PROACTIVE OR REACTIVE: AN ANALYSIS OF THE EFFECT OF AGENT STYLE ON ORGANIZATIONAL DECISION MAKING PERFORMANCE

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ABSTRACT

This paper addresses the issue of agent style — proactive and reactive, from a theoretical perspective. The results show that agent style, though often considered key in decision making, only affects the organization's performance when the organization is under moderate time pressure. Further, the effect of agent style depends on the type of training given to organizational agents and the internal condition under which the organization operates. This research suggests that, when resources are scarce, organizations should spend these resources on organizational design and on increasing the accuracy of incoming information rather than on altering the agents' style.

INTRODUCTION

Organizations vary in the rate at which they respond to organizational problems, even when they are in similar task environments or are facing similar stress conditions (Scott 1987). This rate of response and (presumably) the accuracy of the response is due, in part, to the way agents approach problems (Kets de Vries and Miller 1986; LaPorte and Consolini 1991; Roberts 1989, 1990). An agent's problem solving style, which we refer to as agent style, varies on many dimensions, such as proactiveness or creativeness. A proactive agent engages in decision making and information gathering whenever possible. A reactive agent waits until being asked or until absolutely necessary to gather information or make a decision (Larson et al. 1986). Proactive and reactive agents once they begin their information search spend the same amount of time on a single search. Proactive and reactive agents once they begin the decision making process spend the same amount of time making a decision and communicating a decision. The difference between these agents lies in their coordination. Proactive agents begin their information search, decision making, and communication without being told to do so by their manager. Reactive agents essentially do not do anything unless asked to do so. We analyze how the proactiveness or reactiveness of an organization's agents affects organizational performance.

Organizations composed of proactive agents should respond to organizational problems faster than organizations composed of reactive agents. A consequence is that organizations of proactive agents should outperform organizations of reactive agents (LaPorte and Consolini 1991; Pauchant et al. 1990). The conventional evaluation of agent style typically regards the proactive style as being better for the organization than the reactive style. The wisdom is that proactive organizations are more active (Smiar 1992), more cooperative (Rice 1977), more prepared (Das 1986; Newman 1989), and thus are supposed to be better performers (Jauch and Kraft 1986; Smiar 1992). This argument can be summarized by a famous Chinese proverb: One can always get credit for sweat if not for achievement.

Given that we are interested in proactive versus reactive behavior, another factor of paramount consideration is timing. That is, for many tasks, it is important that the organization makes both accurate and timely decisions. Numerous studies show that under time pressure, organizations tend to rearrange their decision making process (Means et al. 1992; Rothstein 1986) and perhaps coordination processes. In many cases, time pressure causes errors due to loss of information because it stresses the limit of human cognition (Magazannik 1982). When time is short a proactive agent has an advantage because he or she is prepared and always ready to make a decision (Pauchant et al. 1990). In contrast, the organization filled with a set of reactive agents is at a disadvantage as precious problem solving and information gathering time must be spent telling the agents to start gathering information and making decisions. However, when timing is not critical, reactive agents may be an economical solution as they may need less training, and may have lower information processing costs (Pauchant et al. 1990; Sussman 1984).

The arguments that agent style matters are largely drawn from micro-level studies of organizational behavior and case studies of organizations facing crises. While proactive agents are often touted as effecting high organizational performance, the relative benefit to the organization of having proactive versus reactive agents has not been systematically studied. Nevertheless, we know that organizations differ in whether their agents are proactive or reactive. In the Chernobyl case (Silver 1987), organizational agents were proactive and tended to make decisions on their own, some of which were incorrect. While in the Vincennes case (Rochlin 1991), organizational agents were reactive and acted when ordered. Detailed case studies of organizations under stress point to agent style as well as many other factors (such as the structure of the organization and the nature of the task environment) when delineating the determinants of organizational performance. Theoretical and empirical studies have shown that organizational structure (Carley 1991, 1992; Carley and Lin 1992; Mackenzie 1978; Mintzberg 1983; Padget 1980), task decomposition scheme (Carley and Lin 1992; Cohen, March, and Olsen 1972; Mackenzie 1978; Thompson 1967), training (Carley 1992; Carley and Lin 1992; Hammond 1973; Perrow 1984), and stress (Carley and Lin 1992; Krackhardt and Stern 1988; Staw et al. 1981) all affect performance. All of which suggests that a systematic analysis of organizations under stress should look at agent style, but should also control for these other factors.

In contrast to the literature just discussed, there is a scientific tradition that treats agent style as irrelevant. Network studies (e.g., Mayhew 1980; Wellman 1988) argue that performance is a function of the structure of relations connecting agents in the organization and in the roles that individuals hold. Contingency theorists (e.g., Burton and Obel 1984, 1990; Lupton 1976; Woodward 1965) argue that performance is a function of the fit between organizational structure and task environment. Both the network perspective and the contingency perspective implicitly suggest that agent style will not determine organizational performance when these other factors are controlled.

In this paper, we will examine, from a meso-perspective, whether the agent's proactive or reactive problem-solving style affects organizational performance. We are particularly concerned with the effect of time pressure on the performance of organizations composed of either proactive or reactive agents. This study goes beyond many studies of organizational design as it not only considers both timing of the decision and the proactiveness/reactiveness style of the agents, but also controls for factors such as organizational structure, task decomposition scheme, training, nature of the task environment, and stress. This study is carried out using simulation.

We examine agent style using a dynamic and interactive computational model that integrates a set of factors that may influence organizational performance. There are several reasons to examine the effect of agent style using simulation. First, in the real world there is little consensus on what constitutes organizational performance. Research has shown that it is impossible to obtain the best or sufficient indicator of organizational performance, and that whether an organization is said to perform well depends on "the purposes and constraints" placed on the organizational performance measure (Cameron 1986). Performance has been viewed from a variety of perspectives, such as productivity (Argote and Epple 1990), profitability (Lawrence and Lorsch 1967), reliability (Roberts 1989), etc. While such measures may tell you what the organization is doing, they do not necessary tell you how well it is doing it. because of the lack of a good measure of organizational performance, empirical comparison across real organizations such as those with different designs are somewhat suspect.

Second, assuming that we find a reasonable indicator of organizational performance that let us gauge action against an objective indicator, it is virtually impossible to obtain sufficient data for comparing organizations with a range of designs under both normal and stressful situations. The difficulty of getting such data includes time limits on data acquisition, confidentiality, insufficient information on specific operating conditions within organizations, and lack of comparability across industries. Such difficulties tend to result in an unbalanced design from an analysis standpoint and so call into questions of the generalizability of the results. A related difficulty with field studies of performance is that they typically focus on successful firms (Child 1974; Drazin and Van de Ven 1985; Lawrence and Lorsch 1967; Long 1980). As such, they provide little insight from a design perspective as to whether "failed" firms differ in design from "successful" firms.

