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Adapting the Job Demand/Control Model to a Team Level

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Adapting the Job Demand/Control Model to a Team Level

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Abstract

A better understanding of sources of stress within a teamwork context might be gained by applying the Job Demands/Control Model of stress (Karasek and Theorell, 1990) to teams as the unit of analysis rather than only to individuals as it is conventionally done. Team performance is frequently treated as a shared team-level outcome; it seems reasonable to assume that shared team characteristics are likely to have effects on stress as well. In particular, teams are unique in their requirement for coordination between team members. Therefore, the present study proposes an adapted Team Job Demands/Control Model of team-level stress phenomena in which team coordination represents a team-level form of control. The current study provides empirical support for the above team-level JDC approach. 40 two-person teams were studied in a laboratory setting using a computer-based team dynamic decision making tasking, including delay in voice transmission between teammates. Team-level task characteristic scales were created using the mean of team members' survey responses. Team demand, coordination and their interaction were hypothesized to predict stress (H1) and team performance (H2). Delay was predicted to influence demand and control (H3). Team performance was expected to influence stress (H4). Hypotheses were supported. The current study provides initial support for the extension of the JDC model from individual job characteristics to team characteristics. Furthermore, there was evidence that quality of team coordination can be considered a key design characteristic for teams.

Adapting the Job Demand/Control Model to a Team Level

The Job Demand/Control Model as originally proposed by Karasek (1979) explains variation in job stress across individuals through differences in job characteristics. According to this model, jobs can be characterized on two dimensions: the psychological demands required and the control (or decision latitude) provided to the individual. Alone, high demand and low control are each associated with increased stress. Together, the interaction of the two is also predictive of stress. According to the Job Strain Hypothesis, a particular imbalance between the two, high demand and low control, is a condition of high job strain. High job demand does not always lead to high strain; the effects of high task demand can be buffered contingent upon the individual's level of control. When high job demands are paired with high control, this combination allows for learning and challenge rather than leading to high strain. Workers in high strain jobs are a high risk population; they experience the highest levels of stress and are vulnerable to illnesses, including heart disease (Karasek et al, 1981; Karasek et al, 1982).

The current version of the Job Demand/Control Model is expanded to also include a social component relevant to worker stress. The model has the addition of social support as a dimension relevant to job stress, resulting in the Job Demand/Control/Support Model (JDCS) (Karasek and Theorell, 1990; Johnson and Hall, 1988). In this model social support is defined as beneficial social interaction available on the job; high social support is protective against stress. Coworkers and supervisors may serve as sources of social support, and this support can serve to mitigate the effects of job demands and any control deficit by providing socioemotional support to the worker. Apart from providing social support, coworkers and supervisors may also provide other forms of support that are protective against stress, such as more tangible instrumental support in the form of resources or assistance.

Prior research using the JDCS Model has not focused on the influence of work systems on stress (and stress-related disease). Outcomes have primarily been considered at the individual level or the occupational level. Workers are treated as isolated units, whose stress is determined primarily by the design of a single job. Alternatively, occupations are treated as a defining a homogenous set of job characteristics, regardless the unique characteristics of the work system in which they are embedded. Social interaction with coworkers is taken into consideration as another design characteristic of a given job or occupation.

A shortcoming of the JDCS is that it treats workers as passive recipients of social support from coworkers, when workers are active agents in their interactions with coworkers, and these interactions can influence other job characteristics besides social support alone. In fact, coworkers have their own job tasks to carry out, their own demands to meet and their own level of control to exert to meet these demands; interaction with one another may be necessary to carry out these tasks, not simply as a means to solicit or provide social support. These individuals are embedded in a larger social system, for example as a member of a work group or a work team. Within such a system, social processes are constantly at play as individuals interact with one another as active agents, all trying to carry out their individual and shared job tasks. Through these social interactions, the characteristics of a given job and the actions individuals take to exert control may influence not just the stress of the individual worker, but the stress of their coworkers in their work group.

Aspects of work organization may shape these social interactions. The design aspects of work organization that are directly relevant to social interactions between workers (such as the formation of work teams) will henceforth be referred to here as the "social organization of work". If individual-level job characteristics influence stress for the individual worker, then the social organization of work forming these social systems can be expected to influence stress for all workers belonging to these systems. Research has yet to determine whether such system-level phenomena are relevant to the experience of job stress and how these relate to the JDCS model. The social system into which workers are placed may uniquely contribute to stress, and if it does the JDCS model could be modified to account for this. Modeling these key system design characteristics may provide a more complete understanding of worker stress, and this could lead to better ways of managing stress in the workplace.

In order to account for the impact of the social organization of work on individual worker stress, one approach would be to add more dimensions to the existing individual-level JDCS model in the same manner that Social Support was added to the earlier version of this model. However, it would make more sense to model the effects of social organizational constructs at a more appropriate level of analysis; individual level characteristics should be added at the individual level of analysis while systems level characteristics should be added at the systems level of analysis. Therefore, a systems level model of job stress is in need of development. This would not require that the JDCS Model be abandoned. Instead, the JDCS Model may be able to be adapted to include predictors at both the system and individual levels. This multilevel approach investigated in the present study has the potential to better explain variance in worker stress by appropriately accounting for shared systems-level influences.

The main goal of the present research is to provide empirical support for an adapted JDCS Model in which group-level phenomena may also be understood in relation to demand, control and stress. This adapted model, which can be referred to as the Team Job Demand/Control Model, may help contribute to an understanding of an additional source of stress among workers functioning as a group, and identify new ways to help reduce stress among group members through improved job design. It will focus on within-group coordination as an example of a group-level phenomenon that may influence job stress. In order to experimentally control for the potential for unanticipated differences across organizational structures, the only type of group analyzed in the present study consist of 2-person work teams.

The following sections of the introduction first describe the importance of coordination to job stress; then, describe the current importance of the social organization of work to the JD/C model through examination of the construct of social support; next, research on work groups that supports the existence of shared group-level influences on stress is reviewed; finally, a case is made as to why the existing JDCS Model and existing research analyzing work groups does not adequately capture the unique characteristics of team work that can impact worker stress, the main motivation for the current study.

Coordination

Coordination occurs when there is worker interdependence designed into a job, such that individuals are reliant upon one another when carrying out their work goals. The quality of within-group coordination was chosen as the construct of interest in the current study due to its intuitive role as a group-level source of stress or source of support. Recent comments by Karasek (2011) emphasized the importance of the concept of social coordination and the need for further research on this construct. Coordination can be thought of as having both fixed and variable components.

The first component of coordination is the need for coordination in a given job. This component can be considered fixed within a given job; it is determined by the structure of the work group and the organization of the jobs comprising it, as well as by the nature of the tasks the group performs. Work group structures may exist along a continuum: at one extreme, workers are completely independent, and can complete their work alone; at the other extreme, coworkers are highly dependent upon one another to carry out their job. This "coordination demand" is likely to be a largely stable trait of the work group: it would not change unless the group itself is restructured. It may also vary across different tasks performed by the group. Since the focus of the current study is only 2-person work teams working under controlled laboratory conditions, and the nature of the laboratory task remains the same throughout the study, this characteristic is fixed across the teams and can be considered a stable work trait.

The second component of coordination, and a critical focus of the current study, is the quality of social coordination within a group. This component of coordination is more likely to vary across different groups and across time within the same group. Regardless of the coordination demands on a given group, it is up to the group members to somehow coordinate with one another. Each individual is expected to contribute to the group's coordination, and conversely is dependent upon the coordination of their coworkers. When coordination is poor, this may serve as an additional source of stress for workers in such a work group because it prevents the group from meeting coordination demands.

The manner of coordination among coworkers may potentially become a surrogate for control operating at the group level, similar to control operating at the individual level. For a group as a unit, meeting shared task demands is likely to require coordinated action from the group. The ability of the group to handle the coordination demand placed on them may either facilitate or inhibit their ability to meet other shared task demands. When coordination among group members is high, the group can choose between different possible strategies to meet these coordination demands. When coordination among group members is poor, the group is constrained in the ways it is capable of responding to coordination demands. When coordination is referred to henceforth, it is meant to refer to coordination as a group-level construct that may potentially serve as a group-level surrogate for the level of joint control exerted by the team.

The present study seeks to look at social coordination in the context of one particular work system that workers are often a part of: the work team. Work teams are characterized by a very high need for coordination between coworkers. Thus, if coordination does indeed influence worker stress, this is the context in which one would expect the effect to be greatest. This makes the work team probably the best context to establish that the design of the social system is indeed relevant to worker stress, using team coordination as an example of a systems-level (i.e., group-level) stressor. As discussed below, few studies have addressed the potential impact of the work team structure on worker stress.

A secondary goal of the current research is to examine the role that coordination plays in determining stress within work teams, whether the stress of the individuals composing the team or the stress experienced by the team as a whole. Good quality team coordination may serve to reduce worker stress, while poor quality team coordination may serve as a unique and significant source of worker stress. In order to pursue this goal, the current research first seeks to develop a set of team-level measures analogous to the individual-level measures currently used for the JDCS model, and then to test whether these can be used to predict worker stress during teamwork. Existing data from laboratory studies of teamwork are used in this research. Due to the use of laboratory data using newly formed teams, the social support dimension is omitted; individuals in the studies were generally strangers to one another, and had no established pattern of coordinated teamwork.

Social Organization of Work and the Job Demand/Control/Support Model

While the JDCS model does not explicitly encompass aspects of the social organization of work, social dimensions of work are already acknowledged as being important to worker stress. Karasek and Theorell (1990) state that it is the organizational structure of work, rather than the demands of the work, that has the most consistent relationship with stress-related illness. The addition of the social support dimension to the model helped to capture an important aspect of the social organization of work. However, not all workplace social interaction is supportive or beneficial; it can also serve as an additional source of stress. Social undermining and hostility from coworkers (Duffy et al., 2002) has been reported to increase job stress; this can be considered to be the low end of the social support scale. However, the coordination required by task interdependency (Turner, 1980) has also been reported to increase job stress; interdependency does not fall anywhere on the current social support scale. In general, the manner in which work is organized can serve to facilitate or impede effective social interaction with coworkers. Thus, the effects of this social interaction on stress are not entirely captured by the construct of social support: such interactions can have detrimental effects as well as beneficial effects, and these effects cannot be explained wholly through either the presence or absence of social support. New approaches are therefore needed to more directly capture the effects of these social interactions on worker stress.

As it stands however, the JDCS model focuses on the demand, control, and support characteristics of only an individual job. However, all of these job characteristics may, in part, derive from the characteristics of the organization of the social system in which a job is embedded; for example, the decision latitude afforded to an individual is partly a result of the allocation of authority within an organization. Task demands are partly a result of the division of labor among coworkers, and social support is partly a result of the opportunities provided by an organizational structure that can reduce the psychological distance between a worker and his supervisors or coworkers. In this manner, the social organization of work may be determining both the individual-level and group-level job characteristics of a job, and is thus indirectly having a large impact on worker stress. These effects are in addition to other direct impacts of work organization on worker stress, through for example, scheduling, overtime, and work pacing.

These direct links between the social organization of work and the resulting job level demand, control, and social support characteristics demonstrate the theoretical importance of the social organization of work to theories of work-related stress. However, if such influences stem from the social organization, they would be expected to affect not only the individual worker; all coworkers in the same organizational work unit should be affected and exhibit some common variance in stress. Such variance would not be completely shared with workers outside the unit, even within jobs with otherwise similar individual job characteristics. The next section will review empirical support for this possibility of a group-level effect on stress.

Work Groups and the Job Demand/Control/Support Model

There is already some empirical evidence available that suggests characteristics of an individual's work group impacts the relationship between demand, control, social support and stress. A work group usually consists of a set of workers operating under a common supervisor. While differences in job characteristics for individuals may play a large role in determining job stress for that individual, all coworkers in the same work group still share some common social influences on their job stress, such as caused by their supervisor or other coworkers. And while coworkers may function in different roles without a high degree of task interdependence, coworkers may still display some degree of interdependence when serving as sources of social support for one another. Several studies have investigated the degree of importance of these shared social influences by looking at group-level influences on worker stress.

Söderfeldt and colleagues (1997) found that there is significant variation in stress between work groups and that a substantial part of the variation in demand and control reported by workers exists at the work group level. Within two large Swedish organizations, in which workers were nested in local work groups, self-report measures were used to assess indices of quantitative job demands (i.e., work pace and work load), emotional job demands (i.e., the emotional exertion of the job), control, workplace social support, and stress-related health symptoms. The method the authors used to quantify strain is somewhat unusual, and is worth describing here. The control index was inverted, so that all measures of stressors were scaled in the same direction: high scores on the quantitative job demand index, high scores on the emotional job demand index, and high scores on the inverted control index all indicated that a job was perceived as more stressful. Finally, two strain variables were constructed. Rather than creating an interaction term by multiplying together demand and control, the two were added together: the index of quantitative job demand was added to the inverted control index to produce a score for quantitative job strain; the index of emotional job demands was added to the inverted control index to produce a score for emotional job demands. Thus, quantitative job strain and emotional job strain were added to the model separately, despite both being created based on the same measure of control. This method makes it difficult to interpret what is the actual work group level source of stress; after adding together demand and control, it becomes impossible to tell which component is driving of job strain.

In contrast to the approach by Söderfeldt and colleagues described above, strain is commonly calculated from the dimensions of the JDCS Model, usually when using the Job Content Questionnaire (Karasek et al, 1998) as a measure of job characteristics. A high-strain job is one characterized by high demands and low control, and is at the greatest vulnerability to stress and resulting stress-related illness. Several methods are commonly used for calculating strain: additive, multiplicative, and divisive. The index of demand and the index of control can be added together to creative an additive interaction term as was done by Söderfeldt and colleagues, such that demand and control act independently as stressors. The index of demands and the index of control can be multiplied, such that they interact, and one may moderate the effects of the other on stress. Or the index of demand may be divided by the index of control, such that demand is considered stressful to the extent that it exceeds the level of control allowed to an individual to meet that demand.

Söderfeldt and colleagues analyzed their results within the framework of a multilevel model, looking at individuals nested within work groups but only entering predictors at the individual level. The results of their study indicated that even when psychological symptoms of stress are measured at the individual level, significant variance exists between work groups.

Furthermore, even though the demand and control indices were collected as measures of individual job characteristics, they seemed to be partially influenced by differences between work groups rather than differences between jobs. Söderfeldt et al. provide initial support for the importance of social organization, in the form of work groups, to symptoms of stress. However, by using demand and control to calculate a difference score in their analysis, it becomes impossible to decompose their unique effects on stress. In the context of their study, it cannot be determined whether stress is influenced by the interaction of demand and control or if stress is caused entirely by either high demand or low control alone. Furthermore the specific aspects of the shared social influence that explained the common variance in coworker stress were not identified in their study; they only reported that variance existed at the work group level in their multilevel model of stress.

Van Yperen and Snijders (2000) address both of these unanswered questions in their study. They more directly quantified group-level influences by computing new group-level variables from data collected at the individual-level. Drawing a sample from a Netherlands national bank, demand, control, and psychological stress were assessed through self-report. Workers in this organization were naturally nested into work groups that reported to a common supervisor. To test one possible mechanism by which a work group could influence an individual worker’s stress, the authors considered not just group mean of demand and control, but also each individual worker's deviations from their group means. For each worker, deviation scores were calculated to quantify the perceptions of demand and control characteristics of their job relative to the perceptions of the rest of the work group. Interaction terms were calculated for all possible combinations of group mean and individual deviation for both demand and control, leading to four different interaction variables:

1. The interaction of group mean demand and group mean control
2. The interaction of group mean demand and individual deviation from group mean control
3. The interaction of individual deviation from group mean demand and group mean control
4. The interaction of individual deviation from group mean demand and individual deviation from group mean control.

Results indicated that there were both between-group and between-individual differences in stress. Variance in stress-related health symptoms between work groups was predicted by work group mean demand, while variance between individuals was predicted by the deviation of the individual worker's control from the mean control of their work group. Of the most relevance to the current study were the results concerning the interaction effects. The interaction between demand and control only had a significant effect on an individual's stress when the analysis approach included the interaction of an individual's deviation from both their work group mean of demand and their work group mean of control, rather than using the interaction of the group means of demand and control themselves. These results suggest that the demand and control experienced by a worker are not simply due to fixed characteristics of the individual's job nor are they due to fixed characteristics of the work group. Some aspect of the social processes within the group also plays a role (in this case in the form of social comparison processes), such that the stress experienced by the individual is contingent upon both their specified role within the social system and the functioning of the social system in which they are embedded.

The two studies described above conducted by Söderfeldt et al. and Van Yperen and Snijders illustrate that group-level constructs are partly responsible for variance in worker stress, and that this variance is not fully captured by existing individual-level measures of job demand and control. Therefore there is a need to introduce new group-level variables into the JD/C model to explain this variance. Söderfeldt et al. and Van Yperen and Snijders attempted to do so by computing new group-level variables from data collected at the individual-level. However, these new variables only provided an empirically derived set of predictors and lacked an underlying theoretical justification. Rather than computing the complex interaction effects based on within-group comparisons that were used by Van Yperen and Snijders, a more parsimonious solution may be to directly measure the social processes that are going on within the work groups, rather than extrapolate from individual-level measures. Social processes appear to be potentially valuable predictors: social support already plays a role in the JDCS at the job level, but as reviewed earlier, it is not able to capture all of the social processes in play. Karasek and Theorell (1990) suggested that the reason social processes like the ones discussed here may be relevant to the job stress experienced by workers within work groups is that changes in the social relationships between workers and changes in decision latitude are closely tied to one another. Thus, as the jobs performed by coworkers become more interdependent, the dimensions of control and social support become less distinct. For example, when task completion is highly dependent on other coworkers, this interdependence may serve to constrain the decision latitude of the individual coworker (and reduce his/her control) while at the same time providing increased social support.

In order to explore the role of task interdependence as the aspect of the social organization of work that is most relevant to worker stress, it may be very difficult to collect the necessary data from work groups in a field setting. The degree of interdependence between coworkers within a naturally occurring work group is not always clear, nor can it be easily manipulated by a researcher. In contrast, study of highly interdependent individuals functioning in work teams under controlled laboratory conditions permits more detailed study of the effects of within-group social processes on worker stress.

Unique Characteristics of Teams and Teamwork

Compared to a work group, a work team is a qualitatively distinct social organization of workers. In the workplace, these two terms are sometimes used interchangeably but in team research a more precise definition in often used. Salas et al. (1992) defined a team as “a distinguishable set of two or more people who interact, dynamically, interdependently, and adaptively toward a common and valued goal/objective/mission, who have each been assigned specific roles or functions to perform, and who have a limited life-span membership” (p.4).

