Cover Sheet

Organizational Structure and Dynamic Information Awareness In Command Teams

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Abstract

The Navy has embraced the concept of network centric warfare as a means to develop innovative and effective command and control (C^2) structures for the future. One such C^2 structure is FORCEnet. Modeling of various FORCEnet-derived structures produced a prediction that a C^2 structure that includes an intelligence, surveillance, and reconnaissance (ISR) coordinator would significantly improve mission performance. Network centric warfare, however, has increased the information load commanders must deal with. As part of this effort we investigated the effects of information load on certain decision making heuristics. Counter to modeling predictions, a FORCEnet derived organization with an ISR coordinator was not superior in performance to an organization without an ISR coordinator. There was evidence, however, that increased familiarity and practice with a structure including an ISR coordinator may produce findings supportive of model predictions. Findings also indicate that high information load may exacerbate the negative effects of certain decision making heuristics.

Introduction

As it seeks to develop innovative and effective command structures for the 21st century the Navy has embraced the concept of network-centric warfare as espoused by Admiral Cebrowski and others. One such innovative command and control (C^2) structure to receive attention is FORCEnet. The principles of FORCEnet C^2 have been described as: "(a) **Distribution** of forces to achieve tactical stability; (b) **Networking** technology as an enabler of new, evolutionary organizational structures, allowing distributed forces to collaborate at a distance; (c) **Evolution** of the tactical organization as it adapts to changing demands of the mission; and (d) **Collaboration** as a way of life …, coming from changes in the overlap of responsibilities in the organization structure during execution and increased collaboration during planning" (Serfaty et al., 2002, p 2).

These principles guided a modeling and simulation (M&S) effort conducted for the Strategic Studies Group XXI to investigate the effects a FORCEnet structure might have for a large naval organization like a battle group (Serfaty et al., 2002). The M & S efforts predicted an increase in shared knowledge in a FORCEnet structure which in turn allows the organization to respond more effectively to new and unexpected situations, making a FORCEnet structure more adaptable. Overall, the modeling effort predicts that a FORCEnet structure will handle complex tasks that require coordination more effectively than current organizational structures. In FORCEnet, collaboration is envisioned as a way of life, and this collaboration provides an advantage in both speed of command and in the adaptability of the organization to new situations.

Modeling aspects of a FORCEnet structure also revealed that some structural changes promoted by FORCEnet appear to have a facilitating effect on mission performance. One such structural change is the presence of an intelligence, surveillance, and reconnaissance (ISR) coordinator, a new command position that would coordinate all theater sensors and maintain situational awareness for the organization. Modeling results indicated a 25% increase in mission performance when an ISR coordinator is present compared to when no ISR coordinator was present (Serfaty et al., 2002).

A primary goal of this research was to empirically test this model prediction. We experimentally contrasted an organizational structure with an ISR coordinator to a traditional Composite Warfare Commander (CWC) like structure where no such coordinator is present, using a man-in-the-loop simulation. We predicted that an organizational structure that includes an ISR coordinator to direct sensor assets and maintain situational awareness would outperform an organization structure without such a coordinator.

At the same time, the move toward network-centric warfare and the introduction of new technologies have also increased the volume of available information commanders must deal with. Commanders face increasingly larger data sets that they are expected to integrate and interpret within increasingly shorter periods of time. Research literature (see, for example, Entin, Kerrigan, Serfaty, Klein, and Wolf, 1998) suggests that high information loads can derogate situation assessments and decrease mission performance. To empirically investigate the effects of increased information load on decision making and mission performance brought about by the technologies enabling network-centric warfare we manipulated information load across the two organizational structures. To further focus on the critical aspects of decision making we created a tactical judgment task that ran parallel to the simulation scenario and we embedded confirming or disconfirming information necessary for the judgment task in the information flow. The tactical judgment task was derived from a task used by Entin and Serfaty (1997).

Entin and Serfaty (1997) addressed the process of sequential revision of beliefs or judgments in complex situations. They note that C^2 structures provide decision makers with opportunities to revise their tactical judgments as streams of information flow in for their consideration. A contrast-inertia model, based on Hogath and Einhorn's (1992) belief-adjustment heuristics model, was postulated by Entin & Serfaty (1997) to describe participants' sequential revision of beliefs when attempting to integrate pieces of confirming and disconfirming evidence. Results indicated that the sequential order of confirming or disconfirming evidence had a profound effect on participants' judgments. That is, participants arrived at completely different decisions depending on whether confirmatory evidence precedes disconfirmatory evidence or whether disconfirmatory evidence precedes confirmatory evidence. These results, predicted by the contrast-inertia model, are referred to as the order effect.

