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EFFECTS OF ORGANIZATIONAL STRUCTURE ON PERFORMANCE: EXPERIMENTAL RESULTS*

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ABSTRACT

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INTRODUCTION

Distributed decision making (DDM) organizations consist of human decision makers (DMs) and equipment, structured so as to accomplish a set of given tasks. In the past few years, several research efforts have been started to explore the characteristics of DDM organizations and related design and evaluation methodologies.

One such effort has focussed on the development of a design and evaluation methodology for distributed decision making organizations (Boettcher and Levis, 1983, Tomovic and Levis, 1984, Jin, Remy, and Levis, 1986, Andreadakis and Levis 1987, and Remy, Levis, and Jin, 1988). The theory is based on the mathematical model of the interacting decision maker with bounded rationality (Boettcher and Levis, 1982). The design process starts with the generation of organizational structures for a given task. Then, the procedures and protocols needed to perform the task are determined. The task is characterized by the input uncertainty that needs to be reduced in order to make decisions. Information theory is applied to compute the entropy of the input, a measure of uncertainty. Then, the performance of the organizational design can be evaluated (Levis, 1990). While the model and the methodology were motivated by empirical evidence from a variety of experiments and by the concept of bounded rationality, there were no direct experimental data to support it. An experimental program was undertaken to test the theory and obtain values for the model parameters. The problems under study are those that relate organizational structure directly to performance, as measured by accuracy and timeliness and, more indirectly, to cognitive workload. The first experiment was a single person experiment designed to verify the existence of the bounded rationality constraint (Louvet, Casey, and Levis, 1988). The experiment provided evidence that bounded rationality exists and that for well-defined tasks the onset of degradation of performance that it causes can be predicted.

To explore the characteristics of organizational performance, multi-person experiments are necessary. The study reported in this paper shows the results from a model-driven, multi-person experiment which is designed to investigate the effect of organizational structure on performance of DDM organizations.

METHODOLOGY

In the experiments involving distributed decision making and human subjects, the major difficulties are that too many variables are involved and too many uncertainties exist in controlling the experiment. Furthermore, which variables should be varied and over what range become critical question in the experimental design. A methodology is presented in this section that addresses these issues and guides the design of model-driven experiments.

Distributed decision making organizations operate in an environment which changes dynamically. A change in the environment acts as a stimulus to the organization which in turn senses the stimulus and processes it to infer what the situation is. Then, according to rules and procedures, the organization selects a response to the environmental change.

In many distributed decision making tasks, time constraints play an important role. For a given task, there is only a limited period of time during which the organizational response will be effective. This time period is called the window of opportunity. A response produced too early or too late, i.e., outside of the window of opportunity, does not address the requirement of the task. Therefore, in order to respond effectively, the tempo of operations has to adjust to the available time.

Human decision makers are a critical component in DDM organizations. Because of their bounded rationality in processing information and making decisions, organizational performance degrades if human DMs are overloaded.

These three features specify the context in which a model-driven experiment will be conducted.

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There are four major stages in the methodology for designing model-driven experiments: (1) Theoretical analysis; (2) Experimental investigation; (3) Experimental data analysis; and (4) Comparison of the theoretical and experimental results. In addition, there is a step for time scale calibration. This is not considered as a major stage because a small separate pilot experiment is sufficient to determine the time range for a given task. Figure 1 shows the block diagram of the methodology.

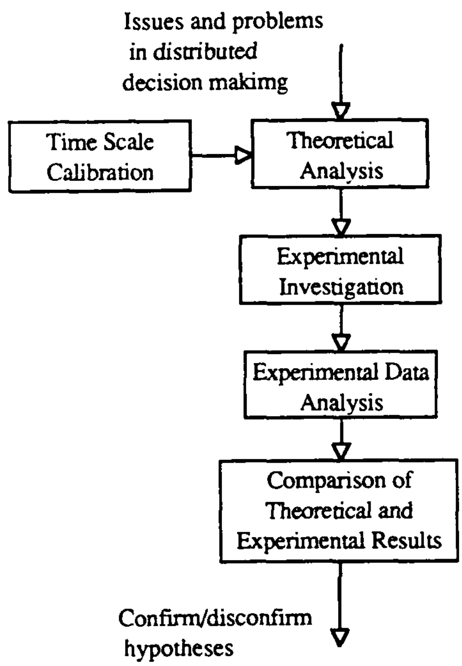

Figure 1 The Methodology for Experimental Design

The steps in each of the four design stages of the methodology are described in the following. The implementation of these steps will be shown through an application in the next section. It is assumed that the time scale calibration has been done (see Jin, 1990).

Theoretical Analysis

A task which will be performed by an organization is selected. This task should reflect the problems and issues to be investigated. The same task is used both in the theoretical analysis and in the experiment.

After defining the task, an organization is designed to carry out the task. The design of an organization includes the determination of the protocol and the procedures to be used in carrying out the task. The organization is modeled using the Petri Net representation.