Task demands are shared among teammates; therefore the ability of each individual team member to meet these task demands is contingent upon the functioning of the team as a whole. Thus, in order to meet these demands, teammates must coordinate their actions. This mutual interdependence of team members may not simply increase or decrease worker stress; instead, the functioning of the team as a unit, or its dysfunction, may be what determines worker stress. Therefore, the best way to understand sources of worker stress in such a team may be to consider the work team as an additional unit of analysis in the JDCS model rather than considering individuals as the only unit of analysis as is usually done. Consequently, the present study proposes an adapted Team Job Demand/Control Model in which team coordination represents a team-level form of control, and which is expected to predict team-level stress phenomena. Social support may also have a team-level component, but was not measured in the present study. In order to test the role of team coordination as a predictor, a multilevel modeling approach can be used if the data support it.

Coordination is predicted to function as a buffer against stress, thus can be considered as an analogue for control at the team level. Adapting the JDC Model to a team level model yields the familiar 4-quadrant demand/control combinations but these will relate instead to team levels of stress (See Figure 1). The reasoning is as follows: during highly coordinated teamwork, teammates function together as a unit or system. Effective coordination between teammates allows the team to meet task demands. Effective coordination between teammates can also enable the team to complete tasks that an individual cannot. Applying the Team Job Demand/Control Model would predict that a team with a capability to meet task demands via effective internal control over team behaviors would be characterized as a work system under low stress. In contrast, team members who are not coordinating well would not function effectively as a system. A lack of effective coordination between teammates imposes a constraint on the joint task-related actions available to the members of the team, resulting in team members who are unable to respond jointly to task demands. This is expected to put strain on the team as a system. Karasek and Theorell (1990) similarly describe how "…system-strain leads to irrational, disorganized, and non-productive behavior and to the inability to coordinate subsystems in usable plans." This poor coordination would also be expected to limit the team's ability to meet task demands, resulting in a team (i.e., a work system) with a high level of stress. Thus, at the group level, team coordination can serve as an analog of control in a JDCS model at the team level. This is the basis to use a measurement of team coordination in the present study to serve as team-level form of control in the proposed Team Job Demand/Control Model.

While past research has not assessed the role of team coordination within the JDCS model, a few aspects of the proposed adapted Team Job Demand/Control Model have already been studied. While Rau (1996) did not specifically analyze team coordination, he did show that the manner in which a team is organized does impact job stress. Rau analyzed team function within dyadic teams. One teammate was designated the supervisor and the other “the co-operator”. Beyond assigning decision authority to the supervisor, it is unclear whether these roles had any other impact on team structure and the division of labor between teammates. Teams carried out a number of simulated work tasks varying in demand and control that was pretested. Tasks were designed to simulate actual job tasks, and so a quasi-experimental design had to be used; demand and control were not independently manipulated. Both self-report and psychophysiological measures (heart rate and blood pressure) were used as indicators of individual stress.

Rau’s reported results indicated that self-reported stress and physiological stress both varied as a function of an individual’s job task characteristics, with jobs carrying out low control/high demand tasks associated with higher heart rate and blood pressure. An individual’s role on the team was also found to have an effect, with supervisors displaying higher heart rate and reporting lower control than the cooperator. Despite these differences there were no differences between team roles in self-reported individual stress. Rau suggested that despite the lack of differences in self-reported stress, supervisors’ physiological states indicated that they were under greater stress than cooperators, and that a more equitable distribution of decision authority across the team could help decrease the stress experienced by supervisors.

The results of this study highlight the value of laboratory studies in being able to contribute to a better understanding of the JD/C model. Rau was able to use multiple experimental tasks, allowing for direct comparison between task characteristics. Moreover, the availability of psychophysiological data allowed for a more complete and objective assessment of the stress response. The results of Rau's study suggest that both task design and social organization have effects on workers, and that each of these may have a different effect. However, unlike Söderfeldt et al. or Van Yperen and Snijders, Rau did not use a multilevel modeling approach, making it difficult to determine whether these effects varied between teams. Furthermore, it is unclear whether team members were required to coordinate with one another in order to complete their task. Some measure of the extent of coordination between team members would be necessary to determine this. Candidate measures to meet this need are proposed in the Methods of the present study.

One potentially promising method of measuring team coordination is through an analysis of the communication behavior between teammates. An analysis of the communication between team members may provide insight into the nature of their coordination with one another, and would also allow researchers to determine whether coordination has an effect on worker stress. While Fischer et al. (2007) did not look at worker stress, their study closely analyzed the communication between members of work teams and determined its effects on performance. Four-person teams were engaged in a simulated microworld-based task. In addition to task performance, all communications within the team were recorded. Analysis of team communication patterns indicated that successful teams displayed inclusive communication, wherein each team member communicated with all other members of the team; unsuccessful teams were characterized instead by reciprocal communication between a subset of the team members that excluded the remainder of the team.

Results of this study strongly support the role of some form of internal coordination within a team as a determinant of task performance; in this case internal coordination takes the form of communication behavior. However, this study was not conducted within the framework of the JDCS model, and thus stress was not examined as an outcome. Additionally, poor team performance does not necessarily indicate that the team experienced high levels of stress. Further study is needed to determine whether increases in the level of team coordination are associated with changes in worker stress. Furthermore, these results suggest that both stress and performance must be considered as outcomes in order to gain a more complete understanding of how social processes may affect teams because team coordination processes that influence team performance as an outcome may also influence stress.

Overview of the Current Study

The current study seeks to develop a new model for explaining the impact of team-level task demands and team coordination on stress. Several methods of quantifying team-level measures in a manner consistent with the proposed Team-level Job Demand/Control Model are compared. Communication between team members is analyzed as a potential indicator of team coordination; both self-report measures and behavioral measures of communication are considered as indicators of coordination. Past studies (e.g., Stout et al., 1994; Marks & Panzer, 2004) have established that team coordination is known to affect performance; therefore both performance and stress are assessed as separate relevant outcomes. After experimental measures were developed, these were tested in both regression and multilevel statistical models to determine whether they predict team stress and team performance. Both self-report measures and physiological measures were considered as indicators of stress.

Hypotheses

Both the Individual-Level and the Group-Level of analysis are used here in order to establish the benefits of the approach proposed. Consistent with the original JDCS model, individual demand and control are expected to predict individual stress. Applying the proposed Team Job Demand/Control Model, team demand and control are expected to predict stress of the team as a unit as well as stress among individual team members. These approaches lead to the following testable hypotheses:

H1A: Team-level task demand will have a main effect on the presence of stress among individual team members and for the team as a group. When team-level demands are high, stress is predicted to increase, controlling for team coordination.

H1B: Team coordination will have a main effect on the presence of stress among individual team members and for the team as a group. When team coordination is high, stress is predicted to decrease, controlling for team demand.

H1C: The interaction of team-level task demand and team coordination will be predictive of the presence of stress among individual team members and for the team as a group. When team-level task demands are high and team coordination is low, stress is predicted to increase beyond the sum of the main effects of team-level task demand and team coordination.

When applying the proposed Team-Level JD/C model to predict team performance:

H2A: Team-level task demand will have a main effect on team-level task performance. When team-level demands are high, team performance is predicted to become worse, controlling for team coordination.

H2B: Team coordination will have a main effect on team-level task performance. When coordination is high, team performance is predicted to improve, controlling for team demand.

H2C: The interaction of team-level task demand and team coordination will be predictive of team-level task performance. When team-level task demands are high and team coordination is low, team task performance is predicted to decline beyond the sum of the main effects of team-level task demand and team coordination.

Experimental Approach

Communication was critical to team performance in the lab task that was used to test the adapted Team Job Demand/Control model. Thus, in order to capture this critical component of teamwork, the presence of verbal communication behaviors was monitored during the task and quantified during data analysis. Apart from verbal communication, social psychophysiological compliance (SPC) was also investigated as an objective indicator of team coordination. SPC refers to a state of physiological coordination established during teamwork (Henning, Boucsein, & Gil, 2001). SPC was calculated based on cardiac measures from both team mates. High levels of SPC occurred when there was a greater correlation between physiological changes across individuals, and thus reflected coordinated action between teammates.

Poor patterns of communication behavior were expected to place a constraint on the ability of the team to respond to task demands. There were two likely patterns of what may constitute poor communication. First, if there were simply low overall amounts of speech within a given team, there may simply have not been enough information exchanged between teammates for the team to function effectively. Second, heavily imbalanced teams, in which one team member dominated verbal communication at the expense of the other, may also result in a form of poor communication. Consistent with the findings of Fischer et al. (2007) discussed earlier, patterns of communication behavior in which one team member dominates the discourse were expected to degrade team performance compared to teams with more balanced communication patterns. Furthermore, the level of team task demand was expected to affect task performance. As the level of demand increased, it is expected to have exacerbated the detrimental effects of poor communication on performance, resulting in a further degradation in team performance.

Fischer et al. did not extend their predictions to stress-related outcomes. However, if communication did function as a form of control, then consistent with the JDCS model, when a decrease in communication quality occurs, the team members are expected to experience high stress, especially if this is also accompanied by excessive task demand.

The JDCS model asserts that task control and task demands interact, with the greatest stress occurring when control is low and demand is high. High task demand alone does not always lead to high stress because the effects of high task demand can be buffered by the individual's level of control. However, support for this interaction effect in the literature is, in fact, inconsistent. Flynn and James (2009) found the interaction to have an effect on performance, but not on stress. The presence or absence of an interaction would support the use of different models of occupational strain for team structured jobs: if this interaction does have an effect on stress (as seen in Van Yperen and Snijders, 2000), this would support the use of the JDCS model to predict stress among team members. If this interaction does not have an effect on stress, this would support the additive model of stress for teams (as used in Söderfeldt et al., 1997). According to an additive model of stress, excessive task demands and lack of control may both serve as sources of stress but the interaction of the two does not have any additional effect on stress. In the current study, team-level demands and coordination were measured separately, thus the effect of the interaction of the two on team outcomes was able to be explicitly tested, as stated in Hypothesis 1C and Hypothesis 2C.

It is possible that the unique aspects of the laboratory task used in the current study may have impacted any potential interaction between team demand and coordination. The laboratory team task was designed so that team task performance was dependent on voice communication transmitted between sound-proof rooms. A time delay in the voice transmissions was introduced artificially, and systematically controlled by the experimenter across trials. Past studies have demonstrated that in conversation, even short delays can be sufficient to disrupt communication, sometimes leading to frustration with the technology used or with the conversation partner him/herself (Pearson et al., 2008; Powers et al., 2011). This delay in the voice transmissions was an aspect of the team task design that was expected to impact both demand and coordination. Therefore its effects on each of these dimensions needed to be explicitly decomposed to take into account both the direct effects of transmission delay on team stress and performance as well as the potential indirect effects of transmission delay on these same outcomes through effects of transmission delay on task demand and team coordination. Specific hypotheses are as follows:

H3A: Time delays in the voice transmissions will function as a source of team-level task demand, such that as delay length increases, so does task difficulty.

H3B: Time delays in the voice transmissions may also serve as a limitation on team level task control, such that as delay length increases, team coordination decreases.

Experimental approach: Apart from the delay in the voice transmissions, task demands were maintained at a constant level between teams and trials through careful design of task scenarios. Delay was included as a task variable in this study in order to manipulate the demands of the team task between trials. Delay was expected to increase the cognitive demands of the task, providing an additional task demand which team members had to work to overcome. Past studies have used delay as a source of task demand; it has been established that the increases in the length of feedback delay for a task can be detrimental to performance (Kao & Smith, 1977; Henning et al., 2007).

Unfortunately, incorporating feedback delay in the voice transmissions rather than another element of the task potentially complicates measurement of team coordination. Given that the delay was in the voice transmissions rather than in another aspect of the task, such as in the responsiveness of controls, increased time delay may have served to decrease team task control. Therefore, this delay potentially added an additional constraint on a team's communication behaviors in response to task demands.

In order to explore the role of transmission delay in the voice communications between teammates as a potential driver of both team demand and team coordination, the relationship between changes in the measures of these two constructs in response to changes in transmission delay were investigated. If the relationship is as hypothesized, and delay affects both demand and coordination which in turn affect stress (and performance), the relationship between these variables would be in the form of a multiple mediation (Preacher & Hayes, 2008). However, statistical techniques are not available to test this form of structural equation model in the context of the multilevel model necessary to account for any non-independence present in the data (that is, because trials were nested in individuals which were nested in teams). Therefore these hypotheses were tested indirectly in data analysis through the stepwise addition of variables, testing whether transmission delay still explains significant variation in outcome measures after adding demand and coordination to the model.

So far team stress and team performance have been discussed as two distinct outcomes to be separately measured and modeled. However, these outcomes can be expected to influence one another:

H4: Team performance will predict team stress.

Each team recruited for the laboratory studies completed multiple trials of the same team task. Throughout the course of each trial, as well as following the completion of each trial, the team received feedback on their task performance in the form of a score out of 100. Thus apart from the effects of the team's perceptions of demands and coordination, information about their task performance may have influenced the level of stress reported by the team. Teams may have chosen to prioritize focusing on controlling either their level of stress or on controlling their task performance. Given the potential influence of stress on performance or vice versa, each must be taken into account when modeling the other.

Method

Participants

Data was collected by Dove-Steinkamp (2012). The original sample was 96 participants organized into 48 two-person teams. A number of these participants had incomplete survey data and were omitted; the sample for survey measures was 80 participants in 40 teams. A number of these participants had missing or incomplete cardiac data, and were dropped from secondary analyses when physiological measures were examined as a stress outcome, leaving 68 participants in 34 teams. Most participants were freshman or sophomore undergraduate students who participated to receive course credit. Participant age ranged from 17 to 25 (M=18.9, SD=1.3) and 44 percent of the participants were men. 23 percent of the teams were composed of two men, 32 percent of the teams were composed of two women, while the remaining 45 percent of teams were composed of one man and one woman. All participants signed an informed consent form.

Task Description

The Networked Fire Chief program (NFC; Omodei et al., 2010) was designed to simulate a firefighting task, in which frequent communication is required between a central dispatch office and remotely-located team members in charge of fire engines in the field. NFC is a low fidelity but highly versatile computer-based simulated microworld task. It is highly customizable by the experimenter; customizable elements include: number and social organization of simultaneous participants, landscape map design, properties of landscape elements, performance scoring criteria, and resources available to participants, among others.

Teams were given the task of protecting a simulated landscape from periodic outbreaks of fire. The team was responsible for controlling four fire engines capable of fighting these fires. Each team member was assigned to one of two distinct roles. One team member was designated the commander, and the other team member was designated the subordinate.

The commander was responsible for visually monitoring the map within the NFC program, looking for the periodically occurring fire outbreaks, and communicating the location of these fires and other status updates to the subordinate. The commander was able to see the entire map and their view of the spread of fires updated in real time. Furthermore, the commander was able to see the team's current score, the current wind speed, and the direction the wind was blowing.

The subordinate was responsible for moving firefighting equipment around to fight fires. Apart from communications from the commander, the individual in the subordinate role had only limited access to information concerning the current system status. They could not see information about the team's score or wind characteristics. More importantly, their view of the map was severely restricted. Their view of the map only updated in real time in a very small range around each of the firefighting appliances. That is, unless they moved the firefighting appliances directly on top of a target location, they were unable to see where the fire was spreading and what landscape elements had been consumed by fire. However, the subordinate was the only team member who could control the fire engines, and thus complete the team's task goals by extinguishing fire outbreaks.

The team task was designed to require that team members must speak with one another in order to coordinate the activities necessary to perform the task. Thus, each team member was reliant upon the other in order to achieve successful team performance. Individually, their control over the task was constrained by their assigned role; only the commander had full information about the current status of the task, while only the subordinate could directly use firefighting equipment to fight fires. At the end of each trial, the NFC system provided a performance score indicating how much of the landscape the team had managed to protect from fire. These team performance scores range from 0 to 100, indicating the percentage of landscape elements that remained untouched by fire. Landscape elements were assigned differing point values based on their importance; final team performance scores reflected these weights. This weighting scheme was made clear to participants during task training. Furthermore, an information sheet providing the point values was posted in each participant's cubicle next to their computer monitor for easy reference during task execution.

While the raw performance scores generated by the NFC program can range from 0 to 100, a score of 0 was not possible within the current task design. In each fire-fighting scenario created, fires ignited at fixed time points. Other factors affecting fire spread, such as wind speed and direction, were also fully fixed in the scenario design stage. Therefore, within a given fire-fighting scenario, the maximum possible fire damage always had an upper limit. That is, if the fire is allowed 'freely burn' and to spread entirely unopposed throughout the 10-minute trial period, the minimum possible performance score that would result is termed the 'freeburn score'. Freeburn scores can be calculated for each fire-fighting scenario, and were used to set a lower boundary on team performance. The different scenarios were designed to have equal freeburn scores, as a method of matching them on level of difficulty. Before team performance scores were used for statistical analysis, the freeburn score of the associated simulation was subtracted from the raw system generated performance score, in order to quantify the portion of the score that it was possible for the team to influence.

Delay in the Voice Transmissions

In order to coordinate their team's actions within a time sensitive, dynamic task environment, team members had to be in constant communication. All speech was transmitted between team members via an electronic audio system. This system was designed to allow the voice transmissions to be delayed by specific lengths of time. This time delay in the voice transmission from one team member to the other team member is considered a form of task demand that is under experimental control, such that task demand increases when the duration of the delay increases. As reviewed in Henning et al. (2007), temporal delay in various modalities of sensory feedback has a disruptive effect on task behavior and hinders task performance. Communication delays in particular have been demonstrated to lead to errors in performance on a two-person team task (Armstead, 2007).

Measures

Post-trial survey items were taken from Armstead (2007), in which they were adapted from the Hart and Staveland (1988) NASA Task Load Index. Survey items were included to assess perceptions of task characteristics. See Table 1 for full item text.

Individual task demand. Two items assessed individual perceptions of psychological demands over the course of the preceding trial (Alpha=0.90). Demand items were: "The amount of effort needed to complete this task was…" and "The mental demands of this task were…".

Individual task control. Three items were intended to assess individual perceptions of the conventional individual-level construct of control. Control items were: "I think I am responsible for how well/poorly the team performed on the task," "I think my partner is responsible for how well/poorly the team performed on the task," "I think the system is responsible for how well/poorly the team performed on the task." However, these items exhibited poor reliability (Alpha=0.52). Reliability was low enough to indicate that these items should not be combined into a single scale. Furthermore, supplemental analyses conducted at the item level indicated that these items all lacked criterion validity as a measure of control. According to the JDCS model, increased control should function to prevent stress, whether this effect is quantified as a main effect or as a buffering effect on demand. These items did not follow this pattern. Agreement with these items was associated with increased stress, whether the items were used individually or averaged into a single scale. Furthermore, they did not serve as a buffer against the effects of demand on stress. These items failed to follow the expected relationship with stress for a measure for control, so they cannot be used as a surrogate measure for control. Therefore, these items were dropped from subsequent analysis. See Appendix A for more details of this supplementary analysis.

