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Effects of Workload on Communication Processes in Decision Making Teams

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This report is a continuation of the research first described by Bowers and his colleagues (Bowers, Urban, & Morgan, 1992), and attempts to investigate those variables which, according to a broad model of team performance, might contribute to a more thorough understanding of team decision making. While the goal of the previous study was to determine the relative effects of two different team structures and two workload levels on team processes and performance, the current investigation incorporated a third structure into the previously employed design. The team structure that was simulated in the current study is a structure that is prevalent in organizations and operational environments, and hence, enhances generalizability to operational teams. Therefore, this report describes the evaluation of the relative performance effectiveness of these three structures under two levels of workload, as well as the identification of team coordination processes associated with effective decision making within these groups.

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EXECUTIVE SUMMARY

This report is a continuation of the research first described by Bowers and his colleagues (Bowers, Urban, & Morgan, 1992), and attempts to investigate those variables which, according to a broad model of team performance, might contribute to a more thorough understanding of team decision making. While the goal of the previous study was to determine the relative effects of two different team structures and two workload levels on team processes and performance, the current investigation incorporated a third structure into the previously employed design. The team structure that was simulated in the current study is a structure that is prevalent in organizations and operational environments, and hence, enhances generalizability to operational teams. Therefore, this report describes the evaluation of the relative performance effectiveness of these three structures under two levels of workload, as well as the identification of team coordination processes associated with effective decision making within these groups.

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INTRODUCTION

Teams are required to perform in numerous and diverse environments. For example, teams are fundamental units of operation in the aviation community (both in the military and commercial sectors), in industry, in the medical community, and in all branches of the military. However, the growing demand for effective team performance has not been matched by a comparable growth of knowledge concerning the interaction processes and performance capabilities of teams. Rather, there is a great need for a thorough understanding of teamwork and team performance, as evidenced by the fact that ineffective teamwork has been implicated in many accidents (Billings & Reynard, 1984; Congressional Hearings, 1988; Foushee, 1987). One such accident involved a US guided missile cruiser, the USS Vincennes, which misidentified and shot down an Iranian commercial airliner. A Congressional investigation cited ineffective teamwork, particularly ineffective tactical team decision making, as a possible cause of this accident (Congressional Hearings, 1988). Because many military and civilian teams are critically dependent upon effective tactical team decision making, a dire need exists for a solid understanding of team decision making, the factors that potentially influence it, and interventions that could optimize it.

Reviews of the existing literature concerning team processes and performance agree that the "state of the art" knowledge in this area is drastically lacking (Converse, Dickinson, Tannenbaum, & Salas, 1988; Dyer, 1984; Meister, 1985; Modrick, 1986). Therefore, a systematic series of research efforts is needed to fulfill the need for an improved understanding of tactical decision making in teams. One such effort, begun by Bowers and his colleagues (Bowers, Urban, & Morgan, 1992), attempted to enhance the understanding of tactical team decision making by: 1) incorporating the existing literature on team decision making performance into a theoretical model, 2) using the theoretical model to generate hypotheses for further investigation, and 3) conducting an empirical study to evaluate several such hypotheses. The current research effort represents a continuation of this research program. This report will discuss the relevant literature in light of the theoretical model used by Bowers and his colleagues (Bowers, et al., 1992), and will discuss the results of the second empirical study in this research effort. This investigation sought to further elucidate the effects of various factors hypothesized to influence the processes and performance of decision making teams.

The Team Effectiveness Model

The current research approach attempts to incorporate the available literature into a broad-based team performance model. Such a model, called the Team Effectiveness Model (depicted in Figure 1), was proposed by Tannenbaum, Beard, and Salas (1992).

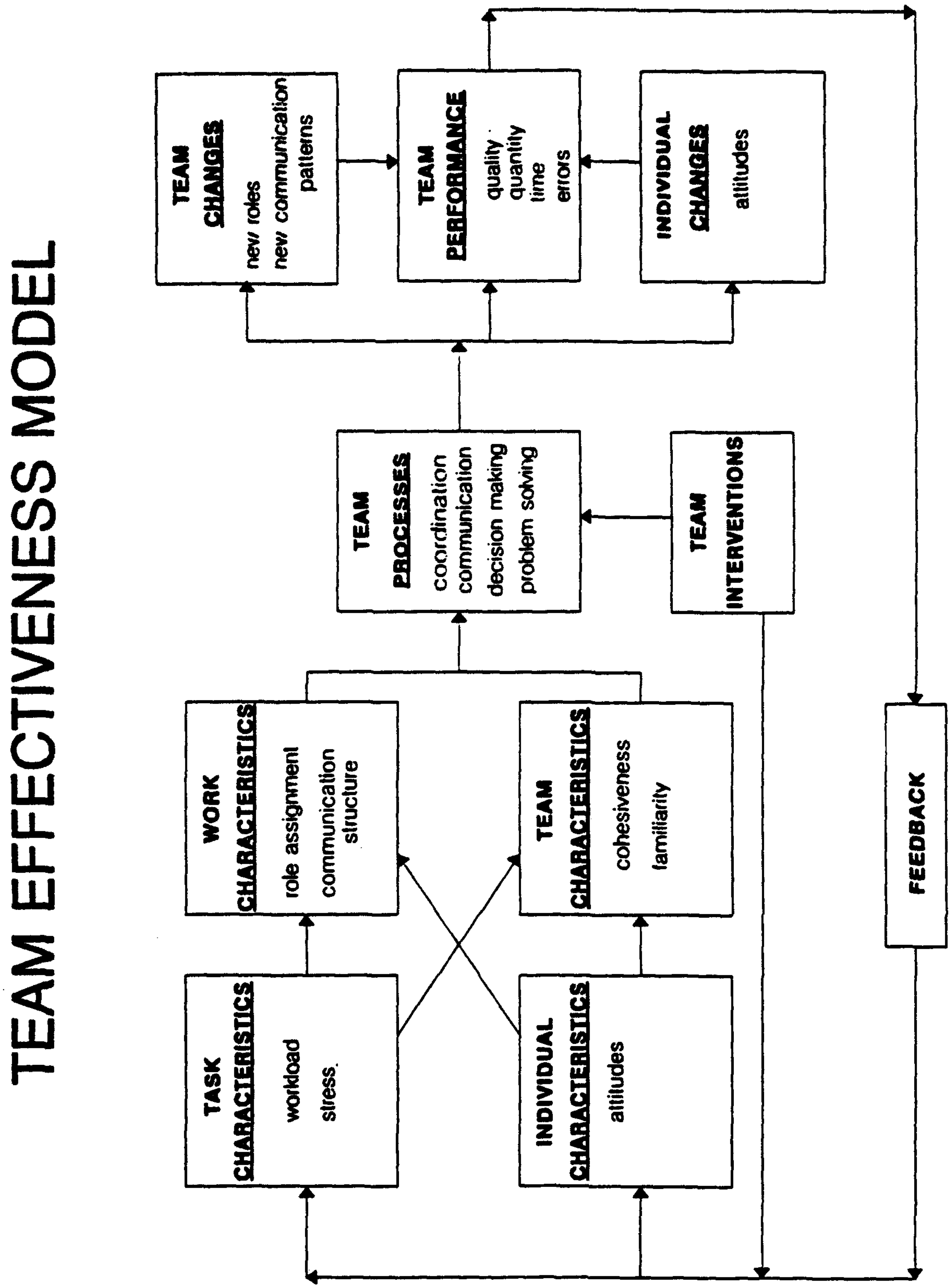

Figure 1. Team Effectiveness Model (Tannenbaum, Beard, & Salas, 1992).

This model presents a classical input-throughput-output representation of the general components of team performance. Input variables include the factors that are hypothesized to influence the performance of tactical decision making teams. The team processes, or team member interactions, are represented as the throughput component of this model. Outputs are the product of the combination of team processes and influential variables. The model depicts another major component, organizational and situational characteristics. These characteristics are inherent in the particular environment in which a given team is required to perform. In the current discussion, this context is considered to be the tactical environment; specifically the naturalistic setting in which CIC teams are required to operate. A review of the literature pertaining to the tactical environment is beyond the scope of the current discussion and will not be specifically addressed here. However, the primary characteristics of the operational context for tactical team decision making has been described by other authors (Athans, 1982; Johnson & Levis, 1989; Orasanu, 1990). Based upon these descriptions, the inputs, processes, and outputs that are addressed in the following sections have been selected because they constitute the essential aspects of the tactical environment that are hypothesized to have an impact upon team performance.

While several input-process-output models of team performance have been described by others (e.g., Gladstein, 1984; Hackman, 1987; McGrath, 1964), the model of Tannenbaum and his colleagues was chosen as a framework for the current research effort for several reasons. Namely, the conceptualization of input variables in the Team Effectiveness Model is simplistic enough to facilitate the generation of hypotheses, yet is sophisticated enough to retain the multi-dimensional nature of these variables. The model depicts four classes of team input variables: task characteristics, work characteristics, individual characteristics, and team characteristics. Task characteristics include aspects of the task that are hypothesized to impact the team at the level of the individual, while work characteristics are those variables that affect the team at the team level. Similarly, individual characteristics are attributes possessed by individual team members, while team characteristics are the attributes possessed by the team as a whole. By representing that both individual and team level variables can influence team processes and performance, and that these categories of variables can have an interactive effect, this model appropriately demonstrates the complexity of the determinants of team performance. This complexity is also represented in the model's multi-dimensional representation of output which views outcomes in terms of team and individual changes as well as team performance effects.

Thus, the Team Effectiveness Model proposed by

Tannenbaum and his colleagues (Tannenbaum, et al., 1992) was selected as the theoretical framework for the current investigation. With reference to this model, the following discussion summarizes the work performed by Bowers and his colleagues (Bowers, et al., 1992) which integrated the existing empirical knowledge that has been gained about team processes and the effects of various factors, acting alone and in interactions with other factors to influence team performance.

Input Variables

As discussed previously, input variables include the stimuli and conditions that are expected to influence team processes and performances. Tannenbaum et al. (1992) categorize these variables into four classes: task characteristics, work characteristics, individual characteristics, and team characteristics.