We expected, based on Entin, et al. (1998) for example, that high information load would lower mission performance. We also predicted that participants would revise there judgments in accordance with the Hogath and Einhorn's (1992) belief-adjustment model and Entin and Serfaty (1997) contrast-inertia model. Although, past work holds no predictions on how information load might interact with judgment revision or the order effect we offer two speculations. High information load may obscure the confirming and disconfirming evidence making it difficult for decision makers to revise their beliefs. Or high information load may heighten decision makers' stress levels leading to greater susceptibility to heuristic errors like the order effect. A phenomenon that can lead a commander to arrive at opposite beliefs by the mere presentation of the same evidence in different orders deserves careful investigation (Entin & Serfaty, 1997).

Method

Participants

Thirty-two officers provided by the Surface Warfare Office School, Naval War College, Newport, RI were organized into eight teams of four individuals each. Most of the officers were male and at the 03 level. Each team spent about 75 minutes in training and 75 minutes in data collection.

Experimental Design and Independent Variables

The experimental design manipulated three independent variables. Organizational structure and confirmation order were manipulated as between-subjects factors, and information load as a within-subjects factor.

The between-subjects variable *organization structure* was comprised of two conditions: ISR coordinator present and ISR coordinator not present. When the ISR coordinator was present that position owned all the ISR assets (mainly unmanned surveillance vehicles) and fulfilled the job of coordinating the sensor picture and maintaining situational awareness. When the ISR coordinator was not present the team member in that position was the Surface Warfare Commander and ISR assets were distributed among all team positions and all team members were required to coordinate to manage the sensor picture and maintain situational awareness.

Information load was operationalized in a manner similar to that described by Entin, Entin, & Hess (2000) and implemented with two levels: low and high. The low information load condition was characterized by approximately 3.5 messages per minute, whereas in the high information load condition team members experienced a message rate that was 2.5 times higher or approximately 9 messages per minute. These information flow rates were derived from team communication rates observed in Entin (1999) and Entin et al. (2003). All information was conveyed to participants via electronic mail messages.

Confirmation order was manipulated as a between-subjects independent variable and drew on the methodology described by Entin & Serfaty (1997). An anchor or initial probability that the enemy will launch a counter-attack against Blue's follow on forces was established by a written "intelligence message." The intelligence message indicated that the likelihood of an attack was 75%. During the scenarios the half of the teams that were assigned randomly to the "confirm – disconfirm" order condition received information via Email/Intel messages imbedded in the general Email/Intel traffic that first confirmed the attack (three messages) and then later disconfirmed the attack (three messages).

Conversely, the half of the teams that were randomly assigned to the "disconfirm – confirm" order condition received Email/Intel messages imbedded in the general Email/Intel traffic that first disconfirming the attack (three messages) and then later confirming the attack (three messages). The first three messages were scheduled to appear approximately 3, 9, and 15 minute into the scenario, and the second set of three messages appeared at approximately 20, 26, and 32 minutes into the scenario. Participants were specifically tasked to monitor the Email/Intel traffic.

Simulator and Scenario

The Distributed Dynamic Decision-making (DDD) environment was used to simulate two mission scenarios. The DDD is a distributed client/server simulator that allows extensive mission customization in order to investigate individual and team performance in an operationally rich, experimentally valid environment. In general, DDD simulations involve individual and team decision-making about complex situations based on information and resources provided by both 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. A variety of performance measures can be recorded within the DDD (i.e., tasks processed, latencies, and accuracies) to assess performance. The two scenarios we used involve land, sea, and air operations to prepare the battle space for insertion of forces for follow-on actions.

Dependent Measures

The DDD simulator enables the measurement of several variables related to individual and team performance such as latency to process a task, accuracy in processing a task, percentage of tasks process, and percentage of task processed at 100% accuracy. In this effort, we focused on the percent of tasks processed (the number of tasks attacked/the number of tasks that arrived in the scenario).