Individual task coordination. A single item assessed individual perceptions of the team's coordination over the course of the preceding trial as reflected in communication quality. This item was "The quality of communication on this task was…".

Individual task stress. Two items assessed stress experienced during the preceding trial (Alpha=0.88). Stress items were: "The level of stress I experienced during this task was…" and "The level of frustration I experienced during this task was…".

Team task demand. The psychological demand experienced by the teams is expected to result primarily from the interaction of the design of the laboratory team task and the task-related capabilities of the teams carrying out this team task. Teams are required to monitor the state of the task and respond rapidly and accurately, all while working under both an explicit time limit (in the form of a 10 minute trial, which the commander can watch countdown to zero) and implicit time limit (in the form of the destruction of landscape elements and reduction in score if the team fails to respond to the fires in a timely fashion). However, these design elements of the task demand are fixed between teams, through the use matched, pretested scenarios. Thus any *reported* differences in demand are the result of differences in between teams in ability to carry out the task rather than resulting from differences between teams in the objective characteristics of the assigned task itself. These differences in *reported* demand are likely to be randomly distributed between teams; they are necessarily a function of differences between teams in composition and team member abilities.

The effects of team task demand may interact with the role to which a team member is assigned. Team member roles on the team are distinguishable, involving different capabilities and responsibilities in the context of the team task. One of the roles may be more vulnerable to the effects of the shared team task demands than the other role. For example, it may be the case that since the commander has access to a wider variety of information about the current state of the shared team task than the subordinate, shared team demands are more salient, and as a result this role experiences more stress as a result of these shared team demands.

As described above, team task demand may also be influenced by the length of delay in the voice transmission between teammates. Delay length could vary across teams as a function of condition, which could be fixed or random for a given team. Within teams in the random delay condition, delay varied across trials. Delay is a task element is predicted to have a systematic effect on team demand, such that regardless of team condition, longer durations of delay for a given trial make that trial of the task more demanding to the team.

Team task coordination. Task control is usually thought of as a fixed characteristic describing the constraints on the control actions available to the individual. However, within a team task, even while environmental constraints on team control behaviors remain constant, a drop in team coordination may serve as an unanticipated constraint on team control. When team coordination is low, team members are constrained to the control actions available to them through acting individually. At the extreme, when communication is severely disrupted, coordination in NFC is impossible. Control options for participants drop to nearly zero; the commander cannot fight fires, and the subordinate has almost no information on which to base their movement of firefighting appliances. In contrast, when team coordination in NFC is high, additional control actions involving the team as a whole become available, such as those that would require the individuals in the team to act in a highly interdependent manner. Increasing levels of coordination therefore provides one means for team members to overcome task constraints. Thus, coordination behavior was be used as an indicator of the team exerting control.

The effects of team task coordination may interact with the role to which a team member is assigned. Team member roles on the team are distinguishable, involving different capabilities and responsibilities in the context of the team task. One of the roles may be more vulnerable to the effects of the poor team task coordination than the other role. For example, it may be the case that since the subordinate is reliant upon the commander for updates on the current status of the shared team task, the subordinate may experience a greater increase in stress than the commander when team task coordination is low.

Special care must be taken when choosing a measure of job control for teams in the same manner as it has been done for individuals. Fox, Dwyer, and Ganster (1993) outlined some of the potential pitfalls in assessing control for individuals, including common-instrument bias due to the use of self-report assessments for both independent and dependent variables, as well as the use of vague definitions of control that make it difficult to distinguish from demand. In order to address these concerns, the current study attempts to choose a measure of control that is both consistent with Karasek's original conceptualization of control, as well as being properly measurable at the team level of analysis through two means other than self-report. Two measures of team coordination are proposed as separate objective means of assessing for team control: (1) patterns of speech communication behavior between team members, and (2) the level of social psychophysiological compliance (SPC) between team members. An increase in either was considered to be an increase in coordination.

Speech coordination. The only way team members were able to establish shared control over the team task was through speech coordination. The task was designed so that coordination between team members was required to be successful, and that speech was the only method available to establish this coordination. Therefore, the quantitative aspects of speech communication (for example the percentage of time a team member was speaking, or the number of times they spoke) were considered reflective of the efforts by the team to exert control.

A potential argument against only looking at the quantity of speech as a measure of speech coordination is that some of this speech may be off topic and not task-relevant. Only task-relevant speech would be pertinent to the exertion of task control by the team. A more common research method would have been to conduct a content analysis. However, conducting a content analysis of the speech between team members was outside the scope of the current study. A limit content analysis was conducted looking only at a sample of teams; this preliminary content analysis indicated that off-topic speech occurred only rarely in these experiments. As long as the majority of speech is task relevant, then irrespective of specific content any speech activity represents an effort by team members to coordinate their activities with each other in order to exert control over the task. Furthermore, a content analysis may be inappropriate at this stage in the research on team coordination; we don't yet know what speech content is necessary for optimum performance on the NFC task. Using quantitative measures of speech sidesteps this decision regarding what speech content is most important; as long as the team members were speaking to one another, and it was on task, this speech alone was sufficient to indicate that the team members are trying to coordinate their actions to complete the task.

Speech activity was tracked using custom computerized algorithms that score speech amplitude that was sampled continuously during task trials. Some reliability testing was necessary to determine appropriate scoring parameters that accurately capture the team's assertion of control over the task. Four possible methods of quantifying team communication were used: (1) total time of all speech, (2) the number of closely coupled speech events between team members, (3) the number of replies to the commander, and (4) the ratio of the commander's total speech time over the subordinate's total speech time.

Using speech activity as a measure of team control was an exploratory measurement method; additional support was needed to establish their utility as a measure of team control. Before the proposed speech measures were used in the Team JD/C model, these measures were validated using a preexisting set of recorded speech data from a conversational laboratory task. This was done in order to ensure that the measures function properly and in order to provide convergent support to justify this choice of measures. Furthermore, data from the post-trial surveys administered in these experiments served as an additional source of convergent support for validating these measures.

Due to the critical importance of regular voice communication between team members for successful team task completion, the presence of time delays in the voice transmissions between team members may serve to limit a team's task control. Participants in the current study were not informed that their communications would be delayed, but whether they were aware of the delay, the voice transmissions delays were expected to disrupt communication within the team, and may have therefore limited their ability to maintain high levels of coordination. Consistent with the hypothesized relationship between coordination and control, this limit on team coordination would have then systematically limited the ability of the team to exert control.

Social psychophysiological compliance. Social psychophysiological compliance (SPC) was used as a second means to assess team control. SPC assesses the coordinated physiological responsiveness that may develop between team members as they work towards a common goal (Henning et al., 2009). The extent of SPC may also reflect a team's readiness to handle increased task demands that require teamwork (Henning and Korbelak, 2005). If task design places limits upon motor-sensory control, this is likely to be reflected in reduced team members' SPC. Task design that limits team control, or a lack of communication between team members, may work against team members establishing high levels of SPC.

Stress. Physiological measures of stress have often been used in the past, including cortisol levels, blood pressure, and cardiac activity. In the present study, Heart Rate Variability (HRV) was used to assess stress; it is a noninvasive measure that can be collected continuously across the course of a trial, allowing it to capture second-by-second physiological changes in a dynamic task environment. It has the further advantage of relative ease of use out in the field (e.g. Roscoe, 1993; Miller, 1993; La Rovere, 2003), allowing this approach to be used in settings outside of the lab.

Variability in the interbeat interval was considered as the measure of interest, with a decrease in variability indicating an increase in stress. Various spectral analysis and time domain measures of heart rate variability have been used as indices of stress in the past. Spectral analysis techniques assess the magnitude of individual components of the heart rate power spectrum. Time domain techniques use simpler statistics such as deriving RSA from the interbeat interval time series (Hayano et al., 1991). In general, these measures provide a method to quantify respiratory sinus arrhythmia (RSA). RSA, the cyclical changes in heart rate variability that is linked to breathing between the ranges of 0.15 Hz to 0.50 Hz, can serve as an index of stress due to its responsiveness to levels of parasympathetic activity (Porges, 1995). Acute stress, including that induced by cognitive task demands (Hatch et al., 1986; Vicente et al., 1987; Miller et al., 1993), is reflected physiologically through a decrease in RSA variability. Spectral analysis and time domain techniques usually correlate strongly with one another (Grossman, Van Beek, Wientjes 1990; Hayano, 1991), therefore a time domain technique was chosen due to its relative ease of use in situations in which team members are actively engaged in a task which can result in higher rates of movement artifacts in the time series of interbeat intervals. As per Pentilla et al. (2001) RSA was calculated by taking the root mean square of differences between successive interbeat intervals. Both absolute change from an active baseline and variability measures were considered.

Post-trial survey measures were used as a second means to assess stress. Self-report measures of stress could provide unique information about the stress experienced by the individual that is not captured by the psychophysiological measures of stress. These survey measures reflect the individual's conscious psychological assessment of the stress experienced across an entire trial, in contrast to HRV which provides information about the continuous physiological stress that may be outside of the team members' conscious awareness.

Performance. Task performance was also considered as an outcome. While performance is not central to the JDCS Model, performance is likely to be affected by job demand and control and in past studies it has often been included as an outcome of interest. Stress and performance may be inversely related to one another, such that a team may maintain a low level of stress by allowing their team performance to suffer. Furthermore, demand and control may not have the same effect on performance as they do on stress (Flynn and James, 2009). The score provided by the NFC program at the conclusion of each simulation trial was used as the main measure of team task performance. In order to control for the different between scenarios, the freeburn score for the associated scenario was subtracted from the raw performance score generated by the NFC program to quantify the portion determined by the team's actions rather than the portion determined by the scenario design.

Procedure

Each team member was seated at a computer work station in separate sound-proofed rooms. They were fitted with a telemetry unit in order to measure cardiac activity over the course of the study. In order to establish an active baseline, cardiac activity was recorded as participants filled out a demographic questionnaire. Each participant was then fitted with a microphone and headphones in order to transmit and record voice communication. The communication system was designed to allow delays of a fixed duration, as determined by the experimenters, to be systematically introduced into the audio transmission.

The two-person teams were asked to complete a series of simulated microworld tasks using the Networked Fire Chief (NFC) program (Omodei et al., 2010). A microworld is a computer- based simulation in which users interact with an environment designed to represent a real-world task (Brehmer and Dörner, 1993). The use of a microworld task provides the experimenter with control over the design of the team task while still allowing for a realistic degree of task complexity. Each participant individually completed a single training simulation under instructions from the experimenter. The training simulation was designed to instruct participants in the operation of the NFC program, the criteria by which performance on the task would be scored, as well as provide cross training in the capabilities of each team role. Following training procedures, teams completed five trials under varying lengths of the voice transmission delay, with each trial consisting of a 10-minute long simulation using the NFC program. At the completion of each trial, each participant completed a short survey in order to capture aspects of their experience with the task and their interaction with their fellow team member.

Analysis Strategy

Creating aggregate team-level measures. Literature guidance is limited when it comes to appropriate measures of demands, coordination, and stress at the team level of analysis rather than at the individual level. For other constructs, several commonly used measurement methods for group-level constructs include averaging individual level measures of individual perceptions; averaging individual level measures of perceived group-level perceptions; and requiring teams to reach a consensus regarding their shared perceptions (Campion et al., 1993; Kirkman et al., 2001).

The current study made use of individual-level survey measures, thus it was necessary to use an aggregate method to quantify team-level demand. Although the most common method is to aggregate individual-level measures into group-level means, this is not the only method available. Barrick and colleagues (1998) suggested that in order to quantify composition variables at the team level different aggregation methods may be better suited to different task designs. In this case, the degree to which demand is a function of the design of the task itself informs my choice of aggregation method. In particular, mean aggregates may reflect the overall opinion of individuals within the group, making it an appropriate method to use in the current study. Other methods, such as a standard deviation may instead reflect the degree to which there is disagreement between individuals within the group; however, use of standard deviation was not viable with teams of only two people. Therefore mean aggregation was considered a viable method to quantify team-level task demands.

In order to calculate a stress score for the team as a whole, two methods of combining individual stress scores were compared: the arithmetic mean of the two individuals' scores and geometric mean of the two individuals' scores (in this case, the square root of the product of the two individual scores). The mean scoring approach counts each individual's stress as contributing equally to team-level stress as part of a linear combination. While this approach has the advantage of equally weighting each individual, the resulting mean is insensitive to divergence between the stress level of each individual: a moderate level of team stress would not distinguish between a situation in which each individual in the team had a moderate level of stress, and one where a single individual has a high level of stress and the other low. In contrast, the geometric mean is sensitive to such patterns, and requires that both team members are experiencing stress before the team-level stress score becomes high. The further apart the scores of each individual team member diverge, the lower the resulting geometric mean.

Voice communication record analysis. Following completion of task trials, telemetry records and voice communication activity recorded continuously over the course of each trial were scored using custom algorithms. Measures of specific communication behaviors between teammates were scored from the voice communication records. Physiological stress of each individual, as well as SPC, was calculated based on telemetry records of cardiac activity.

Statistical analysis. Due to the nested nature of the data, multilevel modeling is the most appropriate analysis to answer Hypotheses 1A and Hypothesis 1B. In preparation for this analysis all continuous predictors were standardized to simplify the interpretability of the results (as recommended in Raudenbush and Bryk, 2002).

Modeling temporal trends. Given the ordered temporal nature of the data, I followed the steps for creating a multilevel growth curve model as outlined in Bliese and Ployhart (2002). At each step, the deviance statistics (log likelihood ratios) can be compared between models using the chi-squared goodness of fit test is used in order to determine whether a more complex model is justified. These steps are:

First, estimate the basic model with temporal terms but without any random effects. In their example, Bliese and Ployhart only model a linear temporal trend, but in my modeling I also tested for quadratic curvilinear temporal trends. Without any random effects, this basic model is equivalent to a regression model.

Second, test whether the addition of a random intercept term improves the fit of the basic model. This allows individuals (or teams) to vary in their mean value of the outcome variable.

Third, determine whether there is significant temporal slope variation across clusters (i.e., individuals and/or teams, depending on which analysis) in change in response variables across time. This would allow the magnitude of the linear (or quadratic) slopes to vary across individuals (or teams), representing differential rates of change in the outcome variable for each individual (or team) over time.

Fourth, determine whether the residuals show evidence of autocorrelation or heteroscedasticity; test whether the addition of a term to account for the autocorrelation or heteroscedasticity improves the fit of the model. Multiple responses are collected from each individual (or team), and there is a logical ordering to the responses. Therefore it is possible that responses closer in time are more strongly related than responses farther apart in time (i.e. autocorrelation) or that responses may become more or less variable over time (i.e. heteroscedasticity) due to factors like fatigue.

Model building. After creating a basic multilevel growth curve model, hypothesized predictors were added to the model. I did not have a theoretical reason to expect the influence of the hypothesized predictors to vary across individuals, and so the slopes were fixed across individuals. Thus, apart from potentially random slopes for the linear and quadratic temporal trends, I created a random intercepts model with fixed slopes.

I hypothesized an interaction between demand and coordination. However, in a multilevel model, the specific nature of this interaction could take a number of different forms. It could be between each characteristic at the individual level, each characteristic at the team level, or a cross-level interaction between individual-level demand and team-level coordination (or vice versa). Therefore I tested each of these cross-level interactions.

I followed the general multilevel model building procedures as outlined by Raudenbush and Bryk (2002). All lower-level predictors were added to the model before moving on to predictors at a higher level. First, trial-level predictors were added to the model. Predictors were added stepwise, starting with control variables, then demand, coordination, the demand by coordination interaction, and finally speech measures of coordination. Changes in chi-squared fit statistics were used to guide the retention or deletion of each predictor. For all continuous predictors, both linear and quadratic effects were tested. Once all trial-level predictors were fit to the model, I trimmed out non-significant predictors; if their removal did not significantly reduce model fit, they were deleted from the model.

The same procedure was followed at the next level up. In the two-level models of outcomes within teams, this was the team level. In the three-level model of outcomes within individuals within teams, this was the individual level. At the individual level, role was included as a covariate. Teammates were each assigned to unique roles; the characteristics of these roles may very well differ with regards to their experience of task characteristics.

The same procedure was followed at the team level, adding demand, communication quality, and the demand by communication quality interaction in order as predictors of the intercept. I used the consensus methods of quantifying team-level perceptions of task characteristics as measured by the average across teammates). Furthermore, given the distinguishable roles of the participants on the teams, I considered cross-level interaction with role, such that commander and subordinate might have been differently affected by these same team-level characteristics (i.e., demand, communication quality, and the demand by communication quality interaction).

Results

Preliminary Analyses

Means, standard deviations, and zero-order correlations of the study variables are presented for trials within individuals within teams in Table 2 and trials within teams in Table 3. Figures 2-5 present the values of the study outcome variables over the course of the five trial long study session. Figure 2 presents self-reported individual stress over time, Figure 3 presents physiological individual stress over time (as measured by RMSSD), Figure 4 presents team stress over time, and Figure 5 presents team performance over time. All measures of stress presented in the tables are standardized. Values of each outcome are averaged across the relevant unit of analysis, either individuals or teams.

To test the team-level model of stress, team-level variables had to be created. Survey responses collected at the individual level, following each trial, were aggregated up by averaging values for each task characteristics across the two team members' responses for the trial. This aggregation resulted in a single team-level measure for each task characteristic, with team responses for each trial. For example, the commander's demand score rating for Trial 1 and the subordinate's demand score rating for Trial 1 were averaged, producing a single team-level demand score for Trial 1.

Intraclass correlations were computed to quantify group level variance (James, 1982; McGraw & Wong, 1996). The intraclass correlations across task characteristic variables justify this use of mean aggregation in order to quantify team-level task characteristics. ICC(1) and

ICC(2) values are for individual trial-level variables within team trial-level are shown in Table 4. ICC(1) values are high, indicating that a substantial proportion of the variance in perceptions of task characteristic across trials fall at the team level rather than the individual level.

Following this aggregation procedure, there still remains sufficient variance across teams in reported team-level stress, as well as in team task performance, to conduct multilevel modeling. Intraclass correlations for aggregated team trial-level variables within teams are reported in Table 5. The ICC(1) values indicate substantial group-level variance, indicating that I am justified in making teams the focal unit of analysis.

Team-Level Stress as the Outcome

The major focus of the current study was on team-level effects; therefore the aggregate team-level stress as the outcome is reported first. The same analytical strategy used to model team-level stress was replicated using two different analytical methods. First, a stepwise regression was conducted. This provides a simpler analysis, but cannot effectively model the non-independence of the data, with repeated measures nested within each team. Therefore the outcome of this regression was compared with the results of a two-level multilevel modeling analysis, with trials nested within team.

Regression with team-level stress as the outcome. Mean team-level stress across each of the five trials was first modeled using stepwise regression. Predictors were added in the following blocks; r-squared change is indicated in parentheses: first, linear longitudinal trends across team trials were added (n.s.); second, quadratic longitudinal trends ($p<.10$); third, delay length was added as a control variable ($p<.05$); fourth, team task performance ($p<.001$); fifth, demand and coordination were added as the main predictors ($p<.001$); sixth, the interaction of the two ($p<.10$); finally, speech quantity was added (n.s.). Results are summarized in Table 6.