The evaluation procedure (CAESAR[1]), which includes simulating the operation of the organizations and computing the cognitive workload using information theory (Boettcher and Levis, 1983), is used to obtain performance measures analytically. From these predictions, the Performance-Workload locus (P-W locus) can be constructed. The characteristics of the P-W locus lead to the generation of hypotheses on organizational behavior.

Experimental Investigation

An experiment is designed to test the hypotheses. The complexity of the DDM organization results in a large number of parameters and in much uncertainty regarding their values. To determine the controlled and the measured parameters, dimensional analysis is applied after being extended to include the cognitive aspects of distributed decision making (Jin and Levis, 1988). Dimensional analysis (Hunsacker, 1947, Gerhart, 1985) is a scientific and engineering method for designing experiments.

In order to carry out the experiment, the range of the controlled parameters needs to be specified. The result from the time scale calibration can be used to estimate a range for the available time. The number of trials for each value of controlled parameters must also to be determined.

A pilot experiment is necessary to test the entire experimental design. Then, the actual experiment is carried out and experimental data are collected.

Experimental Data Analysis

In this stage, the collected data are analyzed and processed to obtain the measures of performance. The procedures for testing the hypotheses are determined. These procedures are usually statistical ones. To apply the procedures, the hypotheses developed in the theoretical analysis may need to be transformed into an explicit form which can be tested directly. All variables involved in the hypothesis testing are gathered and stored in an appropriate format for the test.

Comparison of Theoretical and Experimental Results

This is the last stage in which the hypotheses are tested using the experimental data. The theoretical and experimental results are compared to assess the model's ability to predict organizational behavior. Final conclusions are drawn.

APPLICATION

The methodology described in the previous section is used to design a multi-person experiment for investigating the effect of organizational structure on performance. In this section, the experiment is described. The first stage and the second stage of the methodology are implemented.

Description of the Task

Defense in a naval outer air battle is chosen as the task to be performed by two small (three person) decision making organizations. The objective of a naval outer air battle is to monitor incoming enemy aircraft and deploy interceptors to engage threats so as to prevent the enemy from entering the range where missiles can be fired at ships in the battle group.

In this environment, a team of DMs forms an outer air battle group to perform the above task. Specifically, the task of the DMs is to detect incoming enemy aircraft ("threats"); find out the type and the number of threats; then allocate their own aircraft ("resources") to intercept the threats.

Figure 2 depicts a hypothetical naval outer air battle environment. The carrier is at the center of the circles. Airborne warning radar aircraft (E2C) patrol the area at a distance R_p from the carrier. Each E2C commands several squadrons of interceptors, which can intercept directly the threats. The E2Cs are equipped with passive radar (ESM) and active radar. ESM

[1] CAESAR (Computer Aided Evaluation of Systems Architectures) is a noncommercial set of programs developed at MIT.

receives the radar transmission of other aircraft while active radar receives the reflection of its transmission by other objects. The ESM has a range of R_0 and the active radar has a range of R_a ($R_0 > R_a$). Assume that the range of the enemy's missiles is R_m.

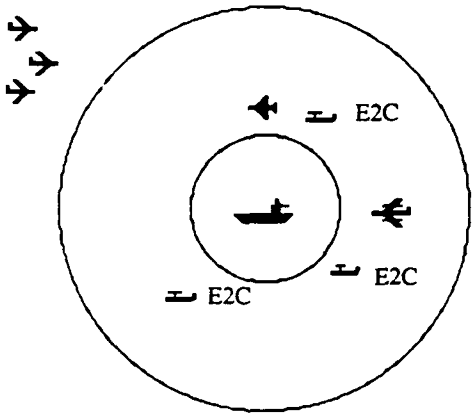

Figure 2 A Naval Outer Air Battle Environment

ESM has a larger range for detecting incoming threats but provides less specific data than the active radar: the presence and bearing (direction to) of the threats. The active radar provides more detailed data such as the position and speed of a threat. The signature of an aircraft is provided by ESM when the threat is closer. An emitter signature indicates the existence of an aircraft with its corresponding emitter.

The E2C initially operates only ESM to avoid being detected by the enemy's radar. When enemy aircraft approach the E2C, and are within a range R_a, the E2C turns on the active radar. When all information (speed, emitter signature, and so on) about a threat is available, the enemy aircraft can be identified. Correlation between the emitter signature and the speed of the aircraft can be used to classify the type of the aircraft with some level of certainty.

Based on the assessment of incoming threats, the E2C mission commanders allocate resources to intercept the enemy aircraft. The resources are Tomcat fighter aircraft (F14), Hornet fighter/attack aircraft (F18), and Prowler aircraft (EA-6B).

There are situations in which uncertainty and conflict exist. For example, there may be a threat detected by more than one E2C. Then, the question becomes one of determining who is going to deal with it. In a situation like this, coordination between organizational members is necessary. The coordination is done through communication. In addition, the E2C mission commanders may have to communicate with the outer air warfare commander on the carrier to report the situation or to ask him to launch more interceptors. The protocol for communication is different for different organizational structures.

