Cover Sheet

When Do Organizations Need to Change (Part I)? Coping with Incongruence

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Abstract

Different organizational structures are better matched to certain mission types than others (organizational congruence). Consequently, one way to achieve superior mission effectiveness is to switch between organizational structures when circumstances dictate. However, little is known about the variables that signal the need for such structural adaptation. To explore this issue, we used a model-based design process to create mission scenarios that were either matched (congruent) or mismatched (incongruent) with two organizational structures (Functional, Divisional). Results indicated that, as predicted on the basis of the coordination requirements imposed by the model-based design process, performance in the incongruent cases was characterized by increased communication, increased perceived workload, and degraded performance. Given these overall results, we explored these data further by analyzing communication patterns to identify how the organizations attempted to cope with the congruence problem. Our results indicated that the communication strategies employed in the face of incongruence depended on organizational structure/mission scenario pairings, suggesting that the specific signals of the need for structural adaptation will likely depend on context.

Introduction

Mission effectiveness depends on a number of factors, ranging from training excellence to technical superiority to effective planning. In the work reported here, we focus on one contributing factor, "congruence," which has until recent years gone largely unaddressed. From a human engineering perspective, congruence is about the "fit" between organizational structures, technology, people, and mission requirements. Mission effectiveness can be optimized when these items are well matched. In particular, here we focus on the central theme of the Adaptive Architectures for Command and Control (A2C2) Research Program, which is creation of organizations that fit mission requirements.

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Broadly speaking, different organizations may be better matched to certain missions than others, and in fact, empirical results indicate that modeling techniques can be used to design organizations such that there is a tight fit or alignment between their structures and mission requirements (e.g., Entin, 1999; Hocevar, 2000; Hutchins, Hocevar, Kemple, Kleinman, Entin, and Serfaty, 2000; Levchuk, Merina, Levchuk, Pattipati, & Kleinman, 2001). In other words, organizational effectiveness can be mediated by the congruence between an organization's structural design and an environment or task (e.g., Donaldson, 2001; Van de Ven & Drazin, 1985). If organizational structure is out of "alignment" with the organization's mission, then quality of performance should be reduced. Performance may be affected by whether the right person has the right resources at the right place at the right time.

Accordingly, one way to achieve superior mission effectiveness may be to change organizational structures when circumstances dictate in order to achieve a better fit. However, little is known about when and how organizations can and should adapt their structures, and about the variables that signal the need for such structural adaptation. This paper addresses this issue by focusing on an experimental study of how organizations cope with incongruence. Based on our modeling approach, our empirical strategy was to contrast performance under conditions in which organizational structures and missions were congruent with performance under conditions in which they were incongruent.

Ultimately, through this work, our goal is to identify "leading indicators" that signal the need to adapt organizational structure in order to enhance mission effectiveness. We define leading indicators as measures that signal that an organization is "out of alignment" with its mission and needs to change its structure to improve performance. However, the ability to accurately identify leading indicators depends on the creation of conditions in which an organizational structure is measurably incongruent with its mission, and in which this incongruence results in significant performance decrements. Given the presence of observed decreases in performance due to incongruence, we can then ask what observable behaviors were present that could be used as signals of misalignment.

Toward this goal, this paper addresses: 1) The effectiveness of our model-based congruence manipulation, as fully presented in Kleinman, Levchuk, Hutchins, & Kemple (2003) and Levchuk, Kleinman, Ruan, & Pattipati (2003); and 2) The ways in which the organizations studied attempted to cope with incongruence. In this paper, we address these items by focusing on performance measures over the entire mission scenarios. In this manner, we verify the basic manipulation and provide initial insight into how incongruence affected organizational performance and process. This work therefore speaks to identification of leading indicators. Moreover, this work sets the stage for exploration of performance and process changes *over time*, as presented in our companion paper, Entin, Diedrich, Kleinman, Kemple, Hocevar, Rubineau, & Serfaty (2003), which directly addresses what incongruence looks like in action. This second paper focuses on performance and processes over time, for ultimately, the goal is to identify the state of incongruence early in a mission, long before performance significantly depreciates.

Engineering of Organizational Congruence

Our research strategy is to use a set of modeling techniques to design organizational structures and mission scenarios. The modeling techniques, based on a variety of approaches (e.g., Carley & Lee, 1998; Handley, Zaidi, & Levis, 1999; Levchuk, Levchuk, Luo, Pattipati, & Kleinman, 2002a, 2002b), are used first for organizational design and then for simulation to evaluate proposed designs prior to implementation and experimentation. In the case presented here, our basic approach to studying congruence was to define two disparate organizational structures and then design two missions (scenarios) that exploited the differences between the two structures. Thus, the objective was for the first mission scenario to be "matched" to organization 1 through a high degree of congruence, while also being "mismatched" (i.e., exhibit low congruence) with organization 2. The goal was for the reverse to be true for the second scenario. The organizational structures and scenarios were implemented through the use of the Distributed Dynamic Decision-making (DDD) simulation testbed.

We begin by addressing the creation of the organizations and mission scenarios used to investigate the congruence concept. In this paper, we briefly outline the strategy, whereas complete details can be found in Kleinman et al. (2003) and Levchuk et al. (2003). Based on these designs, we then outline our primary hypotheses and experimental methods.

Organizational Structure

Building on previous work (Diedrich, Hocevar, Entin, Hutchins, Kemple, & Kleinman, 2002; Hutchins, Kleinman, Hocevar, Kemple, & Porter, 2001; Moon, Hollenbeck, Ilgen, West, Ellis, Humphrey, & Porter, 2000), the two organizational structures that we explored are commonly referred to as Functional (F) and Divisional (D). The functional structure was organized such that each participant specialized in one or two aspects of a mission such as Strike or Air Warfare, where the specific assets controlled were distributed across multiple platforms (ships). In contrast, in the divisional structure, each participant had control over a single multifunctional platform that was able to process a variety of functional tasks in a given location.