The addition of speech quantity during the stepwise regression failed to produce a significant r-squared change, thus was dropped from the final model. Although the addition of delay produced a significant change in r-squared, it was no longer a significant predictor after all predictors had been added, thus was dropped from the final model.

The final model for team-level stress included the linear time trend (0.084), the quadratic curvilinear time trend (-0.055), team task performance (-0.163), mean team-level demand (0.573), and mean team-level communication quality (-0.183), and the interaction of demand and communication quality (-0.089) as predictors. Beta weights are indicated in parentheses. In this final regression model of team stress: increased team-level demand increased team stress, increased team-level communication quality reduced stress, and the interaction of the two served to further reduce steam stress, supporting Hypotheses 1 A, B, and C. Furthermore, increased team performance reduced team stress, supporting Hypothesis 4. Together this final combination of predictors explained 49.1 percent of the variance in team-level stress over time.

2-level HLM model with team-level stress as the outcome.

Baseline analyses for 2-level model of team-level stress. 42 percent of the total variance in team stress was within teams (over time) and 58 percent of the total variance was between teams. The baseline multilevel model of team stress was created using the procedure outlined by Mathieu & Rapp (2009), as described above. For more detail regarding the model building process comparing nested models using chi-squared fit statistics, see Table 7.

The final best fitting baseline temporal model of team stress included a linear temporal trend randomly varying across teams and a quadratic temporal trend fixed across teams, with a homogeneous error structure. These linear and quadratic temporal trends together accounted for approximately 36 percent of the variance in stress between teams. There was no evidence of autocorrelation or heteroscedasticity.

Intercept analyses for 2-level model of team-level stress. In order to test my hypotheses involving team-level influences on team stress, I performed omnibus tests using a series of nested model comparisons using the same strategy of stepwise addition of blocks of variables as used in the earlier regression analyses. For each block that produced a significant improvement in model fit, I followed up with focused analyses of each variable in the block to determine the specific nature of any significant effects on stress. In this series of nested model comparisons, delay in speech transmission, team task performance scores, Demand, Communication Quality and the Demand by Communication Quality interaction all significant improved model when predicting team-level stress intercepts. Table 7 presents a summary of the team stress intercepts analyses model building, including changes in fit statistics.

After all hypothesized predictors were added to the model, delay in speech transmission was no longer a significant predictor of the team stress intercept. Trimming it from the model did not significantly reduce model fit (delta chi-squared(3)=3.33, ns). Delay related positively to the team stress intercept before Demand and Communication Quality are added to the model (Tau=0.12, SE=0.06, $p<.05$), but not in the final model (Tau=0.00, SE=0.05, ns).

Model coefficients are presented in Table 8. The final model of team stress included team task performance (Tau=-0.22, SE=0.05, $p<.001$), mean team demand (Tau=0.57, SE=0.07,

$p<.001$), mean team communication quality (Tau=-0.12, SE=0.04, $p<.01$) and the mean team demand by communication quality interaction (Tau=-0.10, SE=0.03, $p<.01$) all as predictors of the team stress intercept. In this final multilevel model of team stress, increased team-level demand increased team stress, increased team-level communication quality reduced stress, and the interaction of the two served to further reduce team stress (as presented in Figure 6), supporting Hypotheses 1A, 1B, and 1C. Furthermore, increased team performance reduced team stress, supporting Hypothesis 4. Together, this combination of predictors accounted for approximately 69 percent of the variance in team stress within a team over time, and accounted for approximately 42 percent of the variance in team stress between teams. This corresponds to roughly 53 percent of the total variance in team stress (based on the Snijders & Bosker, 1999, formulas; using the pseudo R-squared calculation tool from Mathieu, 2008).

Individual-Level Stress as the Outcome

Establishing a model of team-level stress is the main focus of the current study, and as discussed previously from a theoretical perspective, the concept of team-level stress is justifiable. However, in the current study, stress was not measured at the team level, merely aggregated upward from individual-level measurements. Ideally, all constructs should be measured at the appropriate level of analysis rather than using such aggregation procedures. As discussed above, the intraclass correlations of the study variables that were aggregated meet the accepted criteria for use of an aggregate measure. However, to further demonstrate that the results demonstrated above for a team-level model of stress are not purely an artifact of the aggregation procedures, a three level model was also estimated, using repeated measures individual trial-level responses, nested within individuals, and nested within teams. This model foregoes the aggregation procedure, instead estimating a more complex model. However, results from this three-level model would not be directly analogous to the results in the regression and two-level models estimated above: without aggregation, level one represents time varying *individual-level* characteristics and level two of the model represents stable individual-level characteristics. In contrast, in the other two analyses above, level one represents time varying *team-level* characteristics. In all models, the highest level represents stable team-level characteristics.

Baseline analyses for 3-level model of individual-level stress. 37 percent of the total variance in individual stress was within individuals (over time), 50 percent of the total variance was between individuals, and 13 percent of the total variance was between teams. The baseline multilevel model of team stress outlined below was created using the procedure outlined by Mathieu & Rapp (2009), as described above. For more detail regarding the model building process comparing nested models using chi-squared fit statistics, see Table 9.

The final best fitting baseline temporal model of individual stress included a linear temporal trend randomly varying across both individuals and teams and a quadratic temporal trend fixed across both individuals and teams, with a homogeneous error structure. These linear and quadratic temporal trends together accounted for approximately 30 percent of the variance in stress within individuals over time, respectively. There was no evidence of autocorrelation or heteroscedasticity.

Intercept analyses for 3-level model of individual-level stress. In order to test my hypotheses involving team-level influences on individual stress, I performed omnibus tests using a series of nested model comparisons using the same strategy of stepwise addition of blocks of variables as used in the regression analyses. For each block that produced a significant improvement in model fit, I followed up with focused analyses of each variable in the block to determine the specific nature of any significant effects on stress. In this series of nested model comparisons, at Level-1, addition of Delay in speech transmission, task performance, quadratic curvilinear effect of task performance, Demand, Communication Quality and the Demand by Communication Quality interaction all significantly improved model fit when predicting individual-level stress intercepts. Table 9 presents a summary of the Level-1 model building for the individual stress intercepts analyses, including changes in fit statistics.

After all hypothesized predictors were added to the model, delay in speech transmission was no longer a significant predictor of the individual stress intercept. Trimming it from the model did not significantly reduce model fit (delta chi-squared(1)=0.01, ns). Delay related positively to the individual stress intercept before Demand and Communication Quality are added to the model (Tau=0.14, SE=0.07, p<.05), but not in the final Level-1 model (Tau=0.00, SE=0.06, ns).

Model coefficients are presented in Table 10. In the final Level-1 model, Performance related negatively to individual stress intercepts (Tau=-0.04, SE=0.01, p<.001), with a weak but significant quadratic curvilinear trend. Demand (Tau=0.79, SE=0.07, p<.001) related positively and Communication Quality (Tau=-0.17, SE=0.05, p<.001) related negatively to the individual stress intercept. The Demand by Communication Quality interaction related negatively to the individual stress intercept (Tau=-0.14, SE=0.04, p<.01).

At Level-2, I added the only stable individual level task characteristics: Role. Role did not significantly relate to the stress intercept (delta chi-square(1)=0.31, ns). However, it was retained in the model to allow for subsequent analyses to test for cross-level effects of team task characteristics through role.

At Level-3, I added the stable team-level task characteristics, created by aggregation of individual responses across team members and trials. In this series of nested model comparisons, none of the team level aggregate Demand and Communication Quality characteristics significantly improved model fit in predicting individual stress characteristics; thus, model coefficients are omitted.

Analyses of cross-level effects through role for 3-level model of individual stress. Due to the use of a task with distinguishable roles, the role-related tasks of team members might be differentially impacted by team characteristics. I added the stable team-level task characteristics, created by aggregation of individual responses across team members and trials as cross-level predictors of the individual stress intercept through the distinguishable task roles. In this series of nested model comparisons, Mean Communication Quality significantly improved model fit. None of the other team level aggregate task characteristics improved model fit. Table 9 presents a summary of the model building for level 3 of the model, adding the cross-level effects of team level task characteristics through team member role, including changes in fit statistics.

Model coefficients are presented in Table 10. Through their effects on role, Mean Communication Quality (Tau=-.40, SE=0.16, $p<.05$) related negatively to the stress intercept.

In the final Level-3 model, this combination of predictors accounted for approximately 58 percent of the variance in individual stress within an individual over time, 27 percent of the variance in individual stress between individuals, and 69 percent of the variance in individual stress between teams. Overall, this final multilevel model of individual stress accounted for 44 percent of the variation in individual stress (based on the Kreft & de Leeuw (1998) and Singer

(1998) formulas). At level one, individual demand increased individual stress, individual communication quality reduced stress, and the interaction of individual demand and communication quality reduced stress (as presented in Figure 7). None of the direct effects of mean team-level task characteristics predicted the individual stress intercepts, however there was a cross-level interaction such that mean team-level communication quality influenced individual-level stress through an individual's task role (as presented in Figure 8). Thus in the multilevel model of individual stress Hypotheses 1A, 1B, and 1C were partially supported. Furthermore, increased team task performance reduced individual stress; thus in the multilevel model of individual stress Hypothesis 4 was supported.

Team-Level Performance as Outcome

Team-level demand and communication quality were also hypothesized to influence team performance. The same modeling strategy as above was used, using the same predictors, but instead using performance as an outcome. First, a stepwise regression was performed. Then, a two-level multilevel model was created. Due to the nature of the task used in the current study, the analysis could not be extended to the individual level, as was done above. Performance was measured solely at the team-level; no individual-level performance outcomes were collected.

Regression with team-level performance as the outcome. Team-level performance across each of the five trials was modeled using stepwise linear regression. Predictors were added in the following blocks; significance of the change in r-squared indicated in parentheses: linear longitudinal trends across team trials ($p<.001$); quadratic curvilinear longitudinal trends (n.s.); delay length (n.s.); quadratic curvilinear delay length (n.s.); team stress ($p<.001$); quadratic curvilinear team stress ($p<.05$); team demand and team communication quality

($p<.001$); quadratic curvilinear team demand and team communication quality ($p<.01$); the interaction team demand and team communication quality ($p<.001$); speech quantity (n.s.); and quadratic curvilinear speech quantity (n.s.).

The final regression model included the linear time trend (0.313), mean team-level stress (-0.145), mean team-level demand (-0.175), mean team-level communication quality (0.351), quadratic curvilinear mean team-level communication quality (0.198) and the interaction of team demand and communication quality (-0.226) as significant predictors of team performance. Beta weights in the final model are indicated in parenthesis. The quadratic curvilinear time trend, delay, and mean speech quantity all failed to produce a significant r-squared change when added in the stepwise regression, thus were deleted from the final model. This model is summarized in Table 11.

In the final regression model of team performance, increased demand decreased team performance, increased team communication quality increased team task performance, and the interaction of team demand and communication quality further decreased team task performance. Thus in the regression model of team performance Hypothesis 2A, 2B, and 2C were supported. As team stress increased, team task performance declined. Thus, in the regression model of team performance Hypothesis 4 was supported. Together this combination of predictors explained 41 percent of the variance in team performance over time.

2-level HLM model with team-level performance as the outcome.

Baseline analyses for 2-level model of team-level performance. 78 percent of the total variance in team performance was within teams (over time) and 22 percent of the total variance was between teams. The baseline multilevel model of team stress outlined below was created using the procedure outlined by Mathieu & Rapp (2009), as described above. For more detail regarding the model building process comparing nested models using chi-squared fit statistics, see Table 12.

The final best fitting baseline temporal model of team stress included a linear temporal trend randomly varying across teams, with a heterogeneous error structure. A quadratic temporal trend did not improve model fit. This linear temporal trend accounted for approximately 39 percent of the variance in performance between teams. There was evidence heteroscedasticity in team performance over time: the error structure was best fit by the heterogeneous model. This heterogeneous model fit better than an autocorrelation model.

Intercept analyses for 2-level model of team-level performance. In order to test my hypotheses involving team-level influences on team performance, I performed omnibus tests using a series of nested model comparisons using the same strategy of stepwise addition of blocks of variables as used in the regression analyses. For each block that produced a significant improvement in model fit, I followed up with focused analyses of each variable in the block to determine the specific nature of any significant effects on stress. In a series of nested model comparisons, quadratic curvilinear delay length, team demand and team communication quality, the quadratic curvilinear effects of team demand and team communication quality, and the interaction of team demand and team communication quality all significantly improved model prediction of team performance intercepts. Table 12 presents a summary of the team performance intercepts analyses model building, including changes in fit statistics.

Model coefficients are presented in Table 13. The final multilevel model of team performance included stress (Tau= -0.18, SE=0.07, p<.01), communication quality (Tau= 0.26, SE=0.05, p<.001), quadratic curvilinear communication quality (Tau= 0.12, SE=0.03, p<.001), and the demand by communication quality interaction (Tau= -0.10, SE=0.05, p<.05). In the final multilevel model of team performance, increased demand did not predict team performance, increased team communication quality increased team task performance, and the interaction of team demand and communication quality further reduced team task performance (as presented in Figure 9). Thus in the multilevel model of team performance Hypothesis 2 B and C were supported; Hypothesis 2A was not supported. Increased team stress reduced team task performance; Hypothesis 4 was supported.

Due to the heteroscedasticity in error terms, the predictive power of this final model differed across time points. Relative to an unspecified model with heterogeneous variance, this combination of predictors accounted for approximately 62 percent of the variance in team performance at trial 1, 3 percent at trial 2, 48 percent at trial 3, 66 percent at trial 4, and 91 percent at trial 5 (Based on the Snijders & Bosker, 1999, formulas). This corresponds to an average of 54 percent of the total variance in team stress across trials explained by the model.

Results Summary

Table 14 presents a summary of the results across regression, 2-level HLM and 3-level HLM analyses.

Consistent across methods of analysis, performance, demand, communication quality and the demand-by-communication quality interaction predicted stress, both at the individual and at the team level. High team task performance reduced stress, improved communication quality reduced stress, increased demand increased stress, and the two interact such that improved communication quality helps to buffer against the stressful effects of high demand.

The role each individual played on the team was included as a covariate. Role did not directly influence stress, but did exhibit a cross-level interaction with team communication quality, such that the commander reported less stress as team communication quality increases. In contrast, the subordinate was not further influenced by the team's shared appraisal of the communication quality, only by their own individual perception of the communication quality.

Team task performance was predicted by the same task characteristics as stress. Stress, demand, communication quality and the demand-by-communication quality interaction predicted team performance. High team stress reduced performance, improved communication quality improved performance, increased demand reduced performance, and the two interact such that improved communication quality helps to buffer against the detrimental effects of high demand on performance. However, the role of demand as a predictor of performance was inconsistent across analyses. As indicated in table 14, although team-level demand was a significant predictor of team performance in the regression model, team-level demand was no longer a significant predictor of performance after accounting for non-independence of performance scores within teams as done in the multilevel model.

Discussion

Summary of the Main Findings

The current study sought to develop a better understanding of the sources of stress experienced by teams. The goals of the study were to develop a Team Job Demand/Control Model in order to explain sources of team stress, as well as to test the role of coordination in such a model. Coordination is a crucial component of teamwork, and was hypothesized to function as a team-level form of control in the context of Team Job Demand/Control Model.

The results of this study contribute to a growing body of literature on team stress. Past research by Söderfeldt (1997) and Van Yperen and Snijders (2000) showed that there is substantial group-level variance in stress. The current study replicated these findings in teams, showing that there is substantial team-level variance in stress and underscoring that team-level stressors must be taken into account in order to understand the full experience of stress in a teamwork context. Stress research, especially in the context of occupational stress, has primarily focused on the stress experienced by individuals, but it is not sufficient to look at individual-level stressors alone. The social organization of work should also be considered. In the context of a work system composed of multiple individuals, individual-level stress is only one piece of a larger picture of system-level stress. The current study focused entirely on the team as a unique type of work system. Hypotheses focused on the role of team-level demand and team-level coordination as predictors of team-level stress and team performance. Overall, hypotheses in this study were supported. Support for all hypotheses across the regression, 2-level HLM and 3-level HLM analyses are summarized in Table 15.

Hypothesis 1 stated that:

H1A: Team-level task demand will have a main effect on the presence of stress among team members. When team-level demands are high, stress among team members is predicted to increase.

H1B: Team coordination will have a main effect on the presence of stress among team members. When team coordination is high, stress among team members is predicted to decrease.

H1C: The interaction of team-level task demand and team coordination will be predictive of the presence of stress among team members. When team-level task demands are high and team coordination is low, stress among team members is predicted to increase beyond the sum of the main effects of team-level task demand and team coordination.

Hypothesis 1 was tested across several different analyses. The proposed Team Job Demand/Control Model explains team-level stress as caused by team-level demand and team-level coordination; thus, this theoretical model was tested using a two-level multilevel model, with team trials nested in teams. However, team-level measurement of these constructs was accomplished by averaging across the individual-level measures collected for each team member. The nested structure of the data as it was collected, before aggregation, was better explained by a three-level multilevel model, where individual trials were nested in individuals nested in teams. Therefore, both the two-level and the three-level multilevel models were examined to ensure that results from the two-level model of teams were not simply an artifact resulting from aggregation of individual-level measures up to the team-level.

Hypothesis 1 was fully supported in the regression analysis of team stress and the multilevel model of team stress. However, support for Hypothesis 1 was inconsistent across levels in the three-level model of individual stress within teams. At the trial level, individual self-reported task characteristics did predict individual stress for that trial. However, aggregated up to the team level, only team-level communication quality remained a significant predictor of individual stress, and then only as a cross-level interaction through the effects of role.

The primary focus of this study was explaining sources of team-level stress. Therefore, the fact that the direct effects of team-level task characteristics failed to predict individual-level stress does not necessarily fail to support the team-level model. However, given that two similar analyses based on the same data failed to produce consistent results, a possible explanation should be discussed. This inconsistency may be a result of the differences between the individual roles in the team task. Each role on the team had unique task demands assigned to it. One role primarily consisted of a vigilance task, while the other role required direct interaction with the task. The set of items used to measure demand was not designed to capture the portion of demand unique to each role, only demand in general. Thus, this measure of demand may have been better at explaining the shared stress of the team as a whole and worse at explaining the unique variance in stress associated with each role. An alternate measurement approach directly assessing both the shared team portion of demand, coordination, and stress distinct from the unique individual portion demand, coordination, and stress associated with each role might better capture the distinction between the psychologically relevant team-level variance and individual-level variance.

However, the fact that team communication quality successfully predicted individual stress through its interaction with role provides support for the critical importance of coordination as a team task characteristic in relation to team stress. This serves to provide convergent support for the proposed inclusion of coordination measures in a model of team stress.