Task characteristics. Task characteristics are the individual-level variables that constitute the nature of the specific tasks to be performed. The task characteristics of tactical decision making teams include high levels of workload, acute information processing demands, and extreme time pressure. These task characteristics can induce stress in those who are performing in this environment. For example, individuals are often presented with the threat of imminent death, one's own, that of those around them, and/or that of the enemy. Similarly, tactical confrontations are typically quite brief, and split second choices are vitally important. An untimely decision can often be just as devastating as an inaccurate one. A great information processing demand is also inherent in tactical situations. Highly advanced technological systems that are currently used in the tactical environment present team members with a great deal of information to be processed. Thus, when considered collectively, these task characteristics can contribute significantly to the stress imposed by operational environments. A large body of literature discusses the effects of stress on performance. Summarized briefly, stress has been shown to have detrimental effects on performance, specifically on decision making performance (Janis, 1982; Janis and Mann, 1977). According to Janis and Mann (1977), individuals experiencing stress tend to miss and/or misrepresent available information when making a decision. Because the information that is the basis for decisions is incomplete and/or inaccurate, individuals often make ineffective decisions.

Another task characteristic that might influence team performance is workload. The workload experienced by individuals in a tactical situation can be quite high. Much research has suggested that high levels of workload lead to degraded performance (Beith, 1987; Hart & Hauser, 1987; Vidulich & Pandit, 1986). However, the effect of increased workload on team processes and performance is not yet clear (Morgan & Bowers, In press). Research suggests that membership in a team alone increases individual workload beyond that inherent in individual task demands (Bowers, Braun, & Morgan, 1992; Kidd, 1961; Williges, Johnston, & Briggs, 1966). Because of such findings, studying the effects of individual workload on team processes is warranted.

Furthermore, it has been hypothesized that the coordination demanded by team tasks increases workload (Bowers, Morgan, Salas, & Prince, 1993; Kidd, 1961). However, Kleinman and Serfaty (1989) suggest that team members may adapt their behavior in response to increased workload. In the studies performed by Kleinman and Serfaty (1989), workload is a team level manipulation. Therefore, this concept is discussed more thoroughly in the context of work characteristics.

Work Characteristics. The work characteristics of a team are primarily related to the way in which the team's overall task is organized or structured. The factors that determine a team's structure are numerous and diverse, as demonstrated by the broad definition assigned to structure by Tannenbaum and his colleagues (Tannenbaum, et al., 1992); namely, the manner in which the team approaches its overall task. This definition of structure includes many factors, such as work assignment, norms, roles, and communication structure. Although the definition of structure employed in the current research effort refers to work assignment (i.e., the assignment of components of the overall team task to individual team members), empirical work has been performed on many different variables that fit under the definition of team structure given by Tannenbaum and his colleagues (Tannenbaum, et al., 1992). While a thorough review of the literature concerning all aspects of structure is beyond the scope of the current review, several examples of research in which structure is defined more broadly will be briefly discussed. The reason for this inclusion is to illustrate the potential influence of these aspects of structure on team performance. Following these examples, a review of the literature relevant to a more limited definition of structure (i.e., as the assignment of tasks to individuals within the team) is provided.

One of the aspects of structure described by Tannenbaum and his colleagues (Tannenbaum, et al., 1992) involves norms. For example, Hackman (1987) discusses the effect of norms on work team performance in his review of the state of the art in work team design. As used by Hackman (1987), norms refer to "...structural features of a group that summarize members' shared approval (or disapproval) of various behaviors" (p. 328). In order for group norms to facilitate effective performance, they must engender tendencies within the group to regularly evaluate and attempt to improve current task performance strategies. Hackman (1987) contends that the existence of such norms depends upon two prerequisites in the group's behavior. First, norms must facilitate member adherence to a performance strategy in general. That is, the norms must be such that all group members agree to the importance of a given performance strategy, and that adherence to the strategy results in the approval of fellow group members (and, conversely, deviation from the strategy results in the disapproval of other members). Secondly, norms must support a group tendency to periodically evaluate the given performance strategy and to reconsider it in the context of alternative strategies. Because, as Hackman (1987) suggests, it is unusual for this tendency to spontaneously develop in groups, intervention may be required in order to develop this evaluation tendency. If these two prerequisites can be met within a team, such that members develop the norm of striving to improve the team's performance strategy, this aspect of structure can facilitate effective team performance.

Another aspect of structure has been investigated by David and his colleagues (David, Pearce, & Randolph, 1989). In this context, structural variables refer to the "nature and strength of patterns of relationships among individuals in work groups" (p. 234). More specifically, these researchers contend that common structure variables include horizontal and vertical differentiation, as well as connectedness. Horizontal differentiation refers to the number of areas of specialization represented within a work team. Vertical differentiation refers to the number of hierarchical tiers within a work team. Connectedness is similar to cohesiveness, in that it refers to the degree to which team members relate to the goals of their team mates (David, et al., 1989). By obtaining measures of the degree of horizontal differentiation, vertical differentiation, and connectedness of managers in banking work groups, David and his colleagues (David, et al., 1989) were able to predict a significant amount of variability in the supervisor ratings of these managers.

Several aspects of structure were investigated in a study performed by Naylor and Dickinson (1969). These researchers investigated the effects of task structure, task organization, and work structure, on the performance of two-person teams. Task structure was defined by Naylor and Dickinson (1969) as "...a function of the individual and joint demand characteristics of the separate task components, namely, component complexity, component organization, and component redundancy" (p. 167). That is, task structure refers to the demands imposed upon an individual team member by the task to which he/she is assigned. Task organization refers to the degree to which an individual's various subtasks are interrelated. Work structure is defined as the assignment of subtasks to individuals within the team. This includes the specific functions to be performed, the order in which they are to be performed, and the nature of the interactions between team members that are required.

The results of this study indicated that task structure and task organization both had significant effects on performance. Specifically, better performance was associated with greater (i.e., more defined) task structure, as well as with lower task organization. That is, subjects performed better when their subtasks were less interrelated (i.e., more independent). Work structure, however, had no significant effect on performance. In response to the lack of a significant effect of work structure, Naylor and Dickinson (1969) hypothesize that it is not work structure, per se, that directly influences performance. Rather, work structure dictates communication structure which has been shown to influence team performance (Williges, et al., 1966).

The association between work structure and *communication* structure is further demonstrated in a study performed by Lanzetta and Roby (1956). These researchers employed three-person teams, each of which performed the team task under two conditions of structure. In this context, structure referred to the amount of information presented to team members. That is, in one condition, each team member was presented with three of the four pieces of information that he/she needed to perform his/her team task responsibility. Therefore, each person in this condition had to obtain one piece of information by communicating with his/her teammates. This was called the high autonomy condition. In the low autonomy condition, team members had to communicate in order to obtain two pieces of relevant information. That is, each team member was presented with only two of the four requisite pieces of team task information. The results of this study indicated that teams made significantly more errors under the low autonomy structure than under the high autonomy structure.

This study emphasizes the fact that the way in which the team task is divided and components assigned to individuals often dictates the nature of the communication that must take place among team members. That is, the effects of work structure and communication structure often cannot be teased apart, as attempted by Naylor and Dickinson (1969). According to Vaughn (1990), "Coordination is the price to be paid for the advantage of having a complex problem decomposed into manageable parts" (p. 13). An important element of this coordination is communication (Franz, Prince, Cannon-Bowers, & Salas, 1990; Glickman, Zimmer, Montero, Guerette, Campbell, Morgan, & Salas, 1987). Therefore, the effect of work structure on communication is discussed more thoroughly below in the context of team processes (i.e., throughput). The remaining discussion of work structure refers to its effect on team performance.

It is clear from the evidence provided by the previously discussed studies that work structure influences team performance. The next obvious step in the investigation of structure would be to identify <u>the optimal</u> structures for team performance. In the context of the definition of structure employed in the current discussion (i.e., as the assignment of components of the overall team task to individual team members), the optimal team structure refers to the optimal manner of decomposing the team task into subtasks to be assigned to individuals. According to Simon (1969), as well as Tsitsiklis and Athans (1985), when dividing most systems into various subsystems, there is so much complexity that finding the optimal structure is nearly impossible. Therefore, much of the research being performed in this area uses mathematical modeling in an attempt to find satisficing designs (Vaughn, 1990).

Compared to the quantitative research that has been performed on team structures (e.g., Carley, 1991; Kleinman, Luh, Pattipati, & Serfaty, 1992; Levis, 1984), relatively little empirical work has focused on identifying effective team structures. In one recent study, Kleinman and Serfaty (1989) manipulated the work structure of teams by altering the degree to which overlap existed among individuals in a two-person resource allocation task. The results of this study indicated that under low and moderate levels of workload, more task overlap resulted in better performance. Under high workload, however, partial task overlap was associated with the best team performance. The authors suggest that, under high workload, a high degree of overlap overwhelms team members with too much information to be assimilated. Hence, partial overlap allows for the best possible performance in this situation.

In another empirical investigation of the effects of team structure and workload, Bowers and his colleagues

(Bowers, et al., 1992) used a five-person resource allocation task somewhat similar to that employed by Kleinman and Serfaty (1989). More specifically, the team decision making task employed in this study was composed of three sub-tasks. Structure was manipulated in terms of the number of team members who could perform each of these sub-tasks. The first sub-task required subjects to monitor a simulated radar display for approaching enemy targets. The second sub-task required subjects to decide how to appropriately distribute a fixed number of team resources to enable individual members to prosecute incoming targets. The third sub-task required subjects to use the resources allotted to them to shoot down enemy targets. In the non-hierarchical structure condition, each of the five team members was able to perform each of the three sub-tasks. In hierarchically structured teams, each team member was presented with specialized information and capabilities for performing the team task. That is, three team members were assigned to the position of scope operator, which required them to monitor the radar scope for incoming targets (i.e., perform the first sub-task). The fourth team member was assigned to the position of resource allocator. This individual was presented with all information concerning each approaching target, as well as with all information concerning the number and type of resources held by each team member. However, this individual could neither identify nor shoot enemy targets. The fifth team member was assigned to the position of target engager. This individual was presented with all information concerning each approaching targ..t, as well as with the capability of shooting down enemy targets. The scope operators and the resource allocator also had the capability to transfer team resources, but they could not specify to whom the resources were to be sent. That is, resources sent by the scope operators automatically were transferred to the resource allocator. In turn, resources transferred by the resource allocator were automatically sent to the target engager.