These organizational structures are illustrated in Table 1, which shows the asset ownership for the two structures. Note that within the DDD, organizational structure is operationally defined on the basis of asset ownership and location. However, more generally, this operational definition reflects differences in roles (single vs. multifunctional areas) and geographic responsibilities (local vs. global responsibility in area of operations). For instance, in the functional organization (Table 1, columns), each of the six decision makers (DMs) had control over one (or two) areas (Strike, BMD, ISR, AWC, SuWC/Mines, SOF/SAR) with assets assigned across all of the geographical areas (e.g., F18S, Anti-ballistic missiles, UAVs, F18A, etc.). In contrast, in the divisional organization (Table 1, rows), each of the six DMs controlled assets across almost all of the functional areas, but these assets were concentrated in proximity to their primary platform (ship). Figure 1 shows the overall view of the area of operations, where the primary platforms are indicated by their colors and specifications. Note that the ranges of the various assets varied depending on the qualities of the modeled systems.

		1	2	3	4	5	6
	Platform	**STRIKE**	**BMD**	**ISR**	**AWC**	**SuWC/MINES**	**SOF/SAR**
1	**CVN**	2F18S	xxx	1UAV	2F18A, E2C	1FAB, 1MH53	1HH60
2	**DDGA**	8TLAM	3ABM,4TTOM	1UAV	6SM2	1FAB, 2HARP	1HH60,1SOF
3	**DDGB**	8TLAM	3ABM,4TTOM	1UAV	6SM2	1FAB, 2HARP	1HH60,1SOF
4	**CG**	8TLAM	3ABM	1UAV	6SM2	1FAB,2HARP,1MH53	1HH60
5	**FFG***	2F18S	xxx	1UAV	2F18A,E2C,4SM2	1FAB,2HARP,1MH53	1HH60
6	**DDGC**	8TLAM	3ABM,4TTOM	1UAV	6SM2	1FAB, 2HARP	1HH60,1SOF

Table 1. Organizational structures where the functional organization (F) is indicated in columns and the divisional organization (D) is indicated in rows.

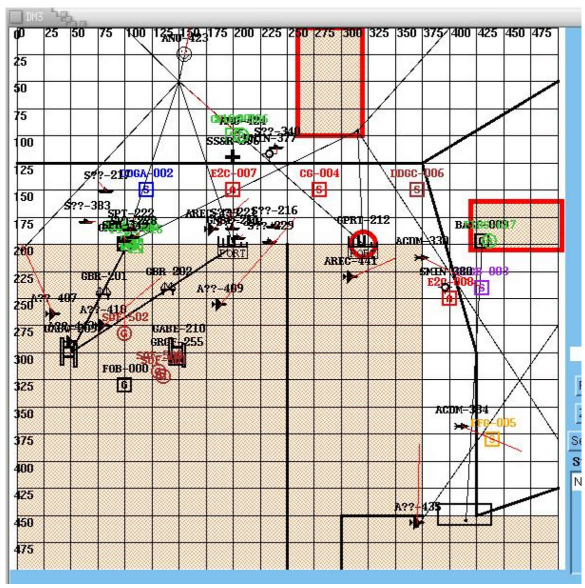

Figure 1. Simulation interface display showing battle space.

Design of Mission Scenarios

Given these organizational structures, our goal was to use the modeling process to design a functional scenario (f) that fit the functional organization (F), while being misfit to the divisional organization (D). Similarly, we wanted to design a divisional scenario (d) that fit D but not F. Several factors went into the design of these two scenarios (see also, Kleinman et al., 2003), but there were two primary strategies: First, we manipulated the selection of resource requirements needed to accomplish particular tasks within the scenarios. Note that the two organizations differed primarily with regard to the assets (and hence the resource capabilities) that each DM owned. In the models used to design the scenarios, the degree of predicted (structural) congruence is inversely related to the amount of inter-DM coordination needed to accomplish the mission. Therefore, by adjusting the resource requirements of selected tasks it is possible to manipulate the inter-player coordination needed to successfully prosecute selected tasks for a given organization-scenario pairing. Accordingly, we designed tasks within f such that little between-DM coordination would be needed within organization F, while significant coordination would be needed by organization D, with the reverse being true for scenario d. For example, a task requiring a single asset in each of three functional areas would need three players to coordinate in F, but could be done by a player in D, provided that he/she had assets in all of the requisite areas. Similarly, a task requiring multiple assets in a single functional area is well suited to F, but would need multiple players in D to coordinate their assets. In general, this manipulation included all of the key "mission" tasks, plus most of the time critical tasks.

Second, we manipulated congruence through the temporal and geographical distribution of tasks. These largely involved tasks that had only one or two functional areas represented in their resource requirements (air attackers, sea attackers, etc.), and aimed to exploit the different geographical responsibilities in D versus F. Note that in D players had responsibilities in a defined area, while in F players had responsibilities that covered the entire battle space. Thus, for example, in scenario d we designed "waves" consisting of single functional area attackers (e.g., air) wherein the individual tasks within each wave were distributed geographically over several players. Clearly, this would impose a significant load upon one DM (e.g., air warfare) in F in both time and space, but the load would be shared among several players in D with little or no coordination needed. In scenario f the attack "waves" consisted of several different functional area tasks where each wave targeted a specific player's area in D. Thus, we could overload a given player in D, but the load would be distributed among several players in F. Task categories used for these manipulations included items such as hostile air and sea platforms, missile launchers, search and rescues, and mine clearing tasks. In general, each of the scenarios had approximately ten waves spaced uniformly in time over the length of the scenario.

