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Autonomous vs. Interdependent Structures: Impact on Unpredicted Tasks in a Simulated Joint Task Force Mission¹

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Abstract

This simulation experiment is the latest in a series conducted by the Adaptive Architecture for Command and Control (A2C2) research team. The focus was to evaluate the relative performance to two organizational structures on tasks that varied in terms of complexity and predictability. One structure represented a more traditional, functional form with interdependent nodes. The second structure was derived from computer-modeling to reduce the need for coordination by creating fairly autonomous divisional units. Results from a previous A2C2 experiment suggested that the more autonomous, divisional structure, while outperforming the functional structure in planned mission tasks, could be less effective with complex unpredictable tasks. Organization theory argues that coordination capability is an important factor in an organization's ability to respond to an uncertain and complex environment. The question examined in this research was whether the different degrees of coordination capability developed by these two structures would influence the performance and process outcomes for both predictable and unpredictable tasks. The results show only limited differences in the results for the two structures, though these are in the direction predicted above. However, a more consistent finding suggests that training and improved teamwork processes override structural differences in influencing performance outcomes. Implications to future research and training implications are discussed.

1. Background

The Adaptive Architectures for Command and Control (A2C2) research program has been pursuing a stream of research over the past several years to identify characteristics of structure and process that will improve the effectiveness of defense organizations. The A2C2 team is comprised of university, government, industry and military participants doing basic-level research involving modeling and laboratory simulation experiments as well as applied research as part of operational activities such as the Global Wargame and Fleet Battle Experiments. The focus of this paper is on the results of the most recent laboratory-based simulation experiment conducted at the Naval Postgraduate School in February 2000. It builds significantly on NPS-

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Experiment 4 that was conducted in 1998 and reported in the 1999 CCRT Symposium (e.g., Entin, 1999; Hocevar, Kemple, Kleinman & Porter, 1999). The premise of this research is that defense operating environments will continue to become increasingly turbulent and unpredictable. According to Vaill's (1989) metaphor, these environments have the challenge of "permanent white water" for the river rafter. Such environmental uncertainty requires increased organizational adaptability and flexibility. The question is, what are the characteristics of organization structure and process that facilitate adaptability?

According to organizational theorists (e.g., Galbraith, 1995; Duncan, 1979, Mintzberg, 1993), organizational adaptability can be enhanced through structural coordination mechanisms (Galbraith, 1995) and processes of mutual adjustment (Mintzberg, 1993). Duncan's (1979) model argues that if the task, market, or mission environment can be segmented, organizational divisions can be structured with all the necessary functions to meet the requirements of that segment. A "divisional" structure is characterized by autonomous units that can readily respond to changes in their target environment when the new demands or opportunities are within the division's resource capability. However, when the environment becomes increasingly unpredictable, and the demands require a response that cuts across divisional capabilities, inter-divisional coordination capabilities are required. Because divisional autonomy is emphasized in this structural form, these coordination mechanisms are not inherent, and thus this form may not perform effectively in the face of task demands that require inter-divisional response. In fact, a common criticism of the limitation of divisional structures is the over-emphasis on unit-level goals to the detriment of overall organizational performance (Mintzberg, 1993). The traditional counter-point structure to a divisional form has been the functional structure (Duncan, 1979). This structural form inherently requires more coordination capabilities when facing complex tasks because organizational units are designed around functional domains that are interdependent in accomplishing those tasks. Historically, however, this type of structure has not proven to be very "adaptable" in responding to changing environments because much of the coordination was managed vertically through centralization of authority.

Organizational theorists argue that whether a structure is divisional or functional, coordination mechanisms are needed for organizations to be able to effectively respond to environmental unpredictability and complex task requirements that have significant elements of uncertainty (e.g., Burton & Obel, 1998). Lateral coordination mechanisms that don't require significant hierarchic control, facilitate adaptive response. These mechanisms can include as information technology, linkage roles, inter-unit teams, and decentralized authority allowing lower-level "mutual adjustment" (Galbraith, 1995; Mintzberg, 1993).

A2C2 Experiment 4, conducted in 1998, was designed to evaluate the effectiveness of a model-based structure (see Levchuk *et al.*, 1998) in the performance of a simulated Joint Task Force (JTF) mission. This structure (A1-6) was derived from computer modeling that analyzed mission task requirements and the resource options and used design criteria of workload balance, speed of execution, and minimized coordination requirements. Following organization theory concepts, the A1-6 structure can be defined as having a divisional form with the divisions being defined based on tasks. In other words, nodes (i.e., divisions) within the command structure were assigned assets such that they were able to accomplish fairly complex tasks without significant coordination with other command cells. The hypothesis of Experiment 4 was that this

model-based structure (A1-6) would outperform an alternative structure (A0-6) that was more functionally defined and required significantly more coordination to accomplish the major planned mission tasks. The justification for this hypothesis was that A1-6 would operate more efficiently with unit-level autonomy in accomplishing the planned mission tasks. This hypothesis was supported by the results of Experiment 4 (see Entin, 1999; Hocevar et al., 1999). These results reinforce the design benefits of a divisional structure when the environment or task set can be segmented and the environment is fairly predictable. This finding has important implications to the design of Joint Task Forces and supports the concept of mission-defined units.

