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EFFECTS OF MOOD AND STRESS ON GROUP COMMUNICATION AND PERFORMANCE IN A SIMULATED TASK ENVIRONMENT

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ABSTRACT

In technologically complex work environments, human error is frequently cited as the primary failure in many large-scale accidents. These errors are often attributed to the high physical and emotional stress common in time-pressured and hazardous work environments. Emerging research in human-computer interaction (HCI) suggests that these accidents may also be attributed to errors in system design, particularly those features which fail to account for user frustration, anxiety, stress, and boredom.

Overlapping findings in the stress and emotion research literatures suggest possible interactions between mood states and stressors in terms of their joint impact on cognitive task performance. This research explored these effects further in the context of group task performance.

This research extended the NeoCITIES simulation, a simulated task environment (STE) based around the context of geo-collaborative crisis management, to run team-based human subject experiments designed to explore possible mediating or moderating effects of positive and negative moods on the complex relationship between stress and distributed decision making. These effects were assessed in terms of multiple dimensions of task performance including timeliness and accuracy of resource allocation tasks and content analysis of communications data.

These effects were investigated in two similar experiments, each applying a qualitatively different stressor to teams in happy and sad mood states across a series of within-subjects trials. Performance data, self-reported mood and stress measures, and team communications were analyzed for interactions between mood and stress. The first experiment revealed evidence that negative affect mediated the impact of a task load stressor on team task performance. In the second experiment, the negative mood manipulation diminished team perspective to the extent that participants were unmotivated by a team-level performance pressure stressor. Additional findings provided insight into multiple main effects and interactions between mood and stress on specific communication behaviors and perceptions of within-team cooperation.

Contributions of this study include extensions to the theories relating moods, stress, and team cognition. Among these are demonstrations of both mediation and moderation of stressors by mood states and additional evidence of the orthogonality of positive and negative affect. Methodological advances were made through the development of a new chat coding scheme to analyze within-team behaviors. The study also led to the development of a robust experimental platform for reliably implementing and automating complex psychological manipulations and measures in a team-based simulated task environment. Together these aid in the development of additional studies on team cognition as well as suggest new concerns in the design of systems use in team decision making under stress.

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CHAPTER 1
INTRODUCTION

Scholarly interest in the effects of stress on human performance has risen considerably in the wake of multiple high-profile accidents. Three widely cited examples are the partial core meltdown at the Three Mile Island nuclear plant (Wickens, 1992), the accidental targeting and destruction of an Iranian airbus by the U.S.S. Vincennes (Collyer & Malecki, 1998), and the Exxon Valdez oil spill in Alaska's Prince William Sound, the worst oil spill in U.S. history (Salas, Driskell, & Hughes, 1996). Individual and group cognition have been tested at high levels of many kinds of stressors during the responses to such crises as the September 11, 2001 attacks on the World Trade Center and the 2005 Hurricane Katrina.

These diverse domains share a number of common features: interdependent collaborative work processes, technologically complex environments, ill-structured problems, dynamic and competing goals, and conflicts between organizational norms and personal expertise. Also common among these domains are considerable physical, cognitive, and emotional challenges including time-pressure, high uncertainty, hazardous conditions, and high-risk outcomes (Orasanu & Connolly, 1993). These characteristics are also familiar to those in commercial aviation, emergency medicine, fire-fighting, and police work (Salas et al., 1996)

Retrospective analysis of events such as these often cites operator error as the primary failure (Perrow, 1984), with official reports giving an oversimplified explanation that stress caused the error. The Fogarty report following the Vincennes tragedy concluded that, overall, the officers in charge had performed properly and acted within the rules of engagement, yet "stress, task fixation, and unconscious distortion of data may have played a major role in this incident."

(Fogarty, 1988, p. 63) The simple view is that stress causes mistakes, but it is often unclear which specific sorts of stress – or consequences of stress – are to blame.

Emerging research in human-computer interaction (HCI) suggests that these accidents may be attributed not just to human error during the incident, but to errors in system design, particularly those features which fail to account for psychological states such as frustration, anxiety, fear, or boredom (e.g.Ahn & Picard, 2006; Hudlicka, 2003; Kapoor, Burleson, & Picard, 2007). In such dynamic and difficult work environments, the effects of stress and emotion are both factors worth investigating, though the emotional components tend to be subsumed by the more popular target of stress. As a result, emotions are less frequently discussed in detail due to the overwhelmingly negative emotional connotation of stress in the research literature.

Stress is not consistently detrimental to all aspects of performance. Indeed, in certain contexts (such as military training) some stressors are not only expected, but serve to motivate operators to high levels of performance (Morris, Hancock, & Shirkey, 2004). However, the task or environmental characteristics that make a stressful situation beneficial or detrimental to performance are unclear. In order to find more clarity in this matter, this study explored whether emotional responses to these characteristics were playing a mediating or moderating role in the relationship between stress and performance.

To explore these issues it is necessary to conceptually differentiate stress and emotion while unpacking their relationship to each other. This is an ambitious task. Both stress and mood consist of multiple complex dimensions. “High stress” and “low mood” are phrases that may work colloquially but are otherwise unquantifiable statements. There are ongoing debates in the literatures of emotion and stress regarding which models best capture how each construct truly operates in the context of human cognition and behavior. These individual battles have spilled into each other in some cases to debate whether stress includes emotional dimensions or if stress itself is subsumed among the emotions.

Research into these problems must explore both individual and distributed cognition in context in order to understand the specific interrelationships of multiple actors in the technologically complex group situations described above. Many bodies of research investigate the effects of specific emotional conditions or stressors upon individual cognitive activities, but research in these topics at the group level is far less common. In this study, careful manipulations of mood and stress states were applied during group problem solving tasks to try to draw out what really happens within and between individuals when working under stress.

DECISION MAKING UNDER STRESS

Classical views of decision making maintain that emotions and stress derail otherwise optimal rationalistic thought. Poor decisions are frequently criticized for having been made with emotion rather than reason (Hammond, 2000). Contemporary views of naturalistic decision making, on the other hand, are interested in how severely stressed decision makers can perform as well as they do in spite of a demonstrable departure from rationalistic decision processes. In fact, even *unstressed* individuals depart from normative, rationalistic decision models (Klein, 1998).

The Recognition-Primed Decision (RPD) Model (Klein, 1993) describes how individuals utilize expertise to make rapid and accurate decisions in complex situations without systematically evaluating multiple courses of action. When cues or patterns in a given situation are recognized as a known case, the appropriate course of action is immediately selected without further analysis. In less typical cases, mental simulations generate potential solutions until the first one that appears to work is selected as the course of action. No further time is spent weighing options against each other. The RPD model has been applied extensively to domains in which critical (often life or death) decisions must be made on a moment's notice, such as fire fighting, crisis response, and emergency medicine. Recognition-primed decision making actually harmonizes *better* with stressors than do strictly rational decision methods, especially for experienced decision makers. The challenges posed by stressors (such as noise, pain, or time pressure) to attention, memory, and information gathering are more disruptive to structured decision systems than to recognitional methods (Klein, 1998).

If most decisions in complex work domains are made by groups, does RPD apply to group decision making? Hayne, Smith, and Vijayasarathy (2005) extended the RPD model to determine whether this pattern recognition strategy could function at the group level. Three-member distributed teams playing a strategy game against a computer were supplied with a tool to share pattern "chunks" between members. Use of the tool increased collective pattern recognition by the team, while outcome quality was unaffected by time pressure. This serves as one demonstration that characteristics of the RPD model may also be observed in group decision making tasks. The tasks implemented in this study rely on effective distributed cognition for successful results, which provides the opportunity to further explore the characteristics and results of team decision making under stress.

DISTRIBUTED COGNITION

In the context of group work, cognition does not stay neatly confined to the individual level. The theory of distributed cognition (Hollan, Hutchins, & Kirsh, 2000) extends the concept of cognition beyond one individual's skull to identify cognitive processes distributed among multiple individuals and objects in an environment over time. Three primary questions in distributed cognition are: (1) how do individual cognitive processes map to group activities, (2) what are the differences between individual and group cognitive processes, and (3) how do group activities shape individual cognition? Research on distributed cognition relies extensively on fieldwork, recordings of actual work practices, as well as simulations and experiments. This approach is ideally suited for research in computer-supported cooperative work (CSCW). It helps to identify mismatches between work practices and technological artifacts which aids in the development of enhanced systems and procedures. It reveals tendencies and behaviors that will not emerge in the studies of individuals.

Team performance research simultaneously considers the individual and group level of analysis. Only individuals perform actions and experience stressors in an environment; the team as an entity does not *do* or *feel* anything. Yet the regulating processes and collective outcomes of these interactions are clearly in the domain of group activity. Researchers are often challenged to distinguish which aspects of a problem belong to the individual and which belong to the group. In this study, actions and behaviors have been captured at both levels in order to better understand which are which. This data in turn painted a picture of distributed cognition in action.