Testing Organizational Congruence

Based on these organizational and mission scenario designs, to test this model-based method of engineering organizational congruence, we designed an experiment in which 8 teams of 6 participants each engaged in both scenarios in one organizational structure. Hence, 4 teams performed in D and 4 teams performed in F, and each of these teams played both the d and f scenarios (order was counterbalanced across teams). There were two matched (congruent) cases (D-d and F-f) and two mismatched (incongruent) cases (D-f and F-d).

Based on the mission scenarios and organizational definitions, there were three overall predictions:

- The overall level of communications should be higher in the mismatched cases because, based on the models, coordination requirements were manipulated to be much higher in the mismatched cases (i.e., players would have to communicate verbally to process tasks requiring shared resources).

- The overall level of workload should be higher in the mismatch cases. Because coordination demands were manipulated to be high in the mismatched cases, this would result in increased communication requirements and an increased need for coordinated actions to prosecute tasks. Hence, we expected that the perceived workload would be higher in the mismatched cases.
- Overall, performance should be worse in the mismatched cases because the greater coordination requirements should lead to more communications and higher workloads, resulting in some decrements in the ability to perform multiple tasks quickly and accurately.

Note that these are general predictions regarding the overall effects of the experimental manipulation. Validation of these predictions therefore provides evidence that the experimental manipulations worked as intended, providing us with a "license" to further explore in detail how the organizations studied attempted to cope with incongruence, thus shedding light on potential "leading indicators" of the need for organizational adaptation.

Hence, beyond these global predictions, we focus our analyses on strategies for coping with incongruence. Within the context of this investigation, the organizations were not permitted to adapt their structures, for instance, from D to F in the context of the functional scenario. Nevertheless, the organizations were free to adapt their strategies as they attempted to deal with the mismatched situations. We believe that these strategies might offer insight into leading indicators of the need for change because they reflect how an organization attempts to cope with incongruence prior to a change in organizational structure. In other words, it is possible that strategy changes might consistently predict the need for structural change, and as such, the strategy changes might serve as potential leading indicators. We therefore focused our analyses on communications, for communication is the primary mechanism through which the organizations could express their attempts to deal collectively with the misfit situations.

Moreover, we also focused our analyses on differences between how the F and D organizations attempted to cope with the various scenarios. This is a critical issue, for as stated above, our ultimate goal is to understand the signals for change (leading indicators). Consequently, it is imperative to ascertain how organizational structures and mission scenarios, which may be more or less congruent, interact to shape the behaviors observed. These behaviors (e.g., strategies) will only serve as valid leading indicators to the extent that we understand the contextual factors that shape performance and process.

Method

Participants

Forty-eight officers attending the Naval Postgraduate School in Monterey, CA, served as participants. Most of the officers were 03 or 04 and several services and nations were represented. Participants were organized into eight teams of six individuals each. Participants received no compensation for study participation.

Apparatus

The simulation was implemented within the Distributed Dynamic Decision-making (DDD) environment. The DDD is a distributed client server simulation that provides a flexible framework in which to study individual and team performance. In general, DDD simulations involve individual (and team) decision-making about complex situations based on information and resources provided by the simulation and other team members (Serfaty & Kleinman, 1985; Kleinman & Serfaty, 1989). The simulation enables the manipulation of variables such as organizational structure and mission scenario tasking. In addition, a variety of performance measures can be recorded including items such as tasks processed, latencies, and accuracies. In this case, the organizational structures were implemented in the DDD simulation by varying the ownership of different kinds of assets. Thus, we designed a functional organization (F) and a divisional organization (D), as defined in Table 1. With respect to scenario design, as specified in the above section "Engineering of Organizational Congruence," we varied a number of items in order to design the functional (f) and divisional (d) scenarios including task timings, locations, and resource requirements.

Procedure

Participants began the experiment by signing an informed consent form and then completing two hours of DDD "buttonology" training to learn how to control the various assets and how to use the various functions contained in the DDD simulation. A second two-hour session provided training designed to provide experience on the skills necessary to perform either the divisional or functional scenarios, without creating a bias for either kind of scenario. In general, these training scenarios exposed participants to the general mission task flow and the task resource requirements. However, these training scenarios were composites of the actual mission scenarios with respect to resource requirements, and as such, neither of the two training scenarios were explicitly designed to favor one organizational structure over another. Following training, each team engaged in a two-hour data collection session followed by a second two-hour data collection session. Thus, in total, each team participated in four hours of training and four hours of testing over four sessions over multiple days. At the end of the experiment, all teams were debriefed as to the nature and purpose of the experiment.

Each team was assigned to either the D or F organizational structure, which was maintained throughout all training and testing. Thus, organizational structure was manipulated as a between-subjects variable with 4 teams in F and 4 teams in D. In contrast, during each of the two experimental sessions, the teams each performed the d scenario and the f scenario. Thus, scenario was manipulated as a within-subjects variable. Across the two sessions, the scenarios were counterbalanced as d-f-f-d for half the teams and f-d-d-f for half of the teams.

The experimental scenarios involved a Joint Forces mission that lasted approximately 35 minutes or until the final Port task was captured, whichever came first. The teams used a variety of sea, land, and air assets to complete a specified mission that included destroying or capturing a command center, two naval bases, two air bases, and a port. Along the way, the teams encountered a variety of obstacles including hostile ground, sea, and air assets. In addition, players had to defend neighboring foreign friendly areas from SCUD missile attacks, while also defending friendly assets. Critically, the mission environment was significantly characterized by a variety of time-critical tasks (e.g., SCUD missile launchers, coastal defense launchers, search and rescue) that required immediate response. The area of operations also contained neutral parties and hostile assets that did not directly engage friendly forces, and therefore were deemed to be low on the list of priorities as specified by the rules of engagement and commander's intent.

