

Responses of Decision Making Teams to Adaptive Architectures:

A Final Report

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| 13. SUPPLEMENTARY NOTES | | | | | | |
| 14. ABSTRACT The research reported here is part of a larger project designed to develop, assess and understand adaptive structures for command and control teams. Much of that project, the A2C2 project, uses a simulated command and control exercise (the Distributed Dynamic Decision-making Simulation (DDD)) and naval personnel who perform experimental exercises presented to them under controlled conditions. Our research is designed to focus on human behaviors relevant to the A2C2 project that cannot be sufficiently assessed in the simulation. Specifically, the effort reported here involved adapting the DDD exercise for use with large numbers of teams and to compare individual and team performance across these teams. The research assessed the impact of different team architectures, situational demands and team composition on the performance and adaptability of teams on the command and control exercise. An appendix to this report lists products produced during the funding period with citations to articles and presentations for the interested reader. | | | | | | |
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Responses of Decision Making Teams to Adaptive Architectures

Introduction

Since its inception in the early 1990s, our research program has focused on understanding decision making in small teams with leaders and expertise distributed across team members. Such teams are ubiquitous in public and private organizations performing a wide variety of production and service tasks from manufacturing to health care delivery to national defense. Frequently these teams are called upon to perform under high stress such is the case with emergency or operating rooms in health care or command and control conditions in fast-paced military operations.

The protocol used throughout this research effort has involved training team members on a team decision making simulation, then creating a number of conditions under which teams make decisions. The initial work using this paradigm led to the development of simplified information processing simulation and a theory of team decision-making accuracy.

The current research shifted the focus from internal team processes to consideration of team structure. In dynamic and changing environments, teams working under one structure are often faced with circumstances that force them to restructure in order to meet situational demands. If such change is to be successful, it is necessary to understand what team structures, hereafter referred to as architectures, are most likely to be effective and under what conditions. Furthermore, if the same teams are to restructure themselves as they work in multiple environments over time, we must understand whether teams can adapt and what factors lead to successful adaptation. The current research has focused on the discovering conditions that influence the success of small teams when operating under different architectures and to

investigate factors that effect ability of these teams to successfully adapt to changes in those architectures.

A2C2 Research Team

The research to be described was part of a larger interdisciplinary project. The larger project involved the use of the DDD simulation in which a small number of participants, all of whom were Navy Officers, performed on a simulation that lasted for several hours. The work was designed to develop and test the effectiveness of team architectures for command and control. The architectures were derived from mathematical models. Progressing from an understanding of mathematical models of command and control settings hypotheses are generated. Some hypotheses were tested in a small number of human-computer simulations using military officers as participants. Such simulations yield information valuable for the questions they answer and for the questions they raise. The answered questions reflect on the validity of the mathematical model for command and control systems by assessing the fit between the mathematical model and observed behavior. The unanswered questions allow for exploring ways to modify the models and guide the development of future experimental simulations. The latter information closes the loop for one experimental cycle as results from the simulation are fed back. It also initiates the second cycle in which the models are modified to improve the fit between refinements of the models and behavior in a controlled command and control setting. Over time, the paradigm employs more cycles in an attempt to obtain convergence between models and behaviors observed in the simulations.

The behaviors of those performing the simulations can be considered "on line" in the sense that they are an integral part of the linear progression of events from model building

through feedback to model revision and adaptation. Yet the set of unanswered questions about human behavior in command and control settings raised from observing a small number of participants in the simulations exceeds the ability of the paradigm to capture all important issues and feed them back into model building for the following experimental simulation. For both depth of understanding and practical reasons, it is useful to conduct research "off-line" in parallel with the experimental simulation on some questions that arise from the simulation. It is particularly useful if the off-line work can be well integrated into the research effort. Such integration allows for off line research to be stimulated by issues that are critical for the simulation and for what is learned from the off line work to inform the modeling exercise in an efficient manner.

Team Structure Research

The research reported in this technical report represents an off line research effort integrated with the experimental simulations and subsumed within the total model driven effort. We worked closely with the simulation research team, observed simulations in progress, and identified key elements of human behavior in command and control settings that needed to be better understood. The behaviors identified were then studied under controlled conditions at a research laboratory at our university. What was learned in that setting was fed back to those constructing the models and conducting the simulations. Many of these were conducted at the Naval Postgraduate School. For transfer of the information, the tasks for the off line research were designed to capture key human elements of command and control teams used in the A2C2 simulation research with officers at the Naval Postgraduate School and of command and control settings in general.

The report begins with a description of the research in which a task that is a modification of the DDD task was developed. The report ends with a description of research that involved placing decision-making teams in various team architectures.

Adaptation of the DDD Task

Research participants engaged in a dynamic and networked four person-computer simulation in a laboratory context. Each team worked together in a common room, which was partitioned so that people could not see their teammates' computer screens. Team members were in close proximity, however, and could easily speak to one another.

The task was a modified version of the more generic Distributed Dynamic Decision-making (DDD) Simulation developed for the Department of Defense for research and training purposes (see Miller, Young, Kleinman, & Serfaty, 1998 for a complete description). The generic DDD simulation is a realistic command and control simulator that has wide flexibility for portraying scenarios ranging from low to high fidelity (and complexity).