However, interesting tentative findings based on a very limited set of simulation events also emerged. When faced with unpredicted tasks that required inter-nodal coordination, the performance of the more autonomous task-based structure (A1-6) fell below that of the A0-6 structure. While this finding was not statistically significant due to limits in sample size and statistical power, it is congruent with theories of organization design that propose coordination capabilities provide an adaptive mechanism for responding to environmental and task uncertainty (e.g., Galbraith, 1977, 1995; Duncan, 1979; Burton & Obel, 1998). In other words, theory would argue that the higher degree of interdependence among the organizational units in the more functionally defined A0-6 allowed that JTF structure more practice in coordination as they accomplished the planned mission tasks. This greater practice in coordination could have enhanced this structure's facility in responding to the complex unpredicted events requiring inter-nodal coordination that emerged in the scenario.

This explanation has been reinforced by the recent work of Ensign (1998) who argues that organizations need to develop not only the capabilities to manage existing interdependence, but potential interdependence. Similarly, Weick's and Roberts's (1993) work on aircraft carriers suggests that situations that are fluid, high risk, and highly interdependent require teams to be "heedful" of threatening events and practiced in creating a joint response to these events. The question raised by the tentative findings in Experiment 4 was whether the model-based structure (A1-6) with high unit-level autonomy for planned events had overly constrained the practice of coordination and thus diminished the organization's ability to respond to unpredicted events.

2. Study Purpose and Design

The purpose of this experiment was to gather more data on the relationship between structural types and performance on unpredicted tasks. Specifically, the research question guiding the design of the experiment was: **When faced with the need to respond to an unanticipated, complex, task, does a structural architecture that requires greater levels of inter-unit coordination (i.e., nodes with structural interdependence) provide a performance advantage over an architecture that reduces coordination by using a task-based design (i.e., nodes with structural autonomy)?**

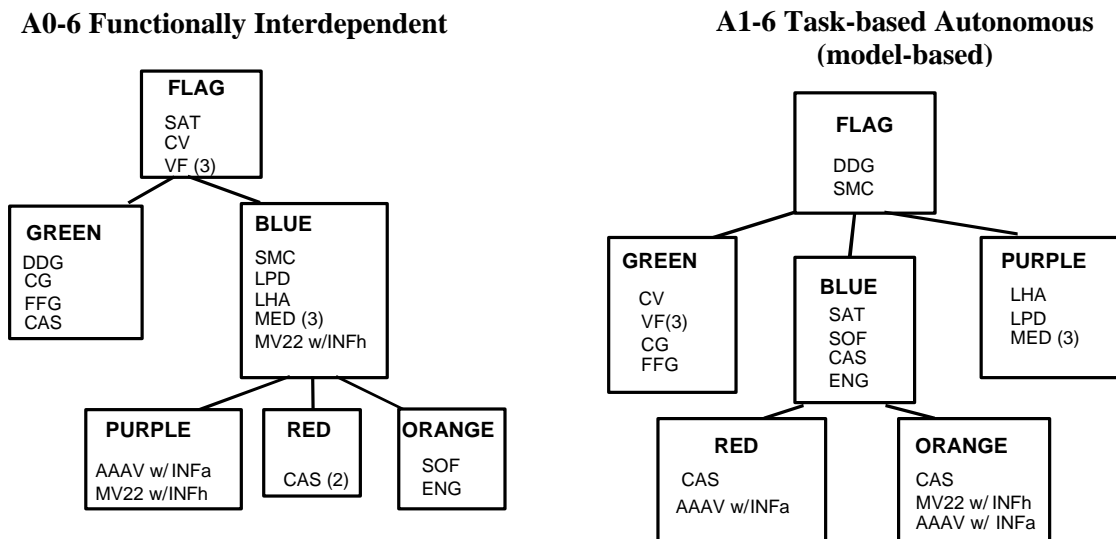
Study participants were 36 military officers (O2-O5) in varying Master of Science programs at the Naval Postgraduate School. These officers represent USN, USA, and USMC as well as foreign national officers from several nations including Germany, Brazil, Canada, and Greece. Students were randomly assigned to 6-person teams maintaining a balance across teams in terms

of service represented, national origin, rank, and support vs. operational experience. Each team played the role of a Joint Task Force engaged in a mission using the Distributed Dynamic Decisionmaking-III (DDD-III) simulation software (Kleinman, Young & Higgins, 1996).

2.1 Independent variables: Organizational structure

The two command structures used in this experiment are presented in Figure 1. These structures were identical to those used in the previous Experiment 4 described above. Specifically, A0-6 represents a more functionally-defined structure where the nodes are interdependent in the accomplishment of complex mission tasks while A1-6 is more divisional with units designed for more autonomous performance of planned mission tasks. There were two structural changes made for this experiment. First, in Experiment 4, both command structures used two separate communication nets that followed the command structure. Flag and the immediate subordinate nodes were on one net and remaining nodes were on separate net with command node 'Blue' acting as the communication link-pin. In the current experiment, a single communication net was used for both structures. The second change from Experiment 4 was the shift of the DDG from Blue to Green in A0-6. This was done in response to participant feedback in Experiment 4 on the heavy workload on Blue. No changes were made to the model-based architecture A1-6 (see Levchuk *et al.*, 1998 for details on the modeling procedure).