When an enemy aircraft enters its missile range R_m without being engaged by interceptors, the nature of the task changes to the inner air battle, and the outer air battle is over. Therefore, if enemy aircraft are not intercepted before they enter the inner air battle region, the outer air battle defense is considered to have failed.

The above description of the naval outer air battle has been abstracted from actual operation for the purpose of the study. However, the abstraction and simplification are such that it may not reflect the reality of naval operations.

The implementation of the first two stages of the methodology are described as follows.

Theoretical Analysis

To perform the task described above, two three-DM organizational structures are considered: a parallel one and a hierarchical one. In the parallel structure (Fig. 3), all DMs are at the same level of authority. They are working together in coordination. In the hierarchical structure (Fig. 4), authority varies with the rank of a DM, that is, the position a DM holds in the organization. DM2 in Fig. 4 plays a supervisory role in the coordinating other two DMs. In both structures, the task is the same and members of the organization have to act as a team to perform the task.

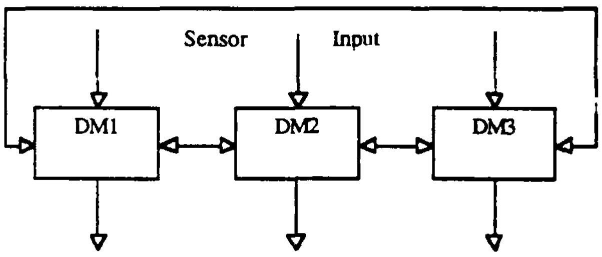

Figure 3 Parallel Organization

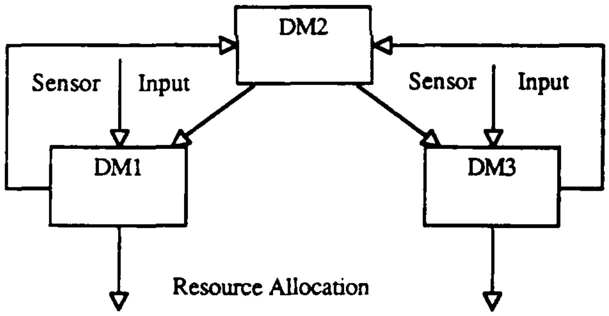

Figure 4 Hierarchical Organization

The procedure is as follows. When threats are detected, the situation has to be assessed. The situation assessment (SA) function provides information such as the number of threats, the position and speed of the threats, the type of the threats, and the number of aircraft in each threat. The situation assessment involves data gathering and processing because some of the information can be directly obtained from the observed data while other information is available only after the raw data are processed. Depending on the particular situation, communication may be required after the situation assessment. The results of the communication are processed in the information fusion stage for the parallel structure and in the command interpretation for the hierarchical structure. The last stage is the response selection stage. On the basis of the fusion data or command interpretation results, resources can be allocated to counter the threats. The task is completed after resources are allocated. The following paragraphs briefly describe the procedures for the parallel and hierarchical organizations. For the detailed description, see Jin (1990).

Parallel Organization

In the parallel organization, the defense area is divided into three sectors. Each DM is an E2C mission commander and is responsible for one sector, that is, this DM is responsible for all threats in the sector and only this sector. There are overlap areas between the sectors. In Fig. 5, the solid straight lines in the radar screen divide the defense area into three sectors. The area of responsibility of a DM is the white sector bounded by two solid straight lines. The unshaded areas bounded by dotted lines are the overlap areas between the sectors. Each DM can see a part of the other two sectors. Therefore, the area that can be seen by a DM, defined as the observation area, is shown by the area without shading. A threat in the shaded area cannot be seen by and is out of the region of responsibility of this DM.

It should be clear that there are two areas for each DM in which the responsibilities are different. One is the observation area, the white area in Fig. 5, which includes the sector and the overlap areas of other two adjacent sectors. Another is the sector, bounded by solid lines in Fig. 5. The threats in the observation area can be detected and the information about these threats can be obtained. However, a DM can only allocate resources and intercept the threats in *his* sector.

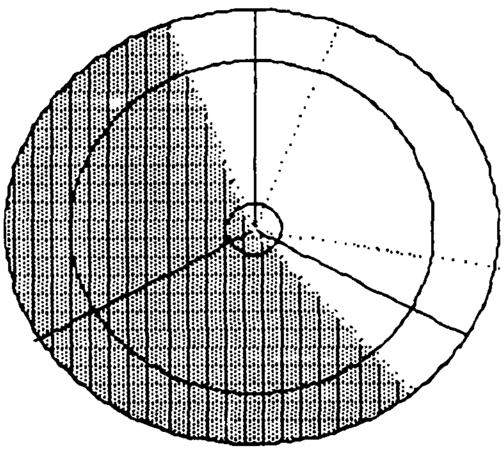

Figure 5 Defense Area Divided into Three Sectors

The threats which are not in the overlap area can be processed without exchanging information with the adjacent DMs because only the local DM can observe these threats. For the threats in the overlap area, partial information is received, therefore, coordination with other DMs in the team is necessary. Coordination takes place through communication. In the real environment of an outer air battle, the procedure for coordination is quite complex. In this experiment, the procedure is simplified so that it is controllable and so that it serves the purpose of the experiment.