Although the commander's intent and rules of engagement were similar across the organizational structures, the precise operational roles given to the participants depended on organizational structure. Hence, mission roles stressed multiple functional responsibilities in a given geographic region for the divisional organization, but functionally specific responsibilities across the entire area of operations for the functional organization. As noted above, in general, in the functional organizational structure a participant charged with one aspect of the mission, such as air warfare, "owned" (had direct control of) all of the assets necessary to do that part of the mission across the area of operations. In contrast, in the divisional organizational structure, participants had direct control over all assets on one multifunctional platform (e.g., a carrier or a guided missile cruiser) that was located in a geographically distinct region. However, there was some overlap of range such that multiple assets from multiple DMs could access the same targets in certain areas.

Data Analysis

Overall, the data collected in the experiment included assessments of performance, communications, and workload. These dependent measures were derived from three different sources: Instruments completed by trained observers, participant self-report measures, and measures derived from the DDD simulator. Below, we describe the instruments employed in each of these areas with respect to global measures. Time-series based measures are presented in Entin et al. (2003).

Performance Measures. In general, the DDD simulator enabled the measurement of several variables related to individual and team performance such as latency to process a task, accuracy in processing a task, number of tasks process, the number of task arrivals (tasks in the scenario), etc. In this paper, we focus on the percent of tasks processed (the number of tasks attacked/the number of tasks arrived in the scenario), the accuracy of task processing (the ratio of assets applied to assets required for tasks attacked), and the latency of tasks attacked (the time from arrival in the scenario to the time of attack).

Team Communications. Using a custom software tool, verbal communications between team members were captured by observers at an intermediate level of detail that incorporated both semantic and quantitative aspects of the communication stream. In brief, during the conduct of a scenario two observers listened to the communications in real time, and used specially designed software and a handheld, touch-sensitive computer to code the source, the recipient, the time, and the type of the verbal communications among the team members. One of the observers coded the communication for three of the team members, while the other observer coded the communications exhibited by the remaining three team members. Broadly speaking, the types of communications were divided into three basic categories: transfers (e.g., provision of information), requests (e.g., demands for information), and acknowledgements (e.g., "aye"). Both transfers and requests were, in turn, classified as requests/transfers for/of information (e.g., "Where is the enemy aircraft"), action (e.g., "Take the bridge"), or coordination ("I need your help on the air base"). Raters were trained prior to the experiment on the basis of tapes and training sessions until reliability was about $r = 0.76$.

Workload. At five-minute intervals throughout the scenario, each team member was prompted by the DDD simulator to provide an estimate of the workload they were experiencing at the moment. The prompt was in the form of a window that opened on the display. The workload rating was made on a seven point Likert scale anchored at on end by the word "low" and the other end by "high." The windows, which were mildly intrusive, could not be closed until a rating was made.

Participant Impressions. Following the final session, participants filled out a brief survey asking about their impressions regarding indications of reduced performance and their impressions regarding potential ways to improve performance.

Results

Overall, we predicted that relative to the congruent cases (D-d, F-f), performance in the incongruent cases (D-f, F-d) would be characterized by increased communications and perceived levels of workload due to the model-based coordination requirements manipulation. Due to these increased coordination requirements, we also expected that performance would be worse in the incongruent cases. Accordingly, due to our interest in congruence, we focused our analyses on the interaction between organizational structure and scenario. Below, we present our results with this emphasis in mind. In general, we evaluated the results through a set of two-within-subjects (scenario and replication) by one-between-subjects (structure) mixed-model multivariate analyses of variance. When computing and reporting means we averaged across replications. We begin by evaluating the primary predictions, and then address communication strategies in detail.

Overall Communications

Based on the modeling approach, we predicted that the overall level of communications should be higher in the mismatched cases because coordination requirements were manipulated to be much higher (i.e., players would have to communicate verbally to process tasks requiring shared resources). Consistent with this prediction, averaged over the entire scenario, the overall volume of communications was higher in the incongruent cases than in the congruent cases, as demonstrated by a significant structure by scenario interaction, $F(1, 6) = 38.75$, $p < 0.002$. This result indicated that the teams talked more when faced with incongruent situations (Figure 2). In addition, there was a greater volume of communications for the d scenario, $F(1, 6) = 6.49$, $p < 0.05$, and a marginally significant main effect for structure, $F(1, 6) = 3.73$, $p \leq 0.1$. These results suggested that there were more communications in the D organization. Note in particular that within the F organization, the volume of communications almost doubled when going from the f to the d scenario, whereas within the D organization, when going from the d to the f scenario communications also increased, but to a much lesser degree. Thus, given these scenarios, in response to incongruence, D organizations talked more, but F organizations talked a lot more.

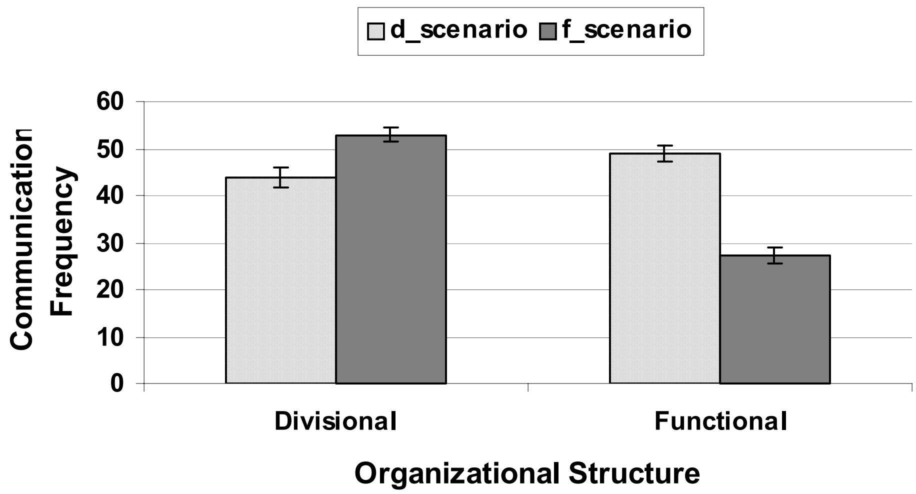

Figure 2. Mean communication frequency for organizational structure and scenario.

