Awareness and C2 Organizational Structure

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Abstract

In this paper we test the hypothesis that organizational structure, and the history of that structure, influences mutual workload awareness. More specifically, we explored the congruence of workload awareness among a number of decision makers acting in two organizational structures (functional vs. divisional) with different histories (divisional followed by functional vs. functional followed by divisional). Seven teams comprised of military officers were assigned to one of the two orders and performed a simulated mission. Findings show that workload awareness was higher in the functional-divisional than in the divisional- functional order indicating that workload awareness can be influenced by factors such as organizational structure and how that structure changes over time. There is also evidence that high workloads may foster higher workload awareness, and that high workload awareness may ameliorate some of the negative effects of high workload.

Introduction

In his discussion of network centric warfare and related concepts, ADM Cebrowski describes self-synchronization as: "The ability of a well-informed force to organize and synchronize complex warfare activities from the bottom up. The organizing principles are unity of effort, clearly articulated commander's intent, and carefully crafted rules of engagement (ROE). Self-synchronization is enabled by a high level of knowledge of one's own forces, enemy forces, and all appropriate elements of the operating environment. It overcomes the loss of combat power inherent in top-down, command-directed synchronization characteristic of more conventional doctrine and converts combat from a step function to a high-speed continuum."

As ADM Cebrowski states, to foster self-synchronization a commander must have a high level of awareness of the battle space and the intentions and actions of other commanders. However, the factors that influence such situational and mutual awareness are not completely understood. Indeed, both the accuracy and need for awareness of others may depend on the structure of the organization to which the commanders belong and the tasks that they are trying to perform. Moreover, awareness may be affected by the history of the organization.

There is a sizeable literature regarding the mediating effects of awareness and particularly situational awareness on performance. For instance, Endsley (e.g., 1988, 1995a, 1995b) has presented a compelling argument linking situational awareness and performance. She notes that obtaining and maintaining good situational awareness often occupies a major portion of an operator's role. Operators of large system such as flexible manufacturing

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systems must constantly revise their knowledge of system parameters to keep the system operating effectively. Similarly, within tactical and strategic systems military commanders depend on situational awareness as a precursor to decision making. When awareness is poor, as it was in the U.S.S. Vincennes incident, the consequences can be dire. In the operational assessment of the AH-64D (Longbow) helicopter, improved performance was attributed to increased situational awareness (Eidelkind, Moffett, Arendt, and McKee, 1995). Likewise, in a review of 18 AH-64 accidents that had occurred in an 8-month time period (Entin and Zeller, 1997), investigators found that in nine of them a loss of situational awareness by one or both crewmembers may have contributed to the accident. It appears that situational awareness can have a profound effect on performance.

The concept of shared mental models also suggests a key role for situational awareness (Stout et al., 1999; Cannon-Bowers, Salas, and Converse, 1993, Rouse, Cannon-Bowers, and Salas, 1992). The essential idea is that shared mental models: "provide team members with a common understanding of who is responsible for what task and what the information requirements are" (Stout et al., 1999, p. 61). The implication is that this common understanding serves to coordinate performance and is an important factor of good team performance outcome.

In our paper we address the awareness team members have of each other. More specifically, the awareness of each other's workload: knowing what other team members around you are doing and how involved they are is a part of situational awareness. It also contributes to good teamwork skills (Glickman and Zimmer, 1989; Glickman et al., 1987). For instance, monitoring and backup behavior are two important teamwork skills (Glickman et al., 1987) and both are linked to an awareness of other team member's workload conditions. Awareness of other team member's workload enhances general situational awareness and provides information team members can use to manage workload balance within the team. Team members who are overwhelmed can be offered help and workload can be shifted to under loaded team members. Such management of workload balance can improve overall team performance.