To assess whether participants were sensitive to the embedded confirming and disconfirm information, employed a contrast and adjustment heuristic when dealing with confirming and disconfirming messages, and experience an order effect, we assessed participants' beliefs about the likelihood of an enemy counter-attack throughout the scenario. Participants responded to four pop-up windows soliciting their beliefs. The response scale in the pop-up window started at 0% likelihood of an attack and increased in 10% increments to 100% likelihood of an attack. The pop-up windows were timed to appear at 500, 1000, 1500, and 2000 seconds into the scenario. However, only the second and last estimates were used in analysis. The second estimate, 17 minutes or about halfway through the scenario, assessed the impact of the first three messages, where as the last estimate at 34 minutes or about one minute form the end of the scenario, captured the impact of the last three messages.

Procedure

Participants received DDD “buttonology” training followed by training designed to provide the skills necessary to perform a functional scenario. Teams next engaged in a 75 minute data collection session, and in a counter-balanced order performed two similar scenarios: one under high information load and one under low information load.

Teams were told that their primary mission was to engage in information gathering to achieve and maintain good situational awareness regarding enemy activities in order to discern if the enemy intended to launch an attack against follow-on Blue forces. To accomplish this, team members were required to monitor the Email/Intel traffic and fuse the information from the various messages to maintain situational awareness. Every 500 seconds, each team member responded to a request from the Commander of the Joint Task Force requesting the likelihood that the enemy would launch an attack. Teams were also instructed to protect their assets against enemy attack and to prevent the enemy from attacking protected zones. As a secondary task the teams were asked to complete the mission tasks which included destroying the enemy’s: command center, air base, bridge, naval base, and seaport, aw well as, finding and destroying SCUD missile launchers. Participants were told that it was likely that they would not complete all these tasks.

Results

Results from the organizational structure X information load X trial analysis for the percentage of tasks processed are depicted in Fig. 1. Unexpectedly the ANOVA showed a significant trial effect ($p < .005$) indicating that teams performed about 25% better in trial 2 than trial 1. Apparently teams were still learning how to perform the mission tasks during trial 1. The results further show that, contrary to prediction, the organizational structure with an ISR coordinator did not out perform the traditional CWC-like structure without an ISR coordinator. Examining the interaction ($p < .07$) within trial 1 we see that the teams without an ISR coordinator performed at a higher level than the teams with an ISR coordinator, and did so more when information load was high than low. In trial 2 the pattern is quite different; teams in both organizational structures performed at the same level when information load was low and almost at the same level when information load was high. Moreover, the increase in performance between trials 1 and 2 for teams without the ISR is small, while the same difference for teams with the ISR coordinator is much larger. The steep increase in performance for teams under the structure with an ISR coordinator makes us wonder if there had been a third trial, whether their performance would have surpassed that of teams under the structure without an ISR coordinator. Perhaps the team members comprising the structures with an ISR coordinator were still learning the aspects of their novel structure?

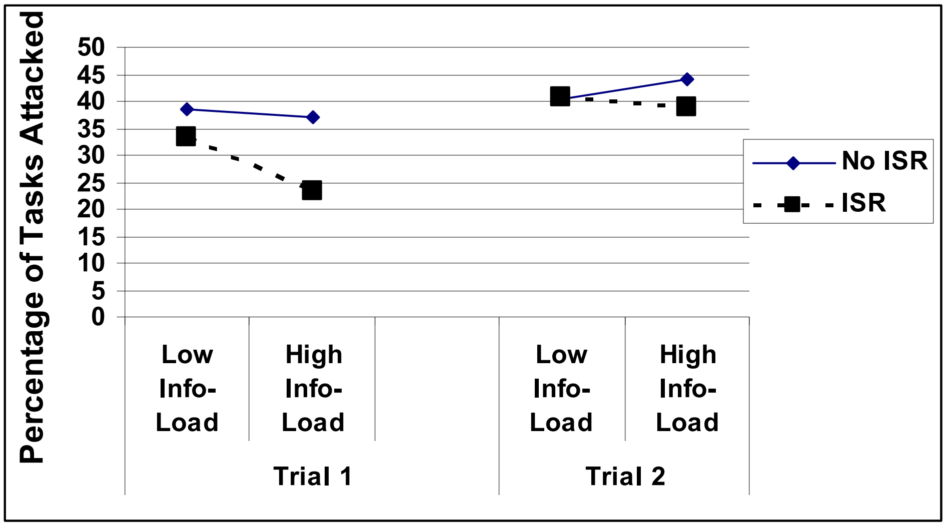

Figure 1. Percentage of Mission Tasks Attacked as a Function of Organizational Structure and Information Load for Trials 1 and 2