Figure 1. Organizational Architectures



The role of hierarchic or centralized command and control was not a manipulated parameter in this experiment. To try to minimize the variation due to leadership style, the following instructions were read to all participants prior to the first mission rehearsal session:

It should be presumed that the JTF has pre-planned this mission, and with clear commander's intent, authority has been delegated to subordinate nodes to laterally coordinate required assets on planned mission tasks. This lateral coordination, or

self-synchronization, can be accomplished without seeking approval of higher authority. HOWEVER, this does not remove Flag's (or Blue's) responsibility to intervene when he/she feels the mission requires refocusing or to resolve conflicts and set priorities when assets are required for multiple tasks.

The experimental design used "within-teams" comparison; all teams executed the simulation using both structures -- one designed for autonomy (A1-6), and one designed for interdependence (A0-6) – with order balanced across teams to control for any learning effect.

2.2 Mission Scenario

The mission of the JTF was a scenario in which the U.S. is taking action in support of an ally, Country Green, that has been invaded by neighboring Country Orange. The ultimate objectives of this mission are to secure Country Green's Airport and Port. A mission briefing document that outlined a specific chronology of mission tasks to be undertaken by the JTF was distributed to all participants. A simplified version is listed below:

1. Amphibious forces will land and take North and South Beach after clearing mines.
2. Prior to taking N. Beach, infantry (INF) and air support will seize the hill overlooking the beach.
3. Infantry will move down roads from S. Beach toward Airport and from N. Beach to Port clearing mines and enemy tanks.
4. Special Operations Force (SOF) and satellite (SAT) must determine which of two roads the enemy plans to use for insertion of forces by assessing traffic. Once the enemy "lead vehicle" is identified, it should be destroyed as well as the bridge being used by that vehicle, while retaining second bridge for friendly traffic.
5. Armored counterattack forces are believed to be at the Airport and Port. If present, they must be identified and destroyed.
6. Both the Port and Airport must be captured and held. The attack on the Airport has priority and should occur first if they cannot be attacked simultaneously.

The above mission tasks are assumed to represent a high level of certainty. They all **MUST** occur, and the sequencing, location, and assets required for each task are clearly specified and documented for team participants. With the exception of clearing the land and sea mines, all of the above mission tasks are somewhat complex in that they required multiple assets to accomplish (e.g., infantry (INF) and close air support (CAS)).

The mission briefing document also defined "Other Tasks That Can Occur Throughout The Operation." These "defensive" tasks include such tasks as the identification and prosecution of hostile aircraft and patrol boats and the elimination of enemy artillery sites. These tasks have some limited unpredictability in that the location and timing is not known, but the likelihood of their appearance is certain. The majority of these tasks are "simple" in that they require only the application of one asset and can thus be accomplished by a single organizational command node.

However, there are three defensive tasks (enemy tanks, Silkworm and SAM missile sites) that are also somewhat unpredictable, but require the use of multiple assets.

The mission scenario used in Experiment 4 was embellished with four additional complex, unexpected, and unrehearsed tasks. These tasks were not introduced until after each team had completed 2 hours of basic software training and had conducted two mission rehearsals using the first structure they had been assigned. Just prior to having the team conduct the mission for the actual data gathering, an announcement was made²:

As in any real mission, we cannot assume that what we rehearse perfectly predicts the events that will unfold. You should expect unanticipated task requirements as you conduct this mission. The handout [given each participant] shows the icon that indicates an “Unanticipated Task” (UT) and explains how to use the software to gather intelligence on both the nature of the task and the resources required to prosecute the task. This task is equally important to all your mission tasks, but does not change the overall, planned mission requirements. UTs are time-critical. Each task bearing this new icon will expire seven minutes after it appears.

After this announcement, each team had a few minutes to discuss a general strategy for addressing UTs. The total time for each team to accomplish the mission scenario was between 33 and 40 minutes (mean 37 minutes).

2.3 Complex Unanticipated Tasks

A key question to be addressed in this experiment is to compare the performance of the two structures on tasks that are both complex and unanticipated and unrehearsed. These tasks (UTs) were designed into the DDD-III simulation software and had the following characteristics:

- UTs appeared with a distinctive icon illustrated on the handout given to participants.
- There were no additional cues other than the visual icon.
- UTs first had to be scanned by the Satellite asset before “intelligence” was available.
- Once scanned, a brief description of the task and the possible asset packages to be used were available using the help window for the task.
- All UTs had to be prosecuted within 7.5 minutes (450 second) or the task score was zero.
- Each UT required the coordination of a minimum of 2-3 nodes.
- UTs were constructed to test the teams’ ability to coordinate in ways previously unrehearsed (i.e., with asset combinations not used in the accomplishment of the primary mission tasks that were the focus of previous training).
- The 4 UTs in each scenario were distinctive from each other
- A unique set of 4 UTs was used for each team’s trial run with the second organizational structure; the two sets of 4 UTs were balanced in terms of difficulty (as measured by the amount of coordination required).

² It is recognized that this announcement diminished the “unpredictability” of these events. However, it was necessary to inform participants of the meaning of the screen icon that represented “Unanticipated Task” (UT) and give them the procedural guidelines for gathering intelligence using the software.

Examples of two of the UTs are given below:

UT1 [information from Task Help screen]: Fishing trawler laying mines in shipping lane. Establish air superiority to protect the SMC [mine sweeper]. Destroy enemy trawler and clear the mines. Time is critical – oil tankers are entering the area.