Overall Workload

We also predicted that the overall level of perceived workload should be higher in the mismatched cases: Since coordination demands were manipulated through the modeling process to be high in the mismatched cases, this would result in increased communication requirements and an increased need for coordinated actions to prosecute mission tasks. Hence, we predicted that the perceived workload should be high in the mismatched cases. Consistent with this prediction, the overall level of perceived workload tended to be higher in the mismatched conditions, although this result was only marginally significant, $F(1, 6) = 2.59$, $p < 0.08$. As shown in Figure 3, teams performing with the D structure tended to report higher workloads when performing the f scenario (incongruent condition) as compared to when they were performing the d scenario (congruent condition), while teams performing with the F structure tended to report higher workload when performing the d scenario (incongruent condition) as compared to when they performed the f scenario (congruent condition). There were no significant main effects for either structure ($F(1, 6) = 0.35$, ns) or scenario ($F(1, 6) = 0.04$, ns). Collectively, these data provide some limited support for the workload hypothesis.

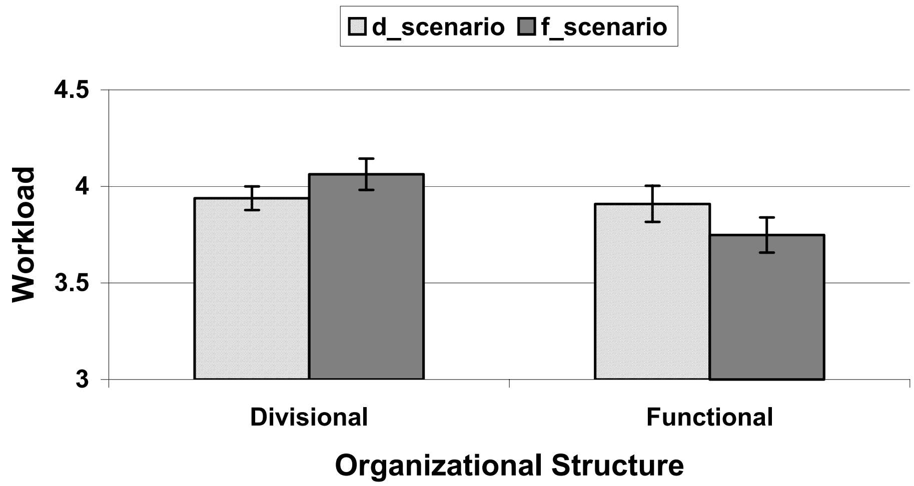

Figure 3. Mean perceived workload for organizational structure and scenario.

Overall Performance

Overall, we predicted that performance should be worse in the mismatch cases because the greater requirements for coordination should lead to more communication and higher workload, resulting in some decrements in the ability to perform multiple tasks quickly and accurately. Consistent with this prediction, we found that the overall percentage of tasks completed tended to be superior in the matched conditions, $F(1, 6) = 50.37$, $p < 0.001$. This measure, defined as the number of tasks attacked divided by the number of tasks arrived in the simulation (times 100), indicated that in both organizations, performance was superior in the congruent cases (Figure 4). The main effect for structure was not significant ($F(1, 6) = 0.21$, ns), but there was a marginally significant main effect for scenario ($F(1, 6) = 3.71$, $p \leq 0.1$). Collectively, these data suggest that teams were less successful at processing the tasks that were present in the incongruent cases.

However, with respect to measures of mean accuracy for tasks attacked (resources applied/resources needed *for tasks processed*) and mean latency for tasks attacked (time of task processing minus time of task arrival in the game *for tasks processed*), there were no significant main effects or interactions, although with respect to accuracy, the main effect for scenario was marginally significant, $F(1, 6) = 5.70$, $p < 0.06$. Nevertheless, there was a small trend toward decreased accuracy for organization D in the incongruent condition. Overall, these data collectively suggest that there was a tradeoff between tasked processed, accuracy, and latency. For both organizational structures, while the percentage of tasks processed suffered in the incongruent conditions, there were no significant drops in accuracy and latency for the tasks that were actually processed.

In total, therefore, these data indicated that the congruence manipulation was effective in that as predicted, performance was worse in the incongruent conditions with respect to the percentage of tasks processed (fewer things got done). Moreover, as predicted by the model-based manipulation of coordination requirements, communications increased in the incongruent cases, especially for the F organization. Similarly, perceived workload also tended to increase in the incongruent conditions. Given these findings, which suggest that the fundamental model-based manipulation of organizational congruence was effective, we now turn to the communication strategies the organizations exhibited given the scenario/structure pairings.

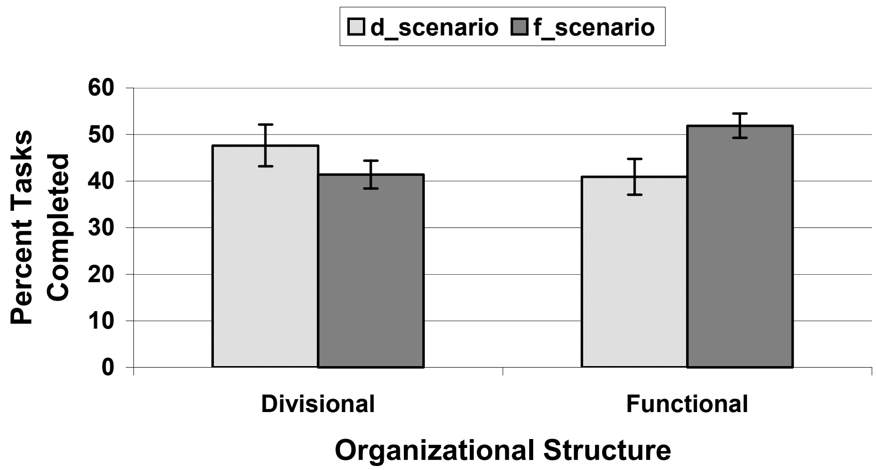

Figure 4. Mean percentage of tasks completed for structure and scenario.