In contrast, simulation has multiple advantages: (1) We can conduct balanced simulation experiments, and control certain factors to examine the effect of other factors. (2) We can consider both successful and failed firms. Thus results will not be biased by looking only at successes. (3) Simulated organizations have been shown to resemble the real world organizations in an idealized way (Lin and Carley 1993). The performance characteristics of simulated organizations are under certain conditions comparable to the performance characteristics observed in the real world; (4) Researchers have also shown that organizational performance is affected by factors such as organizational design (Houskisson and Galbraith 1985; Lawrence and Lorsch 1967), task environment (Drazin and Van de Ven 1985), and stress (Anderson 1977). Only a systematic examination of these factors on organizations can address the issue of what really constitutes organizational performance. By using simulation, we can get insight into these important factors with less cost than conducting human experiments or field studies. Once the dominant factors are examined, human experiments or field studies can be done to test the theoretical results.

To guide our analysis, we will consider how the results of our model fit with, contradict, or elaborate on propositions forwarded in the literature with respect to agent style.

We will briefly describe the model, analyze the results from the model, and finally, we will discuss the results and conclude the paper.

MODEL DESCRIPTION

Task

The organizations we simulate are faced with a limited choice task in which organizations make decision choices regarding the state of moving aircraft under stress from limited alternatives according to information they have through organizational communication processes. The simulation test-bed used in this paper is an adaptation of that in Carley and Lin (1992) that takes into account time and agent style. Choice tasks are very common in the real world. Such choice situations include law-making, price-setting, planning, and a host of other similar things (Allison 1971; March and Olsen 1976; Shull et al. 1970).

We have operationalized this choice task as a stylized radar task. There is a single aircraft in the airspace. This aircraft is moving. The organization has three choices — deciding whether the aircraft in the airspace is friendly, neutral, or hostile. Each aircraft is characterized by 9 parameters (see Carley and Lin 1992 for details).

We measure the organization's performance as the percentage of these problems that the organization has made the correct decision (the true states of all the aircraft are predefined by the task environment and are unknown to the organization). regarding whether the aircraft is friendly, neutral, or hostile. We treat type I error (making the decision that the aircraft is hostile, but in fact the aircraft is friendly) and type II error (making the decision that the aircraft is friendly, but in fact the aircraft is hostile) with equal weight. In organizational literature, organizational performance has also been measured by organizational effectiveness (Mackenzie 1978; Pfeffer and Salancik 1978), and organizational efficiency (Mackenzie 1978; Scott 1987). In many cases, accuracy, effectiveness, and efficiency are indistinguishable and can convert into each other.

Task Environment

Task environments vary on a large number of dimensions. Two such dimensions that have received some attention in the literature are decomposability and biasness. Task environment decomposability measures the interrelationships among task components. A task environment is decomposable if there are no complex interactions among components that need to be understood in order to solve a problem, and non-decomposable if otherwise. In a decomposable task environment, a linear combination of the features is sufficient to produce the decision. In a non-decomposable task environment there are interaction effects. As LaPorte and Consolini (1988, 1991) and Roberts (1988, 1990) note interdependence of task components (i.e., non-decomposability) is a factor that should be considered in designing the organization. Task environment biasness measures the distribution of all possible outcomes. A task environment is unbiased if all the possible outcomes are equally likely to occur, and biased if not. As Aldrich (1979) notes, a biased environment is one in which the problems faced by the organization are concentrated and so highly similar. Based on these two manipulations, we examine four different "realities" or environmental situations. They are: (1) biased decomposable task environment; (2) unbiased decomposable task environment; (3) biased non-decomposable task environment, and (4) unbiased non-decomposable task environment.

Stress

Organizations are often affected by stress (Perrow 1984; Shrivastava 1987). In examining organizational performance it is important to consider multiple sources of stress: internal suboptimal operating conditions or murphies (caused by sub-optimal operating condition within organizational design), external hostile conditions or maydays (caused by hostile task environment), and time pressure.

A murphy refers to a small disruption in the gathering or communicating of information within the organization (Carley and Lin 1992). Murphies are things that move the organization from an optimal to a suboptimal operating condition and thereby create internal stress. We examine five types of murphies. They are: (1) missing information — a piece of the incoming information for a particular problem is not available, (2) incorrect information — a piece incoming information is erroneous, (3) agent unavailability — an analyst is not available to help the organization solve the problem and so does not report his or her decision to his or her manager, (4) communication channel breakdown — an analyst is unable to report to a superior because the communication channel is unavailable, and (5) agent turnover — an analyst leaves the organization and is replaced by a new analyst. For each type of murphy, the number of simultaneous murphies ranges from 0 to 3.

A mayday refers to an external threat to the organization (Carley and Lin 1992). This can be a problem such that the wrong decision may have disastrous consequences. For example, a hostile aircraft would be considered a mayday. We define as maydays those problems that represent hostile aircraft.

In this paper, time pressure occurs when the aircraft is very fast, or when the time required to make the decision is very short. Time pressure is the number of time units before the organization must make a decision. Two factors affect when the organization must make a decision: (1) a decision is demanded by some outside or superior sources (e.g., congress) and (2) a decision is demanded because the aircraft reaches the danger point (the point at which if the organization does not respond and the aircraft is hostile, the aircraft can destroy the organization). In this model, this danger point occurs when the aircraft has a range of 1 mile and/or a range of 5,000 feet. Both numbers were chosen based on characteristics of radar systems.

In this model for each problem (i.e., an aircraft appearing in the airspace), we randomly assign the number of time units prior to a demand for a decision to be between 1 and 60. The characteristics of the aircraft are also randomly chosen for each problem. Each aircraft can also vary with different characteristics such as speed, range, and altitude. Consequently, the time pressure varies randomly across all problems.

We study three levels of time pressure: low (41-60 time units), medium (21-40 time units), and high (1-20 time units). Thus, time pressure varies linearly across the three conditions. A particular organization will be faced with a sequence of problems. Each problem has associated with it a particular time pressure. The time pressure defines how many time units the organization has to determine the state of the aircraft for this problem. Time pressure varies randomly across the problems. Because this is a dynamic environment, agents' interaction with one another in terms of whether to communicate and how to communicate, and the utilization of decision making procedures in terms of which decision making procedure to choose, all depend on the constrained resource — time. How agents react to time pressure is discussed later.

Organizational Design

While most existing definitions of organizational design only focus on either structure or task decomposition scheme or both, in this paper, organizational design is viewed as a combination of organizational structure, task decomposition scheme, training, and agent style. They virtually ignore procedures to process information learned through training. Through an examination of multiple designs, expected relations between design and performance can be computationally deduced.