SUITABLE ASSET PACKAGES FOR THIS TASK:

{SMC+CG+DDG} OR {SMC+2VF+DDG} OR {SMC+2VF+CG}

UT2: F14 crew is downed in hostile waters with casualties reported. Protect SAR [search and rescue] operation from enemy air and surface actions – time is critical!

SUITABLE ASSET PACKAGE FOR THIS TASK:

{MED+VF+CAS}

2.4 *Dependent Measures*

Three categories of measures will be examined in this report – those derived from the simulation software, observer ratings and participant ratings. First, the DDD-III software generates two overall performance scores – Mission and Strength. The Mission score generally reflects offensive performance based on the extent to which all tasks are accomplished with appropriate resources and timely coordination. At the beginning of a simulation, Mission score starts at zero and cumulates to a possible score of 100%. The Strength score generally reflects defensive performance; it starts at 100% and decrements accrue as a result of enemy hits, collisions, or mission tasks attempted with inadequate resources or coordination. Neither the Mission nor the Strength scores include performance of the four Unanticipated Tasks.

In addition to these overall measures, specific task performance can be derived from the DDD dependent variable file generated by the software as teams perform the simulation. Two measures of interest will be evaluated here – accuracy and latency. Accuracy scores are based on 100% and are reduced if assets are not appropriate or timely, or when collisions or enemy penetrations occur related to that task. In addition, some task categories (e.g., patrol boats) represent multiple rather than single events. The accuracy scores for these tasks are reduced proportionately when task events are “missed” (e.g., an enemy patrol boat gets through to the resupply port). Latencies reflect the time taken to accomplish a task.

To evaluate tasks of differing degrees of complexity and unpredictability, the following categories of tasks were evaluated:

- 7 Primary Mission Tasks (complex, predictable and rehearsed)
- 6 Single-node Defensive Tasks (simple, somewhat unpredictable, but rehearsed)
- 3 Coordinating-nodes Defensive Tasks (moderate complexity, somewhat unpredictable, rehearsed)
- 4 Unanticipated Tasks (complex, unpredictable, unrehearsed)

For each data trial, two observers independently evaluated both performance quality and teamwork processes on 7-point rating scales (see Entin *et al.*, 1998; Entin *et al.*, 1997). These observers were military officers who were well-versed in the mission requirements and software operation. The performance instrument included 10 behaviorally-anchored scales assessing performance of specific mission tasks that represented all of the first three task categories cited in the bullet-list above. The teamwork instrument included seven behaviorally-anchored scales that assessed several dimensions of process behaviors including: back-up behaviors, communication effectiveness, coordination, and team orientation.

Finally, participants were asked to complete assessment forms at the completion of the data trial for each structure to evaluate both situation awareness and workload.³ At the conclusion of the second (final) data trial, they also completed a post-experiment questionnaire that asked them to compare the two structures on a number of dimensions related to both performance and process. This form used a 7-point rating scale where 1= “low” and 7= “high” on the focal characteristic.

3. Results

3.1 *Difference in Coordination Practiced Using Two Structures*

The first test conducted was to determine the degree of difference between the two structures in the amount of coordination “practiced” as the teams conducted rehearsal missions. This test is important in order to demonstrate if the key factor of “coordination capability” could be argued as distinctive for the two structures. Only given this, would it be possible to test if the difference in coordination practice would relate to performance on both the predictable primary mission tasks and the Unanticipated Tasks. The average number of command nodes used in the conduct of each mission scenario was calculated from the DDD dependent variable file in three ways – for the seven primary mission tasks, for all task categories, and for all task events. The third calculation differs from the second in that many of the non-primary tasks have multiple occurrences. In the second calculation a task category (e.g., enemy patrol boats) is counted only once. In the third calculation, the average reflects the number of actual patrol boat tasks prosecuted. The three comparisons of the amount of coordination used by the two structures is presented in Table 1.

| | A0-6 (interdependent) | A1-6 (autonomous) | t-test sig |
|-----------------------------|----------------------------------|------------------------------|---------------|
| Seven Primary Mission Tasks | 2.28 | 1.52 | p<.001 |
| All Task Categories | 1.67 | 1.32 | p<.001 |
| All Task Events | 1.42 | 1.30 | p<.003 |

The results of this analysis show that there is a statistically significant difference in the amount of coordination (i.e., mean number of nodes involved in prosecuting tasks) used by the two structures, for all three calculations. The difference is most substantial for the primary mission tasks. The result is reflective of the structural design differences of more interdependence in A0-

³ It was not possible to analyze the Situation Awareness data in time for inclusion in this paper. In addition, all communications during the conduct of each mission trial were coded independently by two members of the research team. These process data are not included in the analysis presented here.

6 (i.e., more coordination among nodes) and more autonomy in A1-6. However, it is important to note that, for both structures, there were a significant number of “simple” tasks requiring only one node. Thus, the overall practice of coordination reflected by All Task Events, while statistically significant, shows only a small real difference between the two structures.