Hypothesis 2 stated that:

H2A: Team-level task demand will have a main effect on team-level task performance. When team-level demands are high, team performance is predicted to become worse.

H2B: Team coordination will have a main effect on team-level task performance. When coordination is high, team performance is predicted to improve.

H2C: The interaction of team-level task demand and team coordination will be predictive of team-level task performance. When team-level task demands are high and team coordination is low, team task performance is predicted to decline beyond the sum of the main effects of team-level task demand and team coordination.

Hypothesis 2 was supported across all analytic methods. However, support for the effect of team-level demand on team task performance was inconsistent. In the regression analysis, increased team-level demand served to impair team performance; however, in the multilevel model, it was no longer a significant predictor. In contrast, team coordination was consistently supported as a predictor of team task performance in both models. Increased team coordination served to facilitate performance, and team coordination also exhibited a buffering effect, allowing teams to still perform well even under increased team demand. This consistent evidence that team coordination has both a main effect on team task performance as well as a buffering effect on the effects of team demands on team task performance provides convergent support for the crucial need for high quality team coordination in order for a team to achieve success.

These results in regard to team performance provide further evidence for the role of demand and coordination as important team task characteristics. Although the proposed model is intended to predict team stress, the same set of predictors is also relevant to performance as an important outcome. This stands in contrast to results from a study by Flynn and James (2009), who found that the effects of individual-level demand and control were not consistent across both stress and performance outcomes. This suggests that while they may not do so at the individual-level, at the team-level demand and coordination may tap into some underlying processes of teamwork. These processes of teamwork may be relevant not just to stress but to other outcomes deriving from team processes. Thus, if a team is able to establish effective "teamwork processes," they are able to effectively meet performance goals. If a team is unable to establish effective teamwork processes, this places the team under stress. Further research is needed to determine what exactly these effective teamwork processes are. However, they might represent a state in which each individual on the team has mutual control over the actions of the team as a unit. When control is not mutual, this places stress upon the team, and the team is unable to operate effectively as a functional unit in order to meet performance goals.

There was inconsistent support for team demand as a predictor of team performance. This may have been due to the presence of multicollinearity between team-level demand and team-level stress. In the analysis described above, where stress was the outcome of the analysis, demand was a significant predictor of stress. Therefore, this may have caused problems when both team demand and team stress were included as predictors of team performance in the same model. The reason both variables were included was that demand was a hypothesized predictor of performance, while there is also evidence that stress can be detrimental to team performance (Ellis, 2006), so stress was also included in the model as a control variable. However, stress and demand are strongly correlated with one another, and thus may have exhibited multicollinearity that was problematic for this model. It has been established in the literature that there is a strong theoretical relationship between psychological demand and stress; demand is a central predictor of job stress in several prominent models (e.g., Job Demand/Control Model, Karasek, 1979; Job Demand-Resources Model, Demerouti et al., 2001). There is also a strong statistical relationship between stress and demand; strong correlations (ranging from .42 to .65 depending on level of analysis and aggregation) were observed between stress and demand at both the individual and team levels. Stress and demand are conceptually distinct, and are both meaningful to the current analysis, so neither could simply be dropped from the model. In order to capture the unique influences of demand and stress on team performance while avoiding multicollinearity, future studies could instead use measures of more specific facets of these constructs (e.g., threat and pressure subscales of stress) rather than a single broad measure of each.

These results provide strong support for the importance of measures of coordination when studying the work within teams. Consistent across both stress and performance, coordination between teammates played an important role. However, in the current study coordination was measured with a single survey item. Future research would benefit from the development of a more complete scale of this construct, in order to allow for both greater reliability, as well as in order to capture more than one possible element of coordination behavior; in the current study, communication quality was the aspect assessed, but other aspects of coordination such as shared mental models might be equally important components.

Hypothesis 3 stated that:

H3A: Time delays in the voice transmissions will function as a source of team-level task demand, such that as delay length increases, so does task difficulty.

H3B: Time delays in the voice transmissions may also serve as a limitation on team level task control, such that as delay length increases, team coordination decreases.

Hypothesis 3 was fully supported. An increase in the length of delay in speech transmission correlates positively with demand, and negatively with communication quality. Furthermore, length of delay only serves as a significant predictor of stress before the addition of demand or coordination to the model. After controlling for either demand or coordination, delay is no longer a significant predictor of stress. Thus it appears that the effects of delay on stress are fully accounted for by the task characteristics of demand and coordination. These results are consistent with previous research looking at the effects of transmission delays (e.g., Kao & Smith, 1977; Henning et al., 2007). Furthermore, they support the use of delay in the current study as a systematic means to experimentally manipulate team task characteristics affecting demand and control rather than introducing other variables that would significantly alter the task and confuse the relationship between demand, control, and stress.

Hypothesis 4 stated that:

H4: Team performance will predict team stress.

Hypothesis 4 was supported. Across trials, high team stress was associated with a reduction in team performance outcomes, and high team performance was associated with a reduction in team stress outcomes. It is likely that team members take into account their team's performance scores or reward awareness of team performance when appraising their own stress levels, apart from specific task characteristics like demand and coordination. Further temporal analyses of the relationship between team stress and team performance may be necessary to determine whether this relationship is genuinely bidirectional; for example, if high stress does impair performance.

General Discussion

The results of the present study provided some strong initial support for the proposed Team Job Demand/Control Model. In particular, the results emphasize that coordination is a new dimension that must be taken into account in developing any theoretical model of stress in teams.

However, there is not yet sufficient evidence to determine whether coordination is in fact a surrogate for control, or a distinctly different construct. Flynn and James (2009) suggest that the boundaries between control and other task characteristics like demand may be unclear at the individual-level. The distinction between team control and other team-level task characteristics may be similarly unclear. More work will need to be done in order to establish whether there is discriminant validity at the team-level between team coordination and team control, or whether team coordination is a facet of the larger construct of team control. In the current study, coordination did vary over time within team; even though task characteristics did not change. Thus, coordination is determined in part by the state of the team (e.g., degree of fatigue, presence of shared mental models) rather than solely determined by job design factors.

The social organization of work was also relevant to performance. In the past, team researchers have often focused on team task performance as the primary outcome of interest (e.g., Cooke et al., 2003; Mathieu et al., 2000; Salas et al., 1995). This same body of research may help inform the development of theories of team stress. My results strongly suggest that there is value is integrating these two bodies of research. In the context of team work, the same characteristics team demand and team coordination behaviors may be relevant to multiple team outcomes; team demand and team coordination were predictive of both team stress and team performance.

These results also suggest that in the context of teams, the occupational health psychology goals of reducing worker stress as well as the business goals of improving performance are both in alignment. Both could benefit by an intervention designed to reduce team demand and improve team coordination. If these results can be replicated, they may provide OHP professionals with valuable new evidence to help make the business case for interventions to improve worker health and well-being. Future research on team stress could test whether other established predictors of team performance are similarly effective in predicting team stress as an outcome.

With the large body of evidence collected over the years using the established JDCS Model, Karasek was able to define certain jobs, at the national level, as high strain jobs, versus other jobs which are either active, passive, or low strain. Through a similar data collection effort the same could be done using the Team Job Demand/Control Model. This means researchers may be able to establish where different types of teams fall with regards to their level of strain. Such a classification scheme for types of teams rather than types of jobs could help guide organizations and practitioners when designing team-based work. It may be the case that some types of team organizational structures should be avoided entirely, or if they must be used, they should be used sparingly.

The results of the current study also contribute to the discussion in the literature on the Strain Hypothesis of stress and the nature of the relationship between demand and control as predictors of job stress. Demand and control have been combined in a variety of ways in past work, including using them to create a quartile split, only looking at their main effects, combining as additive predictors (e.g., Söderfeldt et al., 1997), or looking at both their main effects and the interaction between the two (e.g., Van Yperen and Snijders, 2000). My results suggest that, if coordination can be considered as a form of control in the team context, both the main effects of demand and control as well as the interaction of the two provide incremental validity in predicting stress; furthermore, this relationship exists at both the individual and team levels. This would mean that the effects of control on stress are not limited to solely a buffering of demand; a lack of coordination as a form of control during teamwork in and of itself can serve as a significant stressor.

Beyond contributing to the development of a model of team stress, these results also suggest some more broad implications for theories of occupational health. In recent years there has been a lot of interest among researchers regarding group-level effects on worker health. A common practice is to develop new constructs at the group-level; in fact, several new group-level constructs are being introduced to the Job Content Questionnaire 2.0, to add to the demand, control, and social support dimensions. However in the current study, the primary predictors of stress in teams were not new constructs existing only at the group-level. Instead, they were group-level components of existing, well-researched constructs like stress and demand. Therefore, identifying altogether new group-level constructs is not the only viable approach for future occupational health psychology research in this area. Future research can also investigate whether other existing constructs established at the individual-level have equally important group-level components. Other constructs closely related to stress, such as resources and social support, may have similar group-level components.

Furthermore, there is a need to develop a theory of what these constructs of stress, demand, and coordination mean at the team-level. I've avoided strong theoretical statements regarding what team-level stress, demand, or communication quality represent. The goal of this study was to provide initial support for the Team Job Demand/Control Model, and therefore it was sufficient to demonstrate that (1) a substantial portion of the variance in these constructs exists at the team-level, (2) the team-level demand explains variance in team-level stress, just like their analogues at the individual-level, and (3) team coordination is also important predictor of the team-level portion of stress. A worthwhile next step would be to interpret what these team-level constructs mean. These team-level constructs are likely to be more than simply the sum of the perceptions of the individuals making up the team; team-level stress is unlikely to be purely an epiphenomenon arising when the majority of the individuals composing the team are experiencing individual-level stress. If team-level stress as a construct is distinguishable from individual-level stress, then it follows that it should be possible to have individuals on a team experiencing little stress while the team itself is in a state of great stress, and vice versa. In contrast to being a sum of individual perceptions, team-level stress, along with other constructs like team-level demand and team-level control, likely represent properties of the team as a system. Team-level stress may represent a state where the system is breaking apart into its components rather than functioning together as a whole. The application of such a theory is important to guide the development of measures of team-level stress, demand, and coordination. In the current study I had to use mean aggregation, however this method makes it difficult to distinguish between the individual-level and team-level components of a given construct. For survey measures, it might be sufficient to distinguish between the two levels using two sets of items, one using the individual as the referent and the other using the team as the referent. Other measures based on team consensus (e.g., based on those of Campion et al., 1993; and Kirkman et al., 2001) might be another valuable method. When using a team consensus method for measurement, the whole team meets together to collectively decide on a single response to a survey item assessing a team-level construct.

However, relying too much on survey measures runs the risk of undermining the validity of a study through the introduction of common-method variance. Other methods for measuring group-level stress, demands, and coordination could be explored to help avoid this threat to validity as well as to establish convergent support. In the current study, objective measures of performance were used as an outcome, and this helped provide some evidence for the importance of team demand and team coordination without relying entirely on outcomes derived from the same survey. However, attempts to use alternate measures of stress and coordination were less successful; while attempts were made to use physiological based measures of stress and behavioral measure of coordination, they ultimately lacked the validity necessary to contribute to the results. Nonetheless, these types of measures may represent important directions to further explore in search of effective measures; for example, there may be a specific component of speech coordination behavior we failed to look at that may prove to be a crucial predictor of stress. Another measurement method to capture these group-level constructs may be observer ratings; supervisor ratings are frequently used in organizational settings, and such outsider perspectives might be able to more objectively capture team processes than rating from members of the team.

The results of the current study have a number of implications for practitioners seeking to reduce worker stress. They point to the need to consider stress interventions at the group-level rather than only at the individual-level. If a portion of the variance in stress exists at the team-level, individual-level based solutions may not be sufficient to address it. Interventions designed to improve group coordination may be a practical solution. Both team demand and team coordination were predictors of team stress and team performance. From a practicality standpoint, team demand may be hard to change in the workplace. Work needs to be completed, and there may not be enough workers to split it up into smaller components or enough time to postpone it. Thus, although demand is established as an important contributor to stress, it may often be difficult to develop interventions to reduce demand. Coordination occurring within a team may be a characteristic much more open to intervention, and thus a better avenue for interventions designed to reduce stress or improve performance in teamwork settings.

Interventions to improve team coordination would involve reorganizing the social-organizational aspects of the work; different methods of dividing the work, or the creation of different channels of communication, might significantly improve the coordination of teamwork by team members. Alternatively, training methods could be used to improve team coordination. This may be especially effective for ad hoc teams in an organization or teams put together for the sake of a particular project, where team members may have substantial expertise in carrying out their own job tasks but no explicit training in how to work together as a team. If researchers can determine what types of coordination behaviors are most effective in establishing high quality team coordination (e.g., establishing a shared mental model, adopting explicit information sharing procedures, using communication technology more effectively), providing workers with training in these coordination behaviors could help buffer against the stressful effects of team-based work. As another alternative, tasks could be better designed to facilitate team coordination. For example, roles could be designed to purposefully complement one another as part of a team, coordination behavior can be designed into job tasks, and performance appraisal and rewards can be targeted at the team as a unit rather than only at the individuals composing it.

Study Limitations and Future Work

Although a laboratory study affords a high degree of control over the structure of the team and the team task, laboratory methods have the downside of limiting the generalizability of the results. The effects of demand and coordination on stress may vary from those reported here depending on how the team is formed, in particular whether the team forms itself or is formed by an external agent in the organization who has control over them. For example, it is unclear whether the results of the current study would apply to self-formed teams, compared to teams to which workers are assigned. The lab context had individuals assigned to a team and assigned a task, with no opportunity for individual choice over team members. I would expect demand and coordination as a form of control to function the same in a self-formed team, but they may benefit from having greater amounts of other forms of social control. They might also have more flexibility to determine their own style or manner of coordination; it remains to be empirically determined whether personal choice or an enforced best practice would be most advantageous.

It can be noted that only one type of social organization was analyzed in the current study. All participants were organized into teams. Teams were chosen as the focus of the current study due to their unique characteristics. Due to their close interdependence and shared goals, I predicted that the effects of coordination on stress would be readily evident in teams. Although this assumption guided the design of this study, it was not explicitly tested. Follow up work could test whether the same factors of demand and coordination predict stress in other types of work groups. It may be the case that rather than the same coordination processes being weaker or stronger, different social processes become more important in different types of work groups, making these better candidates for assessment of team control and sources of stress.

Apart from only looking at teams as a type of social organizations, the current study was further limited by only looking at teams consisting of two people; ideally, the teams studied would be larger in order to reduce the amount of influence any single individual could have on the team-level measurement. I chose to use a multilevel analytical framework in the current study although the more common method would be to use dyadic analysis for this small of a group. However, dyadic analysis is only useful for one very specific context, and thus would have limited the generalizability of the methods used in this study to any other type of team or group. By adopting a more generalizable procedure in the present study, this same methodology can be applied to teams or groups of any size, not only to dyads.

The generalizability of these results is somewhat limited by the sample. Participants were members of newly formed teams rather than established teams. These novice teams may not function in the same way as established work teams. It is also possible that overt communication may be crucial for mitigating the effects of task demands on group stress only during the startup stage for a new work group. Overt communication may also serve to develop a shared mental model of the work process among team members. Thus, as a group develops established working relationships among team members while working on a stable shared group task, established procedures may develop that substitute implicit forms coordination for more explicit coordination via overt communication. For such a group, overt communication may only again become crucial when handling unexpected task demands or perturbations. If these occur often, teams may need to make an effort to actively maintain overt communication between team members in order to better respond to these unexpected task demands or perturbations.

The generalizability of this study's findings regarding the interaction of demand and coordination (with coordination as a form of team-level control) is limited by the choice of measures in the current study. While I was able to provide evidence for the value of team communication as a way to mitigate the stressful effects of task demands, I did not have the measures (i.e., those found in the Job Content Questionnaire) necessary to demonstrate discriminant validity for communication as a distinct task characteristic apart from other known buffers against task stress, such as decision latitude or social support. Follow-up studies seeking to replicate the effect reported here would benefit from using established measures of stress and task characteristics, as well as to establish the discriminant validity of team communication as a distinct construct.

Furthermore, I lacked separate, distinct measures for the individual-level and team-level components of demand, coordination, and stress. Measures were collected at the individual-level; the team-level component had to be approximated through mean aggregation. Use of this method risks multicollinearity between the measures of the same construct at different levels. Expanded measurements could separately capture variance at each level.

While self-reported coordination was a significant predictor of stress in teams, both coordination and stress were measured with the same survey, risking common method bias. I was unable to establish an effective behavioral measure of coordination through speech as an alternative. While Fischer et al. (2007) were successful in using behavioral measures of coordination in larger teams, I was unable to replicate their methods using two person teams only. Future research can continue to explore objective measures of coordination behaviors, as a substitute for subjective perceptions of coordination quality when determining sources of stress within teams.

Together, the results of this study show that the social organization in which work is embedded provides a crucial context in which the worker is an active component as part of a team. Not only are demands and coordination shared at the team level, so is the resulting outcome of stress. These results provide initial support for the proposed Team Job Demand/Control Model as a means of explaining the sources of team-level stress. The Team Job Demand/Control Model provides a framework for understanding team task characteristics and the unique contributions of teamwork processes to worker stress. With the development of new measures suited to field applications, the Team Job Demand/Control Model can be used to guide the development of new interventions designed to create healthy teamwork.

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Tables and Figures

Table 1

Post-Trial Survey (from team task dataset)

Circle the number that best matches your feelings about the statements below.

(All item responses are on a scale from 1, very low, to 7, very high)

1. I think my <u>personal level of performance</u> on this task was:
2. I think the <u>team's level of performance</u> on this task was:
3. The <u>level of stress</u> I experienced during this task was:
4. The <u>level of frustration</u> I experienced during this task was:
5. The amount of <u>effort needed</u> to complete this task was:
6. The <u>mental demands</u> of this task were:
7. The <u>quality of communication</u> on this task was:
8. My <u>ability to concentrate</u> on this task was:

Circle the number that best matches your level of agreement to the statements below.

(All item responses are on a scale from 1, strongly disagree, to 7, strongly agree)

9. I think <u>I am responsible</u> for how well/poorly the team performed on the task.
10. I think <u>my partner is responsible</u> for how well/poorly the team performed on the task.
11. I think <u>the system is responsible</u> for how well/poorly the team performed on the task.