Organizational structures are defined in terms of the network of relations among agents. We study four stylized organizational structures. They are: (1) team with voting — a totally decentralized structure in which organizational decision is through majority voting of each members of the organization, (2) team with a manager — basically a flat hierarchy such that while each analyst examines information and makes a recommendation, the ultimate organizational decision is made by the manager (or team leader), (3) hierarchy — a multi-leveled communication structure in which each baseline agent 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, (4) matrix — like the hierarchy, is a multi-leveled communication structure, except that each baseline agent has two communication links with two middle managers across divisions.

The task decomposition scheme defines the relations between agents and resources and/or information. We study four stylized task decomposition schemes. They are: (1) segregated — each baseline agent has access to one task component, (3) overlapped — each baseline agent has access to two task components, with one task component being overlapped with another baseline agent, (3) blocked — each baseline agent has access three task components, but usually each three agents within the same division have the same three task components, and (4) distributed — each baseline agent has access to three task components usually across different divisions.

The third and final aspect of organizational design, with which we will be concerned, is the type of training. We study three training scenarios. They are: (1) untrained — each agent in the organization makes decisions by basically guessing, (2) experientially trained — each agent in the organizational makes decisions by referring to historical experience, and (3) operationally trained — each agent in the organization makes decisions by using standard operating procedure. The number of time units required for different types of decision procedure is different given the same amount of information. Due to the different complexity of decision making processes, experiential decision making procedure usually takes more time than operational decision making procedure, and they both take more time than untrained decision making procedure. In this paper all agents are considered to be fully-trained. We examine performance as it varies across the type of training received and not the level of training.

Agent Style

Regardless of agent style, each agent can take the following actions — ask for information, read information, make a decision, pass up a decision, and wait. The amount of time that these actions take depends on the amount of information the agent must process and the type of decision making procedure they use (e.g. experiential) and not on the agent's style. In 1 the number of time units each action takes is displayed. Agent style affects the order preferred by the agent for engaging in these actions and in when the agent initiates these actions. Time pressure does not affect how many units it takes to perform an action. What time pressure affects is how many actions can be taken and how agents choose the preferred order in which to take actions.

Place Table 1 about here

A proactive agent (Figure 1), asks for information, reads information, then if there is information, makes a decision based on the available information, then passes on the decision. This cyclic process repeats until time expires, i.e., the aircraft goes out of range, or the top manager decides to stop the process. Each agent (except the top manager) can be interrupted by a request from an upper manager for decision. Manager interrupts can disrupt this cycle at the points indicated by a box and arrow in Figure 1. When the request from the manager arrives the agent responds to the request during the next time unit. Thus, only actions that take more than one time unit (e.g., make a decision) can be disrupted. When an agent receives a request for information he or she will respond to the request by communicating a decision, if there is one available. After responding to the request the agent returns to the action in which they were engaged when the request arrived. Clearly, the procedures followed by the top manager, middle managers, and baseline analysts differ somewhat on the basis of their organizational position. The top manager cannot be interrupted (since there is no superior), and a baseline analyst cannot ask for information (since there is no subordinate), while a middle manager can be interrupted as well as ask for information. Further, the top manager has the power to decide the final or organizational decision according to certain standards (for a detailed description of the styles at three levels, see Table A1).

Place Figure 1 about here

A reactive agent (Figure 2) reads information again and again until time expires or until the agent is told by the manager to stop. Each agent (except the top manager) can be interrupted by a request from an upper manager for decision as indicated in Figure 2. When the request from the manager arrives the agent responds to the request during the next time unit. Thus, only actions that take more than one time unit (e.g., make a decision) can be disrupted. The agent will then stop reading information (if not finished yet), and begin a cycle of decision making process: ask for information, read information, make a decision and pass up a decision. This cycle may also be interrupted by a new request from an upper manager. When an agent receives a request for information during the cycle, he or she will respond to the request by communicating a decision, if there is one available, otherwise simply continue current action. After responding to the request the agent returns to the action in which they were engaged when the request arrived. After finishing the decision making cycle, the agent returns to the default action — read information — again. Unlike the proactive agent, a reactive agent will not make a decision and pass on the decision unless being requested by his or her manager. Again, there are processing differences among agents due to their organizational positions (top, middle, and baseline). The top manager cannot be interrupted, and initiates the decision making process by asking for information. A middle manager will ask for information only when a request from the top manager is received for decision and when there is no decision already being communicated by baseline analysts. A baseline analyst always reads information and never asks for information (for a detailed description of styles at three levels, please see Table A2).

Place Figure 2 about here

The proactive and reactive agent take the same amount of time for each action. However, as can be seen in Figures 1 and 2, the order in which actions are taken by the proactive and reactive agents is different. Furthre, at any point in time, the "position" of the proactive and reactive agents in the decision making cycle may be different. Consequently, proactive agents typically take less time than reactive agents because they are already further along on the cycle when a request for a decision arrives.

METHODOLOGY

The performance of the organizations is generated using a computer simulation test-bed built in C within a VAX/VMS system. Using this test-bed, we are able to systematically alter task environment (4), organizational structure (4), task decomposition scheme (4), training scenario (3), agent style (2) which are all built within the test-bed. Thus, 384 organizational types were examined. By varying type (5) and degree (4) of internal stress, we examine 20 internal conditions, with degree 0 as the optimal operating condition. In this experiment, we examine a total of 7,680 cases.

Each case represents an organization faced with a specific internal condition and task environment. The performance of each case/organization is evaluated by examining performance on 1,000 problems. Each problem represents a specific moving aircraft. This study is carried using Monte-Carlo analysis. All characteristics of each problem are randomly generated. These include: the starting position, speed, and nature of the aircraft, the location of the murphies affecting the organization internal, and the maximum time units allowed the organization to make a decision regarding the aircraft.

The 1,000 problems can be classified as being friendly, neutral, or hostile or as being under low, medium, or high time pressure. We can measure performance overall (percentage of problems for which the organization made the correct decisions) or we can measure performance for a subset of the 1,000 problems (e.g., percentage of problems given the true state is hostile for which the organization made the correct decisions). We only examine post-training performance. That is, all agents in all organizations examined are trained on a large set of aircraft and then performance is measured.

Prior to running these 1000 problems (on which performance is measured) all agents in all organizations are trained. Agents are trained in an environment in which there are no murphies and no time pressure. In this study, we examine the behavior of these organizations composed of fully trained agents on 1000 problems. Learning does not continue while working on these 1000 problems. We use the 1000 problems so that we can get an estimate of the expected performance of the organization composed of fully-trained agents. Learning per se does not drive the results obtained from this model. However, the type of training does affect the organization's behavior.