The concept of *team* requires further definition, particularly in comparison to the term *group*, as the two are often used interchangeably in the literature. Of the two, *group* is the more general term. Groups tend to consist of a less-differentiated membership, coalesce for a given goal, and then disband. Teams generally have a shared history, a projected future, and distinct functions and roles. These are not rigid distinctions, as flexible teams may often interchange roles or redistribute tasks (Brannick & Prince, 1997). In the context of this study, the term *team* refers to a collection of individuals organized in such a manner to serve a function (e.g. police department) for a host organization (e.g. municipal emergency center). To manage a complex event, multiple teams (for example, the police and hazardous materials services) may have to share information and coordinate activities to address a compound threat (such as an overturned chemical truck) as a group.

TEAM DECISION MAKING UNDER STRESS

Multiple theories exist to explain the effects of various stressors and emotions on attention, problem solving, and decision-making in individuals. These have been tested experimentally across a broad range of psychological perspectives: cognitive, behavioral, social, and clinical. However, they have rarely been studied within the context of distributed cognition and group activity. This research gap is partially due to the challenges met in experimentally controlling and measuring several independent and interdependent actions leading toward a group outcome. Other very justifiable reasons include the ethical and technical difficulties in recreating realistic crisis environments to examine group decision making under stress. Many laboratory experiments on stress and emotion utilize highly-abstracted cognitive tasks, such as letter or word recognition (e.g. Gasper, 2003; Mathews, May, Mogg, & Eysenck, 1990; Mogg, Mathews, Bird, & Macgregor-Morris, 1990), or puzzle-solving tasks, such as the Prisoner's Dilemma Game (Axelrod, 1980). Ideally, the interaction and overlap between these theories would be best studied on human subjects in an environment similar to the real setting of the problem, but with the experimental control afforded by laboratory research. One possible solution to this problem is the simulated task environment (STE). This experimental approach facilitates a safe and effective approach to examine specific cognitive and behavioral phenomena with high ecological validity (Gray, 2002).

The STE selected for this research, NeoCITIES, utilizes resource allocation problem scenarios designed with the help of real-world intelligence analysts and field studies in rural, metropolitan, and state-wide emergency response centers (Jones, McNeese, Connors, Jefferson, & Hall, 2004). The domain of emergency crisis management comprises multiple distributed teams responsible for the safety and welfare of a given geographic area. In the peak of a crisis response, individuals within these teams can be subjected to severe emotional and physical challenges, yet must sustain high-cognitive demands in terms of attending to, retaining, processing, and communicating information within and between teams. In NeoCITIES, this group activity consists of distributed individuals jointly gathering information about emergency events, allocating the appropriate type and quantity of resources to address those events, and detecting emerging threats and patterns of activity from the underlying scenario. The group has a complex structure – a team of teams – consisting of three dyads in which each member has a distinct role. This experimental approach provides a holistic assessment of distributed cognition by returning real-time performance metrics, tool use behaviors, and team communication measures.

RESEARCH OBJECTIVES

There is a clear need to study group decision making in its natural setting in order to develop effective decision-support technology, training, and operational practice. Previous studies have tested the effects of specific kinds of stress and mood states upon specific aspects of individual cognition in controlled laboratory settings (e.g. Braunstein-Bercovitz, 2003; Keinan, Friedland, Kahneman, & Roth, 1999). This dissertation, however, reviews and merges findings across the stress and emotion literatures to determine how these effects may manifest in concert in a realistic distributed decision making context. By conducting experiments with human subjects in a STE employed as a "stress simulator" (Yates, Klatzky, & Young, 1995), this research aims to clarify the effects and interactions of specific stressors and moods in complex group decision making tasks.

The primary goal of this research is to improve our understanding of the complex relationship between stress, mood, and group decision making within a simulated task environment. This begins with reviews of the concepts of stress and mood in chapters 2 and 3, respectively. Chapter 4 explores the intersections between the two to justify proposing that mood may be mediating or moderating the effects of stress upon group task performance. This chapter also presents the hypotheses designed to test for those relationships.

Chapter 5 describes the NeoCITIES simulation in detail. To meet the requirements of this study, the NeoCITIES simulation has been extended to support and range of psychological manipulations and measures which are detailed in chapter 6 along with the full experimental methodology. The results of the two experiments conducted are presented in chapter 7. Finally, chapter 8 includes a detailed discussion of these results, followed by the limitations and contributions of this work, plans for future experiments, and an exploration of the practical implications of this work.

BROADER IMPACTS

Group decision making under stress is an ever-growing concern for the domestic and international community as the government, military, and civilian sectors are all showing a shift to larger-scale, distributed, and asynchronous joint efforts for humanitarian response, counter-terrorism efforts, and military actions (McNeese et al., 2006) The emergency management domain utilized in this study serves as an example of a command, control, and communications

(C^3) structure aiming to supply geographically distributed individuals with a common operational picture. As such, the findings of this and future studies are intended to suggest procedural and technological interventions that may help to compensate for (or harmonize with) the inescapably challenging conditions of multiple C^3 domains including military operations, air traffic control, and geo-collaborative crisis management.

CHAPTER 2
STRESS

Multiple vectors of research intersect the phenomena related to group decision making under stress. Complicating matters is the vague and overlapping usage of concepts like *stress*, *stressor*, *emotion*, and *mood*. Some studies refer to "emotional stress" or "stressful moods" (e.g. Christine L. Sheppard-Sawyer, 2000; Matthews, Dorn, & Glendon, 1991) This chapter begins to discriminate among these concepts by examining multiple conceptualizations of stress and reviewing the interactions between this concept and individual and distributed cognition. Chapter 3 continues this effort by examining mood states, and chapter 4 explores the intersections and interactions between mood and stress.

CONCEPTUALIZATIONS OF STRESS

It is commonplace for someone to claim to be "stressed-out" or that a particular encounter was "stressful." The concept of stress may be found as an independent variable, a dependent variable, or a process (Cooper, Dewe, & O'Driscoll, 2001). In its colloquial form, stress may be broadly defined as the opposite of relaxation. However, the specific causes, characteristics, and effects of stress bridge psychological, behavioral, and physiological phenomena. This leads to multiple conceptions of stress depending on the orientation of the research at hand. In this research, the focus is on short-term or situational stress as found during critical incidents or crises, rather than the long-term stress associated with a hazardous career or strenuous living conditions.

Human stress research first emerged from work of two 19th century experimental physiologists, Claude Bernard and Walter Cannon. Bernard (c.f. 1961) argued that organisms survive by regulating their internal environment according to changes in the external environment, a process called “homeostasis.” Cannon demonstrated how animals experience significant deviations from homeostasis (e.g. elevated heart-rate and dilated pupils) when presented with a stressor such as another predator animal, which led to his proposal of the “fight or flight” response (Cannon, 1929).

Hans Selye (1956) later developed a systematic model of this biologically deterministic approach. He defined the stress response, or *strain*, as a deviation from an individual’s homeostatic stability, and defined a stressor to denote the external event or condition causing the stress. In this context, stress in excess, or *distress*, is seen as a disease or syndrome leading to poor health. Selye also identified *eustress*, or good stress, which may stimulate faster or more effective performance. The term “stress” in general usage has become synonymous with Selye’s concept of *distress,* while *eustress* is discussed far less frequently.

A systems model of stress adopts the broad definition that “a situation is considered stressful if it puts pressure on the individual to perform more accurately or faster or differently from his normal mode” (Solley, 1969, p. 1). Socio-behavioral studies of stress define stress as challenging life events or hassles in daily life which lead to unhealthy behaviors, such as substance abuse (Cerbone & Larison, 2000). Family stress theory defines stress as critical life or work events which have a negative impact upon the family (Boss, 1987). Organizational stress theory, the domain most closely aligned with the proposed research, defines it as individuals’ perception of work events combined with their dispositional traits resulting in psychological, physiological, or behavioral strains (Cooper et al., 2001). Note that the systems model stands out as a motivational viewpoint on stress, while the rest associate stress solely with negative outcomes.

From the diverse range of definitions above, stress may be described as a generalized phenomenon with no specific cause and a broad spectrum of effects. Though it is often spoken of as an emotion-like state – "I'm feeling stressed" – stress itself appears to be a process. The definitions descending from the classical views of stress as defined by Cannon and Selye are limited in that they view the stress response as an automatic reaction to something objectively identified as a threat. This one-size-fits-all viewpoint can not readily account for differences in stress responses between individuals or situations. More recent stress research has shown that the psychological process of appraisal, in which a person ascribes meaning to a potentially threatening situation, is generally much more relevant to the stress response than the objective characteristics of the situation. Two individuals experiencing the same objective threat may appraise it differently, and therefore experience two radically different stress responses. Even the same person may appraise identical threats differently on different occasions.

Most contemporary research on stress in the context of work and performance refers to Richard Lazarus' transactional model of stress (Lazarus & Folkman, 1984). According to this model, stress is characterized as the relationship between the perceived demands of the current situation and the individual's ability to respond. When the demands appear to outweigh the ability to respond, the individual experiences stress. The process of appraisal is central to the transactional model. Primary appraisal is the evaluation of the personal relevance of the threat, as well as the potential challenge or harm it may carry. Secondary appraisal is the assessment of the individual's capacity to cope with that particular threat. The discrepancies between the primary and secondary appraisals drive the stress response. This transactional definition states that stress is neither the environmental stimulus, nor the individual response, but the relationship between the two. Therefore, what seems stressful for one individual may be unremarkable for another.