Table 2
Correlations and Reliabilities of Individual Trial-Level, Individual-Level, and Team-Level Measures

	M	SD	1	2	3	4	5	6	7	8	9	10	11	12
Individual Trial-Level														
1 Stress[a]	4.11	1.56	(.90)											
2 Performance	11.28	10.41	-.26**	-										
3 Time	n/a	n/a	-.04	.38**	-									
4 Delay	4.06	1.43	.12*	.06	.02	-								
5 Demand[a]	4.99	1.47	.57**	-.19**	-.05	.14**	(.90)							
6 Communication Quality[a]	4.86	1.42	-.16**	.29**	.12*	-.11*	.04	-						
7 Demand X Communication Quality	.03	1.06	-.20**	-.04	.02	-.04	-.17**	.15**	-					
Individual-Level														
8 Role	n/a	n/a	-.13*	n/a	n/a	n/a	-.19**	-.18**	.05					
Team-Level														
9 Stress[a]	4.11	1.02	.65**	-.14*	n/a	.12*	.46**	-.05	-.16**	n/a	(.92)			
10 Demand[a]	4.99	1.06	.42**	-.12*	n/a	.13*	.71**	.08	-.16**	n/a	.65**	(.95)		
11 Communication Quality[a]	4.86	0.68	-.07	.17**	n/a	-.01	.12*	.47**	.09	n/a	-.11*	.17*	-	
12 Demand X Communication Quality	0.17	1.26	-.08	-.12*	n/a	-.05	-.10*	.05	.46**	n/a	-.12*	-.14**	.11*	-

Notes:
a: Means and standard deviations reported are prior to standardization of the scales.
b: The time variable simply consisted of the number of trials since the start of the experiment, therefore it is not meaningful to report the descriptive statistics for it.
* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Table 3
Correlations and Reliabilities of Team Trial-Level and Team-Level Measures

	M	SD	1	2	3	4	5	6	7	8	9	10	11
Team Trial-Level													
1 Stress[a]	4.11	1.24	-										
2 Performance	11.34	10.42	-.33**	-									
3 Time	n/a	n/a	-.05	.38**	-								
4 Delay	4.06	1.43	.15*	.06	.02	-							
5 Demand[a]	4.99	1.17	.64**	-.24**	-.07	.18*	-						
6 Communication Quality[a]	4.85	1.10	-.28**	.38**	.16*	-.14	-.06	-					
7 Demand X Communication Quality	-0.06	1.15	-.16*	-.15*	.03	-.02	-.14	.14	-				
Team-Level													
8 Stress[a]	4.11	1.02	.82**	-.14	n/a	.12	.58**	-.07	-.10	(.92)			
9 Demand[a]	4.99	1.06	.53**	-.12	n/a	.13	.90**	.11	-.12	.65**	(.95)		
10 Communication Quality[a]	4.86	0.68	-.09	.18*	n/a	-.01	.16*	.62**	.10	-.11	.17	-	
11 Demand X Communication Quality	0.17	1.26	-.10	-.12	n/a	-.05	-.13	.07	.67**	-.12	-.14	.11	-

Note: Means and standard deviations reported are prior to standardization of the scales.
*=p<.05; **=p<.01 (2-tailed).

Table 4
Intraclass Correlations for Individual Trials Within Team Trials

Variable	ICC(1)	ICC(2)
Communication Quality	0.59	0.32
Demand	0.63	0.40
Stress	0.63	0.40

Table 5
Intraclass Correlations for Trials Within Teams

Variable	ICC(1)	ICC(2)
Communication Quality	0.71	0.60
Demand	0.95	0.94
Stress	0.89	0.88
Performance	0.71	0.59
Speech Quantity	0.96	0.96

Table 6
Regression Model for Team-Level Stress

	Model Building		Final Model
Variable	Total R^2	R^2 Change for Block	Beta
Time	0.002	0.002	0.084
Time^2	0.018	0.016~	-0.055
Delay	0.039	0.021*	
Performance	0.160	0.121***	-0.163*
Demand	0.485	0.324***	0.576*
Communication Quality			-0.183*
Demand x Communication Quality	0.492	0.007~	-0.089

~=p<.10; *=p<.05; **=p<.01; ***=p<.001

Table 7
2-Level Multilevel Model for Team-Level Stress; Model Building

Step	Delta df	Delta Deviance	Chi-squared change
Baseline Model			
Time	1	1.05	ns
$Time^2$*	1	7.85	p<.01
Random Time Slope***	2	20.15	p<.001
Random $Time^2$ Slope	2	0.67	n.s.
Autocorrelation Model	1	3.68	n.s.
Heterogeneous Error Model	4	4.46	n.s.
Unrestricted Error Model	11	11.34	n.s.
Level 1 Model			
Delay	1	3.85	p<.05
$Delay^2$	1	0.18	ns
Performance	1	47.34	p<.001
$Performance^2$	1	3.02	ns
Demand and Communication Quality	2	83.43	p<.001
$Demand^2$ and Communication $Quality^2$	2	5.33	p<.10
Demand X Communication Quality	1	6.06	p<.05
Trimming non-significant predictors (Delay, $Demand^2$, Communication $Quality^2$)	3	3.33	ns

*=p<.05; **=p<.01; ***=p<.001

Table 8
2-Level Multilevel Model for Team-Level Stress; Model Coefficients

	Null Model	Baseline Temporal Model	Full Model	Final Trimmed Model
Grand Mean (B0)	0.00 (0.12) (homogeneous)	0.00 (0.13) (homogeneous)	0.00 (0.09) (homogeneous)	0.00 (0.10) (homogeneous)
Trial Level				
Time		-0.03 (0.04)	0.06 (0.03)~	0.07 (0.03)*
$Time^2$		-0.07 (0.03)**	-0.04 (0.02)*	-0.04 (0.02)*
Delay			0.00 (0.05)	
Performance			-0.20 (0.05)***	-0.22 (0.05)***
Demand			0.59 (0.07)***	0.57 (0.07)***
Comm Qual			-0.14 (0.05)**	-0.12 (0.04)**
Demand X Comm			-0.09 (0.04)*	-0.10 (0.03)**
$Demand^2$			0.05 (0.04)	
Comm $Qual^2$			-0.04 (0.02)	
Variance Decomposition				
Trial Level (σ^2)	41.50% 0.41293	30.17 % 0.26433	27.48% 0.12697	27.67% 0.12920
Team Level (τ)	58.50% 0.58207	69.83% .61179	72.52% 0.33515	72.34% 0.33797
Model Fit				
Deviance	474.10	445.04	299.03	302.36
Df	3	7	14	11
Pseudo R^2 (lvl 1)	-	35.99%	69.25%	68.71%
Pseudo R^2 (lvl 2)	-	0%	42.42%	41.94%

*=p<.05; **=p<.01; ***=p<.001

Table 9
Temporal Trends in 3-Level Multilevel Model for Stress of Individuals Within Teams: Model Building

Step	Delta df	Delta Deviance	Sig
Baseline Model			
Time	1	1.47	n.s.
$Time^2$	1	10.87	p<.001
Random Time Slope	4	40.30	p<.001
Random $Time^2$ Slope			n.s.
Autocorrelation Model	1	1.85	n.s.
Heterogeneous Error Model	4	5.14	n.s.
Unrestricted Error Model	11	16.57	n.s.
Level 1 Predictors			
Delay	1	4.30	p<.05
$Delay^2$	1	0.31	ns
Performance	1	54.26	p<.001
$Performance^2$	1	3.90	p<.05
Demand and Communication Quality	2	115.39	p<.001
$Demand^2$ and Communication $Quality^2$	2	3.99	ns
Demand X Communication Quality	1	9.28	p<.01
Trimming non-significant predictors (Delay)	1	0.01	ns
Level 2 Predictors			
Role	1	0.31	ns
Level 3 Predictors – Direct Effect on Intercept			
Mean Demand and Mean Communication Quality	2	0.89	ns
Mean $Demand^2$ and Mean Communication $Quality^2$	2	0.39	ns
Mean Demand x Mean Communication Quality	1	0.00	ns
Level 3 Predictors – Cross-Level Effect Through Role			
Mean Demand	1	0.01	ns
Mean Communication Quality	1	3.62	p=.05
Mean $Demand^2$ and Mean Communication $Quality^2$	2	3.59	ns
Mean Demand x Mean Communication Quality	1	0.00	ns
Trimming non-significant predictors (Mean Demand, Mean $Demand^2$, Communication $Quality^2$, Mean Demand X Communication Quality)	4	3.73	ns

Table 10
Temporal Trends in 3-Level Multilevel Model for Stress of Individuals Within Teams: Model Coefficients

	Null Model	Baseline Temporal Model	Full Model	Final Trimmed Model
Grand Mean (B0)	4.11 (0.16)***	4.11 (0.16)***	4.10 (0.16)***	4.10 (0.17)***
Trial Level				
Time		-0.04 (0.05)	0.08 (0.04)*	0.08 (0.04)*
$Time^2$		-0.09 (0.02)***	-0.06 (0.02)**	-0.06 (0.02)**
Delay				
Performance			-0.04 (0.01)**	-0.04 (0.01)***
$Performance^2$			0.00 (0.00)*	0.00 (0.00)*
Demand			0.78 (0.08)***	0.79 (0.07)***
Comm Qual			-0.16 (0.05)**	-0.16 (0.05)**
Demand X Comm			-0.13 (0.04)**	-0.14 (0.04)**
Individual Level				
Role			-0.13 (.21)	-0.13 (0.22)
Team Level (Through Role)				
Team Demand			-0.06 (0.19)	
Team Comm Qual			-0.37 (0.17)*	-0.32 (0.17)*
Team $Demand^2$			-0.25 (0.17)	
Team Comm $Qual^2$			-0.01 (0.12_	
Team Demand X Comm Qual			0.00 (0.17)	
Variance Decomposition				
Trial Level (σ^2)	37.08% 0.89938	28.56% 0.63150	29.64% 0.37923	27.80% 0.37922
Individual Level (τ_π)	49.88% 1.20987	57.14% 1.26345	59.76% 0.79116	64.92% 0.88537
Team Level (τ_β)	13.03% 0.31615	14.30% 0.31615	11.60% 0.15359	7.28% 0.09927
Model Fit				
Deviance	1271.30	1218.66	1023.87	1027.61
Df	4	10	21	17
Pseudo R^2 (lvl 1)	-	29.78%	57.83%	57.84%
Pseudo R^2 (lvl 2)	-	0%	34.61%	26.82%
Pseudo R^2 (lvl 3)	-	0%	51.42%	68.60%

*=p<.05; **=p<.01; ***=p<.001

Table 11
Regression Model for Team-Level Performance

	Model Building		Final Model
Variable	R^2	R^2 Change	Beta
Time	0.146	0.146***	0.313***
$Time^2$	0.147	0.001	
Delay	0.149	0.003	
$Delay^2$	0.152	0.003	
Stress	0.241	0.095***	-0.145~
$Stress^2$	0.263	0.021*	0.099
Demand	0.334	0.071***	-0.175*
Communication Quality			0.351***
$Demand^2$	0.369	0.35**	-0.043
Communication $Quality^2$			0.198***
Demand x Communication Quality	0.410	0.042***	-0.226***
Speech Quantity	0.413	0.003	
Speech $Quantity^2$	0.413	0.000	

~=p<.10; *=p<.05; **=p<.01; ***=p<.001

Table 12
HLM Model for Team-Level Performance: Model Building

Step	Delta df	Delta Deviance	Sig
Baseline Model			
Time	1	42.38	p<.001
Time^2	1	0.37	n.s.
Random Time Slope	2	37.44	p<.001
Heterogeneous Error Model	4	18.28	p<.001
Heterogeneous Model vs. Autocorrelation Model	3	16.42	p<.001
Heterogeneous Model vs. Unrestricted Model	7	7.28	n.s.
Level 1 Model			
Delay	1	0.07	n.s.
Delay^2	2	4.67	p<.10
Stress	1	19.99	p<.001
Stress^2	1	1.57	n.s.
Demand and Communication Quality	2	16.08	p<.001
Demand^2 and Communication Quality^2	2	10.97	p<.01
Demand X Communication Quality	1	3.91	p<.05
Speech Quantity	1	0.64	n.s.
Speech Quantity^2	2	0.64	n.s.

Table 13
2-Level HLM for Team-Level Performance: Model Coefficients

	Null Model (Homogeneous)	Null Model (Heterogeneous)	Baseline Model (Heterogeneous)	Final Model (Heterogeneous)
Grand Mean (B0)	0 (0.10)	-0.24 (0.07)	-0.02 (0.10)	-0.03 (0.09)
Trial Level				
Time			0.27 (0.05)***	0.28 (0.04)***
Delay				0.04 (0.05)
Delay^2				0.17 (0.05)**
Team Stress				-0.18 (0.07)**
Team Demand				-0.12 (0.08)
Team Communication Quality				0.26 (0.05)***
Team Demand^2				-0.02 (0.05)
Team Communication Quality^2				0.12 (0.03)***
Team Demand X Communication Quality				-0.10 (0.05)*
Variance Decomposition				
Trial Level (σ^2)	78.39% 0.78002	T1: 0.28555 T2: 0.37080 T3: 0.73870 T4: 1.44950 T5: 1.79955	T1: 0.11408 T2: 0.41037 T3: 0.51859 T4: 0.73872 T5: 0.33482	T1: 0.10666 T2: 0.35838 T3: 0.38538 T4: 0.48756 T5: 0.16993
Team Level (τ)	21.61% 0.21498	0.08746	0.32729	0.24434
Model Fit				
Deviance	552.54	526.82	454.44	409.50
Df	3	7	10	14
R^2 (Level 1)				T1: 62.65 T2: 3.35 T3: 47.83 T4: 66.36 T5: 90.56
R^2 (Level 2)	-	-		
Total Psuedo R^2	-	-		

*=p<.05; **=p<.01; ***=p<.001

Table 14
Summary of Results Across Analyses

Outcome	Analysis	Perf.	Stress	Demand	Coord.	D x C	R^2
Team Stress	Regression	−*	n/a	+*	−*	n.s.	.49
	2-level HLM	−***	n/a	+***	−**	−**	.53[1]
Individual Stress	3-level HLM – Trial Level	−***	n/a	+***	−***	−**	
	3-level HLM – Team Level (through intercept)	n/a	n/a	n.s	n.s.	n.s.	.44[2]
	3-level HLM – Team Level (through role)	n/a	n/a	*[3]	−*	n.s.	
Team Performance	Regression	n/a	−~	−*	+***	−***	.41
	2-level HLM	n/a	−**	n.s.	+***	−*	.54[4]

~=p<.10; *=p<.05; **=p<.01; ***=p<.001
Performance and stress are marked as not applicable predictors when they are already included as the outcome in the relevant analysis. Furthermore, in the 3-level model of individual stress, performance is only included at the Trial Level. This is because the only performance scores measured varied within team, across trials; there were no other performance measures to control for at the other levels of this model.

[1] Total modal pseudo r-squared, based on Kreft & de Leeuw (1998) and Singer (1998) formulas.
[2] Total modal pseudo r-squared, based on Kreft & de Leeuw (1998) and Singer (1998) formulas.
[3] For team-level demand, the quadratic trend was significant, but not the linear one.
[4] Due to heteroscedasticity, r-squared varied across trials. Average across trials presented here.

Table 15
Summary of Hypothesis Support Across Analyses

		Outcome: Stress			Outcome: Performance			
		H1A - Demand	H1B - Comm	H1C – DxC	H2A - Demand	H2B - Comm	H2C – DxC	H4
Team Stress	Regression	Yes	Yes	Yes	-	-	-	Yes
	2-level HLM	Yes	Yes	Yes	-	-	-	Yes
Individual Stress	3-level HLM: Individual Level	Yes	Yes	Yes	-	-	-	Yes
	3-level HLM: Team Level through intercept	No	No	No	-	-	-	-
	3-level HLM: Team Level through role	Yes	Yes	No	-	-	-	-
Team Performance	Regression	-	-	-	Yes	Yes	Yes	Yes
	2-level HLM	-	-	-	No	Yes	Yes	Yes

		Team Job Demand	
		Low	High
Team Control	High	Low-Strain Teams	Active Teams
	Low	Passive Teams	High-Strain Teams

Figure 1. The four quadrants of Team Job Demand/Control Model.

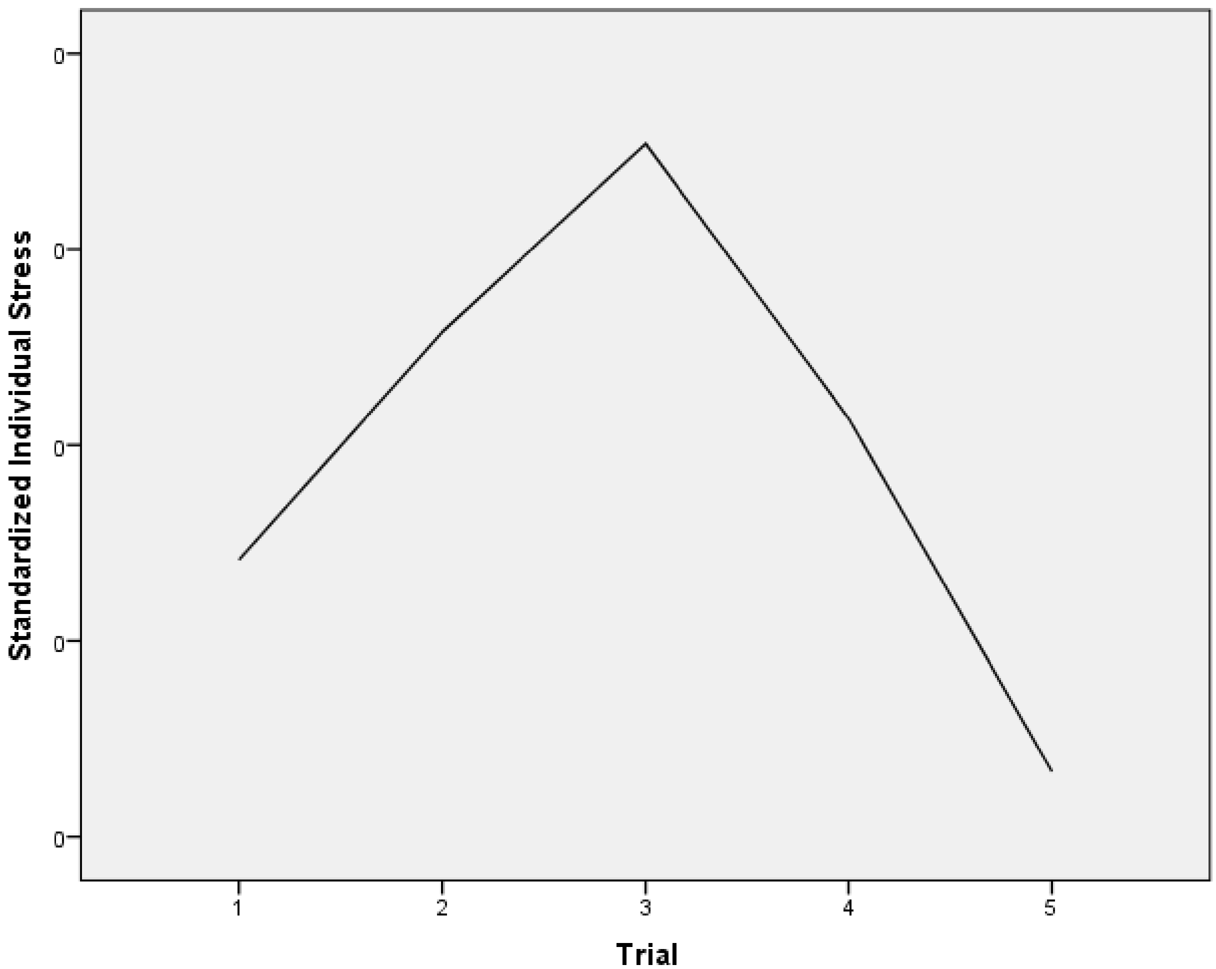

Figure 2. Standardized individual-level stress over time, averaged across individuals.