3.2 Simulation Performance Comparing Two Structures

The results of performance derived from the DDD simulation software are presented first. As described above, Mission and Strength reflect overall measures of performance (excluding the Unanticipated Tasks). Specific task categories are analyzed separately in order to examine whether the structures performed differently depending on the complexity and predictability of the tasks. The results of the DDD-based measures are presented in Table 2.

| Table 2. Simulation Performance Comparing Two Structures | | |
|--|----------------------------------|------------------------------|
| | A0-6 (interdependent) | A1-6 (autonomous) |
| Mission score | 89.8 (6.1) | 92.2 (5.6) |
| Strength score | 87.0 (6.1) | 89.8 (4.1) |
| 7 Primary Offensive Mission Tasks (predictable) –Accuracy | 92.6 (11.7) | 96.7 (5.0) |
| 7 Primary Offensive Mission Tasks (predictable) –Latency | 1065 (116) | 1048 (132) |
| 4 Complex Unanticipated Tasks (unpredictable) –Accuracy | 90.8 (11.7) | 86.0 (13.6) |
| 4 Complex Unanticipated Tasks (unpredictable) –Latency | 283 (42) | 303 (45) |
| Single-node Defensive Tasks –Accuracy | 87.3 (8.6) | 92.4 (6.6) |
| Single-node Defensive Tasks –Latency | 195 (46) | 179 (16) |
| | 71.6 (9.0) | 82.2 (11.7) |
| Coordinating-nodes Defensive Tasks –Latency | 368 (127) | 391 (179) |
| Note: Means and (std dev.). Accuracy based on 100%; Latency is number of seconds. Paired (dependent samples) t-test comparison of means showed all differences to be non-significant (p<.10), (2-tailed test). N=6. | | |

Table 2 presents means and standard deviations for both performance accuracy measures and latencies. Paired t-test comparisons showed no significant differences in the means (p<.10). There are several possible explanations for these results. First, because of the small sample size (N=6), there is limited statistical power to show “true” differences in performance. Second, as shown by the high accuracy scores, and given the feedback from participants, there could be a “ceiling effect.”⁴ In other words, a more challenging scenario may be necessary to distinguish the performance of the structures. Third, any possible differences between the structures were

⁴ All teams received more comprehensive pre-trial training than in previous A2C2 experiments. This training emphasized both the unique asset responsibilities of each command node as well as practicing coordination for complex tasks.

overridden by the strong team cohesion established and coordination practiced by all teams during training and rehearsal.

Even given the lack of statistical evidence, it is interesting to examine the pattern of means in terms of the research question of interest. First, for both the overall measures of Mission and Strength as well as all accuracy measures except those for the Unanticipated Tasks, the model-based structure of A1-6 is slightly, but consistently more effective than the A0-6 structure. In contrast, the comparison of means for the four Unanticipated Tasks shows a different trend. In this case, A0-6 shows a somewhat higher accuracy score and a lower latency (i.e., greater speed of task accomplishment) than A1-6. This pattern could suggest that a structure with more practice in coordination could enhance the ability to respond to unanticipated, but complex task requirements; and that more autonomy facilitates performance of tasks that are both complex and predictable as well as simple tasks of limited unpredictability tasks. However, it is not possible to draw definitive conclusions from these findings given the lack of statistical evidence.

3.3 *Observer Ratings of Performance and Process Comparing Two Structures*

Observer performance rating scales developed by Entin (1998) included 10 questions using a 7-point rating scale. One question pertained to overall mission performance.⁵ The others focused on a selection of specific tasks representing both primary mission tasks and defensive tasks. As described in the discussion of scenario and measures, these two task categories differ in term of the degree of predictability. Participants were aware of the defensive tasks and their role in addressing them; however they did not know the exact location and timing of those tasks. Because observers were not matched with specific teams, the comparison of means used an independent samples test. The results of observer ratings are presented in Table 3.

| | A0-6 (interdependent) | A1-6 (autonomous) | T-test significance |
|---|------------------------------|--------------------------|---------------------|
| Overall Mission | 5.33 | 5.98 | p<.02 |
| Primary Mission Tasks (predictable) | 6.13 | 6.35 | n.s. |
| Defensive Tasks (less predictable) | 4.73 | 5.82 | p<.01 |
| Note: Means based on a rating scale where 1= "poor" and 7= "superior." Independent samples t-test; 2-tailed significance. N=6. | | | |

In contrast with the results derived from the simulation software, there were statistically different results for the comparison of the two structures using observer data. Specifically, the model-based structure (A1-6) with task-defined divisional units showed stronger performance ratings for both the overall mission question and the assessments of the defensive tasks. These statistically significant findings give greater credibility to the similar pattern of means derived from the DDD software presented in Table 2, particularly for the defensive tasks. The observer ratings of the performance of the Primary Mission Tasks showed no difference between structures. It is not possible to use the overall mission performance rating by observers because this included their assessment of teams' processing of Unanticipated Tasks as well as all

⁵ The observers were not asked to separately evaluate UT performance, but UT tasks were included in their rating of overall performance.

rehearsed mission and defensive tasks. In the DDD-derived measures, the overall measures (e.g., Strength, Mission) do not include Unanticipated Tasks performance.