Shared awareness and workload, however, may be mediated by organizational structure. For example, performance outcome and process measures were significantly higher in a non-traditional command and control (C^2) architecture optimized for the mission than a traditional C^2 architecture that was not optimized for the mission (Entin, 1999). Entin (1999) concluded that various elements of the non-traditional optimized C^2 architecture facilitated several underlying team processes that in turn facilitated performance. Hollenbeck et al. (1999) and Moon et al. (2000) have also showed that team organizational structure mediates team performance. Moreover, Moon et al. (2000) reported that performance was higher for teams that transitioned from a functional to divisional structure compared to teams that transitioned from a divisional to functional structure. Generally speaking, a divisional structure provides each entity of the organization with a mix of organizational resources/assets, whereas in a functional structure each entity is specialized to meet a specific need and owns the specific class of assets to do so.

Study Objectives

In this study, we asked how a team's structure, and the history of that structure, influenced workload awareness. More specifically, we explored the congruence of workload awareness among a number of decision makers acting in two organizational structures (functional vs. divisional) with different histories (divisional then functional vs. functional then divisional). To assess workload awareness, we computed the deviation between what a team member said his/her workload was to what each of the other team members thought it was. We expected workload and workload awareness to be differentially affected by the structural manipulations. We also expect a relationship between workload awareness and performance.

Our observations of workload awareness and organizational structures were part of a larger methodological study carried out to examine, among other things, the elements that are necessary to create divisional and functional C^2 organizational structures. We will briefly review the methodology used, but for a more detailed description, see Diedrich et al. (2002, this volume).

Method

Participants

Forty-two officers attending the Naval Postgraduate School served as participants. Most of the officers were 03s or 04s and several services were represented. Participants were organized into seven teams of six individuals each.

Experimental Design and Independent Variables

Organizational structure was varied as a within-subjects factor and contrasted a *functional organization* where each participant specialized in one aspect of the mission such as air warfare with a *divisional organization* where each participant was tasked to perform several aspects of the mission. In the functional organizational structure, a participant charged with one aspect of the mission, such as air warfare, owned the assets necessary to do that part of the mission even if those assets were on various platforms. When participants performed in the divisional organizational structure their platform was multifunctional and to some extent could process air, surface, and subsurface treats.

Order of presentation was counterbalanced across teams: half of the teams started in divisional followed by functional organizational structure and half started in functional followed by divisional organizational structure.

Dependent Measures

The Task Load Index (TLX; Hart & Staveland, 1988) was used to assess individual team members' workload. We have extended the TLX to capture workload awareness as well (Entin, Serfaty, and Kerrigan, 1998). In the first part of a two-part questionnaire team members reported their own workload in terms of the traditional items comprising the TLX (i.e., mental effort, time pressure, performance, effort, and frustration). In the second part of the questionnaire each participant provided an estimate of the overall workload experienced by each of the other team members. Throughout the instrument responses were made to a 21-point scale anchored at one end by the word *low* and at the end by the word *high*. Workload awareness was computed by comparing each team member's estimate of a particular team member's workload to the particular team member's self-rating. The deviations of the estimates from the self-rating were squared, averaged, and the square root taken to arrive at the root mean square deviation (RMS-deviation). RMS-deviation was the measure of workload awareness. The smaller the RMS-deviation, the less each team member's estimate deviates from the self workload rating, thus the greater the awareness. Conversely, the larger the RMS-deviation, the more each team member's estimate deviates from the self workload rating, thus the lower the awareness.

The simulator hosting the experiment was capable of capturing most of a team's actions. Of particular interest were the various tasks comprising the mission. The performance measure for most of the tasks involved counts, such as the number of SCUD launchers destroyed, the number of SCUD missiles shot down, or number of enemy ships destroyed. Performance scores were computed for 18 such tasks.

Simulator and Scenario

The study was hosted on the Dynamic Distributed Decision Making (DDD) simulator. Most experimental work within the A2C2 project has been performed employing the moderate fidelity DDD research simulator (Kleinman, Young, and Higgins, 1996). The DDD has been used extensively since 1989 in research involving "open ocean" naval team decision-making. It has served as the vehicle by which teams of subjects interact in a dynamically evolving tactical scenario. The DDD allows for a high degree of experimental control and provides on-line data collection of subjects' interactions in a log file that can be used to develop performance variables.