The quality of the appraisal predicts the type of response to the stressor. If the situation is deemed a *threat*, the expectation is of imminent harm, leading to feelings of fear and anxiety. On the other hand, if the situation is appraised as a *challenge* (i.e. the demands still exceed the resources to respond, but in a qualitatively different way), the individual may instead experience feelings of confidence and motivation. The bulk of organizational stress research dwells on the type of stress deemed to be a threat, rather than a challenge. This may explain the persistent association of stress with negative affect, as well as the predominant notion of stress as an impediment to performance.

Lazarus' model defines *coping* as "cognitive and behavioral efforts to manage specific external and/or internal demands that are appraised as taxing or exceeding the resources of the person" (Lazarus & Folkman, 1984, p. 141). Following the stress response, which may be one or more of the physiological and emotional reactions mentioned above (and defined in more detail below), the process of coping encompasses the changes in performance style and efficacy observed in individuals performing tasks in a stressful environment. These changes are among the dependent measures of this study.

STRESSORS AND STRESS

It is difficult to use the terms "stress" and "stressor" consistently. In some cases, stressors cause stress. In others, individuals encounter stress and experience strain (cognitive and otherwise). External viewpoints of stress focus on defining and measuring environmental factors causing changes in an individual's psychological or physiological state. Fisher (1984) offers the broad operational definition that stress is "any condition which causes a stress response." In this sense, stress is defined as any common stimuli (heat, noise, fatigue, etc.) experienced beyond the bounds of what would be considered normal and producing a recognizable physiological, cognitive, or behavioral response.

Viewpoints of stress as an internal bodily reaction are not concerned with the characteristics of the stressor (i.e. stress has no specific cause), alarm reactions to the stressor (being startled), or non-specific qualitative assessments of stress. From this perspective, stress is identified in specified ranges of physiological and psychological responses. The two primary components of these responses are modulations of the sympathetic nervous system (SNS) and hypothalmic-pituitary-adrenal (HPA) activation, though other systems in the central and peripheral nervous systems may be measurably affected.

Organizational stress research proposes additional non-physical stressors to the above definitions. Cannon-Bowers and Salas (1998) identified the following list of stressors observed among Naval crews:

- Multiple information sources
- Incomplete, conflicting information
- Rapidly changing, evolving scenarios
- Requirement for team coordination
- Adverse physical conditions (e.g. heat, noise, sleep deprivation)
- Performance pressure
- Time pressure
- High work/information load
- Auditory overload/interference
- Threat (p. 19)

From the organizational viewpoint, stress may consist of simultaneous reactions to external conditions (e.g. time pressure), as well as internal states (e.g. feelings of social inadequacy). For example, Driskell and Salas (1991) operationalized stress as both a threat to the individual's well-being as well as an increase in personal responsibility for group task outcome. Performance pressure has been manipulated experimentally as context-specific stress (e.g. pre-exposure to graphically intense scenes related to the context of the task) which was found to increase the subjects' motivation to succeed (Morris et al., 2004). Other organizational factors relevant to stress include social support in the workplace (Parkes, 1980) and work pace (Broadbent & Gath, 1981).

Operationalizing and Measuring Stress

As there are multiple conceptualizations of stress, there is accordingly a diverse range of approaches for manipulating and measuring the presence, magnitude, and impact of stress. For this research, the unit of observation for stress was the individual, while impact, in the form of task performance measures, was observed at both the individual and group level.

External stress stimuli are operationalized by either measuring or manipulating the external forces acting upon the individual. The stressful tasks administered to subjects may be inherently challenging (such as highly difficult arithmetic operations) or may be routine tasks administered in an adverse environment. Physical stressors have been operationalized in the lab using mild electric shocks or immersing the subject's arm in ice cold water (Aldwin, 1994). Driskell, Salas, and Johnston (1999) manipulated stress in a group decision task through the presence or absence of auditory distractions, high/low time pressure, and high/low task load. Many studies have used extremes of temperature to induce stress (Hancock, 1986).

Certain psychological states are also considered to be precursors to the stress response. The Everly Stress and Symptom Inventory (ESSI) and Impact of Event Scale (IES) (Horowitz, Wilner, & Alvarez, 1979) are surveys used as predictive instruments as well as screening devices. Though internal to the individual, stress measured in this way is seen as a cause, rather than an effect.

Internal stress responses are operationalized through the measurement of physiological responses. SNS activation in the form of positive changes in heart rate and blood pressure indicate the presence of a stressed state. Increases in skin conductance and decreases in skin temperature also indicate stress (Meehan, Insko, Whitton, & Brooks Jr., 2002). Somatic nervous system activation may be assessed via electromyography of the frontalis muscles of the forehead. Increased electrical activity indicates a response to stress. Additionally, increased cerebral activity in response to stress may be measured using an electroencephalogram (EEG) or cerebral blood flow velocity (CBFV) measured using Doppler sonography. CBFV also reveals hemispheric differences in stress response. These techniques provide real-time measurement over the duration of the experimental task, while survey measures are limited to snapshots in time, usually before and after the task. The intrusiveness of physiological measurement equipment needs to be considered carefully with respect to the tasks and setting of the stress experiment.

The transactional perspective focuses on the individual's perception of stress. Multiple self-report measures are used to measure subjective stress states. The Dundee Stress State Questionnaire (DSSQ) assesses the individual's present task engagement, distress, and worry (Matthews et al., 2002) through responses ranging from 1 (not at all) to 5 (extremely). These three factors closely match the classical "mental trilogy" concept of conation, affect, and cognition (Hilgard, 1980). Engagement includes energetic arousal, motivation (as interest as well as to succeed), concentration, task focus, and appraisal of the event as a challenge. High engagement generally enhances an individual’s control over attention and effort. Distress includes tense arousal, low confidence, emotional focus, and appraisal of the event as a threat. High distress tends to disrupt executive control and inhibit multitasking as individuals attempt to alleviate overload. Worry involves self-consciousness, cognitive interference (both personal and task-related), avoidance behaviors, and appraisal of the event as a failure to attain a goal. High worry diminishes global cognition as individuals reassess the personal relevance of the event.

Several context specific stress assessments exist, such as the Combat Exposure Scale (CES) which quantifies combat-related stressors (Keane et al., 1989). In cases where workload is used to manipulate stress, the NASA-TLX (Hart & Staveland, 1988)is a widely-used workload assessment tool for high-demand settings which provides a self-reported score from 0 to 100 computed from the weighted average of six subscales.

Reliability and Validity

Two primary concerns with using self-report questionnaires in stress research are their intrusiveness in the experimental situation and their potential to prime or condition subjects to the stressful stimuli. The DSSQ has proven to be an effective assessment of stress reactions, yet its length, 90 questions, makes it a fatiguing instrument where multiple measurement points are required. The Short Stress State Questionnaire (SSSQ), based on the DSSQ, provides a rapid and reliable assessment of the same three primary dimensions with only 24 questions (Helton & Garland, 2006). The NASA-TLX is used to assess the task load of a wide range of work situations with high reliability. However, the relationship between task load and stress is often an indirect one. Shorter, more contextually targeted surveys such as the CES have shown high construct validity within their intended domain when care is taken to ensure the experimental context is aligned with the assumptions of the survey instrument.

Physiological measurements such as heart rate, skin conductance, and skin temperature provide highly sensitive and real-time measures of the stress responses, which are difficult for the subject to "fake" or consciously control. EMG assessment of stress response is vulnerable to some consistency issues, including training subjects to relax the muscles prior to testing, as well as sensitivity to inconsistent electrode placement and skin preparation. A complication with most psychophysiological techniques is that these sensitive measures are also subject to measurement noise from the subject's involuntary movement or other environmental factors. Usage without proper protocols will negatively impact the reliability and validity of such measures.

Many laboratory measures of stress suffer from sensitization effects. After repeated exposures, the stimulus stressor may produce a gradually diminishing response. This reduces the test-retest stability of the measure. In addition, as multiple distinct stress responses may impact the same physiological measure (e.g. blood pressure), it may be difficult to establish discriminant validity. An alternative approach which partially addresses both of these problems is to additionally measure the time required for the autonomic response to return to its pre-stimulus level, rather than focus solely on the magnitude of the stress response. However, this only identifies the response factor having the greatest impact. This approach has reduced construct validity, as it masks lesser stress response factors (Everly & Sobelman, 1987).

Summary of Stress Measures and Manipulations

In this study, stress is defined as the conscious or unconscious perception of internal or external pressures causing deviation from normal interactions with an individual's environment. From the transactive viewpoint, stress is a multidimensional concept that must incorporate the perception of stress, in addition to the characteristics of the stimulus and coping response. For assessing the perception of stress, the SSSQ was selected as it carries the pedigree of the proven

DSSQ, with considerably less intrusiveness even if administered at multiple points during a simulation. The stress stimuli in these experiments were manipulated through variations of task load and performance feedback, though sensitization effects had to be carefully considered to ensure the manipulations remained effective across multiple exposures. These stimuli were scripted throughout the design of the crisis scenarios subjects were tasked with resolving. Psychophysiological response measures were not used in the present study, but future work is likely to explore the value of real-time measures of stress responses in this experimental context.