A trial X information load X order X estimate time MANOVA was conducted to evaluate the effects of information load on tactical judgments and whether participants would be prone to the order effects described by Hogath and Einhorn's (1992). The analysis revealed several significant main effects and interactions. Of particular interest to our predictions was the significant ($p < .06$) order X estimate time interaction plotted in Figure 2. As predicted, the confirming-disconfirming and disconfirming- confirming confirmation orders elicited different strengths of belief for an attack from the participants, even though the number of confirming and disconfirming pieces of evidence was the same. Further investigation, summarized in Figs 3 and 4, revealed that high information load appears to heighten the order effect. Figure 3 shows the plot for the order X estimate time contrast when information load is low. There is no evidence of an order effect. The pattern in Fig. 4 shows that participants experiencing the disconfirming- confirming confirmation order held a final judgment indicating a moderately strong probability (i.e., 0.75) of an enemy counter-attack. However,

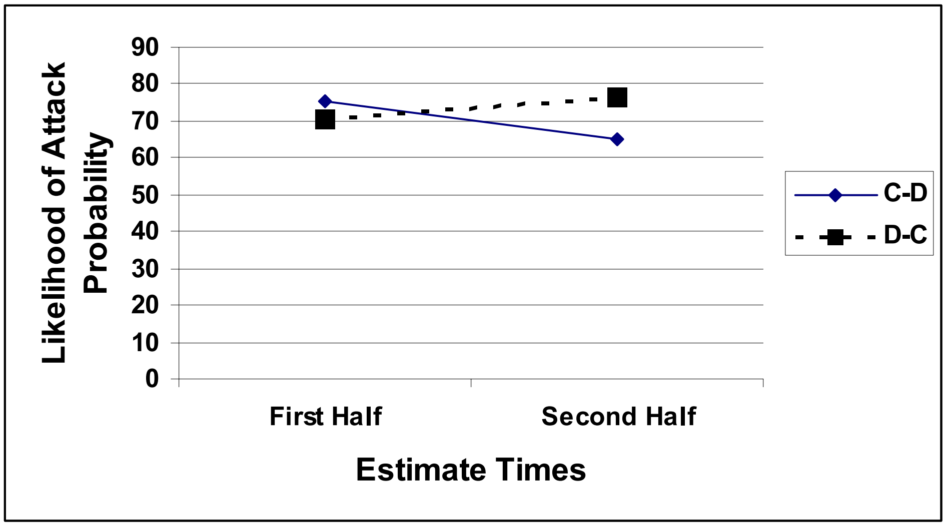

Figure 2. Likelihood of Attack Probability for Confirmation Order (Confirming-Disconfirming and Disconfirming- Confirming) and Estimate Times

participants who experienced the confirming-disconfirming confirmation order arrived at a final judgment that indicated they were undecided (i.e., probability of attack = 0.50) if an enemy counter-attack would occur. Recall that the confirmation information had to be gleaned from the Email/Intel traffic over 75 messages. Even though the two groups of participants received the same information only in a different order, the ordering of confirming followed by disconfirming and the ordering of disconfirming followed by confirming information led the respective groups to arrive at different positions concerning the likelihood that the enemy would launch an attack, supporting predictions from Hogath and Einhorn's (1992). contrast-inertia heuristic model.