The specific variant of this task used in this research, hereafter referred to as MSU-DDD, was developed for contexts where teams are comprised of anywhere from two to five members who have little or no military experience. In this version of the simulation, each participant has a networked PC at his or her workstation and uses a mouse to control various military sub-platforms such as tanks, helicopters, jets and AWACS reconnaissance planes. These sub-platforms are used in an effort to monitor and control a specific geographic area represented in a 20 by 20 grid.

Space partitioning in MSU-DDD. A depiction of the grid used in MSU-DDD is shown in Figure 1. This grid was partitioned in several ways. First, in terms of the team member's physical

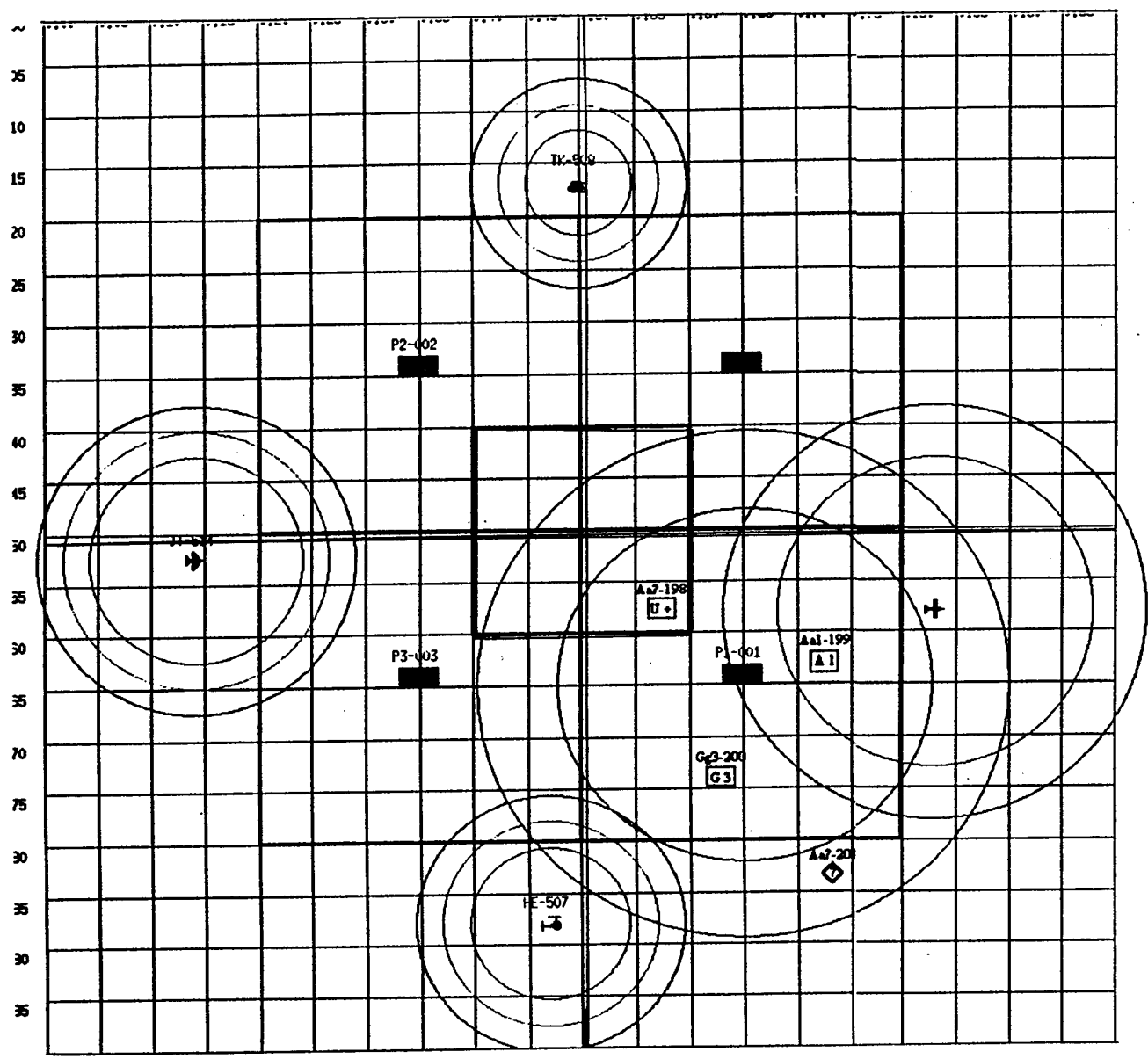


Figure 1. Illustration of the screen depicting the land and air space on the Simulation

location in the simulated geography, the grid is partitioned into four geographic quadrants (see double lines) of equal area (NW, NE, SW, SE), and each area is assigned to one of the team members (in DDD terminology--decision makers or DMs). Decision Maker 1 (DM1) was located in the middle of the Southeast (SE) quadrant (see the small black rectangle), DM2 in the middle of the Northwest quadrant (NW), DM3 in the SW quadrant, and DM4 in the NE quadrant.

Within this overall geographic space, there are friendly and neutral areas depicted on the screen. In the centermost area of the screen was a 4 by 4 grid that represented a highly restricted area. This highly restricted area was contained within a 12 by 12 grid that represented a restricted area. The area outside this restricted area was considered neutral territory. As is apparent from the figure, the two types of geographical partitioning were such that each quadrant had an equal amount of space within it that represented neutral, restricted and highly restricted territory.