In addition to structure, workload was manipulated in this experiment. Low and high workload teams were factorially assigned to either a non-hierarchical or hierarchical structure condition. The results of this study indicated that non-hierarchical teams performed more effectively than hierarchical teams, regardless of workload level.

Individual characteristics. Individual characteristics refer to the skills, knowledge, and personalities of the individuals in the team. Because of the great extent to which military personnel are trained before being placed in a tactical environment, skills and knowledge of members of military teams are not included in the present discussion. However, the influence of personality factors and attitudes on team performance does warrant discussion. In the available literature, there is disagreement concerning whether or not the personality of individuals influences team performance. Kahan, Webb, Shavelson, and Stolzenberg (1985) contend that personality traits are general constructs, and therefore, cannot predict team performance on specific tasks. The position is based on studies such as those conducted by Bouchard (1969), Butler and Burr (1980), and Haythorn (1953), which demonstrate weak, if any, support for the relationship between various aspects of personality and performance.

Research does exist, however, that tends to support the existence of this relationship. For example, Haythorn, Couch, Haefner, Langhan, and Carter (1956) demonstrate that significantly different behaviors were exhibited by authoritarian and nonauthoritarian teams. Furthermore, various measures of personality have been shown to predict the attitudes and coordination behaviors exhibited by aircrews (Gregorich, Helmreich, & Wilhelm, 1990; Helmreich, 1987; Spence & Helmreich, 1978; Spence, Helmreich, & Pred, 1987). The findings of Helmreich and his colleagues concerning the relationship between personality and performance illustrates the need for further research to determine the degree to which the findings obtained with aircrews can be generalized to teams in other operational environments.

Team characteristics. Team characteristics (i.e., those characteristics that collectively denote the "personality" of a particular team), can also influence team processes and team performance. According to Morgan and

Lassiter (1992), team-level variables include "factors which cannot be accounted for in terms of a single individual, but which require the interaction of two or more team members" (p. 24). Several variables, whose effects on team processes and team performance have been studied extensively, will be discussed briefly in order to summarize the available literature on team characteristics. These variables are team size, compatibility, and cohesion (Bass, 1982; Moreland & Levine, 1993; Morgan & Lassiter, 1992).

To a large extent, task demands determine the optimum number of individuals performing as a team (Bass & Ryterband, 1979). However, the effects of team size have been studied extensively, and results indicate that adding team members may be either beneficial or detrimental with respect to team processes and performance (Moreland & Levine, 1993). The beneficial effects of adding individuals to teams have been illustrated by Cattell (1953) who found that larger teams had higher skill levels and more diverse information processing capabilities than smaller teams. These positive effects may arise because each additional individual brings additional performance resources to the team (Shaw, 1976). However, Morgan, Coates, and Rebbin (1970) report that the performance of five-person teams experiencing illness was better when one person was absent than when all five team members participated. The negative effect on team performance associated with increased size may arise because larger teams have the potential for more interactions among individual team members, thus resulting in performance that is slower and less accurate (Bass, 1982). Furthermore, increased team size has been associated with decreased communication (Indik, 1965), feelings of inhibition to participate (Gibb, 1951), and greater conformity (Shaw, 1976; Gerard, Wilhelmy, & Conolley, 1968). When applied to decision making teams, the behaviors exhibited by large teams "might serve to limit the amount of information utilized in arriving at a decision" (Morgan & Bowers, In press, p. 19). Morgan and Bowers (In press) contend that further empirical study is necessary to determine the effects of team size on decision making performance.

Compatibility among team members is also an important team level factor to be taken into consideration. Compatibility is discussed in terms of homogeneity versus heterogeneity among team members. In general, heterogeneous teams (with respect to abilities and interests) are more likely to experience conflict among team members than homogeneous teams (Bass, 1965; Hoffman, 1959). Homogeneity seems to enhance team interaction (Bass, 1982), although the effects of compatibility are moderated by the type of task being performed. For example, Lodahl and Porter (1961) found that cooperation among team members performing a complex physical task was greater in homogeneous teams than in heterogeneous teams. In problem solving tasks, the effect of compatibility is reversed: heterogeneity appears to facilitate performance (Bass & Ryterband, 1979; Hoffman & Maier, 1961). Morgan and Lassiter (1992) suggest that "the high degree of similarity of members in homogeneous teams often acts as an obstacle to creative and thorough solutions because of the team's relative lack of breadth and variety of resources" (p.35). These observations, however, are based on research performed in controlled environments. These findings must be tested in more naturalistic situations to determine their generalizability (Morgan & Bowers, In press).

The third team characteristic variable to be discussed is cohesion. Tannenbaum and his colleagues (1992) describe team cohesion as "a team's feeling of belongingness and sense of teamness" (p. 124). Although a large literature on team cohesion exists, the nature of the relationship between team cohesion and performance is unclear. In general, this relationship is much like the "chicken and the egg" phenomenon. For example, Shaw (1976) suggests that performance is enhanced by high cohesion. Anderson (1975), on the other hand, illustrates that successful team performance increases cohesion. With respect to team decision making performance, a review by Wolfe and Box (1988) suggests that much of the available research fails to support a strong relationship between cohesion and team decision making performance. Wolfe and Box (1988) suggested that motivation must be taken into account when attempting to analyze this relationship. These researchers empirically demonstrated a strong relationship between cohesion and team decision making performance under a high degree of motivation. While the exact nature of the relationship between cohesion and performance remains unclear, the available findings suggest that cohesion seems to be an influential team characteristic, and hence, should be further investigated.

As an extension of the initial work performed by Bowers and his colleagues (Bowers, et al., 1992), the present study attempted to consider the effects of six input variables (namely, workload, task structure, attitudes towards coordination, cohesion, teamness, and familiarity) upon team processes and performance under an additional team structure condition. Analysis of these variables will provide further testing of the theoretical model described by Tannenbaum and his colleagues (Tannenbaum, et al., 1992).

Throughput

Team Processes. Team processes are the interactions among team members that allow them to accomplish the team's common goal. These processes are also referred to as teamwork (Glickman, et al., 1987) or crew coordination (Franz, et al., 1990). Although as much as fifty percent of the variance in team performance can be accounted for by attributes of the particular task being performed (Hackman, 1968), one of the goals of team research is to determine the extent to which the effectiveness of team performance is affected by the interactions of team members. By determining the degree to which performance is influenced by team processes, it is hoped that the specific communication behaviors associated with effective performance can be identified, and that interventions can be developed to train these team process behaviors in order to improve team performance.

Progress on the identification of specific team process behaviors associated with effective performance was made by Glickman and his colleagues (Glickman, et al., 1987). These researchers classified over ninety behaviors exhibited by Naval Gunfire Support teams into one of seven general categories. These seven categories represent the dimensions that are hypothesized to make up teamwork. They are: communication, coordination, team spirit and morale, giving suggestions and criticism, acceptance of suggestions and criticism, cooperation, and adaptability. By analyzing the occurrence of these critical behaviors in Naval Gunfire Support teams, Glickman and his colleagues were able to distinguish effective teams from ineffective teams.

Similarly, Orasanu (1990) found an association between the communication of aircrews performing a simulated emergency flight task and the relative effectiveness of these teams. Orasanu found that teams who performed effectively increased their communication (specifically information exchange and verbalization of plans) under emergency situations, whereas ineffective teams did not. Along the same lines, Foushee and his colleagues (Foushee, Lauber, Baetge, & Acomb, 1986) examined the performance of aircrews confronted with fatigue. These researchers found that crews who had prior flight experience communicated more. The performance of crews who demonstrated higher levels of communication showed resistance to the effects of fatigue.

Clearly, these studies support the hypothesis that specific communication behaviors can lead to more effective team performance. While this is an important finding, generalizability is somewhat difficult in that the communication behaviors required in operational environments (e.g., in the aircrew cockpit) seem, to a large extent, to be highly "environment specific." That is, researchers would have a difficult time distilling the teamwork "essence" of a communication behavior from the task-specific context in which it was expressed. Furthermore, operational environments are extremely diverse. One would highly doubt that the utterance of a specific behavior leads to better performance in any environment (aviation, Naval gunnery, CIC, business, etc.). However, the prior findings demonstrate that teams do exhibit adaptive behaviors through communication in response to various environmental demands (e.g., flight emergencies, fatigue, etc.).

The results of the previously described study by Kleinman and Serfaty (1989) also demonstrate the tendency of teams to use communication to respond to situational demands; namely, the demand of workload. In this study, teams exposed to low and moderate levels of workload exhibited frequencies of team communication that were significantly higher than those exposed to high workload levels. However, the level of team coordination (as observed through the number of resource transfers) was maintained. Under lower workload levels, teams were said to "explicitly coordinate." That is, each transfer was likely to be preceded by a specific request. Because of the decreased frequency of team communication under high workload levels, the coordination of these teams was described as "implicit;" that is, transfers were made without a specific request.

Similarly, the previously described study of Bowers and his colleagues (Bowers, et al., 1992) also illustrates the tendency of teams to adapt through their communication. In this study, teams communicated differentially in response to the demands imposed by team structure. Specifically, five-person teams were arranged according to either a non-hierarchical structure (in which all team members were presented with identical information and capabilities with which to perform the team task), or a hierarchical structure (in which each team member was presented with specialized information and capabilities for performing the team task). The results indicated that in non-hierarchical teams, more communication was associated with effective performance. In hierarchical teams, however, this trend was reversed. That is, in these teams, more communication was associated with ineffective performance. The present study attempts to build upon the work performed by Bowers and his colleagues (Bowers, et al., 1992) to further discern how effective teams adapt to situational demands through their team processes.

<u>Output Variables</u>

Output variables include the measures that reflect the results of team processes, in light of the acting influential variables. The output of interest in the current study is an index of team performance. According to Tannenbaum and his colleagues (Tannenbaum, et al., 1992), team performance includes "quantity and quality of products and services, as well as time, errors, costs, and overall productivity" (p. 10). Before describing the main variable selected for use in the present study, a brief review of the critical issues involved in the measurement of team performance is in order.

