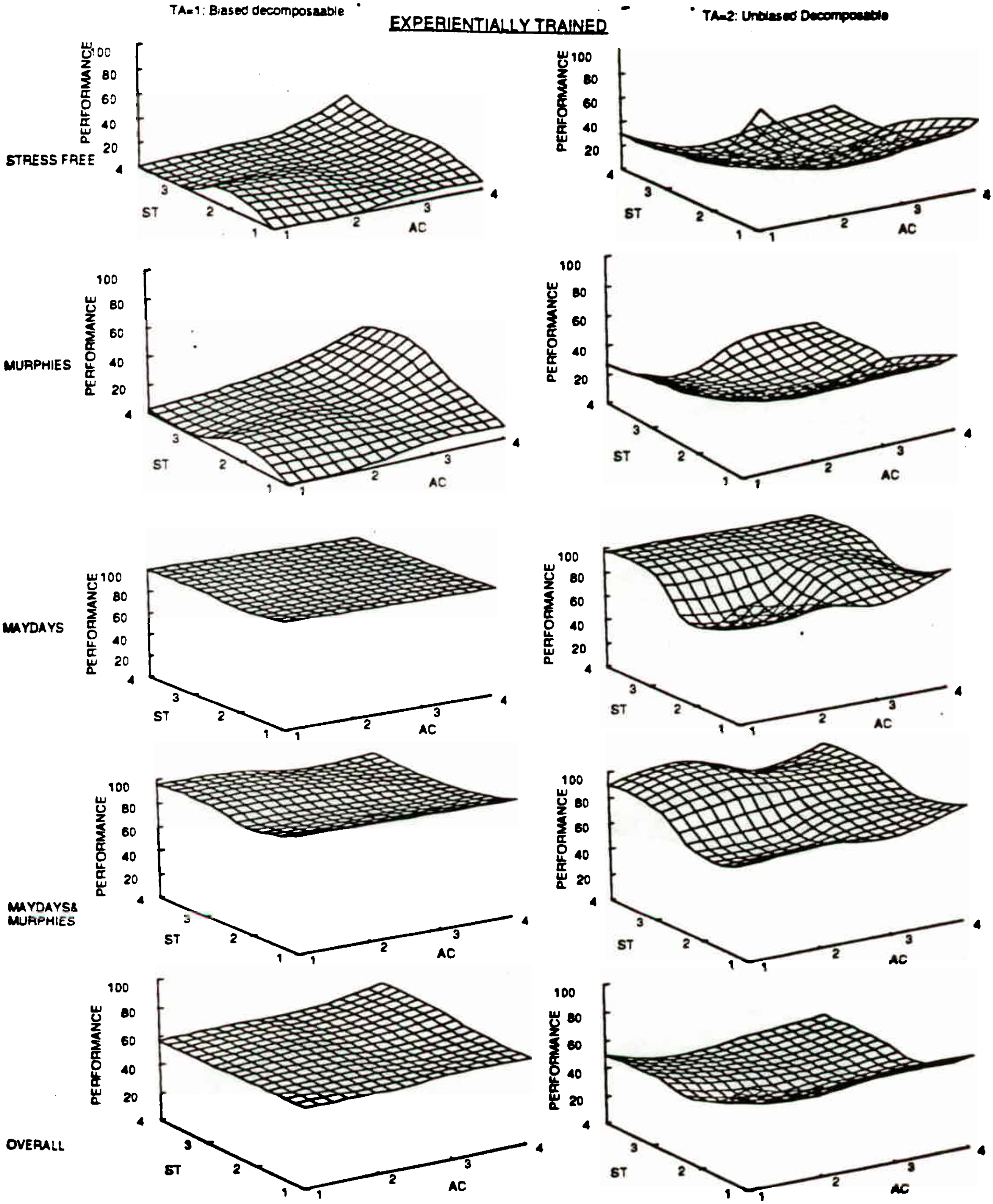


Figure 10. Organizational Performance by Organizational Structure and Resource Access Structure



ST—ORGANIZATIONAL STRUCTURE
1: Team with voting
2: Team with a manager
3: Hierarchy
4: Matrix

AC—RESOURCE ACCESS STRUCTURE
1: Segregated
2: Overlapped
3: Blocked
4: Distributed