The object of the team's mission was to keep unfriendly vehicles from moving into the restricted and highly restricted areas, while at the same time, allowing friendly vehicles to move in and out of the same areas freely. The team's task was to monitor the geographic space, identify all "tracks" (i.e., the radar report of a vehicle) in terms of their nature (friendly versus unfriendly), and then disable any unfriendly tracks that entered the restricted space. At the same time, the teams were to avoid disabling any friendly tracks.

Each team started with a set number of points, and lost points for each unit of time (seconds) that an unfriendly vehicle resided in a restricted or highly restricted zone. Points were also lost whenever a friendly track in any area or an unfriendly track in neutral territory was disabled. The teams that had the most points at the end of the experimental session were eligible for the cash prizes.

Bases and sub-platforms. In terms of monitoring the geographic space, each team member's base (see the small black rectangles labeled DM1, DM2, etc. in Figure 1) had the same radar capacity as every other team member. Specifically, each base had a detection ring radius of roughly six grid units (demarcated by the largest black circle like the one shown in Figure 1). The team member could detect the presence or absence of any track within this radius track. Each base also had an identification ring radius of roughly 4 grid units within which he or she could discern the nature of the track in terms of friendly versus unfriendly status.

Any track outside the detection ring was invisible to a team member, and therefore he/she had to rely on teammates to monitor regions of the space that were outside his/her own quadrant. However, as is clear from the figure, there were areas within each quadrant that could not be monitored from any of the bases. In these areas, the team member relied on sub-platforms to monitor the area outside the base's detection ring.

Each DM had control of sub-platforms that represented various types of vehicles that could be launched from the base and then moved to different areas of the screen. These sub-platforms were "semi-intelligent" agents that could automatically perform certain functions (follow designated tracks, patrol regions in a designated pattern, return to base to refuel, etc.). Hence the DM was a manager of these semi-intelligent agents. Most of the MSU-DDD simulations were played via the sub-platforms, and hence understanding the unique characteristics of each sub-platform was critical to appreciating the complex nature of this task.

There were four different types of sub-platforms used in MSU-DDD: (a) AWACS planes, (b) tanks, (c) helicopters, and (d) jets. Each of these sub-platforms varied in its capacities on four different dimensions: (a) range of vision, (b) speed of movement, (c) duration of operability, and

(d) weapons capacity. The symbols representing each of the four sub-platforms are shown in Figure 1, along with the range of vision that characterized each sub-platform (see surrounding circles).

As is apparent from the figure, the AWACS had the largest range of vision (radius of 4 grid units), followed by the jet, the helicopter and finally the tank (radius of 2 grid units). In terms of speed of movement, the jet moved the fastest (1 grid unit per second), followed by the AWACS, the helicopter and finally the tank (.1 grid units per second).

While the tank was limited in terms of speed and vision, it was the best asset in terms of duration of operation. It could be away from the base for eight minutes without having to refuel. The AWACS could operate away from the base for six minutes, followed by the helicopter at four minutes and the jet at two minutes. The tank also had the most weapons capacity, and could disable virtually any track that came within its attack radius (the third and smallest circle shown around each sub-platform). The helicopter had the second best weapons capacity, followed by the jet, followed by the AWACS which could not disable any track (note the lack of a third ring around the AWACS symbol in Figure 1).

The various sub-platforms constituted a complex set of assets that ranged widely in their capacities. Each team member controlled four such sub-platforms that could all be launched and operated concurrently. The specific configuration of sub-platforms allocated to each base (i.e., team member or DM) was varied as part of the manipulation of the team's structure, and this is described more fully in a later section. The characteristics and qualities of each sub-platform are summarized in the first four rows of Table 1.

Identifying and engaging tracks. Tracks were radar representations of vehicles moving through the geographic space monitored by the team. There were 12 unique types of tracks that varied in terms of (a) being friendly or unfriendly, (b) air-based or ground-based, (c) the amount of power it took to disable the track, and (d) the degree to which the nature of the track could be known when it was first identified. All tracks originated from the various points along the edge of the screen and proceeded inward. The team maintained the integrity of the geographic space they were protecting by disabling (i.e., engaging) any unfriendly track that entered the restricted area. The last twelve rows of Table 1 summarize the nature of the 12 different tracks.

First, it should be noted that prior to identification (e.g., when the track was close enough to be detected but not close enough to be identified) each track was represented by a question mark, followed by a number that was set above a diamond (e.g., see Figure 1). The number reflected each track's unique identification number. Once the track came within the identification ring of either the base or a sub-platform, the DM had the opportunity to identify the track. Identification was not automatically performed by the sub-platform. Rather, the DM had to specifically direct the sub-platform to identify various tracks in a specific order and at a specific time. Once identified, the symbol representing the track changed from a diamond, to a rectangle with a letter-number combination such as those shown in the first column of Table 1.