STRESS AND COGNITION

Figure 1 illustrates the relationship between the concepts of *threat*, *stress*, and *cognition* (Yates et al., 1995). In accordance with Lazarus' transactional theory of stress, a threat is defined as a person's perception that he or she possesses insufficient resources to meet a present demand (e.g. "That bear is larger and faster than I am and will probably eat me."). A *stressor* is any set of situational conditions causing the perception of a threat, with *stress* consisting of the physical and emotional reactions to that threat. That reaction is modulated by individual differences in the form of personal circumstances, traits, or self-appraisals of the current situation. For example, a novice driver in heavy freeway traffic would be overwhelmed with the demands of merging and navigating at high-speed, while an experienced commuter would not. Personal characteristics will bias the reaction to a stressor, as a person predisposed to anxiety may feel greater stress in a given situation than a non-anxious person. Finally, someone greatly underestimating the scale of a threat will obviously feel less stressed than another who has a more accurate appraisal of the same situation. "Other Factors" include everything else interacting with the current cognitive activities (e.g. distractions, stimulants or intoxicants, etc.), since stress may play a large or small role in affecting cognition, depending on the context.

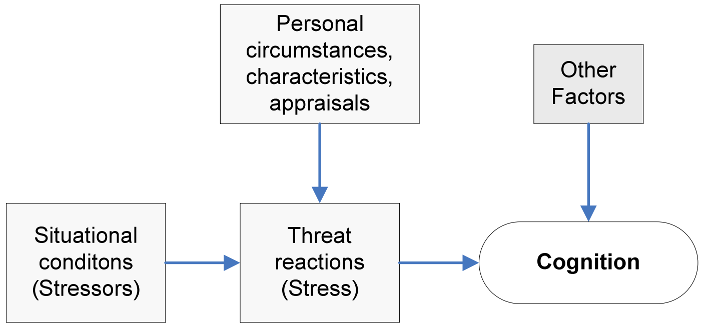


Figure 1: Schematic representation of the effects of stress upon cognition (Yates et al., 1995)

Lazarus would likely point out that this model lacks a feedback loop by which changes to cognition affect changes in the process of appraisal. It is by that process that stressors are constantly reappraised in light of new perspectives on the situation. For example, if an individual does not like the feeling accompanying the reaction to a threat, a conscious decision can be made to reappraise the threat in nonthreatening terms in order to diminish that unpleasant feeling.

The transition between a non-stressful to a stressful situation is not always an increase of task demands. In the case of the novice driver mentioned above, the demands of the task exceeded the ability of this driver to respond, but were unremarkable for the experienced commuter. However, if the commuter driver, in the same objective conditions, was also late for an appointment, stress would likely ensue, increasing the likelihood of a hasty judgment or risky maneuver. In this particular instance, it is a change in *meaning* rather than circumstances that leads to stress.

Figure 2 shows the inverted U-shaped relationship between stress and cognitive performance, known as the Yerkes-Dodson Law (Yerkes & Dodson, 1908), a model which is commonly cited across many areas of stress research. The underlying idea is that individuals perform best at some optimal level of stress or arousal. Too little arousal leads to disinterest and boredom, while too much leads to cognitive overload, both of which negatively impact task performance. Overall, this relationship is consistent with the observation that many different cognitive functions are affected by multiple stressors in similar ways. What this general model lacks, however, is the ability to account for the relevance of specific stress reactions to individual cognitive functions.

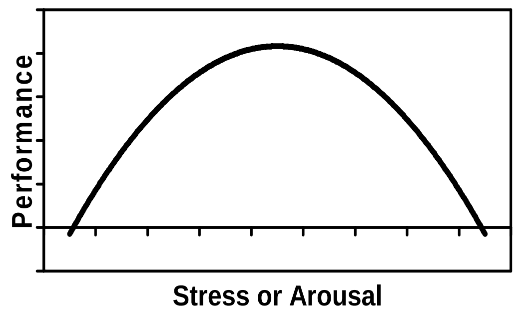


Figure 2: Inverted U-shape curve of the Yerkes-Dodson Law (Yerkes & Dodson, 1908)

The most commonly cited cognitive impacts of the stress response include changes to attention, memory, decision speed, and learning (for a review see Mendl, 1999). The “limited resources” theory of attention (Kahneman, 1973) suggests that the attentional resources available are reduced by the effort required to attend to and cope with other stressors, such as excessive noise, heat, or sleep deprivation. This competition for resources leads to increased errors in directing or sustaining attention on a particular task (Hancock, 1986). There is also a tendency for episodes of stress to lead to a narrowing effect of attention in which central features of an event are more accurately perceived and remembered than peripheral ones. In tasks where peripheral or contextual information is as significant as central information for successful performance, this tendency leads to increased errors (Easterbrook, 1959). Stressful conditions may lead individuals to make decisions using quicker strategies, but with reduced accuracy, for one or more of the following reasons: premature closure (reaching a decision before completely considering all options), nonsystematic scanning (considering options in a frantic and disorganized manner), and temporal narrowing (allocating insufficient time to evaluate each option) (Keinan, 1987). Proponents of recognition-primed decision making would point out that none of those will necessarily lead to poor decisions. One strength of experienced decision makers is their ability to recognize and select a suitable course of action without expending the time and cognitive energy evaluating extraneous options.

Although stress often demonstrates a narrowing effect on attention, the degree to which a person may be distracted by irrelevant or peripheral stimuli may actually increase under stress. One experimental strategy used to explore this particular phenomenon is latent inhibition (LI). LI describes the selective attention process in which pre-exposed irrelevant stimuli continues to be ignored upon later exposure. If the irrelevant stimulus later becomes a target stimulus, the LI effect makes reorientation difficult. Thus, the amount of attention drawn by the irrelevant stimulus is diminished by pre-exposure, making the LI effect useful for measuring distraction by irrelevant stimuli.

High situational stress has been shown to strongly attenuate LI (Braunstein-Bercovitz, Dimentman-Ashkenazi, & Lubow, 2001). In the low-stress condition, pre-exposed subjects performed very poorly compared to non-pre-exposed subjects in a masked letter-identification task (demonstrating the LI effect). Pre-exposed and non-pre-exposed subjects in the high stress conditions, however, performed equally – in fact, they performed nearly the same as non-pre-exposed subjects in the low stress condition. This negative effect of stress upon selective attention has also been demonstrated in the form of negative priming effects (Braunstein-Bercovitz, 2003), and Stroop interference (Keinan et al., 1999). This demonstrates that one cognitive effect of stress is the impairment of selective attention. In an applied context, operators conditioned to ignore certain stimuli will become more distracted by it when under high stress.

Bowers, Weaver, and Morgan (1996) detail additional factors that moderate the effect of stress upon cognitive performance. Individual factors that improve the response to environmental stressors include perceived control, self-control, incentive, and, interestingly, alcohol intake. In dealing with individual stressors in a group context, an internal locus of control (belief that outcomes are governed by internal abilities rather than by external chance), participation in decision making, group cohesion, and supervisor support provide beneficial effects, while anxiety, reactivity, and type A personalities are detrimental to the stress response. Interactions between the mood and stress manipulations in this study and some of these measures are evident in examples such as depression diminishing perceived control while positive affect increases it (Hudlicka, 2003). Hence, following this example, it is very possible that individuals with measureable differences in the locus of control trait to show differential responses to the mood manipulations. Some of these factors were utilized as control measures in this study: trait anxiety, locus of control, and tolerance of ambiguity. Three of the five factors in the five-factor model (FFM) of personality (Digman, 1990) are also suggested for inclusion in this study: extraversion, conscientiousness, and neuroticism.

STRESS IN DISTRIBUTED COGNITION

Group decision making under stress is a topic of great concern to high-complexity and high-stakes sectors, such as the military, aerospace, and energy industries. Wherever human error can lead to catastrophic results, efforts must be made to understand and mitigate the phenomena that negatively impact a group at work. As stress, variously defined, is among the most frequently blamed factors, it is consequently a prominent feature of many models of team performance. Research in this area investigates how some teams successfully adapt to stressful conditions, while others do not.

The Adaptive Team Model (figure 3) illustrates how stress is both an input and an output of team processes (Serfaty, Entin, & Johnston, 1998). This model demonstrates the interaction of the effects of stress upon individual cognition with those stressors found in organizational contexts, such as role uncertainty or miscommunication. Not only does individual stress impact team processes, but difficulties in the team processes themselves can generate stress. Performance feedback also modulates stress – poor performance informs the team that there are failures at one or more layers in the process. Successful teams must be responsive to these feedback structures, rather than rigidly adhere to some fixed approach to teamwork.