The scenario, a collaborative effort of the Naval Postgraduate School, Aptima, and the University of Connecticut, depicts a mission that involved preparing a battlespace for the arrival of follow-on forces by engaging hostile assets perceived as immediate threats (e.g., aircraft, patrol boats, destroyers, and submarines). In addition, players were charged with destroying an enemy air base and an enemy naval base, each heavily guarded by SAMs, and with defending neighboring foreign friendly areas from SCUD missile attacks. An example of a typical display is shown in Fig. 1. The white areas in the figure represent water, the shaded areas represent land, and areas with heavy boarders are the areas Blue is to protect from Red (the enemy). The area to the right of the map is the control area. Important to the workload awareness issue, many tasks require the coordination of different assets that frequently are controlled by different team members. Some tasks are time critical (e.g., SCUD missile launchers, coastal defense launchers) and thus require quick response for effective prosecution.

Procedure

After being trained in the use of the DDD simulation, each team completed two practice trials and a data collection trial for one structure followed several days later with two practice trials and a data collection trial for the other structure.

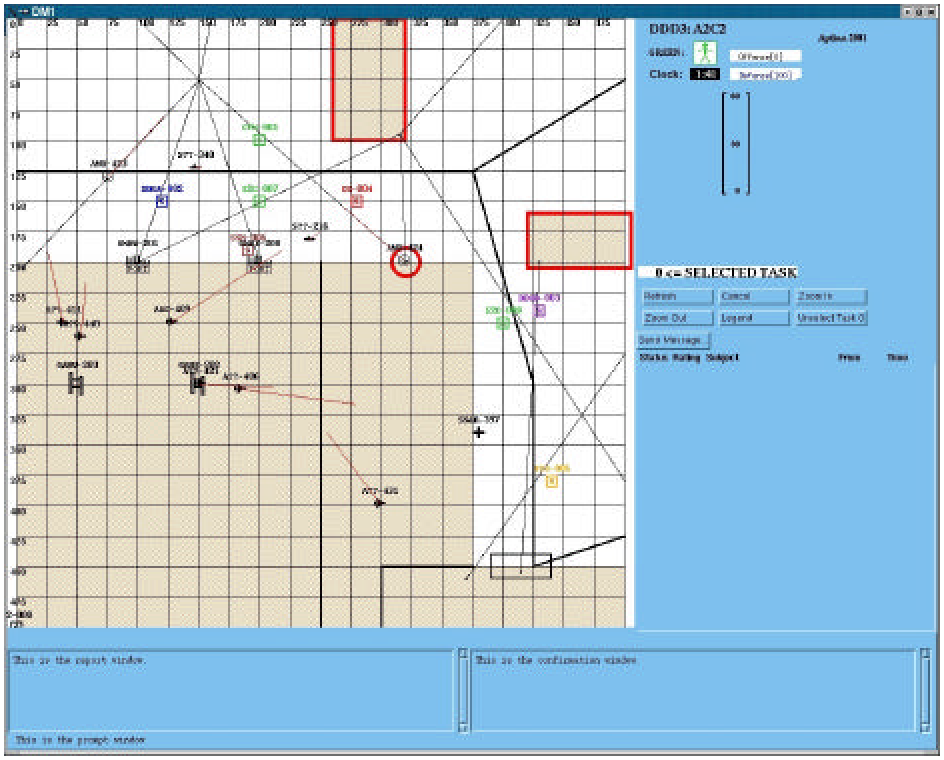

Figure 1. Typical Scenario Display

Results and Discussion

The self-perception of workload for each team member was averaged to form a mean workload for each team. As we can see from Fig. 2, perceived workload was significantly higher in the functional than in the divisional organizational structure, ($p < 0.04$; means for the divisional and functional were 10.8 and 11.6, respectively). Figure 3 shows that workload was perceived to be higher for the functional than divisional organizational structures by just about every team. These results indicate that participants perceived more work was required to perform the mission with a functional architecture. This is a reasonable finding given that the functional architecture engenders a global view, whereas, the divisional architecture tends to foster a more local perspective. These results also imply that workload awareness might be more important for the functional organizational structure due to higher workloads where some team members might require back-up assistance.

The analysis of workload awareness, however, revealed no overall differences in awareness between the divisional and functional organizational structures. These results suggest that higher workloads do not correspond to heightened workload awareness. Yet, the results discussed below suggest this might not be the case.