The number referred to the level of power needed to disable the track (low = 1, medium = 3 and high = 5), and had implications for what platform could perform certain tasks. Tanks could disable all tracks, helicopters could disable those numbered 1 and 3, and jets could only disable

Table 1

Characteristics and Symbol Associated with Sub-platforms and Tracks

| Assets/Tracks | Sub-platform | | | | Nature | Track | |
|----------------|--------------|-----------|--------------|----------|----------|-------|-----------------|
| | Duration | Speed | Vision | Power | | Speed | Need to Disable |
| Tank (T) | 8:00 | Slow | Very limited | High (5) | | | |
| Helicopter (H) | 4:00 | Medium | Limited | Med. (3) | | | |
| Jet (J) | 2:00 | Very fast | Far | Low (1) | | | |
| AWACs | 6:00 | Fast | Very far | None | | | |
| A0 | | | | | Friendly | Fast | T,H,J |
| A1 | | | | | Enemy | Fast | T,H,J |
| A3 | | | | | Enemy | Fast | T,H |
| A5 | | | | | Enemy | Fast | T |
| G0 | | | | | Friendly | Slow | T,H,J |
| G1 | | | | | Enemy | Slow | T,H,J |
| G3 | | | | | Enemy | Slow | T,H |
| G5 | | | | | Enemy | Slow | T |
| U+(A0) | | | | | Friendly | Fast | T,H,J |
| U-(A1) | | | | | Enemy | Fast | T,H,J |
| UX (A3) | | | | | Enemy | Fast | T,H |
| U# (A5) | | | | | Enemy | Fast | T |

Notes. For sub-platforms: Assets/Tracks = Assets held by team members (tanks, helicopters, jets, and AWACs) and tracks that came into the space. A0 through A5 were in the air with characteristics described under the three columns of track and G0 through G5 were on the ground. Those labeled with a U were unidentified when they initially entered the space. A_i and G_i had identifiers on them when they entered the visible space. Duration = amount of time a vehicle may stay away from the base before needing to refuel; Speed = how fast the sub-platform travels across the game screen; Vision = refers to the range of vision the sub-platform has to both see and identify tracks; power = the ability of the sub-platform to engage enemy tracks. For tracks: Nature = whether the track is an enemy or friend; Speed = how fast the track travels across the game screen; Need to Disable = which of the sub-platforms can successfully engage the track.

tracks numbered 1. The number 0 next to a letter indicated that the track was friendly, and that it should not be disabled. The letter indicated whether the track was air-based (A) or ground based (G). Air based tracks moved quickly, whereas ground-based tracks moved slowly.

Once identified, the team member could opt to share this information with other team members by clicking a "share information key." However, team members who were too far away from the track to detect it gained nothing immediately from such sharing. If the track were to move within a person's own detection zone, sharing the ID eliminated the need to repeat the identification process. Thus, whereas the person who shared the identification with other team members lost some time in doing so (and personally gained nothing because the track was already identified on his or her own screen), this type of behavior helped increase the efficiency of the team. In the long run, it eliminated the need for multiple identifications of the same track.

Once a track was identified as unfriendly, its status with respect to the restricted zone had to be monitored. If an unfriendly track moved into the restricted zone, the DM had to direct a weapons-bearing sub-platform with enough power over to the track (i.e., unless the track was already being automatically followed by such a platform) and then engage the platform (i.e., take some action toward it). The sub-platforms did not automatically engage unfriendly tracks that were violating a restricted zone. Rather, DMs had to give a specific order to engage a specific track at a specific time. Once a track was successfully engaged, it disappeared from the screen, and the sub-platform then had to return to base to refuel and reload. In order to maintain the integrity of the structures throughout the entire experiment, the sub-platforms could not be disabled by each other or by the unfriendly tracks. That is, a jet belonging to one team member could not disable one belonging to another or an unfriendly track could not take out a platform

(e.g., a helicopter) belonging to the team. These conditions were established to meet the research needs of the simulations in spite of the fact that they modified fidelity. In particular, since team performance was to be studied over time, we did not want to have teams make one or two errors early in the sequence and then have their performance capabilities severely modified for the remainder of the trials.

A certain sub-set of tracks was not directly identifiable. The nature of these tracks could only be determined via trial and error. That is, once identified, instead of presenting a letter-number combination, these tracks manifested a U (for unidentified) and a symbol (+, -, #, X). All of the U tracks were air-based, and one of them was friendly. The other three were enemies, and the exact power that was needed to disable the track (while shown in Table 1) could only be learned by the team members through trial and error experience.

For example, if someone engaged a U+ track, he or she got an error message indicating a friendly vehicle had been disabled (and lost points from their score), thus learning its nature. If someone engaged a U# track with a jet (which has insufficient power for this track), nothing happened and the track kept on moving deeper into the restricted area. If the same track were engaged with a helicopter, the action would again be unsuccessful, and by a process of elimination, the team member should have learned that a U# represented an A5 type of track. The sub-platforms were semi-intelligent in the sense that they could follow complex orders automatically. But they could not learn from experience. Only human operators could learn the nature of the U tracks.

The presence of unidentified tracks created another level of interdependence among team members in the sense that DMs needed to learn from others' experiences to quickly solve the

problem presented by the unidentifiable tracks. Unlike sharing the track's identification, which could be done via electronic communication, learning about unidentified (U) tracks could only take place through verbal interaction. Much of the verbal communication between team members involved information exchange about unidentified tracks.