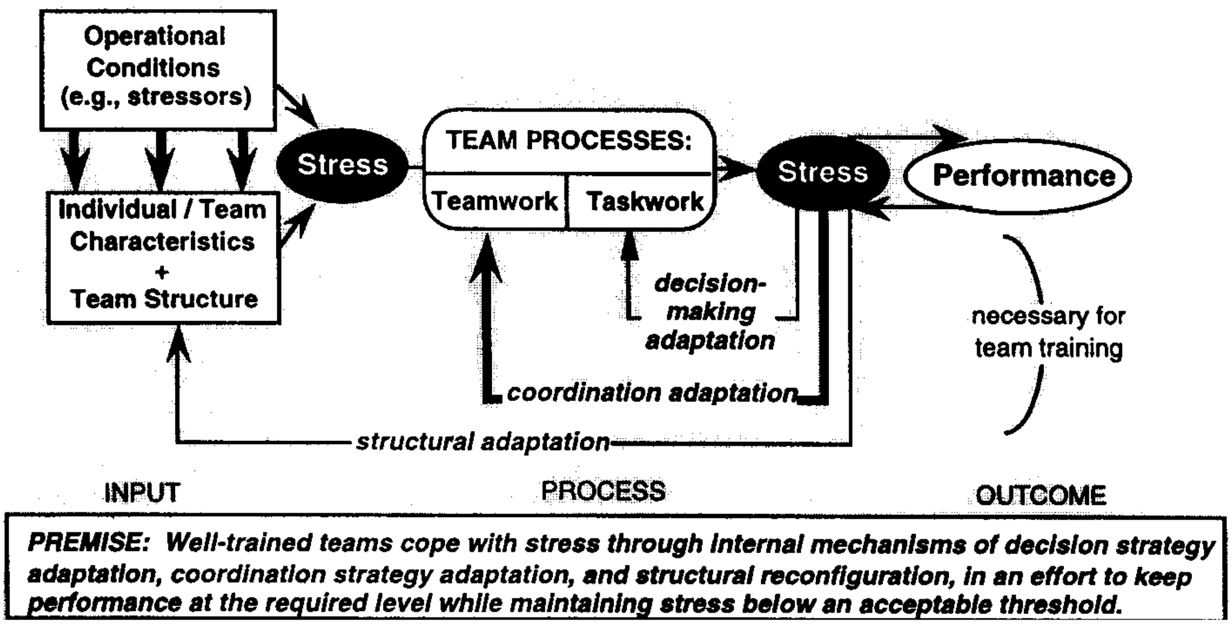


Figure 3: Theoretical framework for team adaptation (Source: Serfaty et al., 1998)

The traditional centralization-of-authority hypothesis, commonly cited in organizational literature, holds that organizations will centralize authority in response to stress, thereby concentrating decision making power higher in the command hierarchy (Staw, Sandelands, & Dutton, 1981). This hypothesis predicts increasingly rigid and narrow information processing and decision making for organizations under stress, analogous to the effects often described for individuals under stress. Recently many organizations, including the military, have been trying to determine when it is more appropriate to move power from the center to the edges, as well as how to successfully study, implement and manage such organizational architectures (Bolia & Nelson, 2007).

Driskell and Salas (1991) tested the centralization-of-authority hypothesis at the small-group level of analysis on U.S. Navy students. The goal was to contrast this hypothesis to other research indicating that group members under stress at all levels of the hierarchy actually become *more* receptive to input from each other. Acute stress was defined as an interaction that was not only a threat to the individual's well-being, but also increased the individual's responsibility for the team's success. They found that low ranking subjects did defer more to authority when under stress, though contrary to the centralization-of-authority hypothesis, higher-ranking subjects under stress were *more* open to input from their lower-ranking partners. Possible explanations for this phenomenon may be a desire for individuals to diffuse responsibility for high-stakes decisions, or that decision makers under stress require more social comparison to validate their own evaluations. The task in this experiment was an ambiguous visual appraisal task (assessing the whiter of two checkerboard patterns), so these results need to be re-examined in a real-world group task setting.

In complex environments, the pressure to perform is a well known situational stressor that can negatively impact the task performance of even the most highly skilled operators. One explanation is that performance pressure focuses attention closely onto monitoring one's own task performance processes. Previously well-rehearsed and automatic procedures become more like the tentative steps of a novice which lead to significant decreases in performance. Studies have demonstrated this effect using multiple performance stressors including competition, monetary incentives, and audience-induced pressure (Baumeister, 1984). Other successful implementations of performance pressure stressors target specific individuals and settings, such as pressures designed for on-base Naval students (Driskell & Salas, 1991). In such cases, experimenters can apply stronger manipulations than would be believed or ethically permitted in the context of using university students as subjects in a lab.

A contrasting viewpoint is that performance pressure produces a distraction from the task at hand, rather than focusing attention too closely upon its execution. Distraction theories suggest that under pressure, working memory and attentional resources are divided between the primary task and thoughts about the importance and consequences of the current situation (Beilock, Kulp, Holt, & Carr, 2004).

The ability of stress to manipulate individuals' attention has also been tested in the group context to examine the relationship between stress, team perspective, and team performance (Driskell et al., 1999). Members of highly interdependent teams who had to collaborate to complete a task showed a broader team perspective than those on teams who worked independently of each other. Conditions of high stress caused a marked reduction in team perspective among interdependent team members, which is analogous to the changes in attention observed among individuals under stress. This narrowing of perspective to a self-focus led to diminished performance, though after the effect of team perspective was controlled for, it was found that neither the level of stress nor the interdependence of team members was a significant predictor of performance. In fact, team perspective mediated the effect of stress on team performance. This finding serves as a demonstration that in stressful situations, it is not necessarily the *stress* alone that leads to changes in performance.

As the research reviewed above indicates, stress is far from a simple unidimensional construct, as the Yerkes-Dodson curve might suggest. Stress is an ongoing process between an individual and his or her environment which has multiple interacting psychological and physiological results, including changes in mood, cognitive ability, and physical performance. In this study, the emphasis is specifically on the interactions between stress and its mood-related outcomes.

CHAPTER 3
MOOD

Until fairly recently, emotions and stress have been considered separate fields of study. Stress was (and still is) a substantial concern to many fields of study, while emotions have been an interesting puzzle with uncertain practical applications. Discussions of mood are often plagued with problems of ambiguity similar to those reviewed previously with the concept of stress. The terms *affect*, *mood*, *emotion*, and *feeling* are often used interchangeably, so additional clarification is necessary before discussing these concepts in terms of their interactions with cognition and task performance (and in chapter 4, with stress).

MODELS OF AFFECT

Russell (2003) has produced a valuable decomposition of the essential concepts underlying what is casually referred to as emotion. According to Russell's taxonomy, emotions may be about a particular object, or may simply *be*. The term *emotion* is used broadly to encompass anything from the thrill of success to prolonged depression to a frightened reaction. These experiences have such profoundly different time scales, intensities, and functions that it is impossible to account for them all in one unified construct. Rather, *prototypical emotional episodes* may be distinguished from *core affect*.

Core affect describes the elementary emotional state a person is in. It is not a cognitive or reflective activity, but rather a backdrop in a person's consciousness that drifts freely in response to conscious or unconscious events without any specific orientation toward an object. For example, simply feeling happy is *core affect*, but feeling happy as a result of receiving a gift is an *emotional episode*. Core affect is similar to the terms *feeling* or *mood* in their common usage.

Russell specifically defines *mood* as a prolonged core affect with no object or a quasi-object, which is the definition used in this research.

The model of core affect (figure 4) provides a two-dimensional representation of primitive emotions. The horizontal Pleasure-Displeasure axis is generally defined as affective *valence*, and the vertical Activation-Deactivation axis is referred to as *activation* or *arousal*. It is not intended to be a descriptive model of how emotions work, but a framework for showing relationships between affective states. Russell explains, "As with [body] temperature, core affect is simple at a subjective level but complex at the biological level." (Russell, 2003, p. 148)

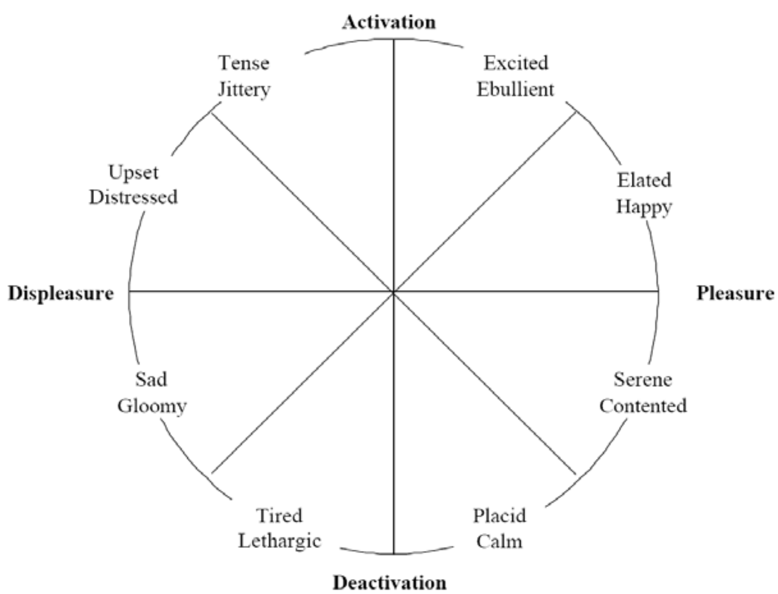


Figure 4: Model of core affect showing axes of pleasure and activation (Source: Russell, 2003)

While this model cannot fully account for the collection of emotional events leading to a particular affective state, it provides a framework to relate affective variables in context. The pleasure axis corresponds to positive or negative affective valence. Anxiety, for example, may be defined as an affective state somewhere in the upper left quadrant – a state of elevated activation and displeasure. Introducing pleasure (e.g. in the form of positive feedback on task performance) to a subject in an anxious state may maintain the *activation* of the former state, but shift toward a more pleasurable emotional state. This new state may have a noticeably different effect upon the individual's cognitive processes.