To further our understanding of the particular processes that contribute to performance differences, observers also rated each team’s scenario performance on a number of questions related to teamwork. The results of these ratings compared by structure are presented in Table 4.

| | A0-6 (interdependent) | A1-6 (autonomous) | T-test significance |
|---|----------------------------------|------------------------------|------------------------|
| Overall Teamwork | 5.14 | 5.56 | n.s. |
| Members anticipate others’ need for assistance | 4.67 | 5.50 | p=.19 (n.s.) |
| Members adjust to redistribute workload | 4.50 | 5.58 | p=.09 * |
| Communication Effectiveness | 4.42 | 5.67 | p=.14 (n.s.) |
| Proactive Communication | 5.42 | 5.17 | n.s. |
| Coordination | 5.58 | 5.92 | n.s. |
| Team Orientation | 5.92 | 6.08 | n.s. |
| Willingness to shift from main mission tasks to UTs | 6.02 | 5.79 | n.s. |
| Extent to which team considered alternatives in processing UTs | 4.67 | 5.10 | n.s. |
| Teams level of activity when UTs appeared | 5.02 | 4.77 | n.s. |
| Note: Means based on a rating scale where 1= “poor” and 7= “superior.” Independent samples t-test; 2-tailed significance (p<.10). N=6. | | | |

Only one measure shows a difference that achieves statistical significance (p<.10). Specifically, observers rated teams using the model-based structure (A1-6) as significantly stronger in their awareness of others’ workload and willingness to adjust to keep workload balanced. The mean ratings show a similar pattern for the related “back-up” behavior of anticipating others’ need for assistance, but the t-test is just below the critical value for significance. Two other teamwork behaviors that support the advantage of the A1-6 structure are general communication effectiveness and coordination, though again not achieving statistical significance. However, given the limited sample size, this consistent pattern of effective teamwork is noteworthy. This result suggests, given the principles of organization theory, that the more limited coordination practiced by the divisional structure designed to increase unit-level autonomy, was sufficient to develop participants’ commitment to team rather than unit-level goals. The additional coordination practice for teams in A0-6 structure did not seem to yield an advantage in these domains of teamwork process. However, no structural advantage seems evident in mean observer ratings of processes evident in the prosecution of Unanticipated Tasks.

3.4 Participant Self-Report Data Comparing Two Structures

At the end of each team’s application of the second structure to the simulated mission, participants completed a survey comparing the two structures. They were asked to rate each structure on a set of questions where 1= “low” on the stated characteristic and 7 = “high” on the stated characteristic. Table 5 presents the results of paired comparison t-tests using two-tailed test of significance (p<.10). Only one of the measures achieves a level of statistical significance. Item number 2 in Table 5 shows that the A0-6 structure where nodes were more interdependent and there was greater practice of coordination, was rated as more effective in performing the

Unanticipated Tasks ($p < .10$). This finding supports organization theorists who argue that the ability to respond to complex and uncertain task environments is enhanced by coordination mechanisms (e.g., Ensign, 1998; Galbraith, 1995; Mintzberg, 1993). It also strengthens the interpretation of the non-significant software-based performance measures in Table 2 that showed both greater accuracy and faster latency for A0-6 for the UTs. Three other items in Table 5 show means in the direction of the hypothesis (though not significant) related to the value of greater coordination capability. Specifically, item 5 (facilitation of communication), item 8 (situational awareness), and item 10 (willingness to shift from planned tasks to UTs) have higher participant ratings for A0-6 as compared with A1-6. However, other items that could also be expected to correlate with greater coordination practice (e.g., flexibility, coordination) do not

| | A0-6 (interdependent) | A1-6 (autonomous) |
|---|----------------------------------|------------------------------|
| 1. How well did each structure perform mission? | 5.49 | 5.58 |
| 2. How well did each structure perform UTs? | 5.78 | 5.48* |
| 3. Flexibility | 5.07 | 5.05 |
| 4. Structure's facilitation of coordination | 5.29 | 5.34 |
| 5. Structure's facilitation of communication | 5.40 | 5.23 |
| 6. Structure's facilitation of development/use of efficient strategies | 5.35 | 5.39 |
| 7. Balance of task distribution across structural nodes | 5.03 | 4.88 |
| 8. Situational awareness | 5.42 | 5.25 |
| 9. Extent to which UTs interfered with execution of planned mission tasks | 4.48 | 4.40 |
| 10. Willingness to shift from planned tasks to UTs | 5.88 | 5.71 |
| 11. To what extent did team consider alternatives in processing UTs? | 4.38 | 4.54 |
| 12. Degree of Flag involvement in processing UTs? | 5.32 | 5.38 |
| Note: Means are based on a rating scale where 1= "low" and 7 = "high" value on the characteristic. * Paired (dependent samples) t-test significant $p < .10$ (2-tailed). All other t-tests not significant. N's ranged from 29 to 36 given missing cases. | | |

show a similar pattern. It is also interesting to note that data from the participants do not confirm the observer ratings of more effective performance of the primary mission tasks under the A1-6 model-based, more autonomous structure. The means on this item (#1) shows no significant difference between the two structures.

3.5 Assessing the Effect of Training on Performance

One obvious design limitation to this experiment is that once participants have experienced Unanticipated Tasks, their degree of uncertainty is greatly diminished. In addition, the practice that teams get in the coordination required to accomplish these tasks in whatever structure they are assigned in Trial 1 will likely improve their ability to perform comparable tasks in Trial 2. Steps were taken in the design of the UTs such that the "cover story" for each task from Trial 1 to Trial 2 was different, as were the timing and location within the scenario. Nevertheless, the possibility of a training effect diminishing the influence of structure on UTs needed to be examined. Table 6 presents results for the same measures derived from the DDD-software that were presented in Table 2. However, in this case the comparison combines both structures used in Trial 1 and compared them with both structures used in Trial 2. Because of the directional nature of this test, t-test comparisons use a one-tailed significance test for $p < .10$.