Figure 11. Performance of Experientially Trained Organizations by Stress Condtions and Task Environment

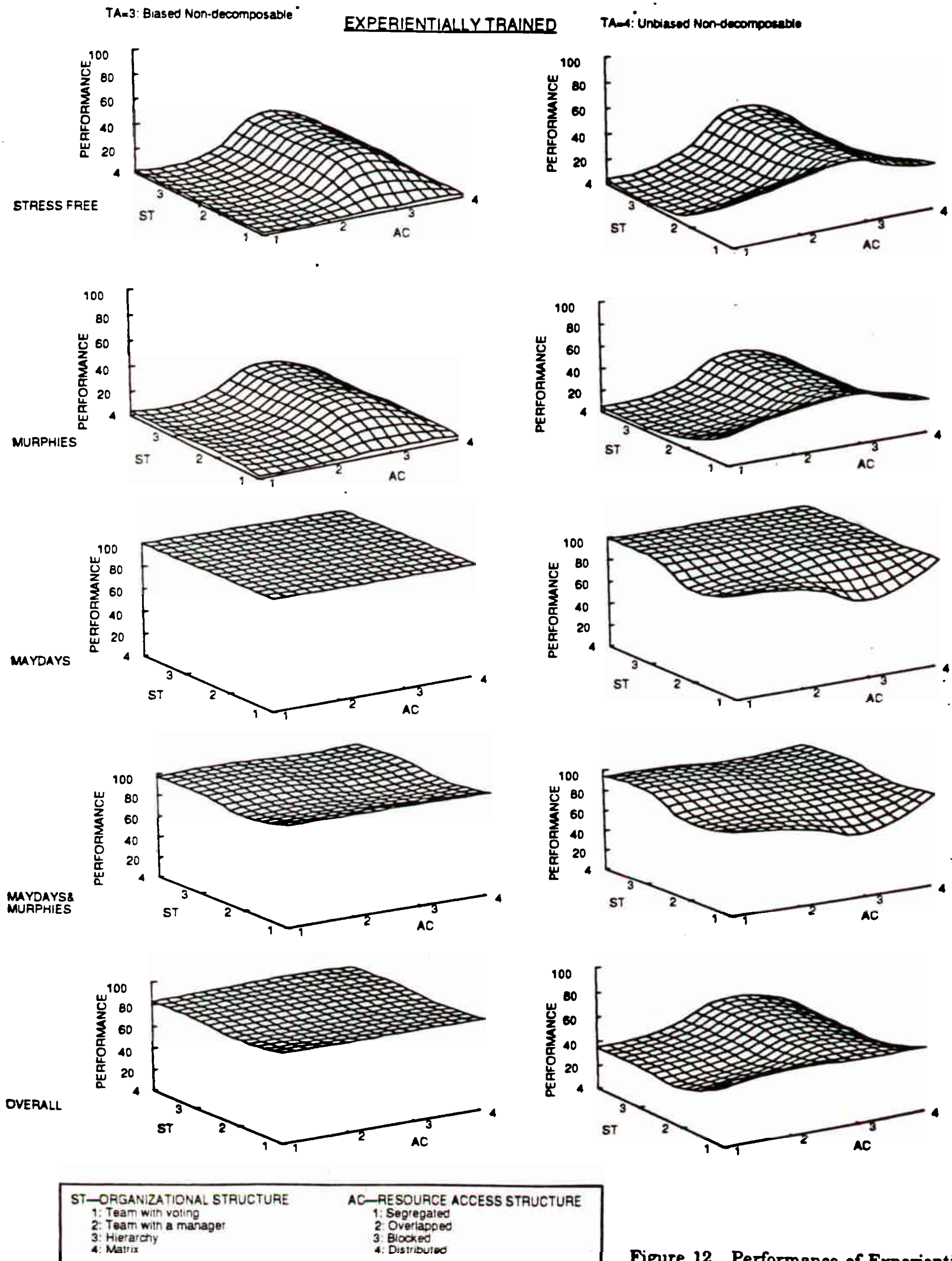


Figure 12. Performance of Experientially Trained Organizations by Stress Conditions and Task Environment