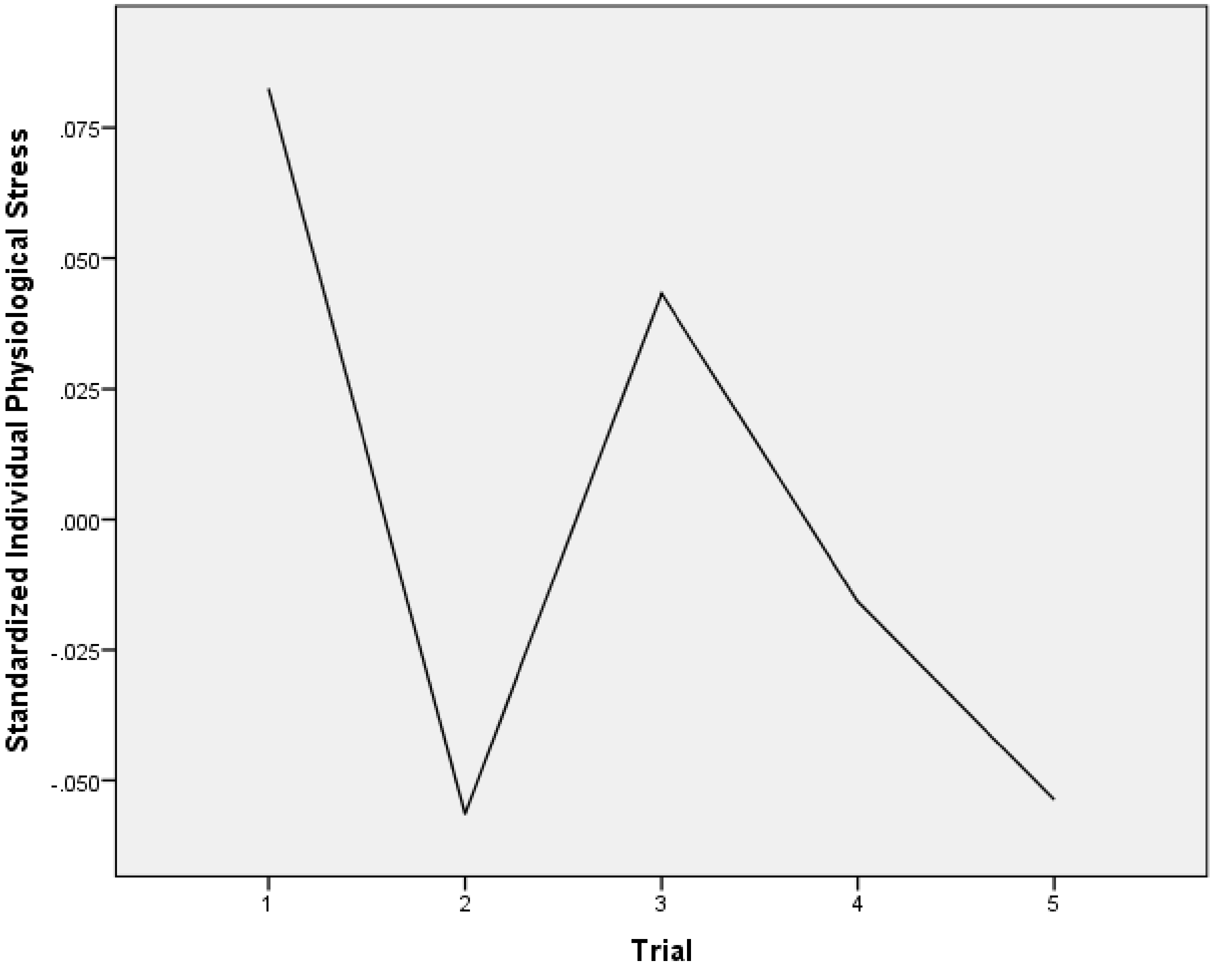

Figure 3. Standardized individual-level physiological stress, as measured by RMSSD of the interbeat interval, averaged across individuals.

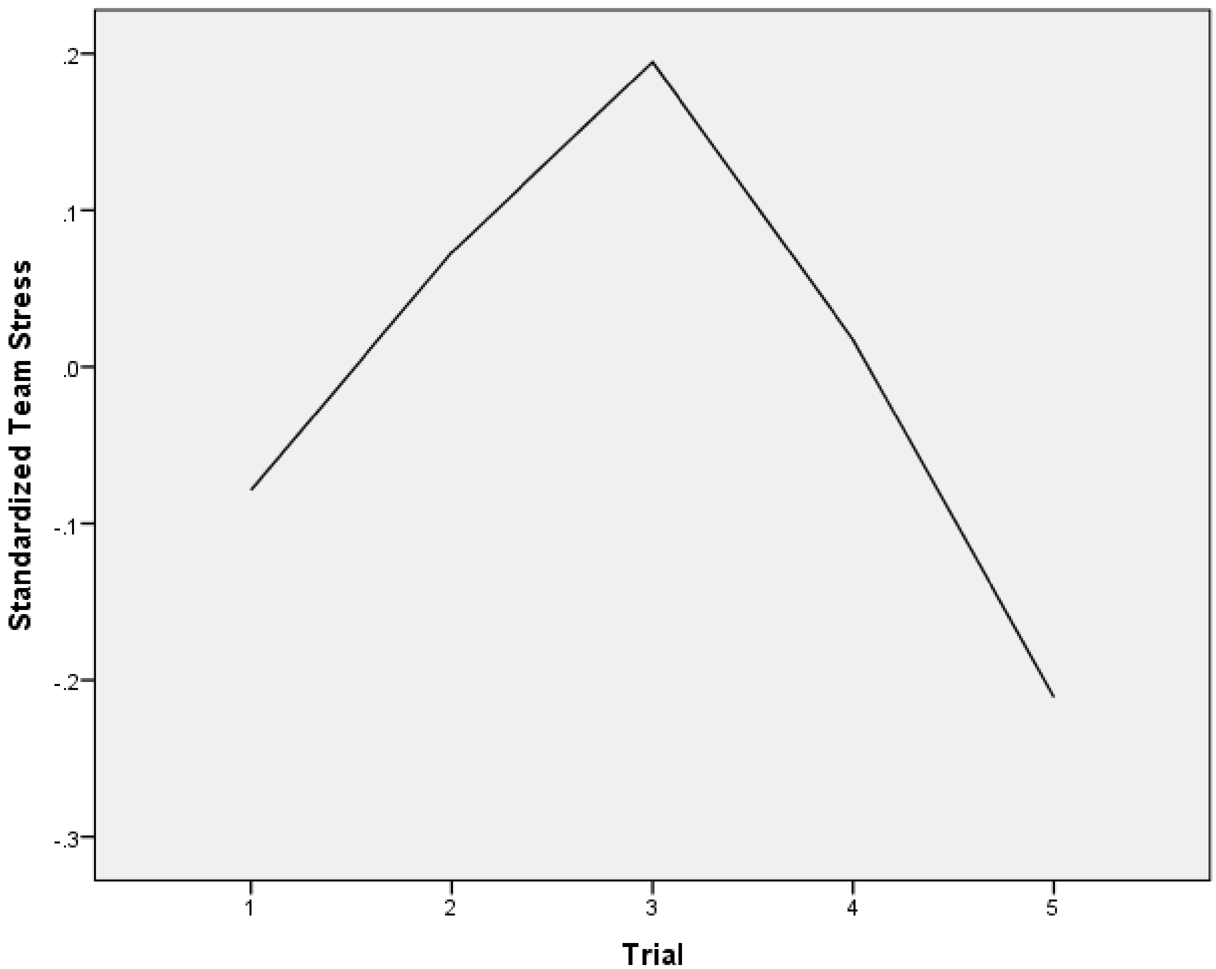

Figure 4. Standardized team-level stress over time, averaged across teams.

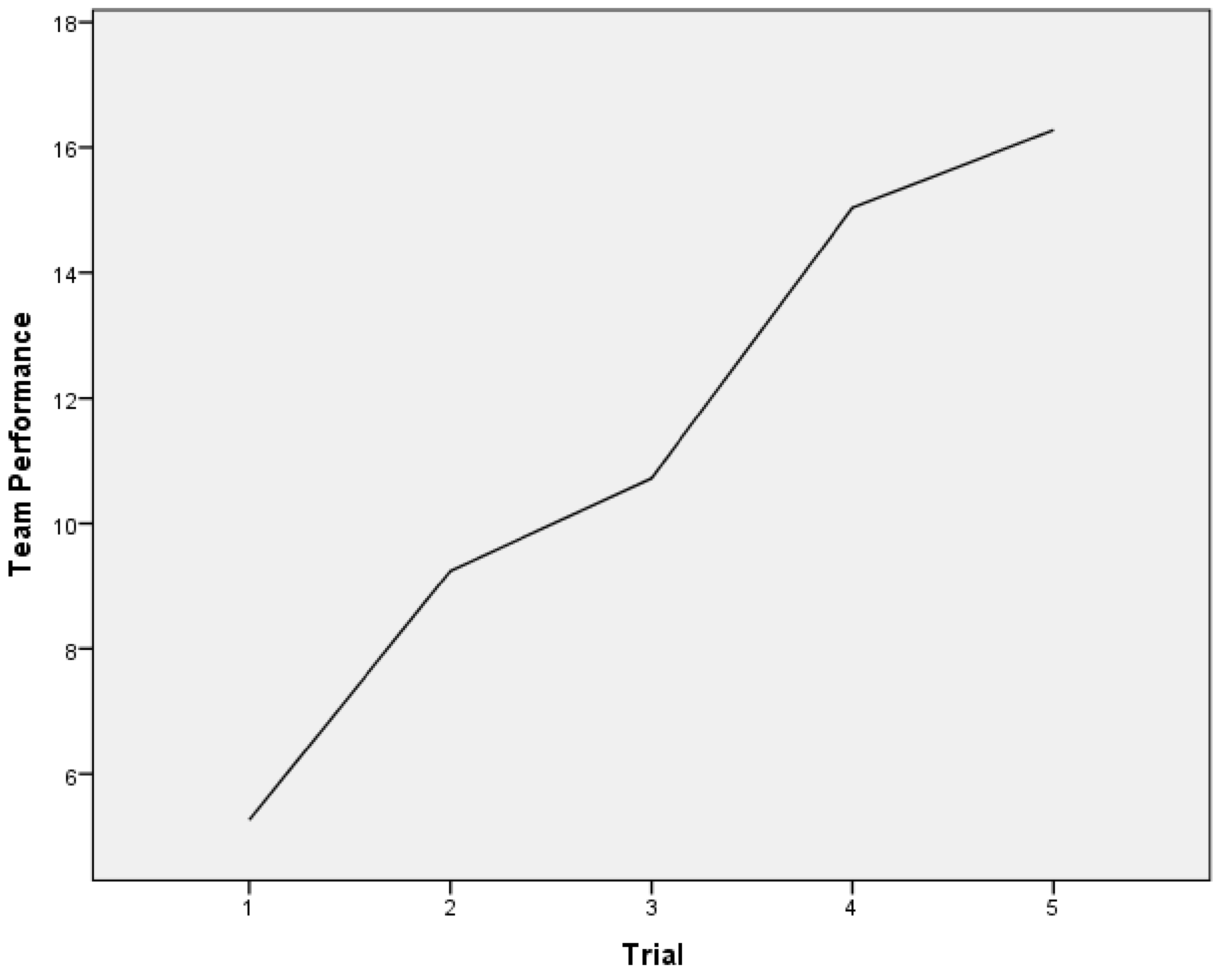

Figure 5. Team performance over time, corrected for freeburn value and averaged across teams.

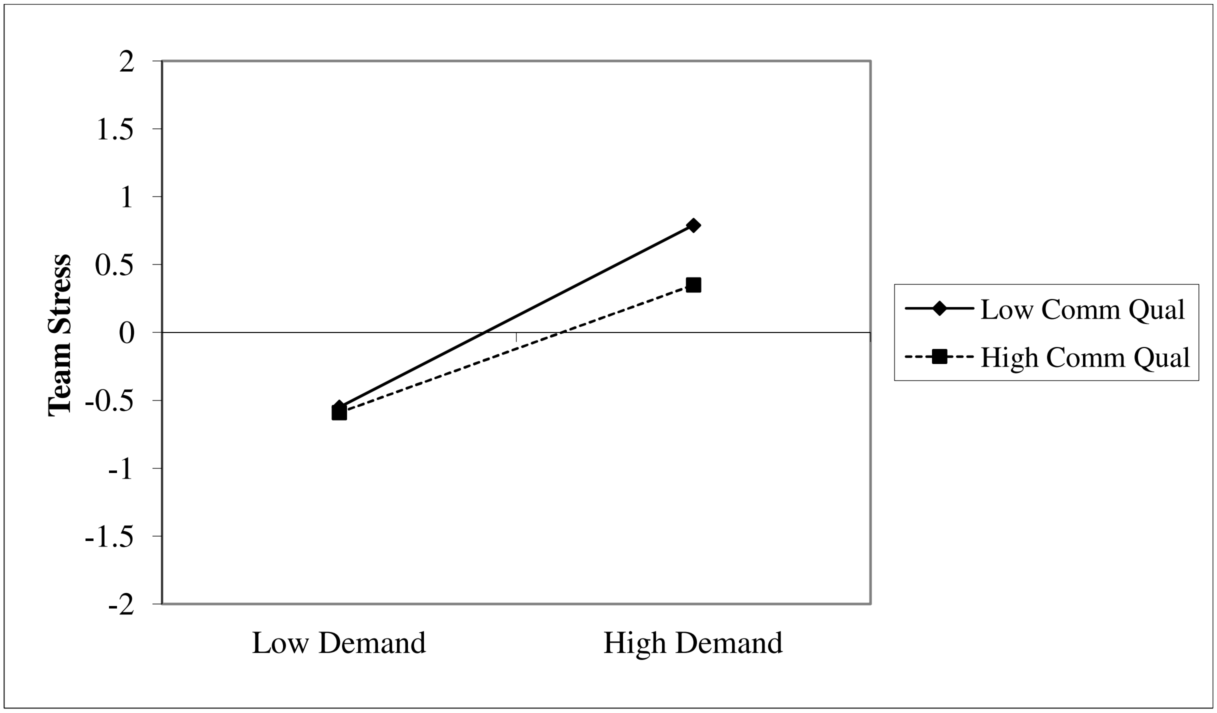

Figure 6. Interaction of team-level demand and communication quality predicting team stress.

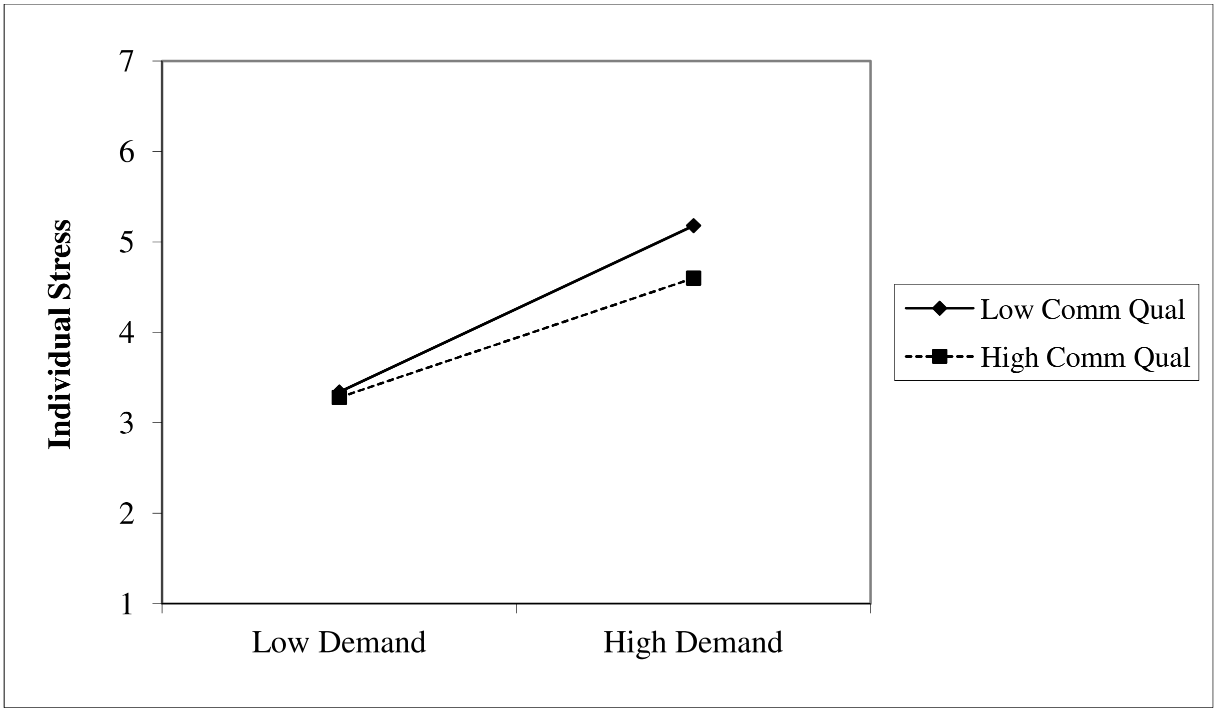

Figure 7. Interaction of individual-level demand and communication quality predicting individual stress.