In summary, in this simulation, the team members monitored a computer screen that presented a complex and dynamic picture, filled with a number of sub-platforms, rings, and tracks that were moving in different directions and at different rates. They were also using a mouse to launch and move various semi-intelligent sub-platforms around the geographic area in an effort to identify all tracks, and engage those that were enemies and violating the restricted area. While team members were doing this, they were exchanging information both electronically and verbally in order to more efficiently manage the task, coordinate actions, support one another and learn from others experiences.

Team Structure

The simulation described above involved considerable modification of the DDD simulation developed by Kleinman and his colleagues (see Miller et al., 1998) and was used for data collection occurring later in the period of this research effort. Three studies were carried out. They examined team performance in fixed structures and changing structures. All three studies shared the same general paradigm, in the sense that we tested the degree to which effects of external fit (the match between the team's structure and the task environment) were affected by aspects of internal fit (the match between the teams structure and the team members' characteristics). Also, because all three studies used the same task conditions, similar team structures and measures of task member existed. Performance in any one cell of an experimental

design, could always be compared directly to performance in any other cell. This allowed for a wide variety of comparisons among structures, environment, types of teams, and critical individual differences.

Manipulating team structure. Because all of the research described below used the same three structures, as well as the same task environments, to appreciate this research, one needs to understand the nature of the team structures and the task environment. Team structure was manipulated between teams via the task, and teams were randomly assigned to either of two primary structural types adapted from structural role theory traced to Burns and Stalker (1961). In the *functional structure*, sub-platforms were grouped by task specialty and assigned to team members in order to create narrow, distinctive functional competencies. As is shown in Figure 2, one team member was responsible for all four AWACS reconnaissance planes; DM2 was responsible for all four tanks; DM3 was responsible for all four helicopters; and DM4 was responsible for all four jets when teams were structured functionally.

In *divisional structures*, shown in Figure 3, sub-platforms were grouped geographically and assigned to team members in order to create broad, general functional competencies. Specifically, each of the four team members was responsible for one AWACS, one tank, one helicopter, and one jet. Regardless of structure, all teams were self-managing in the sense that there was no formal hierarchical leader that could force decisions or mandate cooperative behavior. Instead, decision making was based upon consensus, and the team members themselves had to manage their own interdependence requirements.

Finally, a third structure was created as a hybrid of the other two. The third type of structure employed in this research was called the *robust structure*. Teams with robust structures

Functional Departmentation

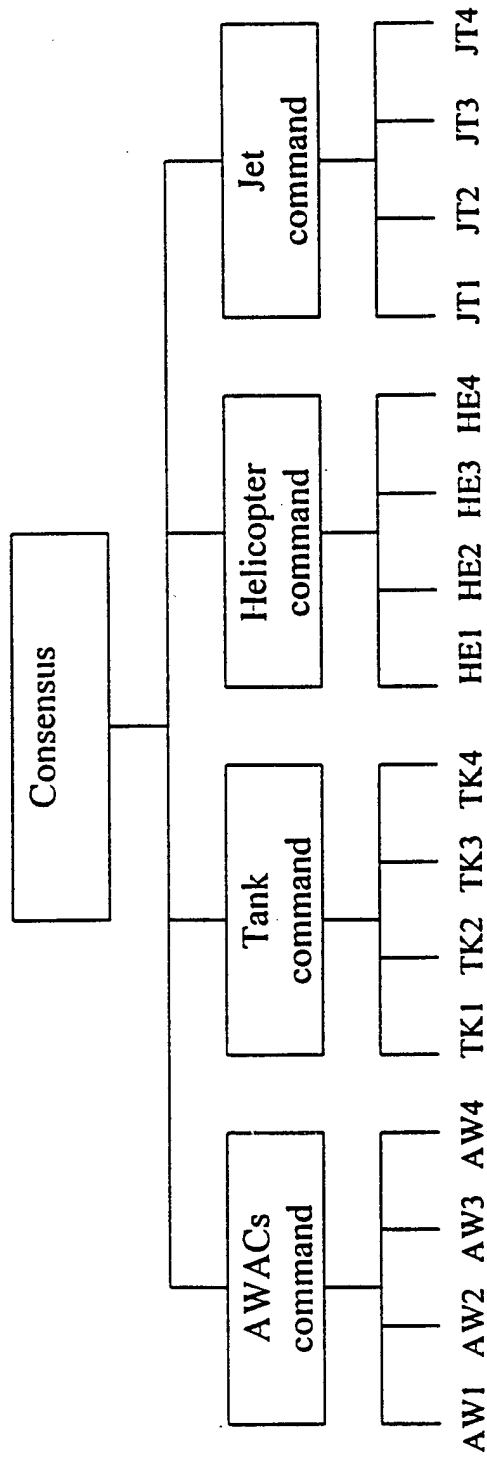


Figure 2. Resource Allocations of Assets to Platforms in the Functional Structure