Communication Strategies

Within the context of this investigation, the organizations were not permitted to adapt their structures. Nevertheless, the organizations were free to adapt their strategies as they attempted to deal with the mismatched situations. Consequently, we believe that these strategies might offer insight into leading indicators because they reflect how an organization attempts to cope with incongruence.

To explore this issue, we focused our analyses in particular on communication patterns, for communication is the primary mechanism through which the organizations could express their attempts to deal collectively with the misfit situation. As noted above, in response to incongruence, both the D and F organizations talked more than they did in congruent situations. However, the F organizations tended to talk a great deal more in the F-d case as compared to the F-f case. To further explore this issue, we now address not only the volume of communications, but also the patterns of communications.

Communications: Who Talked to Whom? To explore the communication patterns, we plotted the communication frequencies for each pair of DMs for each scenario-structure pairing. Example plots are shown in Figures 5 and 6. We then conducted six MANOVAs on the various pair wise groupings (Green to others, Purple to others, Orange to others, Blue to others, Red to others, and Brown to others). To clarify, Green was the CVN in D and Strike in F; Blue was DDGA in D and BMD in F; Purple was DDGB in D and ISR in F; Red was CG in D and AWC in F; Orange was FFG in D and SuWC/Mines in F; and Brown was DDGC in D and SOF/SAR in F. In general, these analyses indicated that for the various positions, communications tended to significantly increase with one or more other positions in at least one of the incongruent conditions. However, the nature of the increases depended on the scenario and structure pairings. For example, although Green talked to Brown a bit more in D-f than D-d (there were no differences in Brown talking to Green), Brown and Green talked a lot more *to each other* in F-d as compared to F-f. For these Brown-Green pairings, these interactions between structure and scenario were significant, $p < 0.01$. Importantly, the model-based design process related to coordination requirements predicted many of these differences. For instance, by definition, Green and Brown had to coordinate more in F-d than F-f based on resource requirements that demanded cooperation. Collectively, these data suggest that, relatively speaking, who talked to who in response to incongruence depended on organizational structure and the particular mission scenario demands.

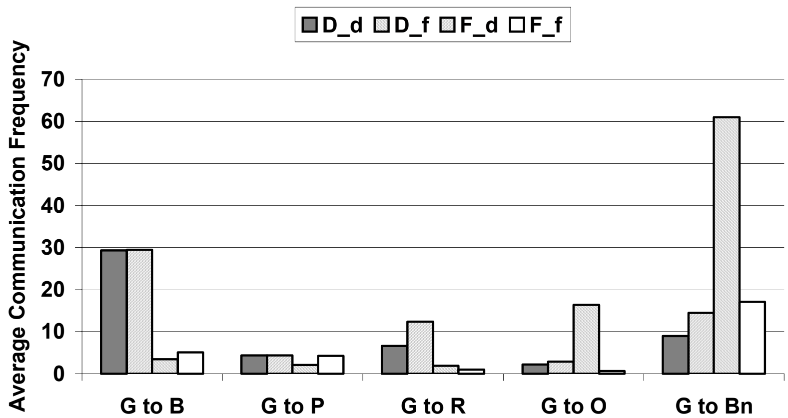

Figure 5. Green's communications with other team members.

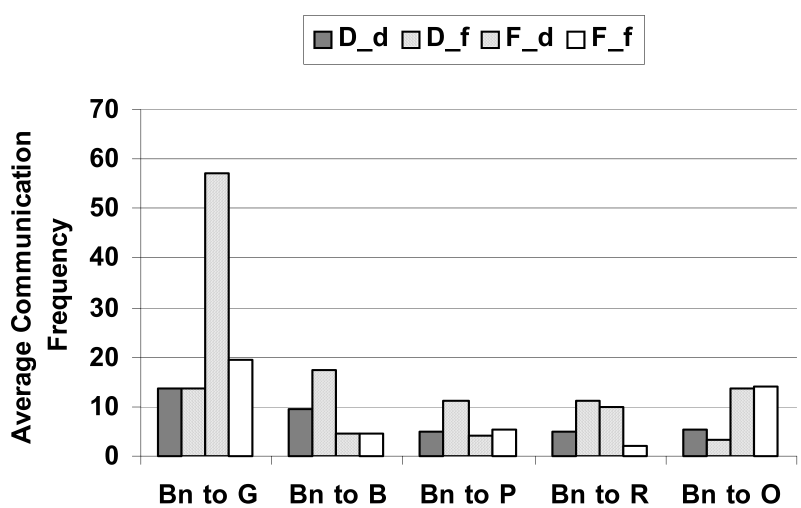

Figure 6. Brown's communications with other team members.

Communications: Talking about What? To explore the content of communications, we used survival analysis techniques (Carroll, 1983). In brief, by looking at the lengths of time between each player's initiation of communications, we derived DM-specific as well as overall condition-specific waiting time distribution functions (Tuma and Hannan, 1984), which in turn yielded incidence rate estimates for communications. Looking at the condition-specific communication rates, congruent and incongruent conditions by architecture were statistically compared using the Mantel-Haenszel test (Dupont, 2002). This analysis once again showed significant differences between congruent and incongruent communication rates in both architectures, controlling for DM-specific effects (D: $X^2(5) = 32.40$, $p < 0.0001$; F: $X^2(5) = 206.95$, $p < 0.0001$). To gain insight into general communication patterns as well as topic-specific communication patterns, we analyzed both an aggregation of all communication types, and separately for the coded communication categories. We looked for changes in a given player's rate of initiating communications relative to that of his or her team between the congruent and incongruent conditions. First, we constructed each player's role-relative incidence rate for communication as the ratio of an individual player's communication incidence rate within one experimental condition to the team's communication incidence rate for that condition. Then, we looked at the change in this ratio from the congruent condition to the incongruent condition. Figures 7 and 8 illustrate large ratio changes (absolute value ≥ 50%) for the Divisional and Functional architectures, respectively (the larger the increase or decrease, the more +'s or -'s, respectively).