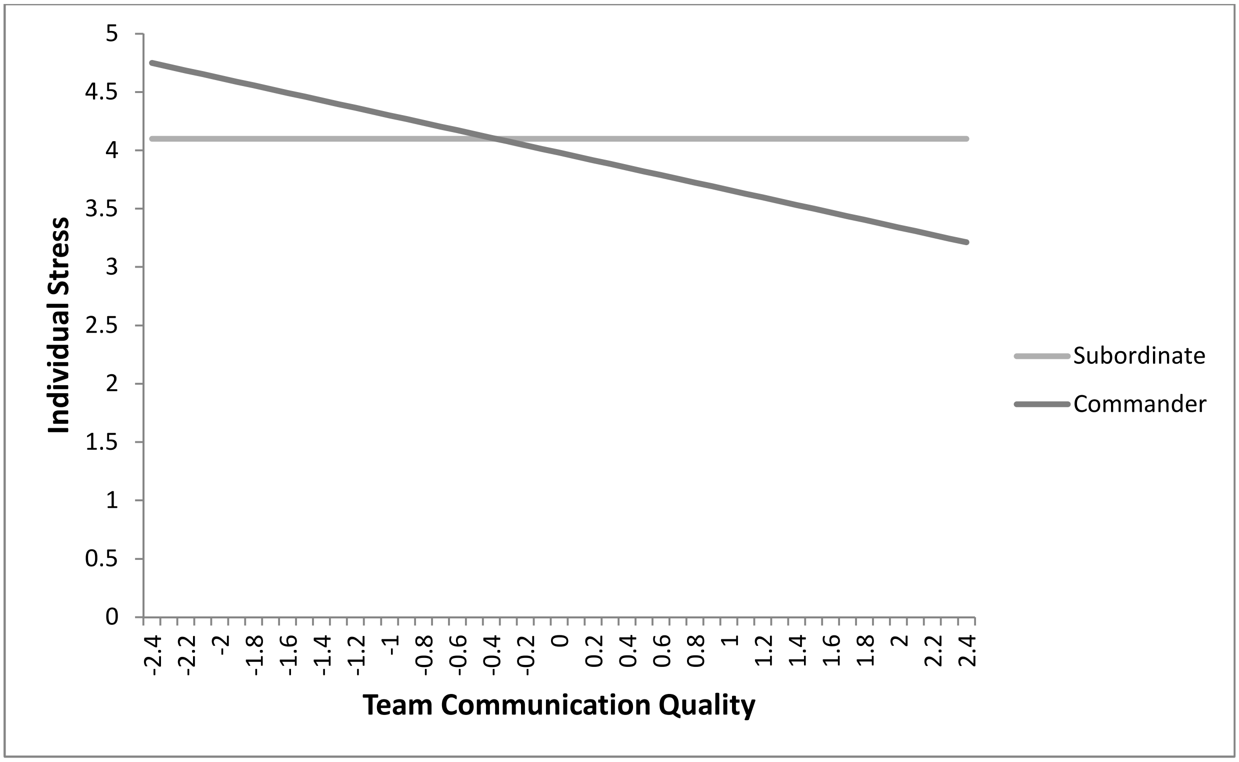

Figure 8. Cross-level interaction of individual role and team communication quality predicting individual stress.

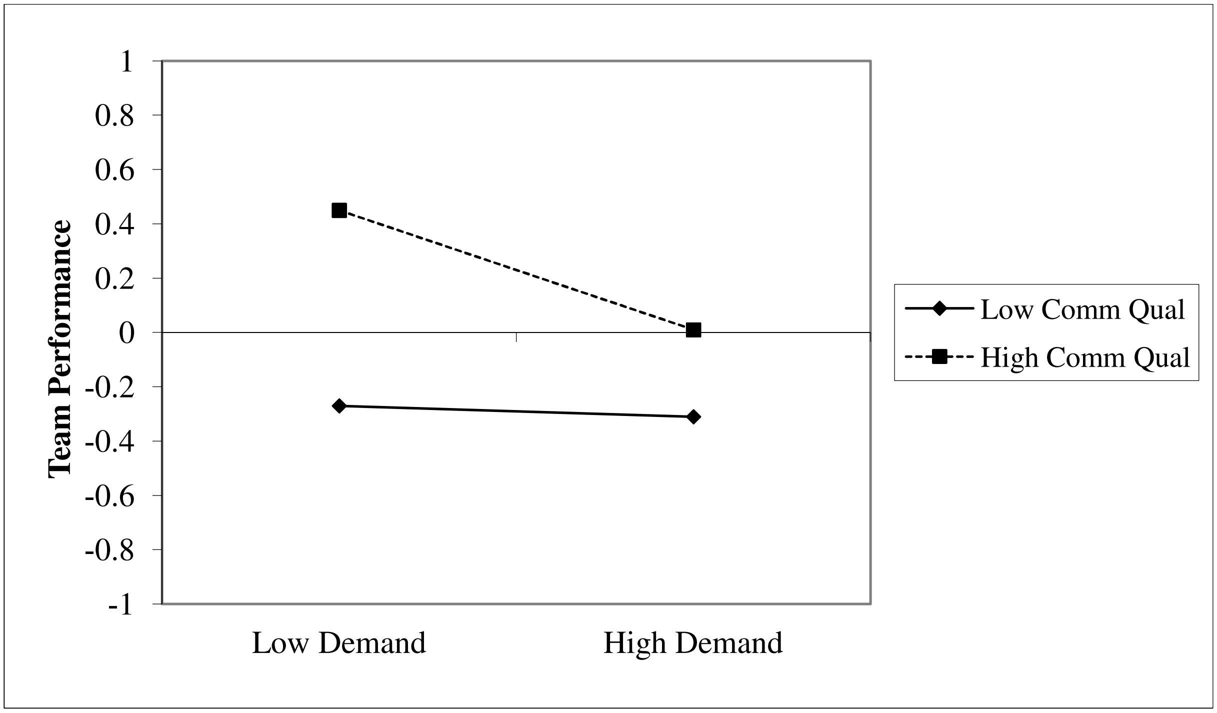

Figure 9. Interaction of team-level demand and communication quality predicting team performance.

Appendix A

Testing Surrogate Measure of Control

Survey items 9, 10, and 11 were proposed as surrogate measures of individual control. According to the JDCS model, control should function to buffer the effects of demand on stress. Although not explicitly stated by the JDCS model, the full model of demand and control as predictors of stress, when taking into account potential curvilinear effects and interactions between the two, would take the form of a quadratic polynomial regression:

$$(1)\ \text{STRESS} = b_0 + b_1(\text{DEMAND}) + b_2(\text{CONTROL}) + b_3(\text{DEMAND})^2 + b_4(\text{DEMAND})(\text{CONTROL}) + b_5(\text{CONTROL})^2 + e$$

Response surface analysis provides a method to visualize this relationship in order to understand how these two variables interact with one another. Therefore surface plots were constructed in order to validate survey items 9, 10, and 11 as surrogate measures of control. These surface plots are presented in Figure A1 through Figure A4. In all figures, the color coding of the surface is used to indicate where the plot falls along the Z-axis, indicating the magnitude of stress associated with the given values of demand and control.

First, a scale consisting of the mean of items 9, 10, and 11 was tested as a possible surrogate for control. Figure A1 shows the relationship between this measure and mean demand as predictors of stress. This scale does not have any clear main effect on stress; it has a weak interaction with demand, but does not function consistently as a buffer across all values of demand.

Since the mean of the three items does not function consistent with the JDCS model's predictions for a measure of control, I instead looked at the items individually. I started with item 9, "I think I am responsible for how well/poorly the team performed on the task." This item interacts with demand to predict stress, but in the reverse direction predicted by the JDCS model. Increased individual responsibility appears to exacerbate the effects of demand on stress. Therefore, item 9 is not a valid measure of control.

Next, I tested item 10, "I think my partner is responsible for how well/poorly the team performed on the task." This item interacts appears to have a weak main effect on stress, but does not interact with demand. Increased partner responsibility simply seems to indicate decreased individual responsibility. When a participant perceived their partner as being responsible for the team's performance, this reduced their own stress. In other words, the less control the individual had, the less stressed they felt. Therefore, item 10 is not a valid measure of control.

Finally, I tested item 11, "I think the system is responsible for how well/poorly the team performed on the task." This item interacts with demand to predict stress, but in the reverse direction predicted by the JDCS model. Increased system responsibility appears to reduce the effects of demand on stress. At least for low levels of demand, the less control the individual had, and the better they were able to deal with task demands. At higher levels of demand this form of responsibility seemed to have little effect on stress at all. Therefore, item 11 is not a valid measure of control.

Overall, this set of items seems to be a poor surrogate for control. Conceptually, control is supposed to mean decision latitude or decision authority, job characteristics that allow the worker greater freedom to meet their job demands. Instead, participants seem to have been interpreting these items more like a form of added psychological demand, in the form of responsibility or culpability for the performance of the team. When responsibility for the team's performance could not be blamed on their partner or the system, the individual reported greater stress. While the relationship between feelings of responsibility and stress may prove to be an interesting area for future research, it does not serve as a good surrogate for control. Therefore, these items were not used as a surrogate for control in the current study, and were dropped from the remainder of the analysis.

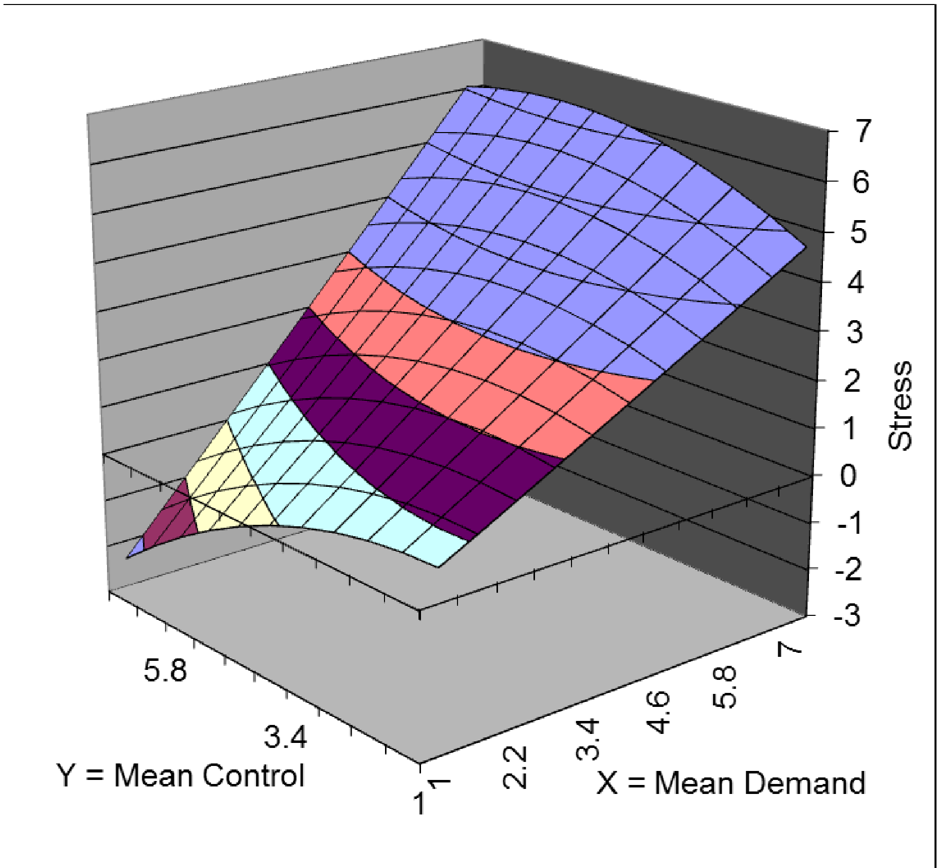

Figure A1: Mean Demand and Mean Control as Predictors of Individual Stress

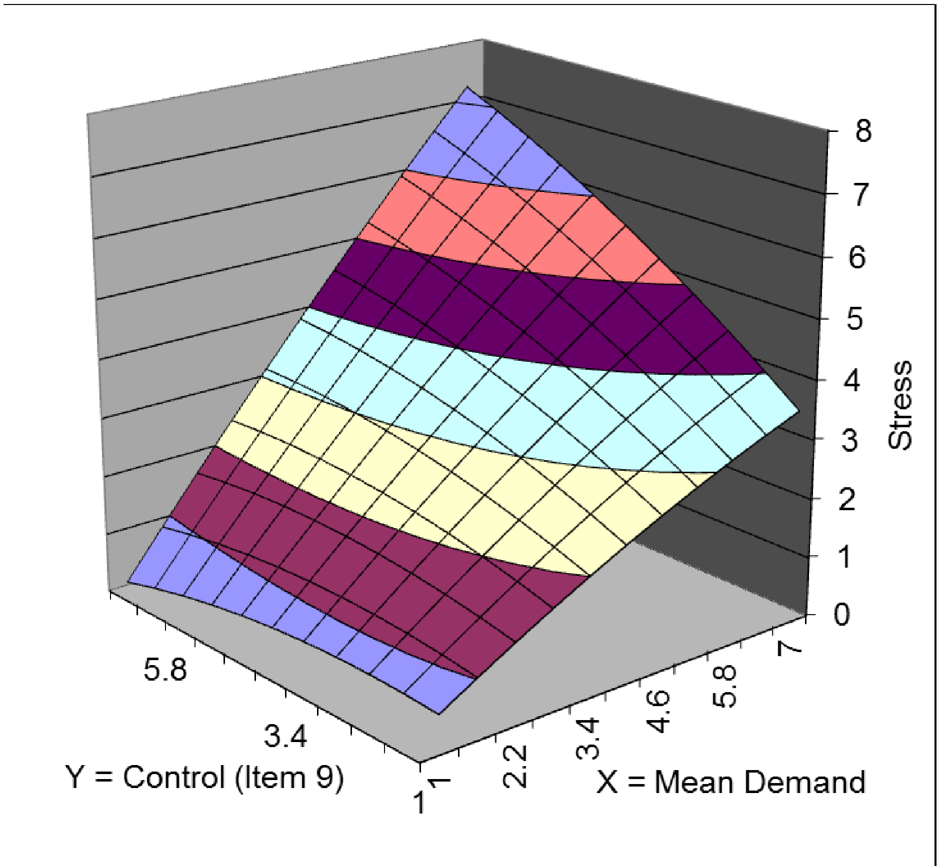

Figure A2: Mean Demand and Control Item 9 as Predictors of Individual Stress

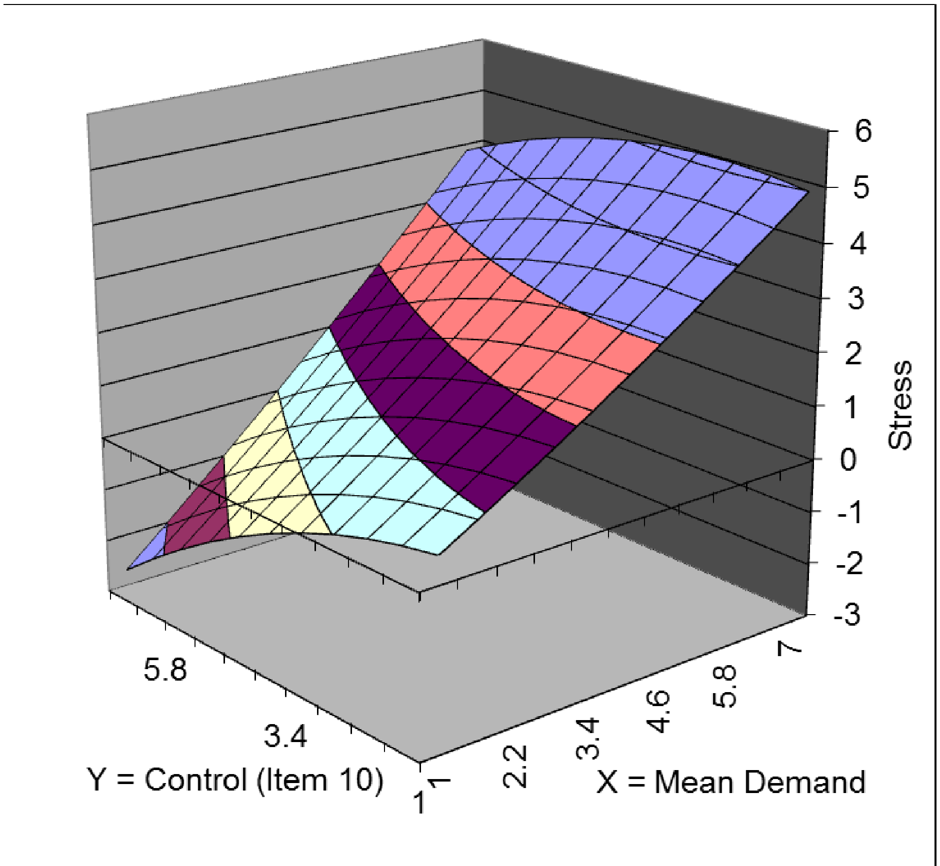

Figure A3: Mean Demand and Control Item 10 as Predictors of Individual Stress

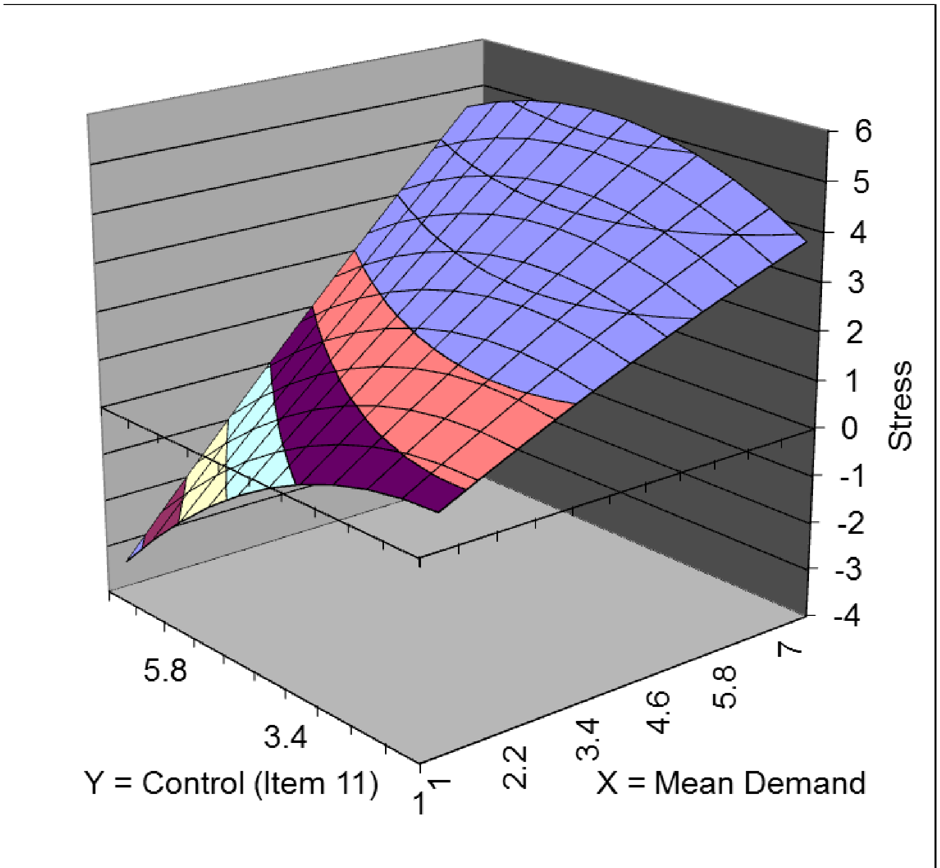

Figure A4: Mean Demand and Control Item 11 as Predictors of Individual Stress