Prototypical emotional episodes (also called full-blown emotions or blue-ribbon emotions) are categorically distinct instances of a commonly identifiable emotion: fright, joy, shame, disgust, and so on. These episodes are each characterized by a particular core affect, specific behaviors (e.g. *smile* with happy, *run away* with fear), attention toward and appraisal of the object relating to this emotion, the awareness of having a specific emotional experience, as well as the physiological reactions to the emotional stimulus. Episodes have a beginning and an end, with the duration measuring the persistence of the emotion. In contrast to the definition in the previous paragraph, anxiety as a prototypical emotional episode could be defined as "an emotional state that results when a stressor is interpreted as requiring avoidance, and some sort of harm is anticipated." (Bowers et al., 1996, p. 173)

Russell's model is similar to a number of two-dimensional representations of affective states (for a review see Yik, Russell, & Feldman Barrett, 1999). One point of contention between these models is whether positive and negative affect are two endpoints of a single bipolar measure, or if they are actually two independent constructs. A model in which the two are independent rotates the valence axes such that positive and negative affectivity are orthogonal, with activation (relabeled *engagement*) shared between the two (see figure 5).

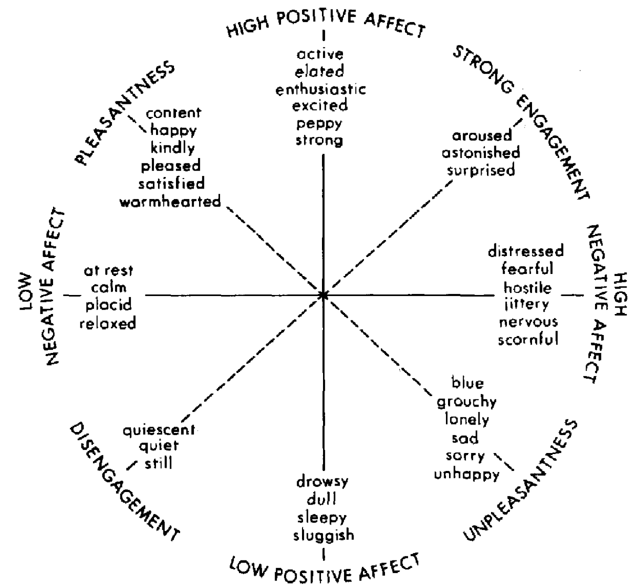


Figure 5: Watson and Tellegen's two-factor model of affect (Source: Watson & Tellegen, 1985)

While it seems logical that oppositely valenced emotions would be inversely correlated, many studies have found occasions of little correlation between negative and positive affectivity (e.g. Cropanzano, Weiss, Hale, & Reb, 2003; Watson & Clark, 1997), which has led to the development of separate scales for positive and negative affectivity. Russell and Carroll (1999) respond that bipolarity provides the most parsimonious explanation and these inconsistencies between positive and negative affect can be explained by imprecise measurement methods and variations in time frame. However, Yik et al (1999) admit that which model is best applied to a given research program is a choice best left to the researcher.

MOODS AND EMOTIONAL EXPERIENCES

There are four general approaches for observing an individual's mood: behaviors and actions, physiological measurements, self-reports, and environmental contexts (Lazarus, 1991). The first approach refers to observing intentional or unintentional actions, such as facial expressions, crying, or physical postures. Physiological reactions such as changes in heart rate, blood pressure, or skin conductance all can indicate changes in an individual's mood. Simply asking people how they feel is one of the most common methods used in emotion research. Finally, observing the events or context around an individual allows for some inference about current emotional states. For example, an individual who has just been insulted is likely to feel hostile and angry, while another watching a sad movie is likely to feel unhappy and distressed. This last approach is also the source of most mood manipulations. By stimulating an individual with a story, song, or a memory associated with a particular emotional state, it is possible to put that individual into the suggested mood temporarily. The intensity and persistence of these mood-induction procedures varies depending on the target mood desired, yet they have proven to be very successful when properly implemented (see a review in Westermann, Spies, Stahl, & Hesse, 1996).

Operationalizing and Measuring Moods

In experimental settings, mood assessments are frequently self-reported using a range of survey instruments calibrated for specific emotional conditions. Typically these involve responses to lists of carefully selected emotional adjectives or short phrases with the subject indicating agreement or disagreement with each item. These may be used to assess feelings at the present moment (state measurements), or over longer periods of time (trait measurements). One such instrument is the Spielberger State-Trait Anxiety Inventory (STAI) (Spielberger, 1983), a popular and reliable measure of both state and trait anxiety. Respondents indicate their agreement with short phrases like “I feel pleasant,” “I tire quickly,” and “I feel like crying.” The Positive and Negative Affect Schedule (PANAS) (Watson, Clark, & Tellegen, 1988) comprises two brief 10-item surveys which provide two independent measures of positive (PA) and negative affectivity (NA). This instrument collects agreement with terms such as "interested," "irritable," "excited," "ashamed," "strong," and "nervous."

The Profile of Mood States (POMS), which has a long (65 adjectives) and short (37 adjectives) form, is used to measure mood along six dimensions: tension-anxiety, depression-dejection, anger-hostility, vigor-activity, fatigue-inertia, and confusion-bewilderment. Though it has some correlation with social desirability, it is often used to measure an individual's mood from a time range extending into the past anywhere from a week to the last three minutes (Curran, Andrykowski, & Studts, 1995). Examples of more focused emotional measurement instruments include the Beck Depression Inventory (BDI) (Beck, Steer, & Carbin, 1988), State Trait Anger Expression Inventory (STAXI) (Spielberger, 1988), and the Dispositional Envy Scale (DES) (Smith, Parrott, Diener, Hoyle, & Kim, 1999).

Ecological Momentary Assessment (EMA) (Stone & Shiffman, 1994) is a self-report technique often used to assess cognitive, behavioral, or affective experiences over time by periodically signaling subjects remotely (e.g. via pager or cell phone) to report or record data at that moment. Repeated measurements taken in the subject's natural environment help avoid the unintended influence of laboratory conditions, and also helps with some limitations of retrospective self-reports which rely upon accurate and honest recall of details over longer periods of time. This technique may be used in conjunction with some of the instruments described above, such as the PANAS scales or short form of the STAI, for longitudinal studies of mood or anxiety.

Many of the psychophysiological methods used to measure stress are also used to measure emotions. Skin conductance measures arousal, or the affective dimension of activation, independent of the affective valence. This measure helps establish the intensity of an emotional response, but cannot identify any other qualities. Laboratory methods that can capture emotional expressions include automatic visual assessments (Kapoor, Qi, & Picard, 2003) or electromyographical (EMG) measurements of the muscles employed in facial expressions (e.g. Partala & Surakka, 2004).

Reliability and Validity

The generally negative connotation of stress makes it difficult to experimentally discriminate stress from negative affect, as similar effects are seen in the presence of either one. As an example, manipulations of mood (Gasper & Clore, 2002), stress (Braunstein-Bercovitz et al., 2001), and anxiety (Derryberry & Reed, 1997) all demonstrated similar cognitive consequences. Therefore, a concern in this research is that measures of stress and measures of mood must not confound each other. In addition, one common point resulting from debate described above regarding the independence or bipolarity of positive and negative affect is that no matter which model a researcher chooses to subscribe to, mood measurements must be taken such that valence and activation do not confound each other.

There is some occasional overlap in the self-report instruments used for stress and mood measurement. In experimental trials, the SSSQ Distress factor has appeared to be exclusively measuring negative affect, while the Engagement factor measures motivation and the Worry factor measures cognitive effects (Helton & Garland, 2006). One could argue that there is little difference between “I feel sad” on the SSSQ Distress factor and “I feel upset” which appears on both the positive affect scale of the PANAS and short form STAI. However, the SSSQ Engagement factor shares two items with the PANAS: “I feel alert” and “I feel active.” This suggests that there is the potential for these instruments to confound stress and mood measurements, which recommends further factor analysis when these instruments are used in conjunction with each other.

EMA can suffer from problems related to compliance by the participant, who may be unavailable or otherwise occupied when prompted to respond. In some cases he or she may simply ignore the prompt in the absence of any experimental supervision.

Stress also appears to play a role in the correlation of positive and negative affectivity. Across a series of three experiments utilizing different stressors, subjects in the stressed conditions showed a significantly stronger inverse correlation between negative and positive affect than those in unstressed conditions (Zautra, Reich, Davis, Potter, & Nicolson, 2000). This finding provides additional evidence that stress and affect interact in significant and complex ways.