Hierarchical Organization

In this organization, the defense area is divided into two sectors. Two DMs are E2C mission commanders and play the role of subordinates. Only subordinates can observe the defended area directly. The third DM is the commander on the carrier; he performs a supervisory role and coordinates the two sectors. As in the parallel organization, each subordinate is responsible for monitoring and intercepting the threats in one sector. If there is any conflict, that is, threats are in the overlap area, subordinates have to report the situation from their perspective to the supervisor. Then they have to wait for commands from the supervisor before prosecuting this threat. After receiving the command, a subordinate interprets the commands by combining the local situation assessment and the commands by combining the local situation assessment and the commands, then makes the final decision on the resource allocation (RS). The level of interaction is higher in the hierarchical organization than in the parallel organization.

Different algorithms can be used to process information and make decisions in the SA and RS stages. The basic algorithms are: (a) quick estimation with attendant risk of errors and, (b) accurate acquisition (probing) but with time delay. Which one should be chosen depends on a particular situation, i.e., on the level of uncertainty, on the time available, and so on. The characteristics of the two algorithms reflect the tradeoffs between time and accuracy. The choice of different algorithms indicates the strategy used during the execution of the task.

In the theoretical analysis, accuracy J and workload G are computed for all possible strategies. Then, the Performance-Workload (J-G) locus is constructed to predict the organizational performance. For the detailed description of the computation, see Jin (1990).

In Fig.6, the projection of J-G locus on the workload plane for decision makers DM1 and DM2 is shown. To each organizational strategy corresponds a point in the G1-G2 locus, G1 and G2 are the workload of DM1 and DM2 respectively. For the hierarchical organization, DM1 is a subordinate while DM2 is the supervisor.

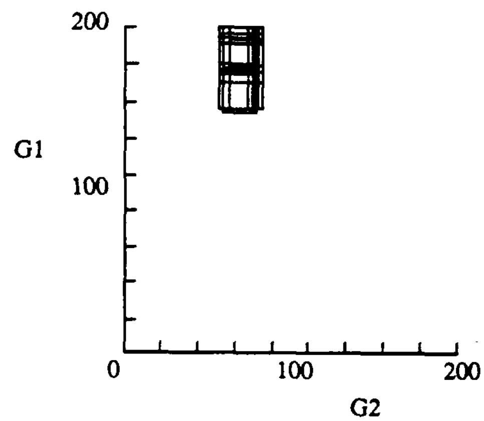

Figure 6 (a) Workload for Hierarchical Organization: Subordinate (G1); Supervisor (G2)

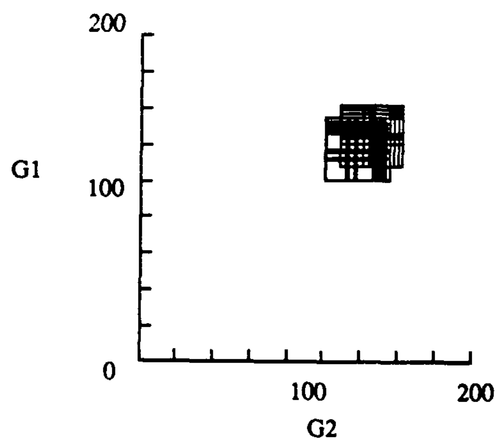

Figure 6 (b) Workload for Parallel Organization: Two Human DMs

It can be seen from Fig. 6 that the subordinate (G1) in the hierarchical organization has the highest workload. Furthermore, while in the parallel organization the workload locus is symmetric - the two DMs shown have the same range for task workload (Fig. 6b) - this is not the case for the hierarchical organization (Fig. 6a). It is argued that in the hierarchical organization with a protocol requiring close interaction among DMs, when one DM's needed task processing rate exceeds his maximum processing rate, the resulting individual degradation in performance will affect organizational performance.

The three dimensional pictures in Fig. 7 show how accuracy changes with workload for both organizational structures for moderate operating times. Hypotheses will be generated now by interpreting the results of the theoretical analysis and aspects of the Performance-Workload locus.

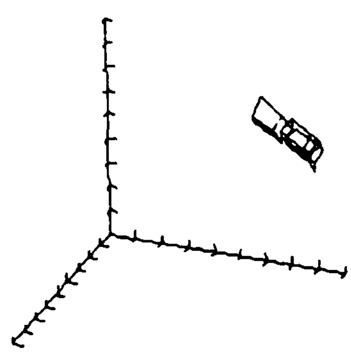

Figure 7 (a) Performance-Workload Locus for Hierarchical Organization: Moderate Speed

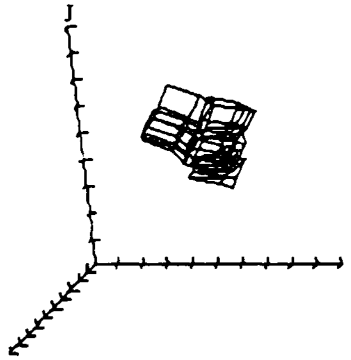

Figure 7 (b) Performance-Workload Locus for Parallel Organization: Moderate Speed

Hypotheses

To generate hypotheses form the model predictions of organizational performance shown in Figs. 6 and 7, let us consider what will happen when the available time decreases.