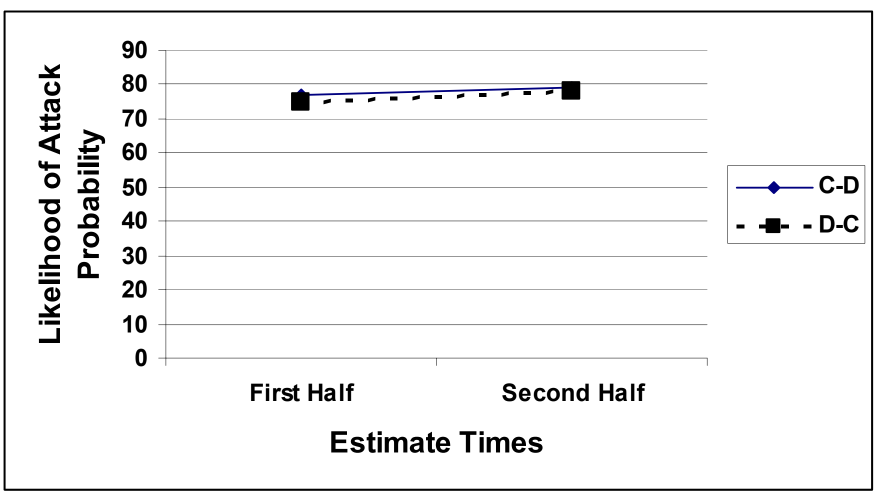

Figure 3. Likelihood of Attack Probability for Confirmation Order (Confirming-Disconfirming and Disconfirming- Confirming) and Estimate Times When Information Load is Low

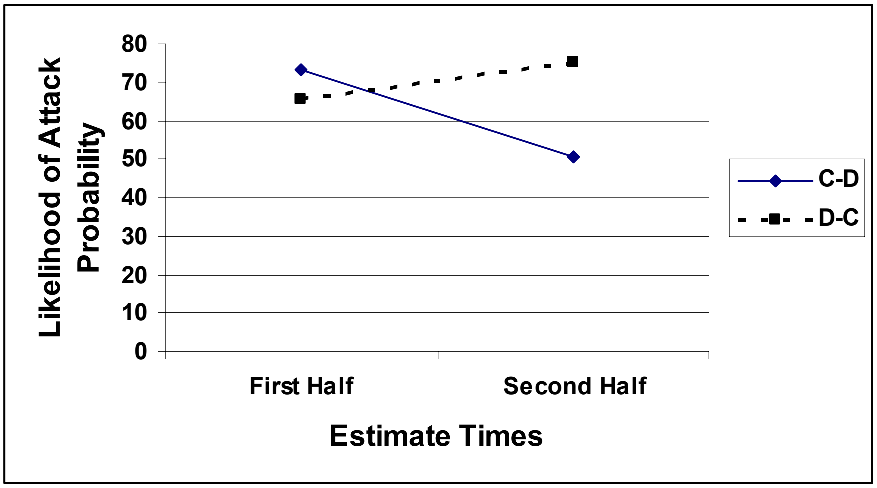

Figure 4. Likelihood of Attack Probability for Confirmation Order (Confirming-Disconfirming and Disconfirming- Confirming) and Estimate Times When Information Load is High

Discussion

We hypothesized that an organizational structure that includes an ISR coordinator would perform at a higher level than an organizational structure that does not include an ISR coordinator. Performance results from the current experimental effort did not support this hypothesis. However, the improvement of the structure with an ISR coordinator from trial 1 to trial 2 was steeper than that of the traditional organization and by trial 2 caught up to the performance of the structure without an ISR coordinator in both low and high information load conditions. This may indicate that the presence of an ISR coordinator does facilitate performance improvement and with more experience and practice teams that have such an ISR coordinator would surpass the performance of the teams without the ISR coordinator.

We suggest that a reason for the initial weak performance of the organization with an ISR coordinator was the lack of familiarity with the position of an ISR coordinator. Organizations with ISR coordinators are new and our Navy officers did not have experience with such an organization. The CWC doctrine, however, is currently a key tenet of Navy training, and the officers fulfilling the CWC roles would certainly be familiar with these positions. Entin, Serfaty, and Kerrigan (1998) describe results similar to this. Teams comprised of military officers performed at a higher level in traditional C^2 organizational structures compared to non-traditional C^2 structures even though the non-traditional structures had been optimized to match the mission because the officers were familiar and practiced with the traditional structures.

Our investigations into information load and the sequential revision of judgments showed that participants exhibited the order effect heuristic even though the confirmatory and disconfirmatory evidence was embedded in Email/Intel traffic and not specifically called out. We are not aware of any findings demonstrating an order effect when the salient evidence is embedded in flood of information. It also appears that the order effect is strengthen by high information load and does not occur under low information load. One speculation is that the higher stress brought on by high information load functions to increase individuals' susceptibility to heuristic errors like the order effect. These results suggest a problem related to network centric warfare's tendency to produce high information loads that must be addressed.

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