The results of the paired t-test comparisons in Table 6 show that there were some significant learning effects evident for specific measures of performance. The most consistent finding was that three of the four latency measures show a significant improvement (i.e., decrease) in Trial 2 and the fourth is in the same direction, though not statistically significant ($p < .10$). Of the six performance measures (mission, strength, and 4 accuracy scores), only the single-node defensive task measure shows a statistically significant improvement, though the improvement in the accuracy of UTs approaches statistical significance ($p = .12$). The latter finding suggests that the practice in Trial 1 may have limited the ability to detect structural differences in the conduct of unanticipated tasks in Trial 2, because the degree of uncertainty was reduced as a result of teams' conduct of the scenario with UTs in Trial 1. The lack of a training effect for accuracy scores is potentially the result of a ceiling effect, given that many of these scores are above 90% for both trials.

| | Trial 1 | Trial 2 | Sig. Level |
|--|----------------|----------------|-------------------|
| Mission score | 91.0 (6.2) | 91.0 (5.8) | n.s. |
| Strength score | 86.5 (6.06) | 90.3 (3.6) | n.s. |
| 7 Primary Offensive Mission Tasks (predictable) –Accuracy | 92.4 (11.5) | 97.0 (5.1) | n.s. |
| 7 Primary Offensive Mission Tasks (predictable) –Latency | 1131 (114) | 982 (69) | $p = .01$ |
| 4 Complex Unanticipated Tasks (unpredictable) –Accuracy | 83.0 (32.5) | 93.9 (15.7) | $p = .12$ (n.s.) |
| 4 Complex Unanticipated Tasks (unpredictable) –Latency | 313 (80) | 273 (75) | $p = .11$ (n.s.) |
| Single-node Defensive Tasks –Accuracy | 85.5 (8.6) | 94.1 (4.0) | $p = .03$ |
| Single-node Defensive Tasks –Latency | 201 (35) | 173 (29) | $p = .07$ |
| Coordinating-nodes Defensive Tasks –Accuracy | 77.3 (12.7) | 76.4 (11.1) | n.s. |
| Coordinating-nodes Defensive Tasks –Latency | 479 (143) | 279 (63) | $p < .01$ |
| Note: Means and (std dev.). Accuracy based on 100%; Latency is number of seconds. Paired t-test comparison of means, 1-tailed significance levels. N=6. | | | |

Table 7 compares observer ratings of teamwork processes across the two trials. Of the ten measures shown, half show Trial 2 as significantly higher than Trial 1 ($p < .10$), with two additional measures showing marginal significance. These findings suggest that teams continue to enhance their teamwork processes with each exposure to the mission simulation. It is likely that these improvements in teamwork contribute to the improvements in performance latency shown in Table 6.

Table 8 presents the participants' ratings of the organizational and process characteristics compared by trial. Items 13 and 14 are most relevant to the question posed at the beginning of this section and show that, indeed, the preparation for UTs was significantly higher in Trial 2

than Trial 1. This suggests that the Trial 2 data cannot be taken as a satisfactory test of the research question regarding the link between structure and performance of complex unpredicted tasks. In addition, participant ratings give specific insights as to which characteristics were most influenced by the training effect (and which were not).

| | Trial 1 | Trial 2 | T-test significance |
|--|----------------|----------------|----------------------------|
| Overall Teamwork | 4.90 | 5.80 | p<.06* |
| Members anticipate others' need for assistance | 4.75 | 5.42 | p=.15 (n.s.) |
| Members adjust to redistribute workload | 4.58 | 5.50 | p<.08 * |
| Communication Effectiveness | 4.67 | 5.42 | n.s. |
| Proactive Communication | 4.83 | 5.75 | p<.07* |
| Coordination | 4.83 | 6.50 | p<.04* |
| Team Orientation | 5.92 | 6.08 | n.s. |
| Willingness to shift from main mission tasks to UTs | 5.83 | 5.98 | n.s. |
| Extent to which team considered alternatives in processing UTs | 4.56 | 5.20 | p<.11 (n.s.) |
| Teams level of activity when UTs appeared | 4.54 | 5.25 | p<.05* |

Note: Means based on a rating scale where 1= "poor" and 7= "superior."
 * Difference significant using independent samples t-test; 1-tailed significance (p<.10). N=6.