Summary of Mood Measures and Manipulations

The Watson and Tellegen model of emotions was determined to be the most effective one for this research, as the implementation of positive and negative affectivity as independent scales does not preclude later reorientation as a single bipolar construct. Rather than taking on the whole range of emotions at once, the two moods happy and sad were selected for this study. In both models described above, happy and sad are polar opposites. In Russell’s model, the happy-sad axis is roughly parallel to the pleasure-displeasure axis. On the other hand, in Watson and Tellegen’s model, the happy-sad axis is perpendicular to the engagement axis. This suggested that Watson and Tellegen’s PANAS Scales would be a valuable complement to the SSSQ Engagement scale. A short six-question form of the STAI was also selected as a reliable but less intrusive version of the original 20 question form (Marteau & Bekker, 1992).

According to Westermann et al (1996), presenting a short film or story is generally the most effective method to manipulate a subject's mood, both positively and negatively. It has proven to be a particularly reliable method across many studies (e.g. Cavallo & Pinto, 2001; Forgas & Moylan, 1987; Göritz & Moser, 2006; Van Tilburg & Vingerhoets, 2002; Wang, LaBar, & McCarthy, 2006; Yuen & Lee, 2003) and is relatively straightforward to implement with a TV and VCR or DVD player, or a computer workstation with sound capabilities.

For the purposes of this research, mood assessment was conducted using survey measures pre- and post-task. However, there is good justification to employ psychophysiological techniques in later experiments to examine these phenomena in real-time. Though not employed in this research (because the simulation software does not yet support it), EMA could potentially be embedded within an experimental task such as NeoCITIES at regular intervals throughout the simulation.

MOOD AND COGNITION

The complexity underlying models such as those above is exemplified by contrasting findings on affect and cognition. For example, many studies show anxiety to have a constricting effect on attention to focus subjects on primary tasks or threats at the exclusion of secondary ones (Solley, 1969), while others have shown the effects of anxiety to broaden attention to peripheral, non-threatening information (Mathews, May, Mogg, & Eysenck, 1990). Hence, the effects of affect upon cognition appear to be sensitive to additional variables inherent in the particular context of the study.

Sun and Zhang's (2006) abstract model of individual interactions with objects (figure 6) shows a generalized way of representing the relationship of affective and cognitive processes that lead to individual behaviors. Note that while *traits* are positioned as the launching point for determining interaction, neither *affective* nor *cognitive* reactions are given precedence in determining how the individual intends to act. In fact, these reactions influence each other (propositions P3-1 and P3-2), a position that aligns with the "parallel-processing" view that cognition and affect are both interactive information processing systems (Norman, Ortony, & Russell, 2003). Minsky integrates affect and cognition even further with the position that each emotional state corresponds to a different way of thinking (Minsky, 2006).

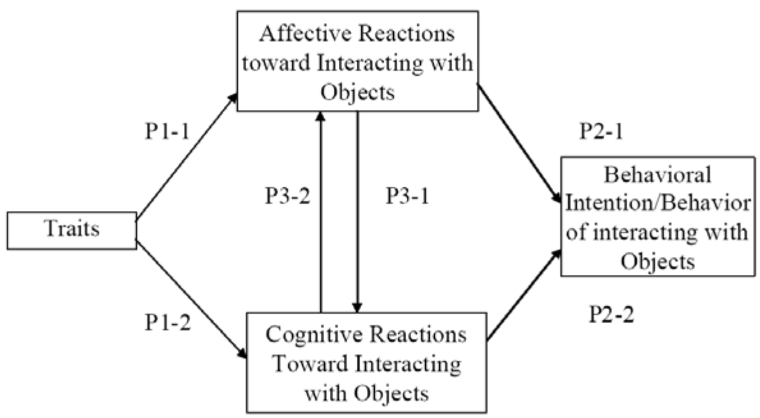


Figure 6: Abstract model of Individual's Interacting with Object (IIO) (Source: Sun & Zhang, 2006)

The affect-as-information perspective (Schwarz & Clore, 1996) has been tested in numerous studies on mood and visual processing of information. According to this approach, affect will influence task performance when it seems to provide task-relevant information. A happy mood, for example, provides the information that the task is proceeding well, while a sad mood indicates there are problems and caution is recommended. That message of caution can result in more rigid thinking, fixation on local details, and a more careful approach in decision-making. Individuals with a positive mood, however, are more likely to detect global features and employ more novel and generative approaches to problem solving.

Gasper and Clore (2002) tested the *levels-of-focus* hypothesis, which proposes that the task-relevance of affective feelings influences the extent of global or local processing. After inducing subjects into a happy or sad mood by asking them to write for nine minutes about a happy or sad life event, subjects performed a feature-matching memory task (experiment 1) or compared shape sets based on global or local properties (experiment 2). Both experiments confirmed that attention to global features was higher in subjects in happy moods.

When this approach was applied to problem solving strategies, subjects in sad moods stuck with their initial strategy until the data proved it unworkable, while those in happy moods freely altered their strategy according to their own internal rules (Gasper, 2003). This clarifies that subjects experiencing a negative mood are not necessarily trapped into narrow thinking or rigid processes, but that they will respond to the evidence when change is clearly necessary, and arguably, when it is needed most.

Gasper (2004) explored this further to demonstrate that a sad mood only decreased global processing when the feelings were relevant to the task, but not when they seemed irrelevant or ambiguous. After the same mood manipulation described above, half of the subjects were reminded that their current feelings were irrelevant to the following visual matching task. Those subjects did not show the effect of mood on attention described above, demonstrating that mood could have a reduced effect on cognitive processing when it is determined to be irrelevant to the task at hand. This may support the notion that a person experiencing emotion-laden problems at home or elsewhere is capable of putting those distracting feelings aside while engaged in work. Gasper also found that the intensity of the mood, whether happy or sad, led to faster processing times. Hence affective valence appears to direct attention, while affective intensity increases processing speed.

Derryberry and Reed (1997) studied several aspects of how anxiety impacts attention. One study examined individual differences and mechanisms related to global vs. local perception. Subjects were divided into low and high trait anxious groups using the State Trait Anxiety Inventory (STAI) (Spielberger, 1983) and manipulated in affect by a positive (gaining points by positive outcomes toward a high score) or negative (losing points through negative outcomes toward zero) score orientation of a computer-based targeting game. Both state and trait anxiety were shown to focus subjects' attention to local details, but only during the negatively-oriented games. Interestingly, a hemispheric effect was discovered for targets in the right visual field, which is consistent with the association of negative affective states increasing left hemispheric activation.

A later study looked specifically at the attention given to threatening stimuli by anxious individuals (Derryberry & Reed, 2002). This also used the positively or negatively oriented targeting game approach to manipulate affect. In this case, the affect manipulation had no effect, but high anxious subjects showed a stronger orientation to threatening cues when compared to low anxious subjects. Attentional control was also assessed, and it was found that anxious subjects with better control of their attention were able to regulate the impact of threatening cues.

These experimental results beg to be extended to the group level of analysis to see how these individual cognitive processes and task parameters manifest collectively in the context of real work tasks conducted with real human collaborators. This research aims to build upon the value of these previous findings by bringing them together and observing them in ecologically relevant situations. A thorough understanding of team cognition has to embrace not only what is inside the head, but what the head is inside of (Mace, 1977).

The findings just described have analogs in the geo-collaborative tasks involved in this research. Attention and problem-solving strategies are critical to the processes of assessing crisis situations and determining how to resolve them. In managing an emerging crisis situation, a local focus (i.e. putting out fires as fast as they happen) is only part of the responsibility. Operators also need to have a global "big picture" view of the situation in order to identify connections between events or emerging patterns of activity, as well as communicate and coordinate with other team members. Should negative moods or anxious states impact the capacity to maintain that attention to global features, the design of visualization tools and procedures intended for situation awareness must take that into account. In summary, the complex relationship between mood, feedback, and problem-solving strategies must factor in to the design of tools for collaborative, distributed cognition.

CHAPTER 4
INTERACTIONS BETWEEN MOOD AND STRESS

The previous two chapters have reviewed stress and mood individually, but it is already evident from the discussion so far that the two have complex relationships with each other. This chapter explores research regarding both mood and stress in order to identify where these concepts overlap (that is, where researchers may be talking about the same thing) and where the two influence one another as distinct phenomena. After reviewing multiple theories addressing both mood and stress, common findings from the previous two chapters are summarized. Based upon these findings, the primary research question of this study is presented along with two proposed models and the four hypotheses to be tested.

DISTINGUISHING MOOD AND STRESS

Lazarus (1999, p. 36) argues that "we cannot sensibly treat stress and emotion as if they were separate fields without doing a great disservice to both." It is true that the literature on the relationship between stress and cognition shows many similarities with the literature on mood and cognition. In some cases, when looking at the manipulations and measures used in both areas of research, one may suspect that emotion researchers and stress researchers are examining similar phenomena but choosing different terminology to describe it. Bootzin and Max (1981) explain that while theorists disagree over the causes of anxiety, there is general agreement over the constitution of the anxiety response, which happens to be a list of verbal reports, behavioral responses, and physiological responses almost identical to the responses attributed to stress.