This simulation test-bed offers us the chance to systematically examine the interactions among, and effect of, the various organizational factors on organizational performance that have concerned researchers. Nevertheless, in this paper, our focus is on agent style.

RESULT AND ANALYSIS

Across All Different Levels of Time Pressure

According to the general discussions of the nature of proactive and reactive agent styles in the literature, one might expect the following propositions to hold:

Proposition 1: Agent style does not matter (Mayhew 1980; Wellman 1988).

What this says is that when the structure of the organization and the fit between task environment and organizational structure are considered, organizations compose exclusively of proactive agents (proactive organizations) and organizations compose exclusively of reactive agents (reactive organizations) should exhibit equivalent performance.

Proposition 2: Proactive organizations perform better than reactive organizations (Kraft 1986; Smiar 1992).

Proactive agents are better prepared and can respond faster. Thus, organizations filled with proactive agents should perform better than organizations filled with reactive agents, controlling for all other factors.

Our analysis supports Proposition 1. Whether we consider just experientially trained organization, or operationally trained organizations, or both, there is no difference between the performance of organizations with proactive and reactive agent styles. This is true regardless of external or internal conditions (Table 2). Using a one-tailed t-test for each pair of pro-active and re-active organizations with the same characteristics, there is no difference at the 0.01 significance level. Degrees of Freedom are reported in Table 2.

Similarly, for different organizational structures, for different task decomposition schemes, and for different task environments, there is no difference in the performance of proactive and reactive organizations.

Agent style appears to simply not matter. This result supports Proposition 1 but not Proposition 2. It shows that proactive organizations do not necessarily perform better overall. This result can be attributed to the fact that organizations composed of intelligent agents act as though they have persistent beliefs. New decisions do not replace old ones unless the organization is both highly confident in the new decision and doubtful about the old one. The unwillingness on the part of the organization to change its decision regardless of whether it is proactive or reactive leads to an entrenchment of ideas. In the reactive organization, this entrenchment has little effect since they are so slow to gather new information and change a new decision. However, in the proactive organization, entrenchment mitigates the value of proactive behavior. Despite continually gathering new information and making new decisions, due to entrenchment, the likelihood of the new decision replacing the old decision is relatively low.

Place Table 2 about here

Under High Time Pressure

Under high time pressure, organizations are often overloaded with information. They give up normal "time spending procedures", or normal decision making procedures and mainly make decisions based on hunches (Rosenthal et al. 1989). Thus, agent style should not matter when time is at a premium, controlling for all other factors. This suggests the following proposition.

Proposition 3: Proactive and reactive organizations have the equivalent performance under high time pressure (Rosenthal et al. 1989).

In our analysis, when there is high time pressure on average there is no difference between the performance of proactive and reactive organizations regardless of external conditions. Using a one-tailed t-test for each pair of pro-active and re-active organizations with the same characteristics, there is no difference at the 0.01 significance level. Degrees of Freedom are reported in Table 3. However, if we consider only optimal internal conditions (no murphies), organizations filled with proactive agents perform worse than organizations filled with reactive agents. This is true across all external conditions (one-tailed t-test, $p < 0.001$, DF shown in Table 3), and when just hostile (mayday) conditions are considered (one-tailed t-test, $p < 0.005$, DF shown in Table 3). It is important to note, however, that all organizations under high time pressure are making the right decision approximately 33.33% of the time. If the agents were simply guessing, then organizational performance would in fact be 33.33%. While the proactive organization is slightly worse than the reactive organization neither is noticeably different than an organization that is simply guessing. We must be cautious in interpreting this result as the fact that proactive organizations appear worse may be an artifact that would be eliminated were we to examine organizational performance over more problems. Notice also (Table 3) that regardless of whether we consider just experientially trained organizations or just operationally trained organizations, performance always hovers around 33.33%.

In summary, under extremely high time pressure, organizational performance is essentially reduced to be equivalent to the best that can be expected when agents guess. Consequently, there are no consistent effects that can be attributed to agent style. This generates mixed support for proposition 3.

Place Table 3 about here

Under Medium Time Pressure

Under moderate time pressure, the organizational decision making process should be tightly constrained by time, though not completely disrupted. Thus agent style should critically affect performance, controlling for all other factors.

> Proposition 4: Proactive organizations perform better than reactive organizations under medium time pressure (Jauch and Kraft 1986; Pauchant et al. 1990; Smiar 1992);

Our analysis suggests that on average there is no difference between the performance of proactive and reactive organizations. Using a one-tailed t-test for each pair of pro-active and re-active organizations with the same characteristics, there is no difference at the 0.01

significance level. Degrees of Freedom are reported in Table 3. This is true regardless of external or internal conditions (Table 3). However, when we consider the type of training that the agents have received, we see significant performance differences due to agent style under suboptimal operating conditions (murphies).

In experientially trained organizations, if we average across all operating conditions, or consider just optimal internal operating conditions, there is no difference between the performance of proactive and reactive organizations, regardless of external conditions. Using a one-tailed t-test for each pair of pro-active and re-active organizations with the same characteristics, there is no difference at the 0.01 significance level. Degrees of Freedom are reported in Table 3. Under suboptimal internal operating conditions, organizations filled with experientially trained proactive agents outperform organizations filled with experientially trained reactive agents. This is true both across all external conditions (one-tailed t-test, $p < 0.001$, DF shown in Table 3), and under maydays (one-tailed t-test, $p < 0.001$, shown in Table 3). The performance comparisons between proactive and reactive organizations are also illustrated in Figure 3. A similar pattern occurs for operationally trained organizations.

Place Figure 3 about here

In summary, under medium time pressure, agent style affects organizational performance only under suboptimal internal operating conditions. In this case, organizations filled with proactive agents outperform organizations filled with reactive agents. Thus, Proposition 4 is supported only, under suboptimal conditions. Proactive agents benefit the organization, but that benefit is most apparent when time is somewhat constrained and things are going wrong.

Under Low Time Pressure

Under low time pressure, organizations have enough time to make decisions regardless of external or internal conditions. It is usually efficient to use reactive style as it offers a comparable performance with proactive style, but with lower operating costs (Sussman 1984). Thus, we should expect no difference in the performance of organizations with either proactive or reactive style when time is not critical, controlling for all other factors.

<u>Proposition 5:</u> Proactive and reactive organizations have the equivalent performance under low time pressure (Sussman 1984).