Divisional Departmentation

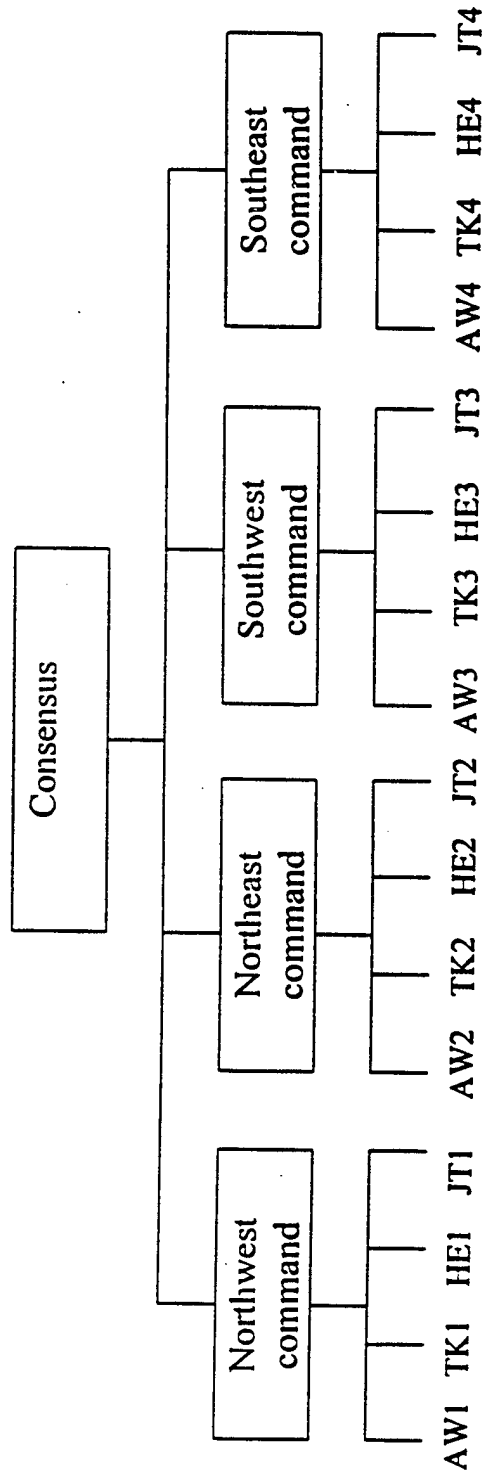


Figure 3. Resource Allocations of Assets to Platforms in the Divisional Structure

were arranged in two dyads. The dyads were divisionally-structured north and south, in the sense that the dyad in the North had all four types of sub-platforms as did the dyad in the South. The dyads were functionally-structured east and west, however, with one of the members in the North dyad controlling the tanks and AWACS while the other member controlling the jets and helicopters (likewise in the Southern dyad).

Regardless of structure, all teams were self-managing in the sense that there was no formal hierarchical leader that could force decisions or mandate cooperative behavior. Instead, decisions were based upon consensus, and team members themselves had to manage their own interdependence requirements.

Across structures, all teams had the same 16 sub-platforms and four team members. Each team member managed four sub-platforms, and each base (DM) was located in the same geographic location. The power structure, communication technology (face-to-face and electronic), and communication network (completely connected) were also the same for all teams regardless of structure. Only the manner by which resources and tasks were allocated to team members (functionally versus divisional) was varied.

Whereas team structure was manipulated between teams (i.e., each team performed with one structure or the other), task structure was manipulated within teams (i.e., each team performed in both task environments). Participants were randomly assigned to the sequence of environmental conditions, and the sequence was counter-balanced to control any order effects or effects for experience.

In the unpredictable task environment, with the exception of tracks that were part of *waves* (described below), the entry and exit point of each track was randomly determined. In

addition, each track changed direction once as it crossed the screen. Thus, the entry vector of the track could not be used to predict its exit point. In the predictable task environment, each track invariably originated somewhere in the northwest quadrant and proceeded in a straight line diagonally across the space, exiting in the southeast quadrant.

In both environments, there were also eight sets of tracks that occurred as part of a wave. Within each of the eight waves, eight tracks with similar entry points converged on the restricted zone of a single DM. These waves consisted of one of each type of air track (A0, A1, A3, A5, U+, U- UX, U#). Each track stayed in the restricted zone for five minutes or until it was successfully engaged. The waves created task interdependence and demanded cooperative behavior on the part of team members. Without support from team members, a team member into whose quadrant the wave was entering did not have enough resources to efficiently identify and engage the total number of tracks the person was experiencing. To do well in such situations, other team members had to help out.

In the unpredictable environment, each DM experienced two high demand waves and the order was randomly determined. The waves in the unpredictable environment originated in the corner of the designated DM's zone (e.g., the southeast corner for DM1) and proceeded to the center of the restricted area. In the predictable environment, all of the waves originated in the northwest corner and proceeded to the center of DM2's restricted area. Thus, in the predictable environment, the nature of the waves could be anticipated, and the functional structure took advantage of this by placing all the slow, high-powered platforms in this quadrant.

Both types of task environments contained 100 separate tracks, and tracks moved through the space for roughly 30 minutes. In addition to containing the same number of tracks, the nature

of the tracks across the two environments was also identical. That is, there was the same number of each different type of track (A0, G3, U#, etc.) in each task environment, and the length of time each track stayed in the restricted area was equal across environments. Thus, with the exception of the predictability of the tracks, all other aspects of the task across the two environments were controlled.