DM	All	Task	Asset	Req	Xfer
Green					
Blue					
Purple			-		
Red					
Orange				-	
Brown					

Figure 7. Role-relative incidence rates for incongruence /role-relative incidence rates for congruence for Organization D. This ratio indicates the change in role-relative probability from congruent to incongruent scenarios.

In general, this analysis revealed a strong distinction in the nature of adaptation to the incongruent scenario. For the D structure, the role-relative communication rates by DM for communication type did not change drastically between the congruence and incongruent scenarios. Of the 30 observed changes in relative incidence rates (6 DMs by 5 communication types), there were large changes for only two conditions (Figure 7). The columns in Figure 7 refer to all communications, communications about enemy tasks, communications about friendly assets, requests for information, and non-requested transfers of information. In contrast, for the F structure, there were strong changes in communication types between the congruent and incongruent scenarios for many categories. Of the 30 observed changes in relative incidence rates, there were large changes for 21 conditions (Figure 8). These data indicated that when F organizations went from f to d, the content of communications changed substantially. However, when D organizations went from d to f, communications content changed in more subtle ways.

Green	+	+	+	+	+
Blue	--	-	-	--	-
Purple	-		--	--	-
Red	++	++		+++	++
Orange		+		+	
Brown			+++		

Figure 8. Role-relative incidence rates for incongruence /role-relative incidence rates for congruence for Organization F. This ratio indicates the change in role-relative probability from congruent to incongruent scenarios.

Collectively, these analyses of the communications data showed that when D organizations went from congruent to incongruent situations, they reacted by talking more. However, the changes in the likelihood of particular pairs of DMs talking to each other were relatively small as were the changes in communications content. In contrast, when F organizations went from congruent to incongruent situations, they reacted by talking more, making substantial changes in whom they talked to, and making substantial changes in what they talked about. These data suggest that the context of being in a particular organization given a particular mission influences how organizations react when trying to cope with incongruence.

Participant Impressions

To further assess the manipulation, and potential reactions to incongruence, a follow-up questionnaire was administered to participants at the end of the experiment to obtain information regarding what cues participants were aware of that specified that performance was beginning to degrade. In addition, participants were also asked what type of changes they thought could have improved performance at the point in the scenario when they noticed that performance was beginning to degrade. This information speaks to potential leading indicators of the need to change.

More specifically, with respect to impressions regarding indicators of performance decrement, we collected seventy responses from 48 participants, which were tallied and categorized into the categories shown in Table 2. Two major categories of response, uncompleted tasks/less than optimal performance (51%) and communication/ coordination demands (23%), comprised 74 % of the responses. Examples of the types of responses listed under uncompleted tasks/less than optimal performance included items such as loss of situational awareness, not prosecuting tasks, own platforms being hit by the enemy, being in a reactive mode (i.e., behind the timeline), not accomplishing unanticipated and pop-up missions, not detecting SCUD launches in time to engage them, lapse of time for use of an asset, failure to complete time-critical tasks, and not engaging a task simultaneously (as required). With respect to communications/coordination demands, responses included items such as increased communications, too much chatter, loss of communications discipline (e.g., people talking over each other, not using call signs), talking faster/louder/ increased inflection, slow radio response from others, and the inability to coordinate due to increased communications. Collectively, these responses were consistent with the findings reported above, and in addition, they point to performance decrements and communications as being likely sources of leading indicators.

Indicators of Degraded Performance	Frequency
Uncompleted tasks/ less than optimal performance	34
Communication and Coordination demands	16
Workload	6
Process/ structure	2
Training	2
Other	7

Table 2. Participant impressions regarding indicators of degraded performance.

Suggestions to Improve Degraded Performance	Frequency
Adapt Process or Structure	23
Provide Decision Aids and Human-Computer Interaction Improvements	16
Communications Changes	12
Change Asset Allocation	7
Training	1
Other	12

Table 3. Participant suggestions to improve degraded performance.

When asked about what type of changes participants thought could have improved performance at the point in the scenario when they noticed that performance was beginning to degrade, participants once again made a variety of responses that we grouped into the categories shown in Table 3. One third (thirty-two percent) of the suggestions recommended by participants to improve degraded performance pertained to adaptation of either the process or the organizational structure, consistent with the goals of the research program. Along these lines, several suggestions involved allowing the burden of tasks to be shifted to less-tasked people — on a task-by-task basis — so that when one individual became overloaded they could shift assets to another individual who would then perform the task in order to level the workload. Several participants (who performed in the D structure) recommended that coordinator positions be established for warfare areas along functional vice geographic lines. In addition, twenty-three percent of the suggestions regarding ways to improve degraded performance involved providing decision aid support to provide an automated means to inform the participant regarding various aspects of the scenario. These suggestions included informing the participants regarding the following conditions: (1) when assets were available for each mission (assets available at that time in the scenario), (2) that an asset is out of ammunition (immediately after it conducts its last engagement), (3) that tasks are waiting to be completed, and (4) that the time remaining to complete a task is low (e.g., five minutes remaining).

Discussion

Based on the modeling work that lead to the organizational definitions and the scenarios, we predicted that relative to the matched cases (D-d and F-f), performance in the mismatched conditions (D-f and F-d) would be characterized by increased communications and increased perceived workload. In addition, we predicted that performance would be worse in the mismatched conditions due to these organization-scenario demands and, more generally, the limitations imposed by the lack of fit between the organizational structures and the mission scenarios.