In our analysis, when considering either experientially trained organizations, or operationally trained organizations, or both, there is no difference between the performance of organizations with proactive and reactive agent styles. Using a one-tailed t-test for each pair of pro-active and re-active organizations with the same characteristics, there is no difference at the 0.01 significance level. Degrees of Freedom are reported in Table 3. This is true regardless of external or internal conditions (Table 3). Thus, under low time pressure, there is virtually no effect of agent style on organizational performance. This result supports Proposition 5.

DISCUSSION AND CONCLUSION

This analysis is mainly based on simulation techniques. Those simulated organizations have enabled us to examine the effect of agent style across numerous factors that have interested researchers in organizations within a reasonably short period of time. In fact, to examine these same factors using human subjects would have taken at least ten years and cost at least one million dollars. Computer simulation is a powerful extension of human cognition. 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". Fararo (1989) also regards computational process as one of the three processes (the other two are theoretical and empirical processes) necessary to the development of any discipline.

In this research, our focus is on the effect of one aspect of agent style (proactiveness/reactiveness) on organizational performance, not on the origin of agent style. We believe further understanding of the sources of agent style is necessary for future research into the effect of agent style. More aspects of agent style such as emotion and creativity may also be included in future research on agent style. In addition, future research, we would also like to examine more real world organizations, thus providing new insight into this theoretical study.

We categorized time pressure into three levels according to the time units assigned to the organization or the time units spent when the organization has to make a decision before the aircraft reaches a certain point. It is difficult to disentangle time pressure from organizational design and task environment, because a high time pressure to some organizations may not be as stressful as to other organizations. In the case of a team with a manager versus a matrix organization given the same task decomposition scheme, the organization will need more time in the matrix organization than in the team with a manager organization, thus time pressure may not have the same effect on them.

Also, the effect of time pressure may also be different on differently trained organizations. An operationally trained organizations usually requires less time to proceed a normal decision than an experientially trained organization. In this paper, this is represented by the time units needed for each operation, with operational decision making procedure needing less time units than experiential decision making procedure given the same amount of information.

The fact that organizational form (structure and task decomposition scheme), and task environment do not change the pattern of effect of agent style shows that this aspect of agent style is a relatively weak factor in organizational decision making performance, compared with factors such as organizational structure, task decomposition scheme, and task environment.

In this paper, we have studied the effect of one aspect of agent style — proactiveness/reactiveness — on organizational performance. Our results show that on average, there is virtually no effect of agent style on organizational performance (support for Proposition 1 but not for Proposition 2). However, if we consider the effect of time pressure we find that in general, only under medium time pressure, does agent style play a large role. Further, under medium time pressure, organizations filled of proactive agents outperform organizations filled with reactive agents, but only if the organization is facing suboptimal operating conditions. Further, there is basically no interaction effect between agent style (proactiveness/reactiveness) and structure, task decomposition scheme, training scenario, or task environment, on performance.

There is, however, an interaction effect between agent style and stress. The results suggest that under optimal operating conditions (without internal stress), agent style does not matter. Under maydays, again, agent style does not matter. However, if murphies are present whether or not the organization is in a mayday situation, agent style matters.

On average, then, we find support for the implication of network theory and contingency theory that agent style does not matter. A closer look, however, where we control for the effects of time pressure, reveals that behaviorists and crisis analysts are indeed right that agent style can matter. Our results suggest that this apparent contradiction is due to agent style being largely irrelevant except in highly specific situations and in those situations, agent style plays a critical role.

The situation where agent style has the most consistent and noticeable effect is when there is moderate time pressure and the organizations is facing various obstacles that limit its information processing capabilities (erroneous information, incomplete information, and so forth). One could argue that this situation is a fairly common situation (March and Olsen 1976).

The result that agent style in most situations is irrelevant to organizational performance shows that the amount and frequency of information used in decision making may not characterize the quality of decisions. The myth around proactive agent style can probably be attributed to the fact that organizations often collect information for "signal and symbol" purpose rather than for decision making purpose (Feldman and March 1981).

To conclude, we find support for the implication of network theory and contingency theory that agent style often does not matter. Organizations should spend more resources on designing better organizations and ensuring the quality of information than about the amount and frequency of information in decision making.

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APPENDIX

Table A1: Preference Function for Proactive Agent

Top Manager:

repeat the following actions until time expires or the decision process is stopped:
if remaining time is enough for another round of decision (either experiential or operational),
check decision buffers for passed up decisions:
    if there are decisions passed up, read decisions from decision buffers, make a decision,
        if the current decision is better according to certain standards,
        update the organizational decision
        else no update, ask for more information
    else ask for information, or wait if already asked
else if there is a previously made decision,
    pass up (or conclude) the decision, and stop the organizational decision process,
    else make a random decision, pass up (or conclude) the decision, and stop the organizational decision process.

Middle Manager:

if there is no request from upper manager for decision, repeat the following actions:
    if remaining time is enough for making another round of decision,
    check decision buffers for passed up decisions:
        if there are decisions passed up, read decisions from decision buffers, make a
        decision, and pass up the decision,
        else ask for information, or wait if already asked,
    else if there is a previously made decision,
        interrupt the current action, pass up the decision, and continue the current action,
        else continue the current action,
else if there is a previously made decision,
    interrupt the current action, pass up the last made decision, continue the interrupted action,
    else continue the current action.

Baseline Analyst:

if there is no request from upper manager for decision, repeat the following actions:
    if remaining time is enough for making another round of decision,
    read radar equipment, make a decision, and pass up the decision,
    else if there is a previously made decision, interrupt the current action, pass up the last made
    decision, continue the interrupted action,
        else continue current action
else if there is a previously made decision, interrupt the current action, pass up the last made decision,
    and continue the interrupted action,
    else continue the current action.

Table A2: Preference Function for Reactive Agents

Top Manager:

repeat the following actions until time expires or the decision process is stopped:
if remaining time is enough for making another round of decision,
check the decision buffers for passed up decisions:
    if there are decisions passed up, read decisions from decision buffers, make a decision, pass up the decision, and stop the organizational decision process,
    else if the action of asking for information was not taken before,
        ask for information,
        else wait,
else make a random decision, pass up (or conclude) the decision, and stop the organizational decision process.

Middle Manager:

if there is no request from upper manager for decision,
repeat the action: wait
else if there is a previously made decision,
    pass up the decision,
    else no decision is passed up;
    if remaining time is enough for making another round of decision,
    check the decision buffers for passed up decisions:
        if there are decisions passed up, interrupt the current action, read decisions from decision buffers, make a decision, pass up the decision, and continue the interrupted action,
        else if the action of asking for information was not taken before,
            ask for information, and continue the interrupted action,
            else continue the interrupted action.