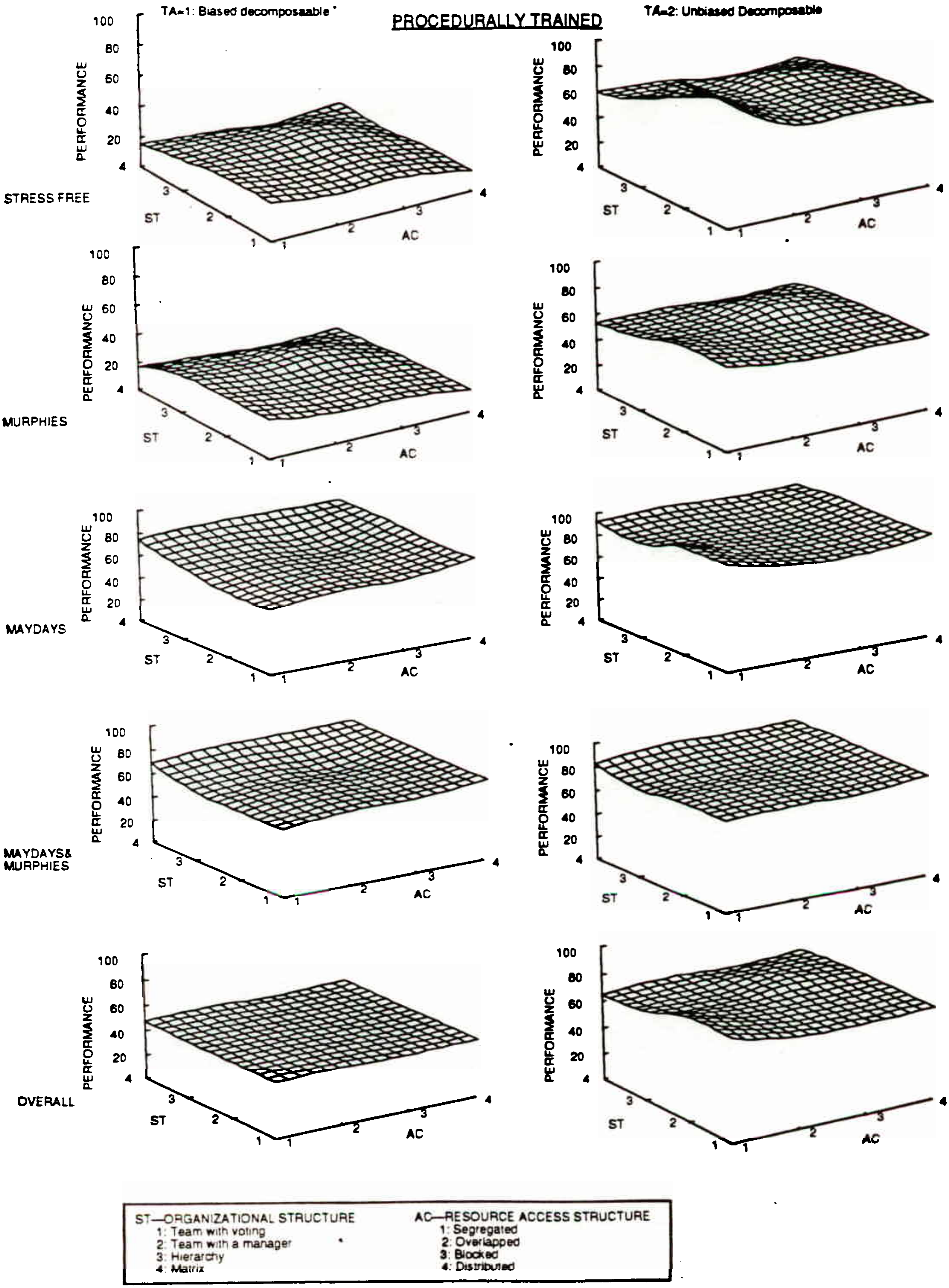