Overall, our results supported these predictions. Communications were increased in the mismatched conditions, and consistent with these findings, the participants remarked on the communications problems associated with the incongruent conditions. Importantly, this change in communications volume likely reflected the model-based manipulation of the need for cross-participant coordination, which was the primary tool employed to engineer congruence. Similarly, consistent with these manipulations, the perceived workload also increased, although this trend was only marginally significant. Once again, these data were generally consistent with the model-based manipulation of coordination requirements. With respect to measures of performance, which included the percent of tasks processed, latencies, and accuracy, results showed reduced performance in the mismatched conditions. Participants in both organizations processed fewer tasks in the incongruent cases, and once again, participants in both organizations remarked on the performance decrements associated with the incongruent scenarios.

In total, these findings were consistent with the model-based predictions. Given this global pattern of results, we take these data as strong evidence that the congruence manipulation was effective. Moreover, the validation of these predictions now provides us with our "license" to further explore in detail how the organizations studied attempted to cope with incongruence, thus shedding light on potential "leading indicators" of the need for organizational adaptation. Here, we address measures averaged over the entire mission scenarios. In our companion paper, Entin et al. (2003), we address measures taken over time.

Strategies as Leading Indicators

Within the context of the present investigation, although the organizations were not permitted to adapt their structures, they were nevertheless free to adapt their strategies as they attempted to deal with the mismatched situations. We believe that these strategies might offer insight into leading indicators of the need for change to the extent that they reliably reflect how an organization attempts to cope with incongruence. In general, we define leading indicators as measures that signal that an organization is "out of alignment" with its mission and needs to change its structure to improve performance and optimize mission effectiveness. Note that these indicators may be "leading" or "lagging" to various degrees. Ideally, leading indicators would predict the need for change prior to any performance decrement. However, some indicators may first surface as performance begins to decline. For instance, the performance decrements that the participants remarked on were likely in this category. Ultimately, measures taken over time will help to clarify the extent to which particular items are truly leading or lagging (Entin et al., 2003).

In this paper, to explore the issue of leading indicators, we focused our work on communication strategies. By strategy, we simply mean the responses that the organizations made in their communications as they coped with incongruence. We focused on communications because they are the primary mechanisms through which the organizations could express their attempts to deal collectively with the misfit situations. Our results showed that both organizations talked more when faced with incongruence. While the D organizations talked more, however, the F organizations talked a great deal more, there were strong differences in the extent to which different people talked to each other, and there were robust changes in the content of the communications. Thus, in trying to cope with the incongruence, the F organization reacted differently when going from f to d than the D organization when going from d to f. The organizations reacted by increasing communications, but the specific contexts of the missions and organizational structures influenced the nature of those reactions.

This finding – that the context mattered – is critically important, for it suggests that the leading indicators, or symptoms of incongruence, may be complex in that they will be shaped by the interaction of mission tasks and organizational structures, as well as a number of other potential factors such as history of the organization, individual proficiencies, fatigue, etc. This means that the appearance of a particular leading indicator such as communication content may be probabilistic rather than absolute, such that it might take a set of measures rather than any one in particular to ascertain the state of congruence. We expect that this will be particularly true when larger and more complex organizations face larger and more complex missions in the "real world." Consequently, it is imperative to ascertain how organizational structures and mission scenarios, which may be more or less congruent or incongruent, interact to shape the behaviors observed, for these behaviors (e.g., strategies) will only serve as valid leading indicators to the extent that we understand how contextual factors shape organizational performance and process.

Next Steps

Building on these data, the mission scenarios, and the organizations, we believe that we are now well positioned to effectively study structural adaptation. In creating the scenarios examined here, our hope was to engineer conditions that made it advantageous for an organization to adapt structure. Our reasoning was that when the structure of an organization becomes too incongruent with its mission, an organization should "feel the pain" and be motivated to change to enhance mission effectiveness. Collectively, our results suggest that we have indeed created conditions in which organizations are burdened by coordination requirements. These results suggest that if given a chance to adapt when faced with misalignment (D-f, F-d), the organizations studied here might be sufficiently motivated to change their organizational structures in order to gain a state of congruence (F-f, D-d).

However, while there is evidence that organizations will institute strategy changes, such as those noted above, they also appear to be quite reluctant to make changes to their structures (Entin, Serfaty, and Kerrigan, 1998; Hollenbeck et al., 1999). Hence, either adaptation needs to be imposed on an organization from above, or alternatively, it is necessary to provide substantial support that moves the organization in the direction of change. Thus, in order to successfully induce and study organizational adaptation that is not imposed on an organization, it is necessary to not only create a state of organizational pain, but also direct the organization's awareness to the source of that pain, provide them with the knowledge that another mode of organization would be superior, and provide them with the tools to adapt. Similarly, in the case of change imposed on an organization from the outside (e.g., via a chain of command), it is necessary to understand the behaviors of organizations coping with incongruence such that a commander could make a decision to impose change based on an understanding of what incongruence looks like in action. Accordingly, building on these data and those presented in Entin et al. (2003), we are now exploring both a variety of measures that could serve collectively as potential leading indicators and different ways of presenting that information to organizations to support structural adaptation. In future empirical work our goal will be to study the processes of on-line structural adaptation by directing attention toward critical leading indicators of the need to change and by exploring how organizations need to be prepared in order to change effectively.

In summary, this set of analyses indicates that our model-based manipulations of organizational congruence were successful. Our results showed that, as predicted, relative to the congruent cases, the incongruent cases indeed lead to less effective mission performance. These results demonstrated the power of model-based organizational design for optimization of mission effectiveness. Moreover, based on this successful manipulation, this work sets the stage for further work on structural adaptation. Our goal is to study the processes that underlie adaptation when an organization moves from one structure to another. The work reported here provides the organizational structures and scenarios necessary to explore adaptation, and importantly, the data on which to further study what organizational congruence looks like in action.

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