Baseline Analyst:

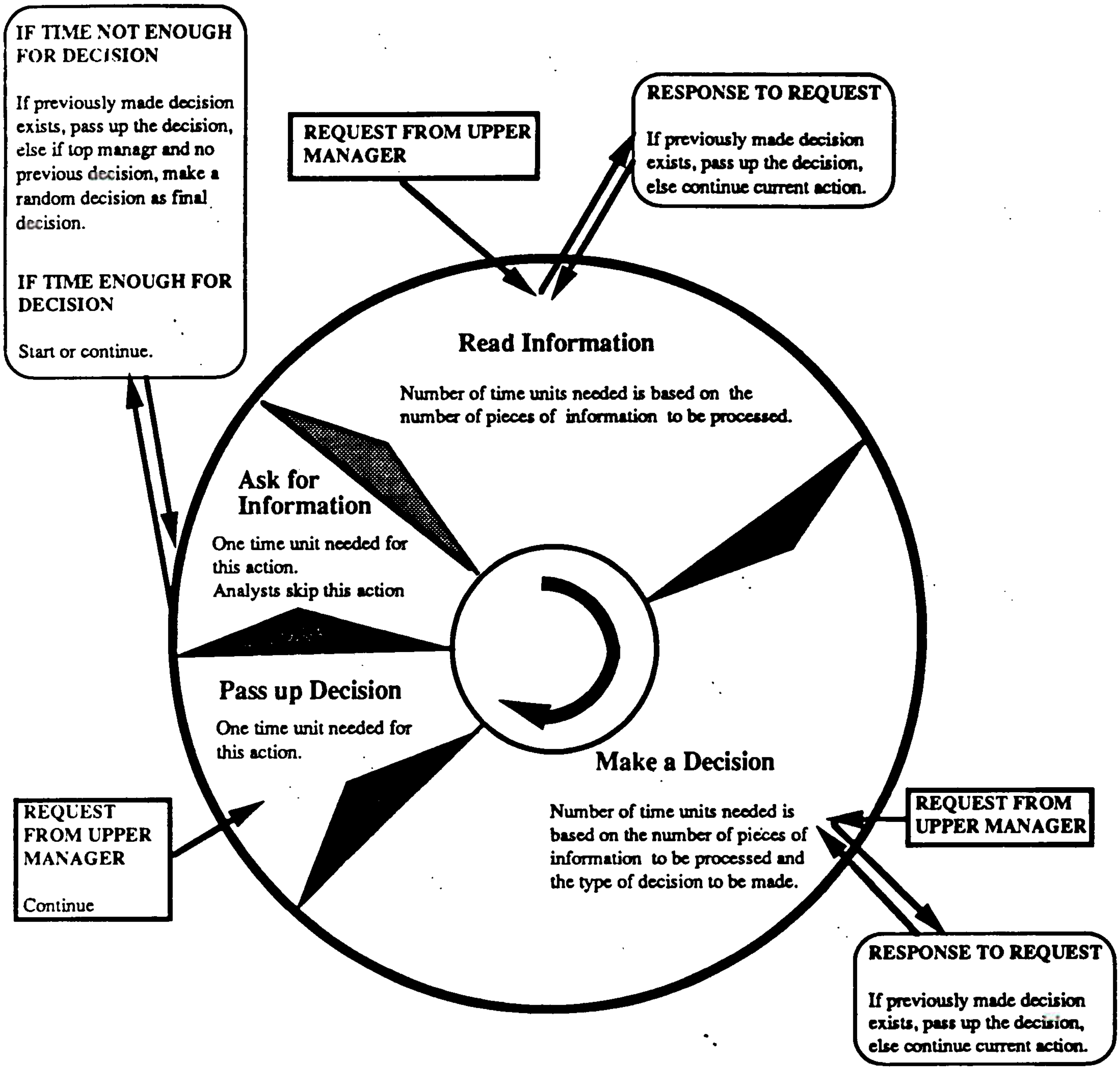
if there is no request from upper manager for decision,
repeat the action: read radar equipment,
else if there is a previously made decision,
    pass up the last made decision,
    else no decision is passed up;
    if remaining time is enough for making another round of decision,
    read radar equipment (if not finished yet), make a decision, pass up the decision, and continue the interrupted action,
    else continue the interrupted action.

Figure 1. Preference Function of Proactive Agents

Figure 2. Preference Function of Reactive Agents

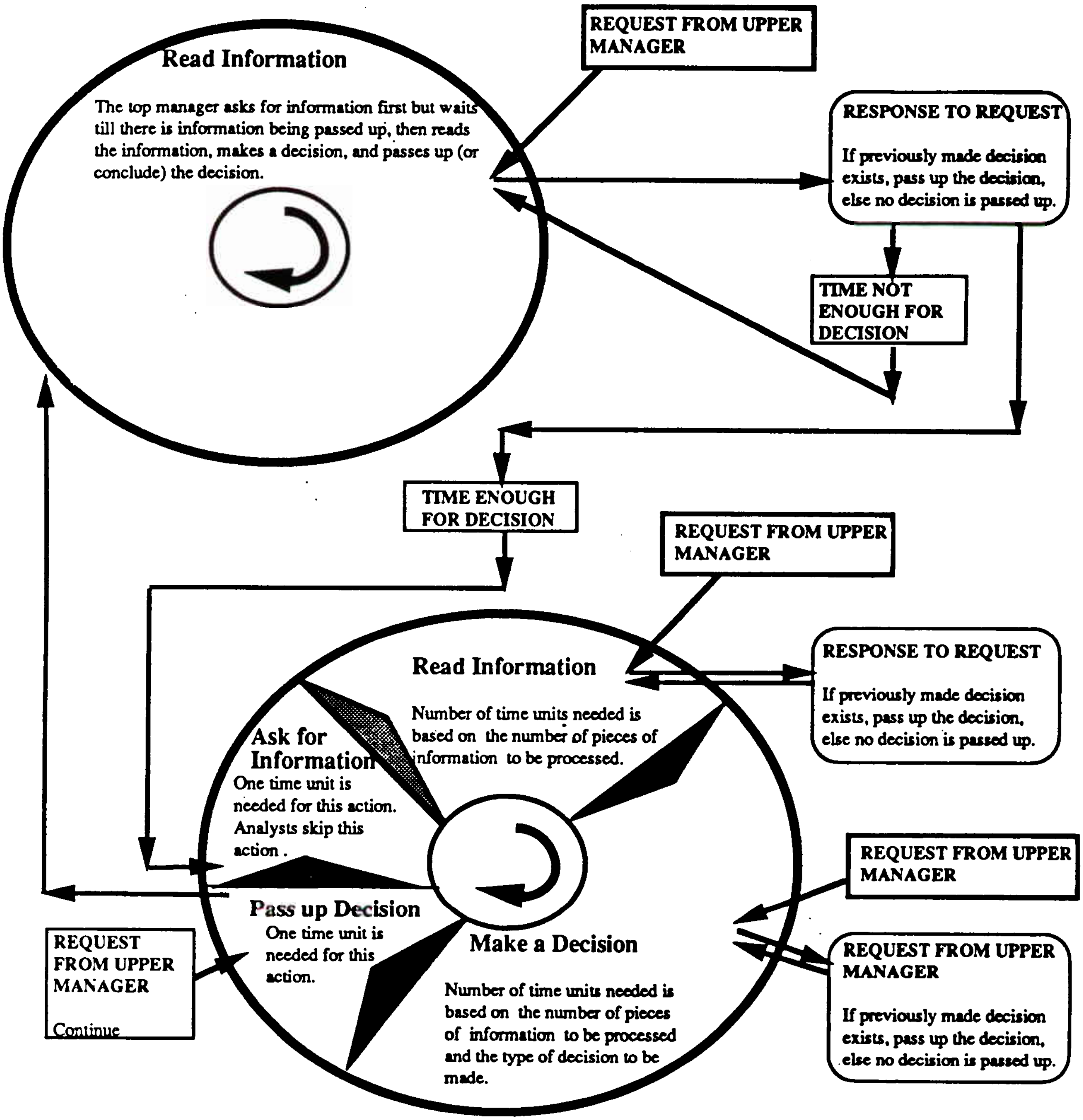
Figure 3. Performance by Agent Style under Medium Time Pressure