Study 1: Fixed structures and structural contingency theory. The first of the three studies examined fixed architectures and tested some general propositions from Structural Contingency Theory regarding the fit of various structures to different environments, as well as the degree to which the nature of the team members affected these relationships. This first study involved 80 four-person teams and is described in detail in a manuscript entitled “Structural Contingency Theory and Individual Differences: An Examination of External and Internal Person-Team Fit” which is currently under review for publication.

The results from this study indicated that no single team structure was best across wide variety of situations. Instead, in line with Structural Contingency Theory, we found that teams that were confronting an unpredictable environment performed best when arrayed in a divisional structure, whereas teams that were confronting a systematic environment performed best when configured via a functional structure. The results also indicated that, with respect to internal fit, the increased complexity associated with divisional structures meant that teams with this type of structure only performed well when their members were high in cognitive ability. If the team members were low in cognitive ability, teams structured in a divisional fashion performed poorly, regardless of the nature of the environment.

This research was also able to document the interactive nature of the two types of fit (internal and external). We were able to show that, even when there was a good internal fit between the nature of the structure and the characteristics of the team members (e.g., high cognitive ability team members in a divisional structure), the beneficial effects of good internal fit were neutralized by a poor external fit. When a team's structure was misaligned with its environment, it was much more important for the team members to be high in emotional stability, as opposed to cognitive ability.

Finally, in contrast to divisional structures, it was found that functional structures were much less sensitive to the nature of the people assigned to the teams. That is, we did not find that general cognitive ability or emotional stability of the team members was related to performance in these structures, and this was the case when the structure was either well-aligned or poorly-aligned with the environment. The simple nature of the roles created by functional structures seemed to make them impervious to individual differences among team members.

Study 2: Structural change and entrainment theory. Implied from the findings of Study 1 that showed no one structure was best for all environments, is that structures should be changed or adapted to the demands of their environment. That is, a team that starts out in a divisional structure that is well matched to its random environment may have to change or adapt to a functional structure, if and when the environment becomes more systematic. Alternatively, a team that starts out in a functional structure that is well suited for its systematic environment may have to change or adapt to a divisional structure, if and when the environment becomes more random or unpredictable.

Although this type of adaptive structural change sounds promising, some research in organizational theory, such as that based upon population ecology models, suggests that this type of successful adaptation is difficult to accomplish and rarely successful (Brittain & Wholley, 1990). Population ecology models see firms as being "selected" by environments so that those organizations whose structures match the environment succeed and those that do not fail. Adaptation at the firm level to changing environments fails because the change in structure creates an initial period where performance falls off so dramatically, the firm cannot survive the transition.

In addition, some research on teams and groups suggests that some types of structural change may be especially difficult to accomplish. For example, Entrainment Theory (Ancona & Chong, 1996) suggests that the early experiences of groups or teams persist over time even though the task demands confronting the team change. If a group starts off working on a task and engages in a great deal of communication and cooperation, this pattern often persists over time, even if the later demands of the task environment do not necessarily call for high levels of communication and coordination. The reverse also occurs. Specifically, groups that start out with low levels of communication and cooperation usually persist in this fashion even when the task environment changes to one that requires a great deal of coordinated effort.

Entrainment Theory (Ancona & Chong, 1996) implies that teams that try a transition from divisional to functional structures struggle much more with the transition than those moving from a functional to a divisional structure. According to the theory, functional teams should develop skills and habits that foster high levels of communication and coordination, and these habits may persist even when they are no longer strictly required (for example, in a

divisional structure). Although these habits may not necessarily be required for the task at hand, these tendencies will not necessarily lead to significant drops in performance. However, the lower levels of required coordination and interdependence among team members working in divisional structures means that they fail to develop habits of communication and coordination. The failure to develop these habits has serious implications for performance in situations where communication and coordination is demanded (e.g., in functional structures), and will harm performance when the group shifts to a functional structure.

We tested this prediction in a study employing 82 four-person teams who worked on the MSU-DDD task described earlier. These 82 teams performed the task in structures that changed over time. Half of the teams started out with a functional structure that switched into a divisional structure halfway through the experiment, whereas the remaining teams started out in a divisional structure that switched into a functional structure halfway through the experiment.

Because these teams engaged in the same simulation and task environment as the 80 teams run in Study 1, we were also able to compare these two types of changing teams to teams that did not change (fixed divisional and fixed functional structures. This allowed us to test for both the degree to which structural instability caused performance decrements, as well as the degree to which one type of transition (divisional to functional) was more disruptive than the other transition (functional to divisional). We also tested the degree to which the characteristics of the team members attenuated or exacerbated the changes in performance attributable to structural changes.

The results of this experiment showed that, consistent with population ecology models, the stable structures outperformed the changing structures. However, in line with Entrainment

Theory, this was almost entirely attributable to the low performance associated with teams that tried to make the transition from divisional to functional structures. Teams that made the transition from functional to divisional structures performed at a level that was very close to that found in stable teams.

An examination of communication patterns of the teams showed that this factor explained much of the problem. That is, the performance decrement could be attributed to the fact that high levels of communication were required to perform well in the functional structure, but that the correlation between communication levels in the first and second half of the experiment were extremely high. This meant that divisional teams did not communicate much in the first half of the experiment and this persisted into the second half, despite their change in structure. Teams that started off in functional structures communicated a great deal early, and although this too persisted when they transitioned into a divisional structure, this was largely irrelevant to performance, not negatively related (i.e., the divisional structures did not demand silence in the way functional structures demanded communication).