Because of the definition of teams (i.e., "individuals working interdependently and adaptively to achieve specified, shared, and valued objectives" (Morgan, et al., 1986; p. 3)), team performance or output occurs because the individuals in the team coordinate their activities. The index of performance, therefore, must reflect the extent to which the team has successfully coordinated (Zalesny, Salas, & Prince, In prep.). Such a requirement has several implications for the selection of measurement indices. First, measuring performance is not merely an exercise in measuring coordination; rather it requires measuring coordination that has been successful in reference to the team goal. Thus, the measurement index must be relevant to the team's accomplishment of the purpose for which it was organized to fulfill.

Second, if the team's measurement index is to reflect the product(s) of individuals' coordinating activities, then this index must be of the appropriate temporal duration to reflect the results of these coordinating activities. That is, in a team situation, members must synchronize or temporally pattern their activities because performance requirements often occur in cycles of a particular duration (Kelly & McGrath, 1985; Zalesny, et al., In prep.). Zalesny and her colleagues (Zalesny, et al., In prep.) contend that the measurement interval must be of a sufficient duration to capture the interaction patterns and their resultant consequences.

Third, in order for the performance index to represent the coordinating activities of two or more individuals within a specific time span, the behavior of these individuals must somehow be aggregated in order to summarize the events of that interval (Roby, 1957). Roby suggests that aggregation, in this context, means that a single measure denotes the behaviors of several individuals over a segment of time (Roby, 1957). When deriving an index of team performance, one must decide the means by which individuals' behaviors are entered into such a composite.

While in some situations, summing across individuals might in fact be the most appropriate means by which to arrive at a team index of performance, it is unlikely that such a simplistic approach is appropriate for operational teams. Therefore, an aggregation rule must be employed that corresponds to the requirement for coordinated activity among team members, and that also results in an index that reflects the extent to which a team has been successful in accomplishing its goal.

The current investigation sought to fulfill these criteria for an index of team performance. Along these lines, a "team score" index was incorporated into the resource allocation task. Given that the goal assigned to all teams in the *current* investigation was to maximize their team score, this index was relevant to the team's collective goal. This score was also designed to represent the coordinated activities of the team members, given that points were accumulated based upon a team's capability to respond to the demands imposed upon its resources (see below for a more detailed description). While the current research approach focuses on the outcome of team performance, Tannenbaum and his colleagues (Tannenbaum, et al., 1992) include individual changes and team changes as additional outcomes. Measurement of these two facets of outcome illustrate the dynamic nature of the team and of the individuals of whom it is composed, hence representing a useful inclusion in the Team Effectiveness Model. Specific assessments of additional types of outcomes need to be included in future research.

Summary

The foregoing discussion attempts to integrate the available empirical findings into a model of team performance, and in so doing, to illustrate the variables that are likely to influence the performance of tactical decision making teams. In the current investigation, the input variables of interest are individual workload, team workload, attitudes toward coordination, cohesion, teamness, and familiarity. The team processes of interest are decision making and coordination as exhibited through communication behaviors. The relevant outcomes are team performance as exhibited by team score, as well as other measures of quantity, quality, time, and errors. The current investigation, therefore, attempts to further elucidate the relationships among these input, process, and outcome variables as they relate to the performance of decision making teams.

Purpose of the Current Research

The objective of the current line of research was first described by Bowers and his colleagues (Bowers, et al., 1992) as an attempt to investigate those variables which, according to the Team Effectiveness model (Tannenbaum, et al., 1992), might contribute to a more thorough understanding of team decision making. The current study in this line of research attempts to continue the previously established focus.

However, the goal of the previous study was to determine the relative effects of two different team structures on the processes and performance of teams under low and high workload. Clearly, team structure significantly influences team performance. Therefore, the current study sought to enhance generalizability to operational teams by simulating a team structure that is prevalent in organizations and operational environments. One such structure has been referred to as a "product" organization (Tosi, Rizzo, & Carroll, 1990). That is, the structure duplicates functions across team members, but these functions are performed in relation to <u>different</u> "products" for each member. This can be likened to a combat information system environment in which operators perform similar functions, but do so in relation to different types of targets (e.g., air, surface, sub-surface). Regardless of the effectiveness of this structure, it is employed in many environments. Therefore, because of its prevalence, it is necessary to create training interventions to optimize performance within this structure, rather than redesigning systems to impose an optimal team structure. The studies described above indicate that team processes are the most likely target for this type of training intervention.

Therefore, the goal of the present study was to create a laboratory analogue of a "product group". Creating such an analogue provided the opportunity to complete the following objectives: 1) to evaluate the performance effectiveness of this structure relative to that of the hierarchical and non-hierarchical structures employed in previous research (i.e., Bowers, et al., 1992) under two levels of workload, and 2) to identify the team coordination processes associated with effective decision-making within these groups. The current study represents the addition of a third team structure condition under two levels of workload to the study performed by Bowers and his colleagues (Bowers, et al., 1992). All data collected in the previous study were re-analyzed with data collected from the product structure according to a three (structure) by two (workload) factorial experimental design.

METHOD

Subjects

Thirty-six five-person teams of undergraduate students from the University of Central Florida voluntarily participated as subjects in this study. Teams were assigned to one of six conditions, such that six teams participated in each of cell of the three by two (structure by workload) design.

Tasks

The tasks performed by subjects were incorporated into a team performance assessment battery (TPAB) and were presented on personal computers linked via a local area network (see Bowers, et al., 1992 for more details concerning the computerized network). The tasks presented via TPAB consisted of three individual watchkeeping tasks and a team distributed decision making task. The tasks are schematically represented in Figure 2, which shows the layout of the various tasks on the screen of a typical computer workstation.

Watchkeeping tasks. Three individual watchkeeping tasks were presented to subjects. These tasks were conceptually and functionally similar to those used in the Multiple-Task Performance Battery (MTPB) developed by Alluisi and his colleagues (Alluisi, 1967, 1969; Morgan & Alluisi, 1972). The combination of the team and individual tasks of the MTPB constituted a synthetic work environment that placed cognitive demands (e.g., watchkeeping, vigilance, and coordination demands) on subjects similar to those found in operational environments.

The three individual performance tasks presented to subjects were the warning lights task, blinking lights task, and probability monitoring task (see Bowers, et al., 1992 for a more detailed description of these tasks). The warning lights task consisted of a pair of simulated warning lights, one green and one red, located in the lower left periphery of the computer display. The subject was instructed that the task was in a "normal" state when the green light was on and the red light was off. At random time intervals there was a change of state in one of the two lights so that either the red light went on or the green light went off. This change indicated a critical condition

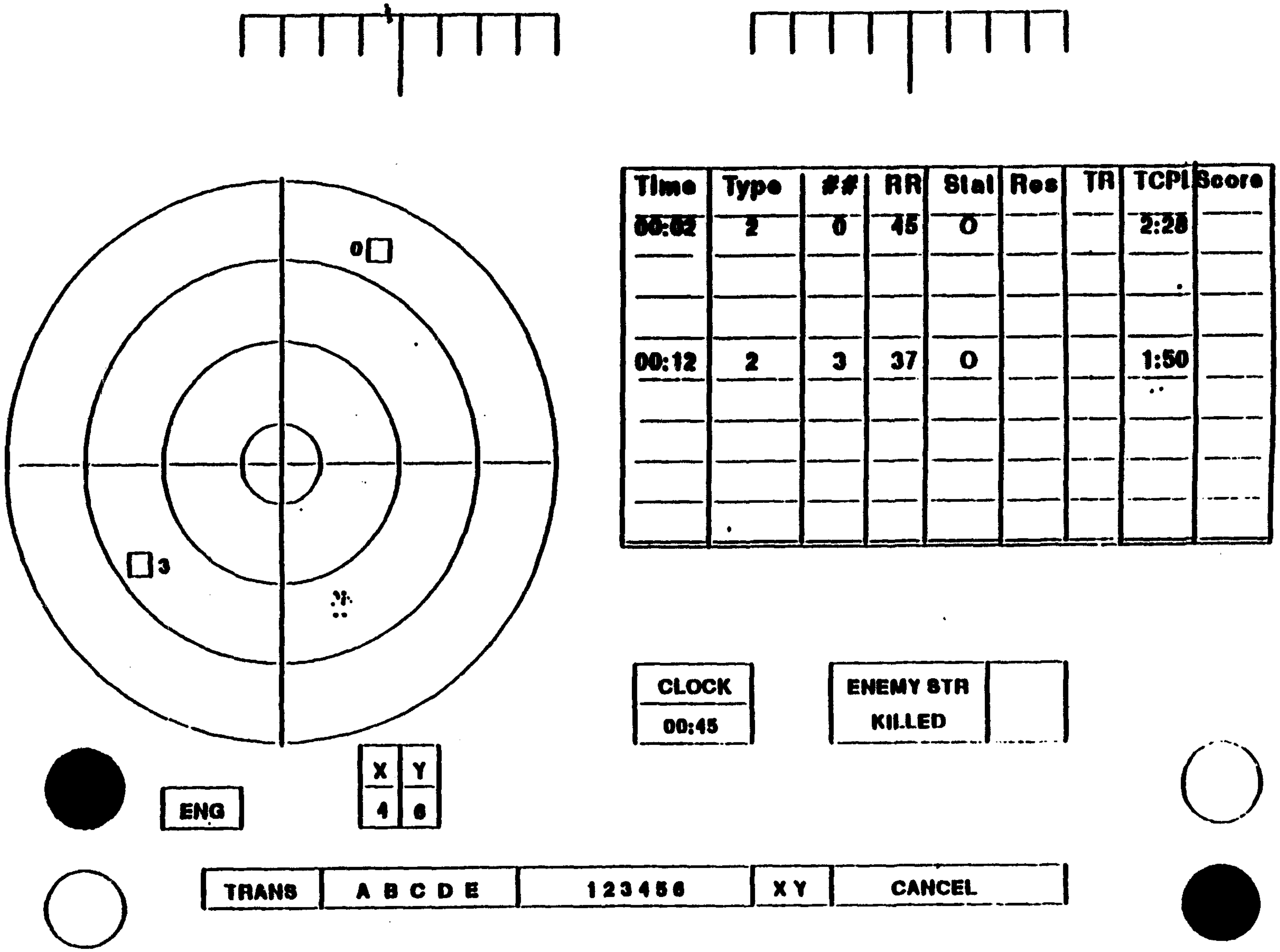

Figure 2. Schematic representation of TPAB individual and team tasks.

to which the subject was to respond as quickly as possible. Subjects corrected a critical condition by using a mouse interface and "clicking" on the critical signal. That is, subjects either clicked on the red light in order to turn it off or clicked on the green light to turn it back on (depending on which condition happened to be occurring at that particular occasion). The subject's response time (latency to .01 sec) to the critical condition was the primary dependent variable for this task. If a subject failed to respond within two minutes, the critical condition was corrected automatically and his/her response time was recorded as the maximum latency (120 sec).