Figure 1. Preference Function of Proactive Agents



Note: If no request from upper manager, the agent continues current action. Also, for the top manager, there is no interruption.

Figure 2. Preference Function of Reactive Agents



Note: If there is no request from an upper manager, the agent continues current action. Also, for the top manager, there is no interruption.

Figure 3. Performance by Agent Style under Medium Time Pressure

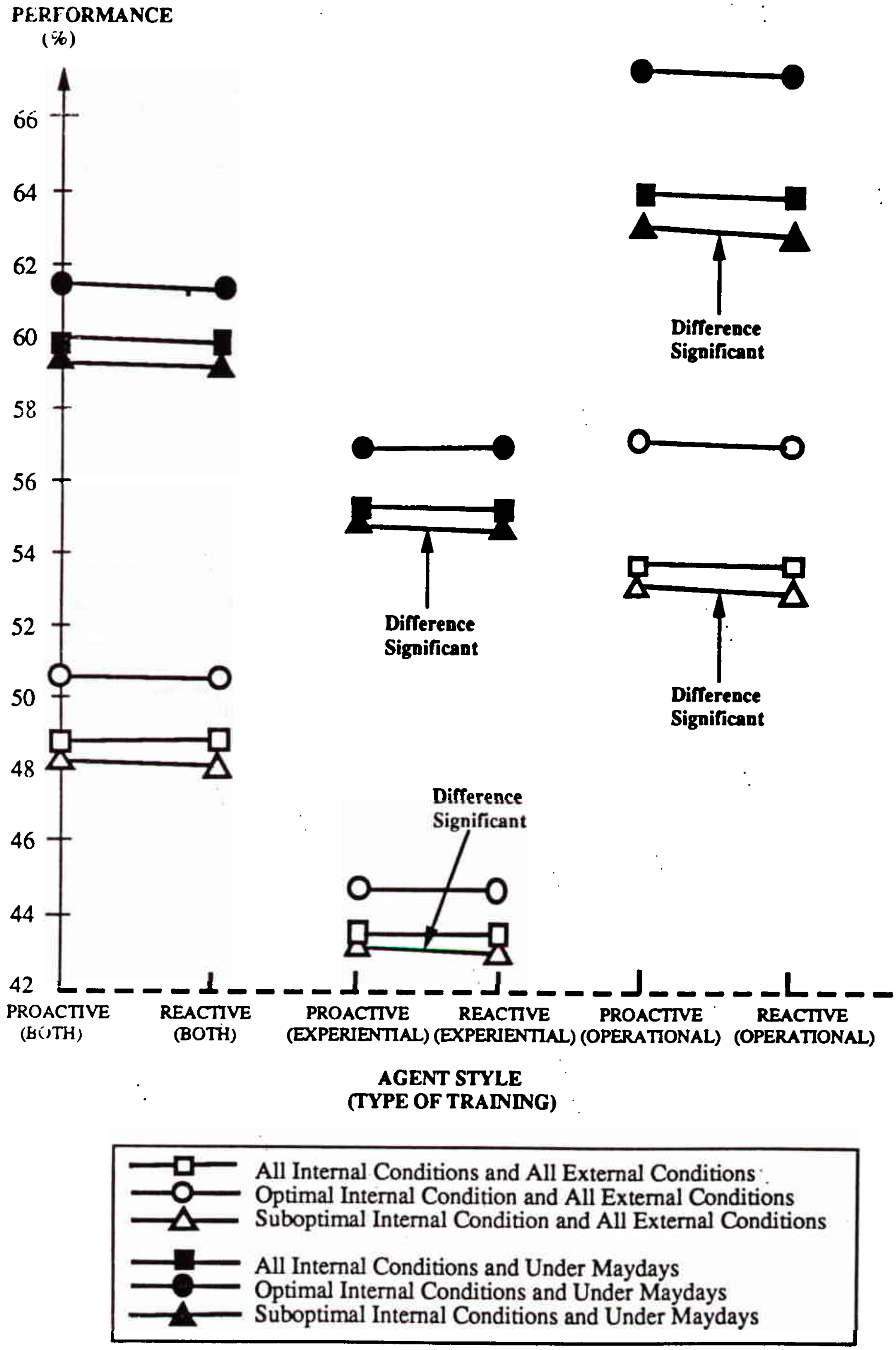

PERFORMANCE
(%)
66
64
62
60
58
56
54
52
50
48
46
44
42
Difference Significant
Difference Significant
Difference Significant
Difference Significant
PROACTIVE (BOTH)
REACTIVE (BOTH)
PROACTIVE (EXPERIENTIAL)
REACTIVE (EXPERIENTIAL)
PROACTIVE (OPERATIONAL)
REACTIVE (OPERATIONAL)
AGENT STYLE
(TYPE OF TRAINING)
All Internal Conditions and All External Conditions
Optimal Internal Condition and All External Conditions
Suboptimal Internal Condition and All External Conditions
All Internal Conditions and Under Maydays
Optimal Internal Conditions and Under Maydays
Suboptimal Internal Conditions and Under Maydays

Table 1: Agent's Possible Actions

Name of Action	Time Units Needed for Action	Prerequisite Action
Ask for Information	1	
Read Information	1 * Number of Pieces of Information to be Processed	Ask for Information
Make a Decision	• Untrained or Random Decision — 1 • Operationally Trained Decision — 1 * Number of Pieces of Information to be Processed • Experientially Trained Decision — 2 * Number of Pieces of Information to be Processed	Read Information
Pass up a Decision	1	Make a Decision
Wait	1	

Note: Each time unit equals 2 seconds of real time. This is according to initial lab experiments using human subjects on decision making by Kathleen Carley and Michael Prietula of Carnegie Mellon University. In the experiment each subject processes 120 problems in about 40 minutes, which is about 20 seconds for each problem. For every problem, a subject reads three pieces of information (3 units), makes experiential decision (6 units), and passes the decision (1 unit). Thus if we let x as the seconds in each time unit, we have $3x + 6x + x = 20$, or $x = 2$. Also, for analysts, there is no prerequisite action for the action Read Information.