To some extent, the deleterious effects of the divisional to functional transition were offset by the nature of the people who constituted the group. Teams comprised of members who were highly extraverted made the transition more successfully than those composed of introverts. The tendency of high extraverts to talk a great deal, regardless of the situation created the type of communication patterns needed to succeed in functional structures. Thus, as in Study 1, we again see evidence of how a good internal fit between the team's structure and the characteristics of its members, can offset the negative effects of a poor external fit between the team's structure and its environment.

Study 3: Promoting adaptive structures. Given the difficulties teams had in terms of changing structures, the third study in this program of research was directed toward developing interventions that ease these types of transitions. In this third experiment, 85 four-person teams were run using the same MSU-DDD simulation described earlier. In this study, four specific factors thought to ease the transition from one type of structure to another were assessed.

First, roughly one fourth of these teams were assigned to a “Robust Structure” that was not optimal for either type of environment, but rather was the “average” of the two “pure structures” (functional and divisional). This robust structure was seen as a means of reducing the negative effects of change by eliminating the need for change. This type of structure can be compared to both of the previously run fixed structures to see if sacrificing initial fit is offset by the gain in subsequent performance when the environment changes to one that is no longer a good match for the initial structure. Although the robust structure was not as good a fit either environment as functional to fixed or divisional to random, it is also never a complete mismatch to either environment. The Robust Structure also served as a point of comparison for the other changing structures run in Study 2 and Study 3.

Second, one fourth of these teams were assigned to a condition where they changed their structure, but only to a small degree. Rather than going all the way from a pure divisional structure to a pure functional structure, these teams transitioned into the type of “average structure” represented by the Robust Structure described above. This is referred to as a “Transitional Structure” because the change was much less than might be considered preferable if there were no costs for change, but represents a trade-off of initial fit and change.

Third, one fourth of the teams were assigned to a condition where teams made the full transition from a divisional to functional structure (or vice versa), but did so in a team that had a designated formal leader. The formal leader introduced centralization into the team as an alternative coordination mechanism. The formal team leader had access to all the information held by any one team member, as well as the power to unilaterally transfer assets from one team member to another. This third condition addressed the degree to which an alternative coordination mechanism like centralization could be used to offset the coordination problems introduced by changes in team structure.

Finally, one fourth of the teams in Study 3 were comprised of experienced team members who had already worked on the MSU-DDD simulation in prior experiments. This group was used primarily to test the degree to which the problems teams in Study 2 had with switching structures might be offset by employing team members who were more experienced with the task. As was the case with Studies 1 and 2, this allows for a test of the degree to which a good internal fit between the team members and their team's structure can offset some of the difficulties created by structural change. All of the teams for Study 3 have been run and data from this study is currently being analyzed for presentation and eventual publication.

Conclusion

Central to all theories of organizations and of human behavior in organizations is the notion of fit. Organizational theories evaluate fit by assessing the extent to which the structure or design of the organization fits the demands of the physical, social and political environments in which the organizations must operate. Models of human behavior in organizations tend to focus on the fit between the knowledge, skills, abilities and other personal dispositions and the jobs and

social interaction conditions in which people find themselves in organizations. Both organizational level models and individual level ones are predicated on the assumption that fit is directly related to effectiveness.

The present work begins the notion of fit and introduces two complexities into the fit process. First, because organizations are populated with humans, and their effectiveness is affected by the extent to which people in organizations perform their roles effectively, issues of fit must consider both organizational level fit and individual level fit simultaneously. Typically, work focuses on one or the other, primarily because expertise of the investigators is concentrated at one level or the other with only limited communication between those who study one level or the other. The current work adopts constructs that come from both levels. Second, since both environments and people change, the problem of maintaining fit is dynamic.

Our work within the A2C2 project addressed the nature and effects of both environment-to-structure fit and person-to-task fit in teams functioning on a team decision making simulation. When fit was assessed statically, it was found that both levels of fit affected performance as expected and that there interactions between fit structure-to-environment fit with person-to-task fit. When fit was considered over time, it was found that the effectiveness of a structure depended not only on the current match between situational demands and team structure but also in the kinds of demands previous structures had placed on the teams. Structures experienced in the past provided ways for teams to learn skills that aided their performance in the future under conditions that differed from the past conditions. Focusing on fit from only an organizational point of view ignores the cumulative effect of experience on organizational members. Learning more about the nature of this affect should aid us in understanding the types of experiences

adaptive teams need to experience in order to respond to shifts in situational demands. Currently, work is being undertaken to map out more completely structural implications for affecting the performance of persons working in teams under various team structures.

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Appendix
Listing of Outputs through February 2000
 Team Effectiveness Research Laboratory(TERL:MSU)
 Michigan State University
 John R. Hollenbeck & Daniel R. Ilgen

Background: In the spring of 1990 John R. Hollenbeck and Daniel R. Ilgen along with their students, began a program of research on team performance. It was initiated by funding from the Office of Naval Research and has been funded by that office since that time. Additional funding has also been provided by the Air Force Office of Scientific Research. Below are listed publications and presentations resulting from this research effort.

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