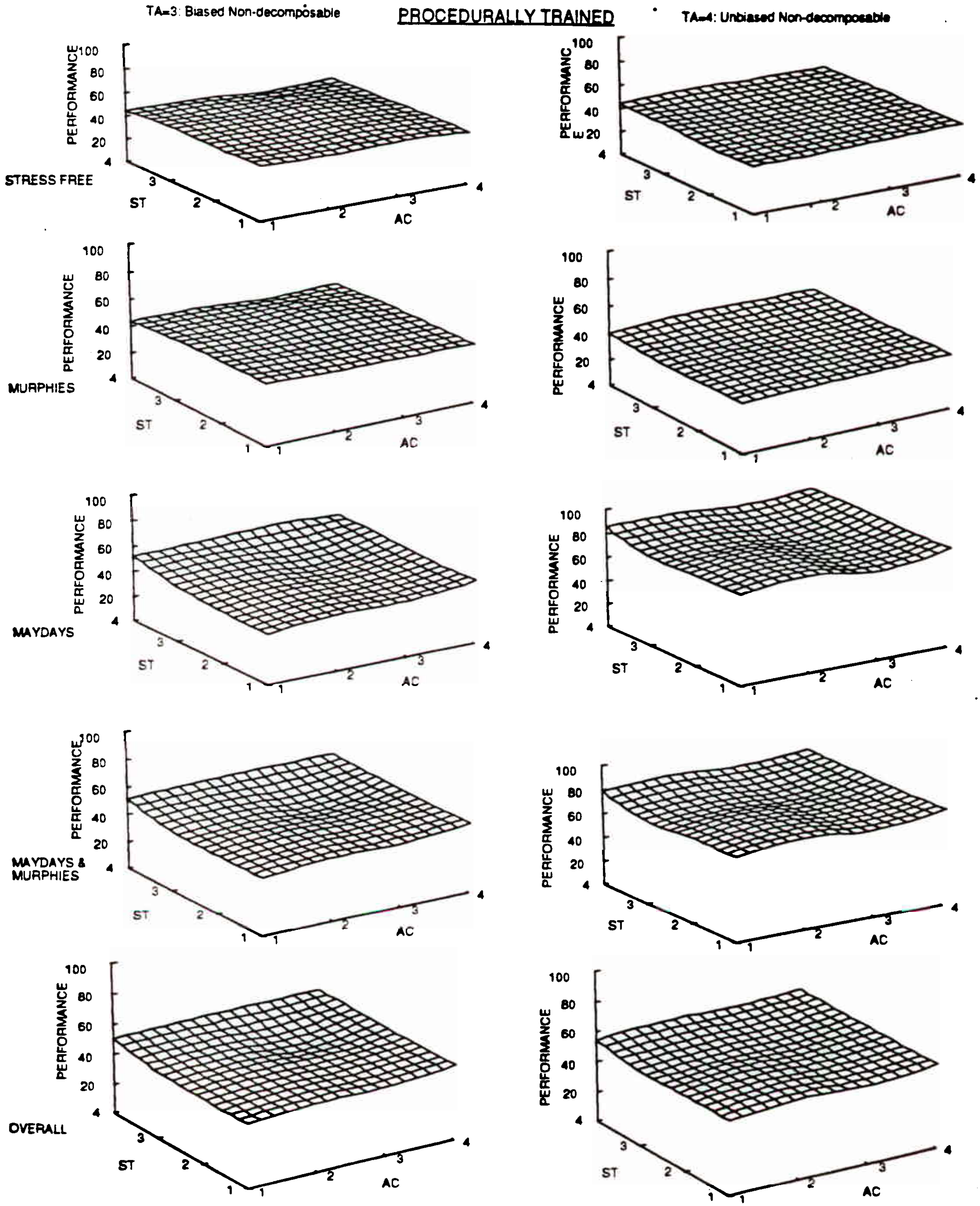