When T_a decreases, the processing rate F increases while the task workload is kept constant (Jin, 1990). If T_a decreases continuously until the processing rate reaches the maximum value F_{max}, further decrease of T_a will force a reduction of workload which is accomplished by the DM selecting a strategy requiring less workload. This method of coping with time pressure works until the maximum rate F_{max} is attained using the strategy with the least required workload. Then a further decrease of T_a will result in a rapid degradation of performance since no strategy is available to do the task completely. The DM will fail to complete the task and may make random errors on the portion of the task that he completes. Therefore, a hypothesis can be formulated as follows.

Hypothesis 1. When the available time is decreasing, the organization with the highest minimum feasible workload for a given set of strategies will exhibit a performance degradation at a larger value of available time than the organizations which have lower minimum workload.

Because of bounded rationality, DMs will change to strategies with less workload when the available time decreases. From Fig.7, it can be seen that accuracy decreases with an increase of workload. Given that in this experiment the minimum workload strategy yields the highest performance, there is no other strategy available for further reduction of the workload to accommodate a shorter available time when a DM reaches the maximum processing rate, F_{max}, using the minimum workload strategy. Then, the ways to cope with the situation are either to reduce the number of communications or to reduce the number of threats being processed. Since the objective of the naval air battle is to process completely all threats, it is hypothesized that a decision maker will omit some required communication in favor of processing threats in his own sector. While this strategy may improve individual performance, it will cause a rapid degradation in organizational performance, Consequently, the onset of degradation of organizational performance should occur at the same time that the number of communications begins to be reduced.

This can be interpreted as selfish, local behavior. Each DM, under pressure, will attempt to respond to the threats in his sector at the expense of organizational performance. Essentially, this means that under pressure, individual DMs will tend to decouple from the organization by reducing coordination and operating in a decoupled mode. If this were not the case, then degradation of performance will begin before reduction in communications and the latter will be more gradual than performance degradation. For this argument, the following hypothesis is formulated.

Hypothesis 2 Since the minimum workload strategy yields highest performance, under increased time pressure decision makers will reduce communications (coordination) with an attendant reduction in organizational performance.

These two hypotheses will be tested by the experiment.

Experiment

The experiment is based on a simulation of a naval outer air battle (OAB) environment. Human operators interact with the computer simulation of the OAB and make decisions for executing the task. The task is divided into subtasks which are carried out by different DMs in the organization. Each DM has a display to observe the OAB situation. The display consists of a simulated radar screen in which threats are displayed, a board for numerical values, a window showing the resource status, and a communications window displaying the incoming and outgoing messages. In addition, several buttons are present that can be pressed by the DM. The detailed description of the display is given in (Jin, 1990). The interaction between decision makers necessary for completing the task is realized by communication through computer networks.

To investigate the effects of organizational structure on performance, two different structures are used in the experiment. In each organizational structure, decision makers are organized into teams and then these teams perform the task. The performance of the teams is measured.

Dimensional analysis was extended to include cognitive aspect and applied to determine the controlled variables and their ranges in the experiment (Jin, 1990). Two dimensionless variables, time ratio and communication ratio, were suggested by dimensional analysis. The time ratio is defined as the ratio of the actual processing time (T_f) and the available time (T_a) to do a task. The communication ratio is defined as the ratio of the actual number of communications (N_c) and the task-required number of communications (N_{rc}). The task-required number of communications depends on the procedure and protocol of an organization. Later in this paper, these ratios are used to characterize organizational behavior.

The experiment was run with fifteen teams in which each team has two human DMs and one DM role played by a computer. There were 30 human subjects. Among the subjects, 28 were students and two were MIT employees. Seven of the 28 students were graduate students, nineteen were undergraduate students, and two were middle school students. Both MIT employees had college or graduate degrees. The teams were numbered 3 to 17; teams 1 and 2 were the ones that participated in the pilot experiment. The experiment was carried out during the winter Independent Study Period 1990 at MIT, which is about one month long.

EXPERIMENTAL RESULTS

In this section, the observations from the experimental data are discussed. Two important results are drawn from these observations: (a) interaction between organizational members compensated for individual differences; and (b) coordination by the supervisor in the hierarchical organization reduced the variance of organizational performance. The hypotheses generated from the model are then tested.

Organization versus Individuals

When the amount of work required by a task is such that it cannot be handled by a single person, an organization is formed. A properly designed organization will maintain performance at a desired level. Furthermore, organizational performance should not be sensitive to variations in individual skills. Figures 8 and 9 show a comparison of the standard deviation of the accuracy measure for each organization and for individual DMs in the two structures.