The blinking-lights task consisted of two vertically arranged amber lights in the lower right periphery of the computer display. These simulated lights were generated in an identical manner as in the warning-lights task. Under normal conditions, the two lights alternated flashing at an overall rate of two flashes per second. The critical condition for this task occurred when one light (either the top or the bottom light) turned off and the other blinked at twice the normal rate (i.e., the overall flash rate remained constant). This change indicated a critical condition to which the subject was to respond as quickly as possible. Subjects corrected a critical condition by using a mouse interface and clicking on the critical signal. That is, subjects clicked on the light that was rapidly blinking (either the top or bottom light, depending on which condition happened to be occurring at that particular occasion) in order to return the lights to their normal state (i.e., alternately blinking). The subject's response time (latency to .01 sec) to the critical condition was the primary dependent variable for this task. If a subject failed to respond within two minutes, the critical condition was corrected automatically and his/her response time was recorded as the maximum latency (120 sec).

The third of the watchkeeping tasks was the probability monitoring task. In this task, two linear scales were located along the top portion of the display. A pointer on each scale was driven by a random-generator that was updated twice per second. Pointer settings were normally distributed with a mean of zero (i.e., average location corresponds to the center of each scale) and a standard deviation of 1.0 scale unit. The critical condition for this task occurred when a "bias" was introduced to the distribution of pointer settings so that the mean of the distribution on one of the two scales shifted one standard deviation to the left or the right of the center of the scale. In performing this task, the subjects were required to detect the presence of a bias in the pointer settings and respond so as to correct (or remove) the biased condition. When a bias was detected, subjects responded with the mouse by dragging the cursor to a designated spot on the left- or right-hand side of the biased meter (i.e., a response was made to the left if a bias-to-the-left was detected, and a response was made to the right if a bias-to-the-right was detected). If a bias was present and a correct response was made, the pointers of both scales froze in their position for six seconds. If a response was made in the absence of a bias, the movement of the pointers was not interrupted. Data recorded on this task were the number of bias signals presented, the number of signals detected correctly, the number of false responses, and the time required to detect each critical signal.

Critical signals were scheduled independently on each of the three tasks according to a half-normal distribution with intersignal intervals that ranged from 250 to 800 seconds as follows:

Intersignal Interval (sec)	Frequency in two hour trial
250	4
300	3
350	3
400	2
450	2
500	1
600	1
650	1
800	1

The three tasks were performed concurrently and continuously during any performance session. Therefore, they may be treated collectively as a single low-demand individual performance requirement to which each operator responded independently. Because most team performance situations require team members to attend to individual-performance requirements as well as team-performance activities, and because monitoring is a basic functional requirement in most work situations, the inclusion of these tasks was expected to enhance realism and operational relevance.

Team Resource Management (REMAN) Task. The resource allocation task in the TPAB was a modification of the Distributed Resource Allocation and Management (DREAM) task (Kohn, Kleinman, & Serfaty, 1987; Kleinman & Serfaty, 1989). This task was designed to assess team skills such as communication, decision making, coordination, and resource allocation in a naval warfare simulation. The DREAM task had been used in several studies to assess team decision making and resource allocation skills and appeared to be of a sufficient difficulty to elicit high-level coordination behaviors from team members (Bushnell, Serfaty, & Kleinman, 1987; Kohn, et al., 1987; Kleinman & Serfaty, 1989). As modified in the TPAB, the resource management (REMAN) task was presented to teams of five subjects via two different displays in the center of the screen. A schematic representation of these displays is shown in Figure 2. One display was a graphically simulated radar display. The center of this circular display was designated as "home base." The home base was circled by three rings which indicated the distance of a threat from the home base. The second major part of the REMAN display was a table which provided text relating to information about approaching threats and amounts of resources available for use. This table included information concerning the current time, expected penetration time for each target, target type and identification number, type and number of resources required to destroy each target, the status of each target, resources to be returned to the team, and target score.

In this task, teams were required to utilize the information from their computer displays in order to manage collective resources and coordinate their actions in order to destroy incoming enemy targets. Each team had a limited number of two different types of renewable resources with which to engage the targets. Team members were able to transfer these resources among themselves as required. There were three different types of targets, each requiring a different number and type of resources to destroy it. It was the team's task to manage the allocation of available resources so as to destroy the maximum number of targets. Targets appeared randomly in any of the three distance rings and moved toward home base at a constant rate. Each target required 30 seconds to be destroyed. Each target was available (displayed) for at least 50 seconds. Thus, team members were required to be aware of both the availability of resources as well as time demands imposed upon those resources.

Furthermore, there were three sub-tasks that constituted REMAN performance. The first sub-task tapped the team's situational awareness by requiring members to monitor a simulated radar display for incoming enemy targets. The second sub-task required team members to decide how to allocate and manage the resources among themselves in order to engage enemy targets. In the third sub-task, team members used the resources allotted to them in order to engage (shoot down) enemy targets.

Enemy targets appeared first as vague ("fuzzy") images on the radar scope. To perform the first sub-task, team members used the mouse to click on these images. Once targets were clicked on, information pertaining to the resources required and length of time available to prosecute the target appeared in the data table. To perform the second sub-task, team members used the mouse to click on specific areas of the display to transfer resources to one another. To perform the third sub-task, team members holding an appropriate number of resources clicked on specific areas of the display in order to shoot down the enemy target.

Teams were arranged according to one of three structures: non-hierarchical, hierarchical, or product. A detailed description of the non-hierarchical and hierarchical structures can be found in Bowers, et al., 1992. In the product structure, teams were arranged such that four team members were presented with identical displays and each was able to perform all three sub-tasks. However, each of these team members could only perform these sub-tasks in a limited, non-overlapping geographic area on the radar display. That is, each of these four team members were presented with information and capabilities pertaining to one quadrant of the radar scope. The fifth team member was presented with all of the information available to the team. However, this team member could only transfer team resources to the other team members. He/she was unable to monitor the radar scope for incoming enemy targets, and he/she was unable to shoot targets down.

Teams in both workload conditions worked with the same number of two types of replenishable team resources. Shooting down an approaching enemy target temporarily depleted a number of these resources according to a weighted, probabilistic distribution. Teams under high workload were presented with the same number of enemy targets as teams under low workload. However, under high workload conditions, more resources were required in order to shoot down a given target. More specifically, the two types of resources were denoted as X and Y resources. In the low workload condition, the number of resources required by approaching targets ranged from 1 X and 1 Y to 7 X and 7 Y, with a mean of 5 X and 5 Y resources required. In the high workload condition, the number of resources required by approaching targets ranged from 1 X and 1 Y to 9 X and 9 Y, with a mean of 7 X and 7 Y resources required. The increased demand on resources required teams to do more planning and to transfer a greater number of resources in order to perform the task.

Procedure

Upon arrival in the research center, each subject filled out a consent form. After the arrival of all five team members, subjects were asked to fill out two questionnaires. One questionnaire assessed the degree to which each individual was familiar with each of the other team members. The other questionnaire assessed individuals' attitudes toward team coordination. Upon completion of these questionnaires, each team was given one hour of training on the tasks before performance was recorded. The materials used for this training were an interactive computerized tutorial accompanied by an experimenter's script. Subjects were given verbal instructions about actions that needed to be taken to perform each of the three watchkeeping tasks. After each task description, subjects were prompted to interact with TPAB to correct all possible stimulus conditions in each of the three individual tasks. Following this portion of the tutorial, subjects were asked to monitor all three individual tasks simultaneously for ten minutes. Subjects were also informed that stimulus states to which they must respond appeared much more frequently during this practice session than they did during the actual experimental session.

After completion of monitoring task practice, subjects were given instructions pertaining to the team task. Subjects were given a verbal description of the objectives of the team task, as well as how to perform each of the three team sub-tasks. The computerized tutorial then presented the team with several targets, allowing for a "walk-through" of target prosecution and resource allocation. In this interactive REMAN training session, each team member was presented with identical information and capabilities for performing the team task. By presenting each team member with all information and capabilities necessary for performing the team task (i.e., by giving full task training), all subjects were given an overview of all aspects of the team task. After performing this interactive training session, team members in the hierarchical and product structure conditions were given a verbal description of the specific requirements of the structure to which they were assigned. Each individual team member was then assigned to his/her position in the hierarchical or product team structure. Each team member received a verbal description of his/her individual task responsibilities. All teams then performed a ten minute practice session of the version of the REMAN task corresponding to the structure to which they were assigned.

In accordance with the characteristics of the synthetic-work approach, the four TPAB tasks were synthesized into a relatively realistic work situation that required team members to time-share the performance of the several tasks. Teams were required to perform the tasks for a total of three 2-hour performance sessions. Within each 2-hour session, the work was divided such that team members were responsible all of the time for monitoring tasks, but only part of the time for the REMAN task. Specifically, each 2-hour session consisted of three repetitions of the following: ten minutes of monitoring performance, thirty minutes of simultaneous monitoring and REMAN performance.

At the end of the first and second 2-hour sessions, team members completed a subjective workload experience questionnaire and a team cohesion questionnaire. Following the third 2-hour session, they completed both the workload and the cohesion questionnaires, a questionnaire pertaining to "teamness", and a team coordination attitude questionnaire (the same one as given at the outset of the experiment).