Figure 13. Performance of Procedurally Trained Organizations by Stress Conditions and Task Environment



ST—ORGANIZATIONAL STRUCTURE	AC—RESOURCE ACCESS STRUCTURE
1: Team with voting	1: Segregated
2: Team with a manager	2: Overlapped
3: Hierarchy	3: Blocked
4: Matrix	4: Distributed

Figure 14. Performance of Procedurally Trained Organizations by Stress Conditions and Task Environment

Table 1: A Summary of the Factors Examined in the Computer Simulation Model

Major Factor	Sub-component
Organizational Design (48 Types)	4 Structures 4 Task Decomposition Schemes 3 Training Scenarios
Task Environments (4 Types)	4 Task Environments
Internal Situations (20 Situations)	5 Internal Stress (Murphy) Types 4 Levels of Severity
	3,840 Total Cases†

† A case is a combination of each aspect of all sub-components.

Table 2: Organizational Performance by Task Environment Across both Training Types

Stress Condition	Task Environment			
	BD	UD	BN	UN
Stress Free	13.04(160,0.44)	53.32(160,1.92)	26.66(160,0.60)	34.38(160,0.89)
Murphies Only	16.23(480,0.37)	45.29(480,0.69)	26.11(480,0.30)	31.19(480,0.50)
Maydays Only	84.59(160,0.40)	92.24(160,0.68)	73.85(160,0.28)	88.41(160,0.56)
Maydays & Murphies	80.61(480,0.45)	84.17(480,0.62)	72.77(480,0.33)	82.99(480,0.53)
Overall	53.80(6400,0.17)	60.11(640,0.52)	65.62(640,0.21)	49.46(640,0.33)

Note: Performance is in percentage. Number of cases and standard errors are in parentheses.
BD — Biased Decomposable, UD — Unbiased Decomposable, BN — Biased Non-decomposable, UN — Unbiased Non-decomposable.

Table 3: A Partial Illustration of Experientially Trained Agents' Memories in a Hierarchy Structure with Distributed Resource Access Structure faced with an Unbiased Decomposable Task Environment

Information Received	Agent Level	Memory of Previous Feedback		
		"Friendly" (or 1)	"Neutral" (or 2)	"Hostile" (or 3)
• • •				
1, 2, 2	CEO	279	201	24
	Middle Manager	28	310	97
	Baseline Analyst	314	322	93
1, 2, 3	CEO	31	58	10
	Middle Manager	10	116	241
	Baseline Analyst	228	273	228
• • •				
1, 3, 2	CEO	25	39	10
	Middle Manager	8	106	217
	Baseline Analyst	228	273	228
• • •				
3, 2, 2	CEO	16	34	4
	Middle Manager	13	133	250
	Baseline Analyst	228	273	228
3, 2, 1	CEO	26	46	6
	Middle Manager	12	124	227
	Baseline Analyst	228	273	228
• • •				
3, 1, 2	CEO	38	378	116
	Middle Manager	0	32	427
	Baseline Analyst	93	322	324

Note: The agents' memories of feedback are averaged at each level.

Table 4: Organizational Performance in General

Stress Condition	Untrained	Training Type Experientially Trained	Operationally Trained
Stress Free	33.33(0.00)	18.99(320,1.10)	44.21(320,1.11)
Murphies Only	33.33(0.00)	18.40(960,0.52)	41.01(960,0.50)
Maydays Only	33.33(0.00)	96.63(320,0.43)	72.92(320,0.98)
Maydays & Murphies	33.33(0.00)	91.30(960,0.43)	68.98(960,0.51)
Overall	33.33(0.00)	59.93(1280,0.48)	54.56(1280,0.31)

Note: Performance is in percentage. Number of cases and standard errors are in parentheses.

Table 5: Performance of Experientially-Trained Organizations Under Optimal Operating Conditions

Task Environment	External Condition: Overall		External Condition: Maydays	
	Top	Bottom	Top	Bottom
Biased Non-decomposable	Hierarchy or matrix Blocked (per=88.83)	Team with voting Except blocked (per=84.58)	Any Structure Except blocked (per=10(0.00)	Any structure Blocked (per=99.92)
Unbiased Decomposable	Team with voting Segregated (per=100.00)	Team with manager Overlapped (per=37.38)	Team with voting Segregated (per=100.00)	Team with manager Overlapped (per=62.79)
Biased Decomposable	Matrix Distributed (per=70.06)	Team with voting Segregated (per=57.97)	Any structure Blocked (per=100.00)	Team with manager Segregated (per=96.02)
Unbiased Non-decomposable	Team with voting Overlapped (per=62.48)	Team with manager Segregated (per=34.50)	Hierarchy or matrix Blocked (per=100.00)	Team with voting Blocked (per=72.40)

Note: Performance is measured as percentage of correct decisions over presented problems.