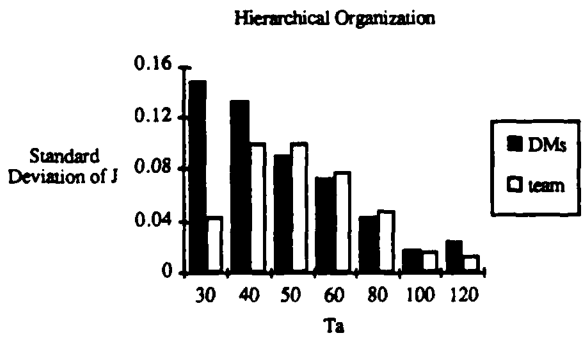

Figure 8 Standard Deviation of J for Teams and Individuals

When the available time is long enough to do the task, the standard deviations between the teams and individuals are very close because the task can be completed accurately and the error is random. However, when time is decreased, individual differences in skills, experience, and capabilities are revealed. The standard deviation of individual performance is high. On the other hand, the organizational performance is more stable. This observation can be explained as follows.

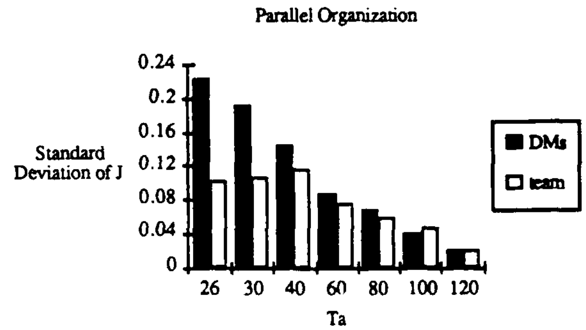

Figure 9 Standard Deviation of J for Teams and Individuals

An organization is designed so that the task is divided into subtasks and allocated to all organizational members. Each of the members in the organization will interact with other organizational members and contribute a part of the effort to perform the task. The decisions of one member will affect the decisions of the other. Therefore, compensatory behavior between the organizational members reduces the variance of organizational performance. As a consequence, organizational performance is less sensitive to individual difference. Both Fig. 8 and Fig. 9 show that the standard deviation of the accuracy measure for teams is much smaller than that of individuals during the fast tempo of the operations.

Although the actual standard deviation is different in the different structures, the phenomenon is observed for both structures. Therefore, it can be concluded that team work reduces the effect of individual differences on performance.

Effects of Organizational Structures

Figure 10 shows the comparison of the standard deviation of the accuracy J for the two structures. The standard deviations are computed across 15 teams for both organizational structures. It can be seen from Fig. 10 that for most values of T_a, J has smaller standard deviation in the hierarchical organization than in the parallel organization. This implies that J of the hierarchical organization is more robust with respect to the individual differences than that of the parallel organization.

The difference in the standard deviation reflects the organizational effects. As already stated, the interaction level in the hierarchical organization is higher than that in the parallel organization. In terms of making decisions, DMs in the parallel organization have more "freedom" to choose what to do than those in the hierarchical organization. Therefore, it is expected that individual difference will have more influence on performance in the parallel organization. On the other hand, the interactions in the hierarchical organization restrict the choices of the decision makers and couple individual decisions with the decisions of other organization members. As a result, individual characteristics tend to be suppressed in the organizational performance.

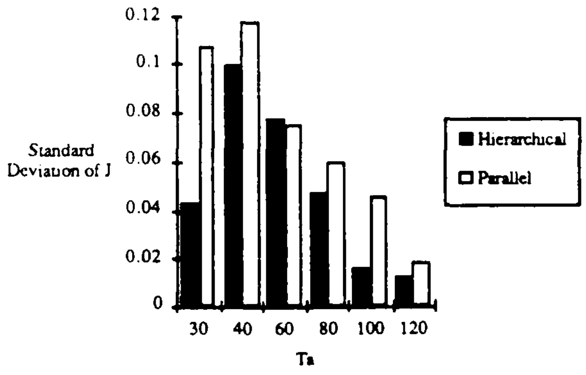

Figure 10 Standard Deviation of J for the Two Structures

Testing the Hypotheses

Hypothesis 1 predicts that the organization with the highest minimum workload will show performance degradation prior to those organizations which have lower minimum workload. From Figs. 6 and 7, it is shown that the subordinates in the hierarchical organization have the highest minimum workload.

Let T^*_h and T^*_p be the available times at which the performance of the hierarchical organization and the parallel organization degrade sharply. Hypothesis 1 can be expressed as follows.

H0: $T^*_h > T^*_p$; Hypothesis 1 is accepted;
H1: $T^*_h \leq T^*_p$; Hypothesis 1 is rejected.

To test Hypothesis 1, the mean values of the critical available times, which is the available time at which performance begins to degrade rapidly, for both organizational structures, need to be computed from the experimental data.

Accuracy versus available time (J-T_a plot) are plotted for each team. Figure 11 is a such plot for one team. The observation from the J-T_a plots indicates that there exists a region in which J starts to degrade rapidly. To estimate the T_a at which such degradation occurs, a piece-wise linear fit is performed. Two asymptotes are found. The intersection point of the two asymptotes can be used to estimate the T* values.