Input Variables

Task characteristics. Workload is the task characteristic of interest for the present research. In the current study, workload was operationally defined in reference to the number of team resources required to prosecute any given target. Because this manipulation increases the demand for team members to coordinate their resources, this manipulation had its impact at the team level. Under high workload, for example, the increased demand placed on resources required teams to do more planning and to transfer a greater number of resources among members in order to perform the task. Such a manipulation of workload cannot be considered as a task characteristic because task characteristics, as specified by Tannenbaum and his colleagues (Tannenbaum, et al., 1992), act at the level of the individual. In the context of the current investigation, workload as an independent variable is discussed as a work characteristic. However, the load imposed by the workload manipulation was also assessed in terms of the subjective workload experience of team members. Clearly, subjective experience is an individual level variable, and is considered as a task characteristic. The NASA Task Load Index (Hart & Staveland, 1988) was selected to provide measurement of subjective workload. The NASA-TLX provides a weighted rating of workload along six dimensions: mental demand, physical demand, temporal demand, performance, effort, and frustration level. Hart and her colleagues (Hart & Staveland, 1988) developed this scale over the course of sixteen experiments, and have demonstrated it to have a test-retest reliability of .83. Recent reviews have also supported the validity of the TLX as a workload assessment instrument (e.g., Hill, Iavecchia, Byers, Bittner, Zaklad, & Christ, 1992).

Work characteristics. The work characteristics that were of interest in this study were team structure and workload. Of primary interest in the current study were the effects of the workload manipulation on the performance of teams in all three structures. Also of interest were the effects of these two variables on team communication, particularly as these effects allowed for discrimination between effective and ineffective teams.

Individual characteristics. The individual characteristic of interest in this study was the attitudes of team members about coordination. The Team Coordination Attitude Scale (TCAS; Weaver, Bowers, & Morgan, 1992) was employed to measure these attitudes. The TCAS was developed as a modification of the Cockpit Management Attitude Questionnaire (CMAQ; Gregorich, Helmreich, & Wilhelm, 1990). However, Weaver and her colleagues used the Aircrew Coordination Observation/Evaluation Scale (ACO/E; Franz, Prince, Cannon-Bowers, & Salas, 1990) and the team performance literature to modify and expand the CMAQ into the TCAS used here. The TCAS includes forty-four, Likert scale items, derived from the results of a factor analysis (Weaver, et al., 1992). The scale measures three factors: coordination, communication, and planning. It also has been demonstrated to yield an alpha reliability coefficient of .81 (Weaver, et al., 1992).

Team characteristics. One of the team characteristics of interest in this study was the sense of teamness experienced by team members as a result of participation in the team in previous trials (i.e., before achieving performance asymptote). To measure teamness, an adaptation of the Trainee Self-Report Questionnaire (James, Gustafson, & Sells, 1985) was employed. This instrument was employed by Morgan and his colleagues (Morgan et al., 1986) in their work with Naval Gunfire Support teams. The Trainee Self-Report Questionnaire was demonstrated to "reflect the perceptions of behaviors and performances that are of greatest importance for successful teams" (p. 50). The Trainee Self-Report Questionnaire was slightly modified in order to make it appropriate for the more general team task employed here. This adaptation, called the Self-Report Questionnaire included eighteen, five-point Likert scale items which measured team members' perceptions along the following dimensions: importance of taskwork, importance of teamwork, importance of interdependence, and importance of the individual (Bowers, et al., 1992).

A second team characteristic, team cohesion, was assessed using the Modified Sport Cohesion Instrument (Yukelson, Weinberg, & Jackson, 1984). Subjects were required to answer twenty-two six-point Likert scale items that assessed four factors of cohesion: attraction to the group, unity of purpose, quality of teamwork, and valued roles. This cohesion scale has been demonstrated to yield an alpha reliability coefficient of .95 (Yukelson, et al., 1984).

The third team characteristic of interest was team familiarity prior to participation in this experiment. A measure of inter-member familiarity was taken in order to rule out selection errors which might confound the measurement of other team characteristics. To assess familiarity, subjects were asked to rate, using a four-point Likert scale, the degree to which they were already familiar with each of the other four team members.

Throughput Variables

All team interactions during performance of team and individual tasks were videotaped. However, teams arranged according to the hierarchical structure were not used in the current analysis of throughput variables. The rationale for this exclusion lies in the fact that in hierarchical teams only, the team task was designed such that the flow of resources among team members was fixed. Team members were therefore not required to spontaneously solicit resources from any other team member in this structure, as they were able to in the non-hierarchical and product structure conditions. Given that the current coding scheme was broadly based upon questioning and answering behaviors, such behaviors were of primary interest in non-hierarchical and product structure teams in that they could be associated with resource transfers among team members. In hierarchical teams, however, questioning and answering behaviors were only of secondary interest because they lacked a parallel performance referent. While the analysis of the communication of hierarchical teams is still an important endeavor, its secondary importance coupled with the "expense" of this analysis (in terms of time and laboratory resources) have prevented this analysis from having been performed to date. Therefore, the current presentation of process/throughput results focuses only on non-hierarchical and product structure teams.

From the non-hierarchical and product structure teams, a five minute sample of videotape was taken during the middle of the sixth 30-minute performance trial of the team task (i.e., during post-asymptotic performance). This five-minute video sample was time-stamped and transcribed. The unit of analysis was defined as a complete thought uttered by a single speaker. Usually, this was equal to a single utterance or "speaking turn" taken by the speaker. However, utterances by the same speaker containing more than one complete thought were partitioned.

These units of speech were coded using an eight category system similar to those used previously by Foushee and Manos (1981); Kanki and Foushee (1989); Krumm and Farina (1962); and Oser, Prince, Morgan, and Simpson (1991). All complete and intelligible thought units were coded based on sentence structure and intonation and loosely fit into one of two categories: initiating and responsive utterances. Initiating utterances consisted of: questions, requests, statements, and other. Responsive utterances were: answers, answers which formed requests, responses to requests, and acknowledgments.

Questions were defined as any utterances phrased as a question or made with a clearly questioning tone. Requests were defined as utterances requesting resources, assistance, or specific action by another member or the team as a whole. Statements were defined as utterances regarding the speaker's status, the status of another team member, or the status of the task (e.g., of a particular target), which did not fit within another category. Answers were defined as utterances which responded to a previous question, either positively or negatively, within ten statements after that question. Answers forming requests were answers which contained within the answer an explicit or implicit request for resources, assistance, or action, and were coded separately because of their dual function. Responses were defined as utterances which responded to a previous request, either positively or negatively, within ten statements after the request. Acknowledgments were made when the speaker simply acknowledged having heard a previous utterance of another team member, without providing further comment, response, or information. Answers and answers forming requests were summed to form the composite variable, "total answers." Answers, answers forming requests, and responses were summed to form the composite variable, "total responses."

Two coders were trained to unitize and code five-minute samples of team communication. Interrater reliability estimates, for both unitizing the data and coding the units, ranged from 0.67 to 0.86 with an average of 0.77 (using Cohen's kappa). Cohen's kappa estimates of the interrater reliability for unitizing alone averaged 0.92 and for coding alone averaged 0.85.

<u>Output Variables</u>

Team performance was measured primarily in terms of the team's accumulated score through a thirty minute trial (which was computed as the summation of the resources required for engaged targets minus the resources required for missed targets), number of targets engaged, average time to engage targets, and efficiency of target engagement. Individual performance on the monitoring tasks was measured in terms of response latencies.

RESULTS

Measures of team score were analyzed using a repeated measures analysis of variance (one score per team per 30-minute team task trial), yielding a significant trial effect ($F = 36.15$, $p < .001$). Subsequent Student Newman-Keuls range tests indicated that asymptotic performance was reached prior to the fourth team task trial (i.e., by the beginning of the third hour of team task performance). Therefore, the results of the analyses reported below are based upon post-asymptotic performance (i.e., based upon data collected in the third hour of simultaneous team and individual task performance).

Input Variables

Task characteristics. A 2 x 3 analysis of variance (workload by team structure) computed on the average team subjective workload score (as measured by the composite score of the NASA-TLX) indicated no significant effects. However, similar analyses performed on the six subscales of the NASA-TLX indicated several significant effects. Specifically, a main effect of team structure was obtained on scores of physical workload experience ($F = 3.98$, $p <$

.05). Subsequent tests indicated that teams in the product structure reported significantly lower physical workload than teams in either of the other two team structure conditions. A main effect of team structure was also obtained on scores of the performance component of workload ($F = 3.94$, $p < .05$), such that teams in the hierarchical condition reported significantly lower workload on the performance subscale than teams in either of the other two structure conditions. A significant structure by workload interaction was also obtained on the performance component of workload ($F = 5.64$, $p < .01$). When subsequent tests were performed, it was shown that low workload teams in the non-hierarchical structure reported significantly higher performance workload than high workload non-hierarchical teams, whereas no significant differences were found between low and high workload teams in either of the other two structure conditions.

Individual Characteristics. Correlations were computed between the TCAS total score (in which higher numbers correspond to more favorable attitudes toward coordination) and team score. These correlations were computed separately for teams in each of the three structure conditions because it was hypothesized that the importance of coordination attitudes would differ as a function of REMAN task structure. As indicated in Table 1, the obtained correlations indicated that performance was not significantly correlated with total TCAS score in any of the three structure conditions.

Table 1. Correlation of TCAS Total Scores and Factor Scores with the Team Performance Score

	TCAS Total	Coordin-ation	Planning	Communi-cation
Non-hierar-chical	- 0.10	0.09	- 0.15	0.14
Hierarchical	- 0.06	- 0.28	- 0.00	0.11
Product	- 0.65	- 0.31	- 0.33	- 0.42

Factor scores were also computed for the three factors of team coordination attitudes: attitudes toward coordination, planning, and communication. As depicted in Table 1, none of these factor scores was significantly correlated with performance in any team structure condition. It might be noted, however, that the obtained correlations were generally higher in the product structure teams.

Work Characteristics. 2 x 3 analyses of variance were performed (team structure by workload) on team score, as well as on other components of team performance. A main effect of workload was obtained across several output variables, although not with respect to team score. Low workload teams engaged significantly more targets than high workload teams ($F = 112.97$, $p < .001$). Low workload teams engaged targets significantly more quickly than high workload teams ($F = 96.12$, $p < .001$), as well as more efficiently than high workload teams ($F = 32.07$, $p < .001$).

A main effect of structure was also obtained across several variables. Analysis of team score yielded a main effect of structure ($F = 19.64$, $p < .001$), and a subsequent test of simple effects indicated that the product teams scored significantly fewer points than non-hierarchical and hierarchical teams. This effect is depicted graphically in Figure 3.

Figure 3. Effect of structure on team score.