Table 6: Performance of Procedurally-Trained Organizations Under Optimal Operating Conditions

Task Environment	External Condition			
	Overall		Maydays	
	Top	Bottom	Top	Bottom
Biased Decomposable	Team with voting or team with manager Segregated (per=50.58)	Hierarchy Overlapped (per=45.20)	Matrix Distributed (per=79.27)	Team with manager Segregated (per=59.16)
Unbiased Decomposable	Team with voting or team with manager Segregated (per=100.00)	Matrix Distributed (per=66.04)	Team with voting or team with manager Segregated (per=100.00)	Hierarchy Overlapped (per=88.62)
Biased Non-decomposable	Matrix Blocked (per=53.62)	Team with voting or team with manager Segregated (per=41.31)	Matrix Blocked (per=56.13)	Team with voting or team with manager Segregated (per=40.30)
Unbiased Non-decomposable	Team with voting Segregated (per=59.99)	Matrix Blocked (per=52.80)	Matrix Distributed (per=88.13)	Team with manager Blocked (per=76.07)

Note: Performance is measured as percentage of correct decisions over presented problems.

Table 7: Organizational Performance by Match of Organizational Complexity and Task Complexity

Stress Condition	Training Type	Match=1	Match=2	Match=3
Stress Free	Experientially Trained	21.99(2.34,40)	18.61(1.69,160)	18.49(1.76,120)
	Procedurally Trained	26.92(2.39,40)	44.99(1.72,160)	48.95(1.38,120)
Murphies Only	Experientially Trained	23.73(1.33,120)	17.69(0.73,480)	17.57(0.86,360)
	Procedurally Trained	26.98(1.17,120)	41.31(0.74,480)	45.30(0.64,360)
Maydays Only	Experientially Trained	95.14(0.90,40)	96.15(0.76,160)	97.76(0.44,120)
	Procedurally Trained	77.42(0.81,40)	73.25(1.42,160)	70.97(1.76,120)
Maydays & Murphies	Experientially Trained	86.93(1.34,120)	90.90(0.65,480)	93.28(0.61,360)
	Procedurally Trained	72.61(0.76,120)	69.04(0.72,480)	67.69(0.90,360)
Overall	Experientially Trained	54.05(0.99,160)	59.45(0.69,640)	62.52(0.79,480)
	Procedurally Trained	49.61(0.37,160)	54.90(0.48,640)	55.77(0.49,480)

Note: Standard errors and number of cases (n) are in parentheses. Match is defined as: 1 -- complex organization with simple task, or simple organization with complex task; 2 -- moderate organization with complex task, or moderate organization with simple task, or complex organization with moderate task, or simple organization with moderate task; 3 -- complex organization with complex task, or simple organization with simple task, or moderate organization with moderate task.

Table 8: Summary of Propositions' Support Status

Stress Condition	Training Type	Task Environment: BD	UD	BN	UN
Stress Free	Experientially Trained		P6, P7		P6, P7
	Procedurally Trained	P5, P8, P12	P6, P7, P12	P5, P8, P12	P5, P6, P7, P12
Murphies Only	Experientially Trained	P2, P12	P2, P12	P2, P12	P2, P12
	Procedurally Trained	P2, P5, P8, P12	P2, P6, P7, P12	P2, P5, P8, P12	P2, P6, P7, P12
Maydays Only	Experientially Trained	P1, P3, P5, P12	P1, P3, P6, P7, P12	P1, P3, P5, P12	P1, P3, P6, P7, P10, P12
	Procedurally Trained	P1, P3, P5, P8, P9	P1, P3, P6, P7	P1, P3, P5, P8, P9	P1, P3, P6, P7, P10
Maydays & Murphies	Experientially Trained	P1,P2, P3, P5, P12	P1, P2, P3, P12	P1,P2, P3, P5, P12	P1,P2, P3, P10, P12
	Procedurally Trained	P1, P3, P5, P8, P9	P1, P3, P6, P7	P1, P3, P5, P8, P9	P1, P3, P6, P7, P10
Overall	Experientially Trained	P3, P12	P3, P6, P7, P12	P3, P12	P3, P6, P7, P10, P12
	Procedurally Trained	P3, P12	P3, P6, P7, P12	P3, P12	P3, P6, P7, P10, P12

Note: BD — Biased Decomposable, UD — Unbiased Decomposable, BN — Biased Non-decomposable, UN — Unbiased Non-decomposable.