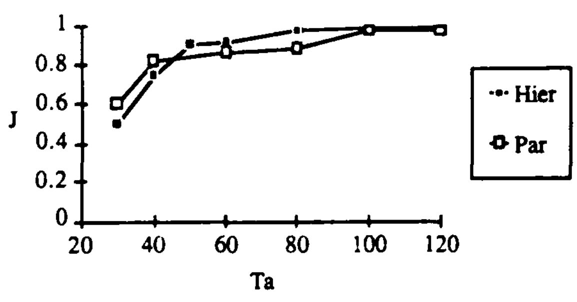

Figure. 11 Accuracy and Available Time for a Team: Team #10

To find the asymptotes, the Least Square (LS) fit is used. As an example, Fig. 12 shows the original curves and the asymptotes found by using the LS fit.

Table 1 show the results computed from the data of 15 teams. The mean value of T_h^* is 62.49 seconds and T_p^* is 58.55 seconds, Hypothesis 1 is confirmed.

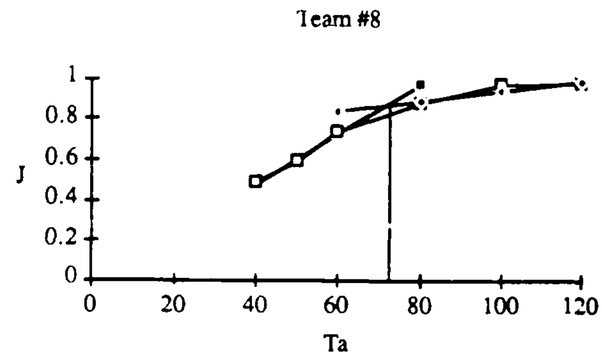

Figure 12 Accuracy and Available Time: Hierarchical

Table 1 T_a* for Both Organizational Structures (unit: in seconds)

	Hierarchical	Parallel
Mean	62.49	58.55
St. Dev.	10.08	17.28

If Hypothesis 2 is correct, the rapid reduction in the number of communications and rapid reduction of organizational performance will occur at the same time. Because of the difference in structures and protocols in the hierarchical organization and the parallel organization, the required number of communications by the task, N_{rc}, is very different. Therefore, it is necessary to take N_{rc} into consideration. The communications ratio, n_c, is constructed by normalizing the actual number of communications, N_c, by the task-required number of communications, N_{rc}.

$$n_c = \frac{N_c}{N_{rc}}$$

Correspondingly, the time ratio, t, is used in the test,

$$t = \frac{T_r}{T_a}$$

Let t^*_c denote the time ratio at which the number of communications reduces rapidly and t^*_J denote the time ratio when the performance starts to drop significantly. Then Hypothesis 2 can be expressed as

H0: $t^*_c = t^*_J$; Hypothesis 2 is accepted;
H1: $t^*_c \neq t^*_J$; Hypothesis 2 is rejected.

To test this hypothesis, two relations need to be analyzed: 1) the relation between the communications ratio and time ratio and, 2) the relation between accuracy and time ratio. When the critical time ratio corresponding to the communications ratio is determined, it can be compared with the critical time ratio found from the relation between accuracy and time ratio to test Hypothesis 2.

Figure 13 is a plot of communication ratio versus the complement of the time ratio ($1 - T_f/T_a$) for a team. To find the value of t^*_c, a piece-wise linear fit is performed. Two asymptotes are found. The intersection point of the two asymptotes can be used to estimate the t^*_c value.

To find the asymptotes, the Least Square (LS) fit is used. As an example, Fig. 14 shows the original curves and the asymptotes found by using the LS fit for the hierarchical organization of the team in Fig. 13.

Team #13

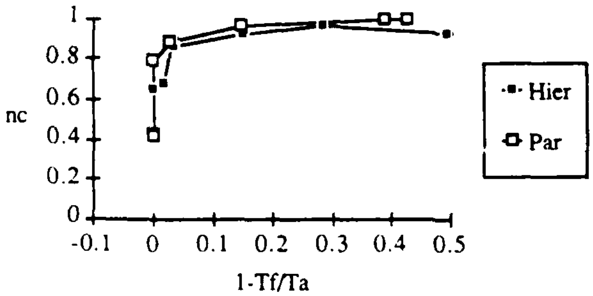

Figure 13 Communications Ratio versus Time Ratio

Team #13: Hierarchical: (Tf/Ta)*=0.95

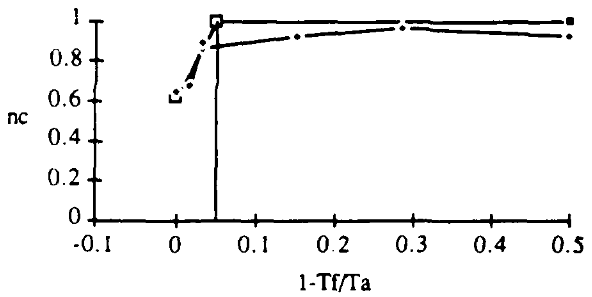

Figure 14 Asymptote for n_c and ($1-T_f/T_a$)

A similar method is used to find the critical time ratio for accuracy. Figure 15 shows the plot of accuracy J versus the complement of the time ratio; Fig. 16 shows the asymptotes for the hierarchical organization. Table 2 displays the mean values and standard deviations of t^*_J and t^*_c for both structures.