Analysis of number of targets engaged indicated a main effect of structure ($F = 19.92$, $p < .001$). A subsequent test of simple effects indicated that non-hierarchical teams engaged significantly more targets than hierarchical or product structure teams. A main effect of structure was also obtained with respect to average engagement time ($F = 68.42$, $p < .001$) and efficiency of target engagement ($F = 12.77$, $p < .001$). Subsequent tests of simple effects indicated that teams in the product structure engaged targets significantly more slowly and significantly less efficiently than teams in the non-hierarchical and hierarchical structures.

A workload by structure interaction was obtained with respect to average time to engagement ($F = 4.09$, $p < .05$). Subsequent Student Newman-Keuls range tests indicated that in low workload teams, product structure teams engaged targets significantly more slowly than non-hierarchical and hierarchical teams, although the engagement times of non-hierarchical and hierarchical teams did not significantly differ from each other. In high workload teams, product structure teams again engaged targets more slowly than teams in either of the other two structure conditions. However, high workload hierarchical teams engaged targets significantly more slowly than high workload non-hierarchical teams.

Analysis of engagement efficiency (number of targets engaged/number of targets presented) also yielded an interaction of workload and structure ($F = 5.13$, $p < .05$). Subsequent Student Newman-Keuls range tests indicated that under low workload, the engagement efficiency of teams in each of the three structure conditions did not significantly differ. Under high workload, however, teams in the product structure engaged targets significantly less efficiently than teams in both the non-hierarchical and hierarchical conditions.

To determine the effect of team structure and workload on average response times to each of the three monitoring tasks, 2 X 3 ANOVAs were performed. A main effect of structure was obtained on the teams' average response latency to each of the three tasks. With respect to the warning lights task ($F = 5.52$, $p < .01$), subsequent tests indicated that non-hierarchical teams took significantly longer to respond to this task than hierarchical or product structure teams. With respect to the blinking lights task ($F = 6.50$, $p < .01$) and the probability monitoring task ($F = 9.79$, $p < .001$), subsequent tests indicated that product teams obtained a significantly shorter response time to each of these tasks than non-hierarchical or hierarchical teams.

<u>Team Characteristics</u>. Correlations were computed between the Self-Report total score (in which higher numbers correspond to a greater perception of teamness) and team score. These correlations were computed separately for teams in each of the structure conditions because it was hypothesized that the importance of teamness would differ depending upon REMAN task structure. As indicated in Table 2, total Self-Report score was significantly correlated with performance only for teams in the hierarchical structure.

Factor scores were computed for the four factors of perceptions of teamness: importance of taskwork, importance

Table 2. Correlations of Teamness Self-Report Total Score and Factor Scores with Team Performance Score

	S-R Total	Task-work	Team-work	Interde-pendence	Indivi-dual
Non-Hierar-chical	0.23	0.53	0.58	0.14	- 0.36
Hierar-chical	0.82*	0.04	- 0.80*	0.42	0.19
Product	0.43	0.61	0.29	- 0.52	- 0.23

of teamwork, importance of interdependence, and importance of the individual. Of these factor scores, the only significant relationship that was obtained indicated that effective performance was associated with negative attitudes toward teamwork in vertically structured teams.

Correlations were computed between the cohesion total score (in which higher numbers correspond to greater cohesion) and team score. These correlations were computed separately for teams in each of the various structure conditions because it was hypothesized that the importance of cohesion would differ depending on team structure. The correlations between the cohesion score and performance for each of the team structure conditions were: horizontal, $r = 0.64$; vertical, $r = 0.69$; product, $r = 0.45$. None of these correlations suggested a significant relationship between cohesion score and team score.

Familiarity among team members prior to team task performance was another factor of interest. A measure of inter-member familiarity was taken to control for any selection differences. A 2 x 3 ANOVA indicated no significant effects, and hence, no selection bias.

Throughput/Communication

Team processes. Given that one of the goals of the current study was to determine the extent to which the effectiveness of team performance is affected by the interactions of team members,a median split based on team performance score was performed on the six teams within each cell of the 2 x 3 (workload by team structure) design. Teams scoring above the median were grouped as good performers in that condition. Similarly, teams scoring below the median were grouped as poor performers. The effects of this two-level grouping variable (i.e., the effects of performance level) were tested in all analyses of the coded team communication. The analyses performed were 2 x 2 x 2 ANOVAs to test the effects of workload (high vs. low), structure (non-hierarchical vs. product teams), and level of performance effectiveness (good vs. poor). These analyses were performed to compare groups' communication frequencies in each of the following categories: questions, requests, answers, answers which formed requests, responses to requests, acknowledgments, statements, and other (i.e., incomplete or non-task related utterances). To provide an organization to the reporting of the communication results, the significant main effects of workload, structure, and performance level, respectively, will be reported first, followed by a summary of the interaction effects.

No main effect of workload was obtained across any of the communication categories analyzed. A main effect of structure was obtained with respect to several aspects of communication. Specifically, product teams asked significantly more questions ($F = 22.47$, $p < .001$), and provided more answers that formed requests ($F = 77.52$, $p < .001$) than non-hierarchical teams. Product teams also made significantly more requests ($F = 15.20$, $p < .001$), provided more responses to requests ($F = 37.96, p < .001$), and made fewer statements ($F = 6.10$, $p < .05$) than non-hierarchical teams. Overall, as depicted in Figure 4, product teams engaged in significantly more asking behavior (sum of questions, requests, and answers that form requests) ($F = 30.81$, $p < .001$), and more responding behavior (sum of answers and answers that form requests) ($F = 15.12$, $p < .001$).

A main effect of performance level was also obtained in some of the coded communication categories. The better performing teams asked significantly fewer questions ($F = 6.42$, $p < .05$), provided fewer answers that form requests ($F = 6.02$, $p < .05$), and provided fewer responses to requests than poorer performing teams ($F = 8.00$, $p < .05$). Overall, as depicted in Figure 5, the better performing teams engaged in significantly less asking behavior (sum of questions, requests, and answers that form

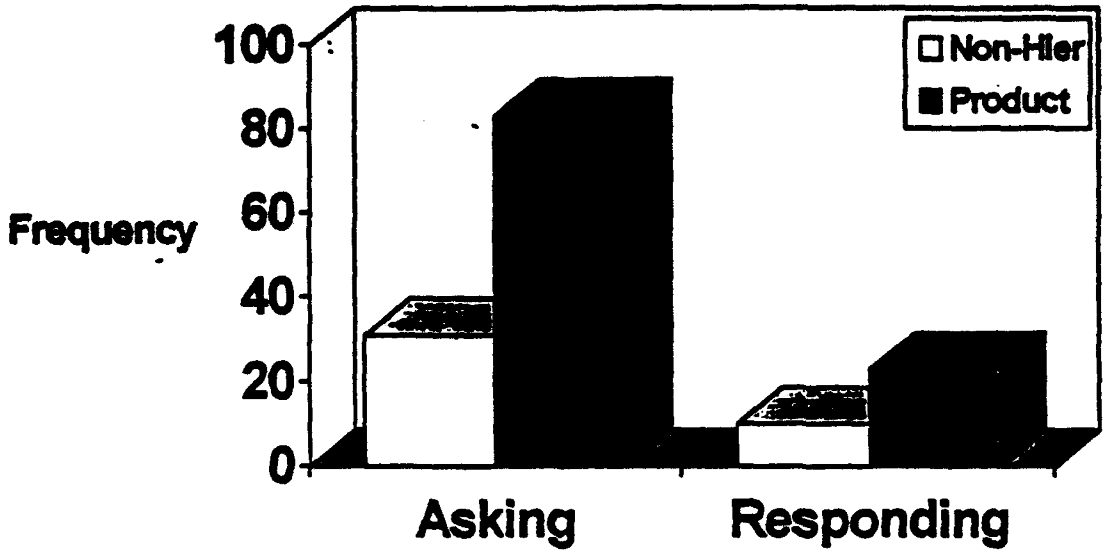

Figure 4. Effect of structure on asking and responding behavior.

requests) ($F = 5.13$, $p < .05$), and less responding behavior (sum of answers and answers that form requests) ($F = 5.30$, $p < .05$) than poorer performing teams.

A significant structure by performance level interaction was obtained concerning answers that form requests ($F = 5.33$, $p < .05$). Subsequent Student Newman-Keuls range tests indicated that in the non-hierarchical structure, the better and poorer performing teams did not exhibit a significantly different amount of these behaviors. In the product structure, however, the better performing teams uttered significantly fewer answers that formed requests than poorer performing teams.

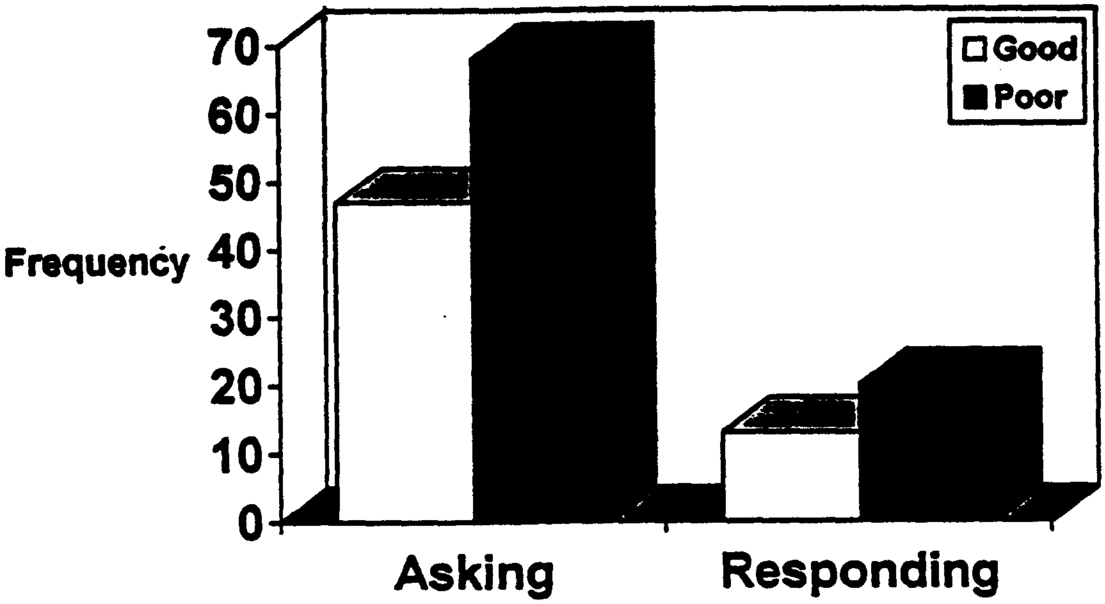

Figure 5. Effect of performance level on asking and responding behavior.