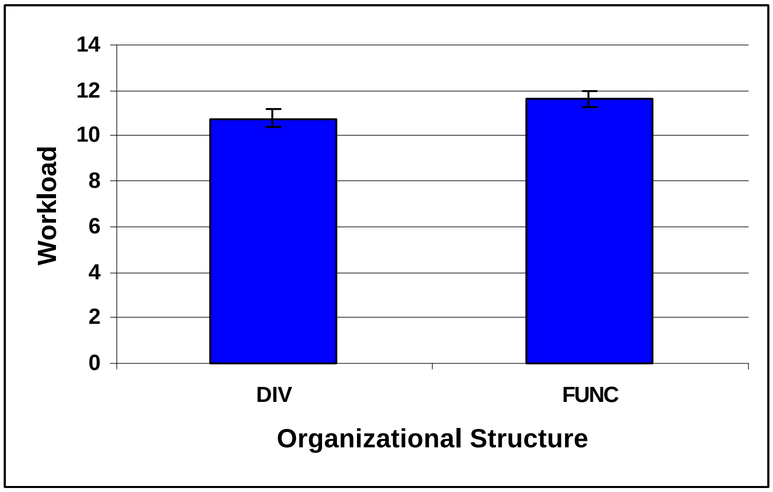

Figure 2. Mean Workload For The Divisional and Functional Organizational Structures

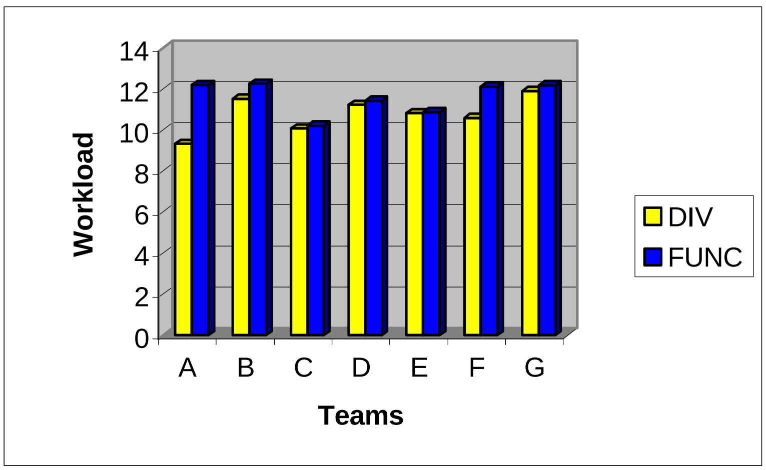

Figure 3. Workload For Each Team By Organizational Structure

Figure 4 presents the mean RMS-deviation for the divisional-functional and functional-divisional orders. These data indicate that awareness tended to be higher (i.e., RMS-deviation smaller) in the functional-divisional than divisional-functional order ($p < .07$). Examining further we see that at Trial 1 the awareness of other's workload was superior in the functional than in the divisional organizational structure ($p < .05$). At Trial 2 workload awareness appeared to improve for both orders, however, more so for the divisional-functional than functional-divisional order, thereby erasing the difference that had existed at Trial 1.

To seek an explanation for these results we examined the perceived workload in Trial 1 and Trial 2. We suspected that heightened workload did foster higher workload awareness, and analysis of the perceived workload for Trial 1 showed that workload was significantly higher under the functional than divisional organizational structures ($p < .05$). The same analysis for Trial 2 revealed an increase in workload for the divisional and slight decrease for the functional structures, hence no statistically significant difference was observed. Thus, an explanation for the observed pattern of results is that teams who had the functional condition first (Trial 1) perceived higher workloads and thus were more aware of their teammates than teams that had the divisional condition first. These teams then stayed at a similar level of awareness as they went into the divisional condition in Trial 2. In contrast, since the perceived workload was less for teams that started out in a divisional structure they were initially less aware of others because there was not as great a need to be aware. These teams, however, had to play "catch-up" when they went to the higher workload environment of the functional organizational structure in Trial 2.