In addition to the two mentioned above, the three factors that increased significantly from Trial 1 to Trial 2 were: the development and use of strategies for processing tasks, situational awareness, and willingness to shift from planned tasks to UTs. It is noteworthy that participant ratings do not show a significant order effect on task performance outcomes for either planned mission tasks or unanticipated tasks. And, unlike the observer-based findings, the differences for coordination and communication are not significantly different. Overall, the findings reported in Tables 6-8 show clear evidence of a training effect particularly in the areas of teamwork strategies, preparedness for UTs, and improved speed of task accomplishment (i.e., latencies).

| | Trial 1 | Trial 2 |
|---|----------------|----------------|
| 1. Mission performance? | 5.50 | 5.57 |
| 2. UT performance? | 5.55 | 5.70 |
| 3. Flexibility | 5.09 | 5.03 |
| 4. Facilitation of coordination | 5.23 | 5.40 |
| 5. Facilitation of communication | 5.25 | 5.38 |
| 6. Facilitation of development/use of efficient strategies | 5.13 | 5.60* |
| 7. Balance of task distribution | 4.89 | 5.02 |
| 8. Situational awareness | 5.19 | 5.49* |
| 9. Extent to which UTs interfered with execution of planned mission tasks | 4.43 | 4.45 |
| 10. Willingness to shift from planned tasks to UTs | 5.70 | 5.90* |
| 11. To what extent did team consider alternatives in processing UTs? | 4.36 | 4.56 |
| 12. Degree of Flag involvement in processing UTs? | 5.45 | 5.25 |
| 13. How prepared for first UT? | 4.51 | 5.60* |
| 14. How prepared for subsequent UTs? | 5.26 | 5.66* |

Note: Means are based on a rating scale where 1= "low" and 7 = "high" value on the characteristic.
 * paired t-test significant p<.10 (1-tailed). All other t-tests not significant.
 N's ranged from 29 to 36 given missing cases.

4. Discussion

The primary purpose of this experiment was to examine the relationship between structure (as differentiated by degree of practiced coordination) and performance of tasks that varied in terms of complexity and predictability. Previous experiments had shown that a model-based structure that was designed for increased unit-level autonomy (A1-6) outperformed a more interdependent, functional structure (A0-6) on the complex, but predictable mission tasks. This finding was not consistently supported by the current experiment. Only observer ratings showed the model-based A1-6 significantly outperforming the traditional, functional A0-6 on mission tasks. The comparison of the two structures on the complex Unanticipated Tasks also shows only limited differences. The prediction derived from organization theory that greater coordination capability would facilitate the ability to respond to complex, unanticipated events was only supported by significant differences in the participants' ratings favoring the more interdependent A0-6.

There are several possible explanations for these results. First, the structural changes made to remove the communication networks used in the previous experiment may have given both structures greater situational awareness. This improved common operational picture and the ability to communicate freely across the entire structure may have overridden the differences in structure based on either task-based or functional asset allocations. A second possible explanation is that there is not sufficient differentiation in the amount of coordination "practiced" by the two structures to test the role of this capability in situations of task uncertainty. A third factor evident is that of a ceiling effect, particularly for accuracy scores. From both data and participant comments, the challenge of the scenario may not have been sufficient to allow performance differences between the structures to emerge. This is particularly problematic in small sample experiments such as this, with limited statistical power.

The final possible explanation for limited results by structure is related to the ceiling effect, but also has theoretical implications. This is the role of training on performance. As shown in the final section of the results reported above, there were many more significant differences in terms of both performance outcomes and teamwork processes in comparing Trial 1 and Trial 2 than there were for the comparisons by structure. This suggests that teams were continuing to develop skills that enhanced their performance.⁶ The testable hypothesis to be derived from this is that the continuing experience of rehearsal was more powerful in determining performance than the differential characteristics of the two structures. The interesting theoretical question is to identify what particular skills are most salient in improving performance. Previous research such as that by Weick and Roberts (1993) on the coordination used in the conduct of operations on the flight deck of aircraft carriers can provide insights as to potential critical dimensions of coordination capability.

The discussion above has clear implications for future research. To further test the relationship between coordination structures and task performance, the following changes to research method are suggested. The ceiling effect can be addressed by increasing the challenge of the scenario through increased task demand and competing requirements. The operationalization of

⁶ It is important to note that the research design was balanced in terms of the order in which teams were assigned structures for their two simulation trials. Thus, the influence of training did not differentially effect either structure.

“coordination capability” can be made more distinctive by re-designing the two structures to increase the unit-level autonomy in A1-6 and the interdependence in A0-6. The role of the communication nets on performance can be re-evaluated by conducting the experiment reported here using the same structures, but with the networks established as they were in Experiment 4 (see Hocevar *et al.*, 1999).

A different research implication, however, is suggested for evaluating the role team rehearsal plays on performance of tasks that vary in terms of complexity and predictability. One question could be to test the relative impact of rehearsal of technical skills (e.g., asset use, information technology, coordination techniques) and interpersonal skills (e.g., team familiarity, cohesion) on performance. A possible research design would be to follow the same training regimen used in this experiment where teams learn both individual skills for use of specific command assets as well as techniques of coordination (in terms of use of software, requirements of scenario, etc.). Then, for actual data trials, half of the teams would be “shuffled” so that each individual is still assigned to the command node for which they trained, but they are naïve to their other team members in terms of interpersonal dynamics. A comparison of teams of equivalent technical competence, but varied in terms of interpersonal familiarity and team cohesion, could provide important insights into the training implications for improved organizational performance in situations of predictability and organizational adaptability to situations of uncertainty.

Overall, the strongest finding from this experiment is that training was more important than structure in determining improved performance. This has significant potential implications for practice, particularly in the current defense environment of complex and interdependent mission areas requiring coalition and joint operations. While continued basic research on the technical and process aspects of coordination capability is needed, this research suggests that increased focus on coordination training and team building can improve operational success in such complex missions. The question of the impact of prior rehearsal in team coordination on performance can also be examined in Tier 2 experiments such as Fleet Battle Experiments or the Global Wargame.

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