A significant structure by workload interaction was also obtained concerning answers that form requests ($F = 4.69$, $p < .05$). Subsequent Student Newman-Keuls range tests indicated that in the non-hierarchical structure, the low and high workload teams did not utter a significantly different amount of this type of communication. In the product structure, low workload teams uttered significantly fewer answers that formed requests than high workload product teams.

A significant workload by performance level interaction was also obtained with respect to answers that formed requests ($F = 4.68$, $p < .05$). Under low workload, better and poorer performing teams did not utter a significantly different number of these statements. Under high workload, better performing teams uttered significantly fewer answers that formed requests than poorer performing teams. A significant workload by performance level interaction was also obtained with respect to questions asked ($F = 4.52$, $p < .05$). Under low workload, better and poorer performing teams asked approximately the same number of questions. Better performing teams asked significantly fewer questions than poorer performing teams under high workload.

DISCUSSION

Input Variables

Task Characteristics. The task characteristic of interest in the present study was subjective workload experience, as measured by the NASA-TLX. In accordance with the findings of Beith (1987), it was hypothesized that increased workload would be associated with poorer performance. Although the results of the workload manipulation did result in poorer performance (see the discussion of this team level manipulation of workload under work characteristics), this difference was not reflected in the measure of subjective workload. One possible explanation of this effect could be that the workload manipulation employed in the current investigation to increase workload did not, in fact, do so. To investigate this possibility further, an investigation is currently underway in which workload is manipulated in terms of time pressure (which is the manipulation classically employed in workload studies), as opposed to resource demand. Another possible explanation for this finding could be that the various team structures emphasized different aspects of the overall task (as demonstrated in the response times to the monitoring tasks). Hence, workload was not reported to be higher because teams were able to adapt through their team structure.

It was also hypothesized that the differential effects of the various structure conditions could be attributable to the differential amounts of workload imposed as a function of these structures. That is, each of the three types of team structure could provide differential emphasis to the different facets of the team task. The results obtained concerning the subscales of the NASA-TLX provide some support to this hypothesis. For example, a main effect of structure was identified such that product structure teams reported significantly lower physical demand than teams in the other two structure conditions. This result could indicate that product team members were relatively more concerned with other elements of the task. That is, perhaps the product team members were more concerned with the more cognitive aspect of determining how to best allocate resources, such that the physical demand was not as salient as it was to the teams in the other structure conditions.

A significant structure effect was also obtained with respect to the performance subscale of the NASA-TLX, such that vertical teams reported lower workload in this dimension than teams in the other two structure conditions. The lower subjective experience of performance workload in hierarchical teams could be attributable to the fact that each team member focuses on his/her individual task components, rather than on the team's performance of its collective team goal.

A significant structure by workload interaction was also obtained with respect to the performance subscale of the NASA-TLX. In the non-hierarchical structure, low workload teams reported significantly higher performance workload than high workload non-hierarchical teams, whereas *no significant differences* were found between low and high workload teams in either *of* the other two structure conditions. While this effect runs counter to the hypothesized effect of the current workload manipulations on subjective workload experience, this finding does indicate that further investigation of the effects of structure on the experience of the various dimensions of workload is necessary.

Individual Characteristics. It was hypothesized that attitudes toward coordination would be associated with performance, and that the importance of coordination attitudes with respect to performance would differ as a function of REMAN task structure. The results, however, failed to support any significant relationship between coordination attitudes and performance for any structure condition.

Work Characteristics. As previously discussed, the product structure was a laboratory analogue of the structure in place in many operational environments. Therefore, there were no specific hypotheses regarding the relative effectiveness of the product structure compared to that associated with the hierarchical and non-hierarchical structures. Instead, the study attempted to empirically test the relative effectiveness of this structure.
With respect to team score (which was the team output of primary interest), results indicated that the product structure was associated with the poorest performance of all three structures. With respect to average time to engagement and engagement efficiency, high workload exacerbated the negative effects associated with the product structure.

A possible explanation for the suboptimal performance associated with the product structure concerns the fact that there was no overlap with respect to target engagement in this structure. That is, only one person was able to engage any given target. While the same was true for the hierarchically arranged teams, product teams did not have the established pattern for resource transfer that was inherent in the hierarchical structure. Therefore, product teams might have failed to find a satisfactory strategy for allocating resources among team members.

With respect to the effect of workload on the performance of product teams, it was hypothesized that high workload would result in degraded performance. The findings supported this hypothesis for number of targets engaged and speed of engagement, but not with respect to team score.

Analyses performed on the average reaction time to each of the three monitoring tasks indicated that, with respect to the warning lights task, non-hierarchical teams performed significantly more slowly than teams in either of the other two structure conditions. Product teams, however, performed significantly more quickly than non-hierarchical and hierarchical teams to the blinking lights and probability monitoring tasks. Interestingly, these results suggest that perhaps a team task/individual task trade-off occurred such that product teams might focus on their individual tasks (and hence, perform these well) to the detriment of their team task performance. Further research is currently underway to determine if team task and individual task performance can be optimized across structure conditions by the inclusion of individual task feedback.

Team Characteristics. Teamness, as measured by the Self-Report Questionnaire, was one of the team characteristics of interest in the present study. Results generally failed to support the existence of a strong relationship between teamness and performance across structure conditions. In the hierarchical structure condition, however, total Self-Report score was significantly positively correlated with performance. This effect could be attributable to the functional division of the team task in the hierarchical condition. That is, each team member might tend to focus on his/her individual task assignment and lose sight of the team's overall goal. A strong sense of teamness seems to be important to keep all members of the team striving to collectively accomplish the team goal. However, the demonstrated negative relationship between performance and the perception of teamwork in vertical teams is somewhat unexpected. Perhaps the functional task division causes team members to feel less like a team, even when they are working as such. This pattern of results suggest that further investigation of the construct of teamness is warranted, as well as its relationship to various team structures.

Team cohesion was also a team characteristic of interest in the present study. In accordance with previous findings (Bowers, et al., 1992) it was hypothesized that team cohesion would be associated with more effective performance, particularly under high workload. The results failed to support this hypothesis.

Familiarity among team members prior to team task performance was another factor of interest. Because no significant effects were found concerning the prior familiarity of team members, the results obtained in the current study apparently are not attributable to prior familiarity.

Throughput/Communication

Team processes. The results of this study suggest that a relationship exists between heavy reliance upon question and answer sequences in verbal team interactions and poorer team performance. In particular, poorer teams appeared to use question and answer sequences to elicit information about resources required to complete their tasks, information which might have been provided without prompting in better teams. The better teams appeared to make more efficient use of their questions to obtain information, which might have reflected a more systematic approach to prosecuting targets. For example, such questions were often formed as part of a consistent verbal sequence to organize information available only to certain team members, in the task of engaging targets (i.e., "The next target is #7, whose is it?" "It's mine. I need the following resources to engage it.").

One possible explanation of the results is that the better teams anticipated each others' needs and provided the necessary information or requests without waiting for their teammates to ask. On the other hand, poorer teams overwhelmed the team communication channels with a barrage of questions, rather than waiting to receive the necessary information.

In the high workload condition, poorer teams exhibited a nonadaptive increase in reliance on questions and answers and also increased other types of communications which were less helpful to them. The better teams were able to minimize nonadaptive communications, but also revised their communication strategies in high workload conditions, de-emphasizing certain types of communication (answers and answer/requests, implicitly phrased questions, questions about identity) which had been adaptive for them in low workload conditions. These findings suggest that the better teams were more flexible in adapting to the higher workload conditions, minimized a tendency to increase the amount of nonadaptive communications as workload increased (i.e., questions and answers), and dropped some types of communications entirely.

The effects of structure that were obtained are rather parallel to the performance level differences in communication that were observed. While causality cannot be inferred from the current paradigm, it can be hypothesized from the obtained results that the effects that the product structure has on team communication contributes somewhat to the suboptimal performance associated with this particular team structure.

CONCLUSIONS

The goal of the present study was to create a laboratory analogue of a "product group" in order to: 1) evaluate the performance effectiveness of this structure relative to that of the hierarchical and non-hierarchical structures employed in previous research (i.e., Bowers, et al., 1992) under two levels of workload, and to 2) identify the team coordination processes associated with effective decision-making within these groups under two levels of workload. These objectives were attempted in the context of the Team Effectiveness Model (Tannenbaum, et al., 1992) of team performance.

Overall, the results obtained through the current study provide only partial support for this model of team performance. Additional research is necessary to fully test the utility of this model. With respect to the first objective (as specified above), the results indicate that the product structure produces the least effective team performance, relative to that exhibited by teams arranged according to non-hierarchical or hierarchical structures. Furthermore, within the product structure, high workload seemed to impair team performance, relative to performance displayed by low workload teams. Because both of these factors (i.e., the product structure and high workload) are unavoidable elements of many environments, the obtained results provided an opportunity to study the team processes through which more effective teams adapt to these potentially aversive conditions. That is, by identifying the communication behaviors that facilitate more effective performance under these conditions, other teams can be trained to behave similarly, and thus, their performance can be enhanced.

These results specifically suggest that teams should be trained to make requests spontaneously, and to provide necessary information in a timely manner rather than wait for team members to ask for needed information. In addition, in order to avoid overwhelming the team's communication channels, they should be trained to present information and requests in a timely fashion at an appropriate pace. These results suggest that, as workload increases, teams should avoid a possible tendency to ask more questions or to rely more heavily on question and answer sequences to transmit needed information and coordinate activity within the team. Training should sensitize team members to the fact that such a strategy will likely not offset the effects of increased workload and may even degrade the team's performance under stress. Finally, team training should also emphasize the development of adaptability such that in high workload conditions, teams will be flexible enough to use communication strategies that are different from those used in low workload conditions.

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