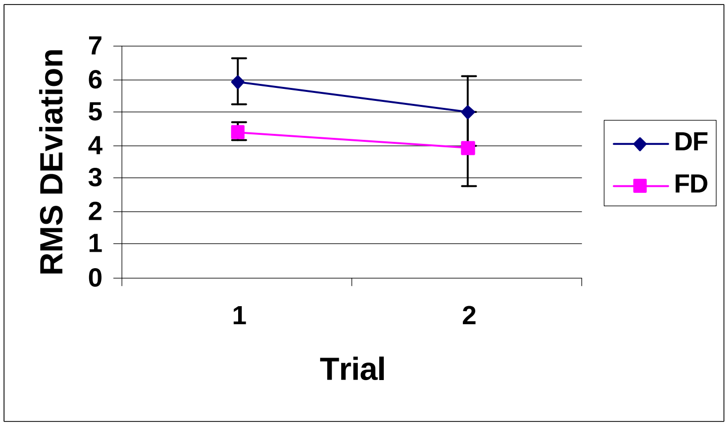

Figure 4. Workload Awareness As Measured By RMS Deviation For The Divisional-Functional And Functional-Divisional Orders By Trial

Next, we examined performance by considering all the tasks (i.e., enemy entities) a team could attack as sanctioned by the standing rules of engagement. Those tasks included, for example, coastal defense missiles, SCUDs, and SCUD launchers. For each task the number of attacks were normalized by the number that could be attacked, thus an attack ratio of 0.75 means that three-quarters of the tasks that could be attacked were attacked. Performance, in terms of mean attack ratio, is depicted for the divisional and functional-organizational structures in Fig. 5. There were no statistical differences between performances in the two organizational structures. However, as shown above, workload was higher in the functional than in the divisional structure, and we know that performance is usually negatively related to workload (see for example Entin, 1999). Why then were there no performance differences between the two organizational structures? We surmise that the higher workload awareness in the functional organizational structure helped ameliorate the negative effects of high workload.

Conclusion

Collectively, these data show that workload awareness can be influenced by factors such as organizational structure and how that structure changes over time. Workload awareness was found to be higher in a functional-divisional ordering of organizational structures than in the divisional-functional ordering. Hollenbeck et al (1999) have surmised that communication among team members is facilitated more by a functional than a divisional structure. The greater exchange of information initiated by the functional structure may partially explain the higher workload awareness observed in the functional-divisional order. There is also evidence that high workloads may foster higher workload awareness and that high workload awareness may ameliorate some of the negative effects of high workload. We must, however, keep in mind that the reported workload for the conditions studied here was in the moderate range at best. As workload increases to higher levels, these observations may no longer hold.

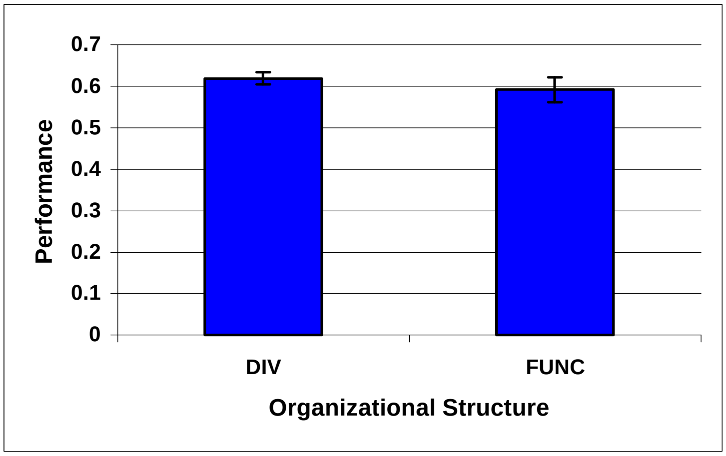

Figure 5. Performance For The Divisional And Functional Organizational Structures

If we can assume that workload awareness is an important component of situational awareness, than it is reasonable to assume the situational awareness may be impacted by organizational structure and how that structure evolves over time. Indeed, since accurate awareness provides a foundation for self-synchronization, these data imply that efforts to foster self-synchronization and coordination among commanders will necessarily be influenced by a myriad of factors associated with the command environment. The work reported here represents initial efforts to define how some of these factors interrelate.

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