Team #13

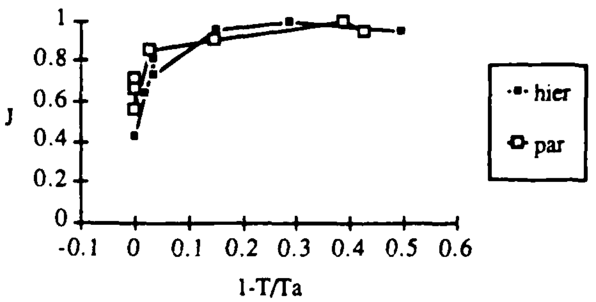

Figure 15 Accuracy and Time Ratio

Team #13: Hierarchical: (Tf/Ta)*=0.95

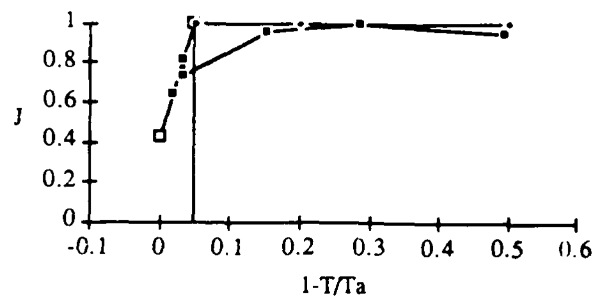

Figure 16 Asymptote for J and (1-Tf/Ta)

Table 2 t^* Values for J and n_c
(Unit: in Seconds)

	Hierarchical		Parallel	
	t^*_J	t^*_c	t^*_J	t^*_c
Mean	0.89	0.89	0.89	0.94
St. Dev.	0.06	0.06	0.10	0.04

In Table 2, both of t^*'s vary over a narrow range. The standard deviations of t^*_J are 0.06 and 0.1 for the hierarchical organization and the parallel organization, respectively, and 0.06 and 0.04 for t^*_c.

For the hierarchical organization, Table 2 shows that

$$\text{mean } t_J^* = \text{mean } t_c^* = 0.89$$

Therefore, Hypothesis 2 is confirmed for the hierarchical organization. However, for the parallel organization,

$$\text{mean } t_J^* = 0.89 \quad \text{and} \quad \text{mean } t_c^* = 0.94$$

Therefore, Hypothesis 2 is disproved for the parallel organization. Since t^*_c is larger than t^*_J, it follows that when the number of communication drops significantly, performance does not yet degrade rapidly. The explanation is the following.

As discussed when Hypothesis 2 was formulated, there are two ways to reduce load in the absence of a strategy that permits completion of the task: to reduce the number of communications or to process fewer threats. There are a few teams that chose the second way to cope with time pressure when operating in parallel. In addition, recall that the objective is to process completely all threats. When time pressure is very high, the DMs attempted to reduce the number of communications in order to complete the threats in their own sector. However, communications in the parallel organization affect only a small portion of the total threats that need to be processed. Therefore, a partial reduction in communications does not affect organizational performance significantly.

CONCLUSIONS

The study is focussed on the effect of organizational structure on performance of decision making teams. There are two aspects which will affect organizational performance. One is the task attributes. Another is the information processing and decision making ability of the organizational members. Task attributes change the operating conditions in which a DDM organization operates. Individual differences of DMs result in a variability of organizational performance. Both aspects were studied. The results are as follows.

The main task attributes that was changed was the available time. When T_a decreases, time pressure is introduced in the organization and DMs have to adjust their processing rate. However, when the processing rate reaches its maximum value, further decrease of the available time causes transition to lower workload strategies until the minimum workload strategy is reached. When no strategy is available to reduce the workload in order to accommodate a shorter available time, rapid degradation in performance occurs. The experimental results confirm a hypothesis which predicts that with decreasing available time, a significant degradation of performance occurs first in the organization which has the highest minimum workload.

When individual performance and team performance are compared, the result shows that organizational performance is more predictable than individual performance. The reason is that the interaction among DMs compensates for differences in individual performance characteristics.

Individual difference has more influence on performance in the parallel organization. On the other hand, the interactions in the hierarchical organization restrict the choices of the decision makers and couple individual decisions with the decisions of other organization members. As a result, individual characteristics tend to be suppressed in the organizational performance.

In addition to the results shown in the previous section, the time ratio introduced by dimensional analysis provides useful information on the determination of the available time organization design. The critical time ratio at which organizational performance degrades rapidly implies the shortest available time for doing a task. This ratio, together with information from the time calibration, can be used to specify the range of available time for a given task in a new design.

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