Table 2: Performance by Agent Style across all Levels of Time Pressure

With Either Experiential or Operational Training			
External Condition	Internal Condition	Agent Style: Proactive	Agent Style: Reactive
Across All	Overall	47.00 (7680,0.20)	46.94 (7680,0.20)
	Optimal	48.64 (1920,0.39)	48.69 (1920,0.39)
	Murphies	46.44 (5760,0.20)	46.36 (5760,0.20)
Maydays	Overall	57.14 (7680,0.26)	57.04 (7680,0.26)
	Optimal	59.01 (1920,0.57)	59.01 (1920,0.57)
	Murphies	56.53 (5760,0.30)	56.39 (5760,0.30)

With Experiential Training			
External Condition	Internal Condition	Agent Style: Proactive	Agent Style: Reactive
Across All	Overall	46.11 (3840,0.29)	46.08 (3840,0.29)
	Optimal	47.28 (960,0.57)	47.32 (960,0.57)
	Murphies	45.72 (2880,0.31)	45.66 (2880,0.31)
Maydays	Overall	59.47 (3840,0.32)	59.39 (3840,0.32)
	Optimal	61.30 (960,0.90)	61.35 (960,0.89)
	Murphies	58.85 (2880,0.49)	58.74 (2880,0.49)

With Operational Training			
External Condition	Internal Condition	Agent Style: Proactive	Agent Style: Reactive
Across All	Overall	47.86 (3840,0.24)	47.81 (3840,0.24)
	Optimal	49.99 (960,0.53)	50.06 (960,0.53)
	Murphies	47.16 (2880,0.24)	47.06 (2880,0.24)
Maydays	Overall	54.83 (3840,0.33)	54.70 (3840,0.33)
	Optimal	56.71 (960,0.70)	56.68 (960,0.69)
	Murphies	54.20 (2880,0.36)	54.04 (2880,0.36)

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

Table 3: Performance by Agent Style and Level of Time Pressure

Training Type	External Condition	Internal Condition	Level of Time Pressure: High Time Pressure, Agent Style: Proactive	High Time Pressure, Agent Style: Reactive	Medium Time Pressure, Agent Style: Proactive	Medium Time Pressure, Agent Style: Reactive	Low Time Pressure, Agent Style: Proactive	Low Time Pressure, Agent Style: Reactive
Across Both Training	Overall	Overall	33.47	33.47	48.70	48.55	58.79	58.81
		(2560)	(0.05)	(0.05)	(0.23)	(0.23)	(0.31)	(0.31)
		Optimal	33.52	33.66	50.41	50.39	61.98	62.02
		(640)	(0.10)	(0.10)	(0.52)	(0.52)	(0.68)	(0.67)
		Murphies	33.46	33.41	48.13	47.94	57.73	57.74
		(1920)	(0.06)	(0.06)	(0.25)	(0.25)	(0.35)	(0.35)
	Maydays	Overall	33.43	33.41	59.73	59.51	78.27	78.21
		(2560)	(0.08)	(0.07)	(0.32)	(0.31)	(0.39)	(0.39)
		Optimal	33.52	33.63	61.67	61.61	81.82	81.80
		(640)	(0.15)	(0.15)	(0.68)	(0.67)	(0.78)	(0.78)
		Murphies	33.41	33.34	59.09	58.81	77.09	77.02
		(1920)	(0.09)	(0.09)	(0.36)	(0.35)	(0.44)	(0.44)
Experiential Training	Overall	Overall	33.27	33.24	43.69	43.54	61.38	61.45
		(1280)	(0.07)	(0.07)	(0.29)	(0.29)	(0.51)	(0.51)
		Optimal	33.27	33.31	44.38	44.39	64.18	64.27
		(320)	(0.13)	(0.14)	(0.60)	(0.59)	(1.02)	(1.02)
		Murphies	33.27	33.22	43.45	43.26	60.44	60.51
		(960)	(0.08)	(0.08)	(0.33)	(0.33)	(0.59)	(0.58)
	Maydays	Overall	33.18	33.25	55.38	55.14	89.84	89.79
		(1280)	(0.10)	(0.10)	(0.45)	(0.43)	(0.42)	(0.42)
		Optimal	33.27	33.41	56.39	56.42	94.25	94.21
		(320)	(0.21)	(0.20)	(0.93)	(0.90)	(0.65)	(0.67)
		Murphies	33.15	33.19	55.05	54.71	88.37	88.31
		(960)	(0.12)	(0.12)	(0.51)	(0.49)	(0.51)	(0.50)
Operational Training	Overall	Overall	33.67	33.71	53.71	53.56	56.21	56.17
		(1280)	(0.08)	(0.07)	(0.29)	(0.29)	(0.35)	(0.36)
		Optimal	33.77	34.01	56.44	56.40	59.77	59.77
		(320)	(0.16)	(0.15)	(0.71)	(0.70)	(0.86)	(0.86)
		Murphies	33.64	33.61	52.80	52.61	55.02	54.97
		(960)	(0.08)	(0.08)	(0.31)	(0.31)	(0.37)	(0.37)
	Maydays	Overall	33.69	33.57	64.09	63.88	66.71	66.64
		(1280)	(0.11)	(0.11)	(0.42)	(0.42)	(0.46)	(0.46)
		Optimal	33.77	33.85	66.96	66.79	69.40	69.40
		(320)	(0.22)	(0.21)	(0.91)	(0.89)	(1.01)	(1.01)
		Murphies	33.66	33.48	63.13	62.92	65.81	65.72
		(960)	(0.12)	(0.12)	(0.47)	(0.47)	(0.51)	(0.52)

Note: Performance is in percentage. Number of cases for each row is listed in the parenthesis in the column titled Internal Conditions. Standard errors are in parentheses below performance.