In organizational stress research, emotions are included among the individual differences in reacting to stress, and generally with very negative connotations: "When emotions are directly involved in action, they tend to overwhelm or subvert rational mental processes, not to supplement them" (Elster, 1985, p. 379). Dysfunctional reasoning is blamed on "emotional stress" (Sjöberg & Olsson, 1981). This perspective holds that stress may be inescapable in high stakes circumstances, but emotions (apparently positive and negative ones) are something to be avoided at all costs. However, many researchers have shown this broad generalization to be untrue.

For example, Mogg et al (1990) admit that they could not be certain whether their manipulation (difficult task with false negative feedback or easy task with false positive feedback) was actually a manipulation of stress, mood, anxiety, or performance feedback. They chose *stress* as the most non-specific term, though the intended outcome of the manipulation was in fact *anxiety* – a mood state. Many conceptual frameworks of stress show stress leading to negative affect, which in turn leads to various physiological and psychological outcomes, though some also suggest a direct effect of stress in addition to one mediated by negative affect (Aldwin, 1994).

However, stress and mood are also conceptually distinct and independent of each other, at least to some degree. One can feel happy or sad, but not stressed; one could be stressed and feel exhilarated, depressed, or neither. Many studies have shown how people may experience both positive and negative moods in the presence of stress (Lazarus, 2003). For example, observations of caregivers of terminal patients demonstrated that a small positive event amidst a majority of negative events can prompt a positive affective response despite ongoing stress (Folkman & Moskowitz, 2000). This shows that positive moods may coexist with stressful conditions and such positive responses have a meaningful coping function. The matter that follows is to investigate the role of affect in coping with stress, and under what conditions and for how long these effects occur.

CAUSE AND EFFECT

Theorists have long debated the causal directionality between stress and emotions (Cassidy, 1999). The James-Lange theory of emotion maintained that physiological arousal (i.e. the stress response) causes cognitive and emotional changes. In response to a threat, the increase in heart rate and activity of fleeing cause the emotional state of fear. The Cannon-Bard theory argued the opposite position that the perception of a threat causes the emotional reaction which then leads to the stress response (Cannon, 1929).

Schachter and Singer's (1962) two-factor model of emotion proposed (and demonstrated experimentally) that the same physiological state could be labeled by the subject as any number of emotional states, including a state of no emotion. Their conclusion was that physiological measures could only predict emotional states to the extent that interactions with cognitive and situational factors were also taken into account. This aligns with the transactive theory of stress by demonstrating that an individual's cognitive appraisal moderates the emotional reaction to a threat.

Lazarus and Folkman (1984) emphasized the primacy of the cognitive process of appraisal preceding any reaction to stress, emotional or otherwise. Zajonc (1984), on the other hand, responded that the emotional reaction precedes cognitive processing of the threat, and these two reactions may sometimes be in conflict with each other. Sun and Zhang's previously described model of individuals interacting with objects (figure 6) suggests that both are right. Consciousness comprises processing systems which are independent of each other to varying degrees, which suggests that emotional and cognitive reactions can occur in either order and may act to inform each other of the meaning of the present circumstances. Lazarus (1991) later incorporated this reciprocal causality with his description of appraisal to allow for simultaneous and *potentially contradictory* appraisals of a situation. He gives the example of a plane during takeoff when a person may emotionally feel a sense of fear and dread from one appraisal, while another appraisal assesses the chance of a disaster occurring to be next to none. In these ways, appraisal is shown to be a complex and multi-threaded process. However, persistently faulty appraisal and coping patterns can lead to neuroses, compulsions, phobias, and panics (Lazarus, 1991).

THEORIES OF MOOD AND STRESS

Lazarus (1991) proposed a cognitive-motivational-relational (CMR) theory of emotion which incorporated stress and emotion through the mechanisms of appraisal, coping, and relational meanings. The emotions in this model are distinct emotional categories, not unlike Russell's prototypical emotional episodes (e.g. love, guilt, sadness, pride), rather than dimensional ones (i.e. valence and activation). Lazarus defined 15 emotions: four positive, nine negative, and two mixed. These emotions occur in response to relational meanings, and therefore each emotion has its "core relational theme." For example, the theme for happiness is "making reasonable progress toward the realization of a goal." Sadness' theme is "having experienced an irrevocable loss." An emotion is aroused when its theme matches the current appraisal of the relationship between one's self and the object of the appraisal. This theory also maintains that these emotional relationships are goal-oriented, for these relationships are meaningless without some motivation to either approach or avoid the object.

From this model, Lazarus (1993) argued that stress should be considered a subset of the emotions. Noting the overlapping similarities between the multi-dimensional models employed in both domains, he claimed that consideration of the full range of emotions provides a far more comprehensive description of how individuals adapt to stressful conditions when compared to assessing stress alone. However, his so-called "stress emotions" (anger, envy, jealousy, anxiety, fright, guilt, shame, and sadness (Lazarus, 1999, p. 36)) are rooted in the causes and effects of objects and environments, as well as self-awareness of the emotional state, these are not the objectless moods defined earlier as the affective phenomena of interest in this study. Lazarus is correct that emotions and stress are interdependent, but they are not so fully intertwined as to be the same thing. The fact that there appears to be independence between perceptions of stress and mood states was the inspiration to manipulate both factors individually in this study.

The complex effects of stress upon individuals – particularly the individual differences in the appraisal of stressors – amplify the need to better understand the similarities, differences, and interactions between stress and emotion in collaborative settings. The findings regarding stress, mood, and cognitive performance detailed above demonstrate several effects relevant to the conditions individuals encounter in group problem solving contexts. However, they do not specifically explain how individual moods or reactions to stress will impact group cognition and the outcome of group-based activities.

SUMMARY OF FINDINGS

Taken collectively, the following trends emerge from the research detailed in the preceding chapters:

1. **Cognitive processing is restricted by negative affect.**
    a. Negative affect diminishes attention to global details (Gasper & Clore, 2002).
    b. Negative affect inhibits flexible problem solving (Gasper, 2003).

    c. Increased task relevance of affect increases the effect of affect upon task performance (Gasper, 2004).
2. **Cognitive processing is disrupted by stress**
    a. Decision making under stress increases speed at the expense of accuracy (Keinan, 1987)
    b. Stressful events impair the formation of memories after the event (Mendl, 1999)
3. **Attention is difficult to control under high anxiety and stress.**
    a. Negative affect focuses attention on local details, regardless of anxiety (Derryberry & Reed, 1997; Solley, 1969).
    b. High anxiety focuses attention on threatening cues, regardless of affect (Derryberry & Reed, 2002).
    c. High stress inhibits selective attention (Braunstein-Bercovitz et al., 2001).
    d. Pressure to perform disrupts the ability to regulate attention (Beilock et al., 2004)
4. **Stress disrupts team coherence.**
    a. High stress diminishes adherence to status and authority structures (Driskell & Salas, 1991).
    b. Stress diminishes team perspective, a strong predictor of team performance (Driskell et al., 1999).

The overall goal of this study is to re-explore these laboratory findings within an ecologically valid team setting to address this research question:

For emergency crisis response teams, what is the relationship between levels of cognitive stressors, mood states, and the efficacy of group decision making in a simulated task environment?

Given the considerable similarities between the cognitive outcomes of multiple mood and stress states, two possible outcomes were envisioned in this study. The first was that mood mediated the relationship between stress and cognition (Figure 7). This would mean that stress leads to a change in mood (e.g. negative affect), but it is the change in mood that results in the changes in cognition (e.g. narrowed attention). A series of statistical tests can demonstrate whether or not this effect is occurring.

Figure 7: Model of mood mediating the effect of stress on cognition

A second possibility is that mood moderates the impact of stress upon cognition (Figure 8). This would mean that the effect of stress upon cognition changes under different mood states. For example, stress and a sad mood may impair certain aspects of cognition, while stress and a happy mood would not. Moderation can be demonstrated by identifying a significant interaction effect between mood and stress.

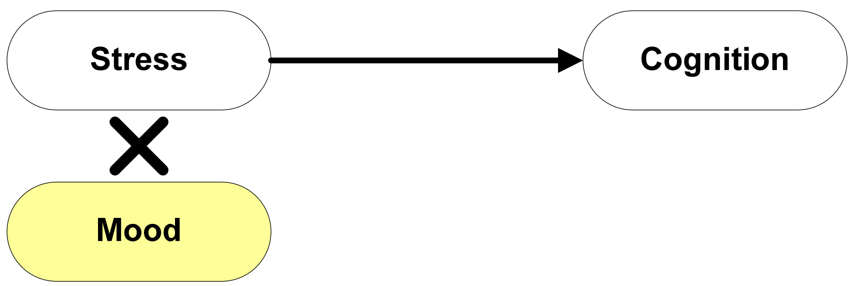


Figure 8: Model of mood moderating the effect of stress on cognition

In an exploratory study such as this, one experiment is often not sufficient to reliably test phenomena so enigmatic as stress and mood. A repeated experiment is generally used to verify the results of the first to be confident that the phenomena of interest are not just a fortuitous discovery of what the experimenters expected to find. The second experiment is also an opportunity to alter the conditions of the experiment in some fashion to try to test the boundaries of the effects uncovered – are the hypotheses supported under some conditions but not others? Does mood mediate the effects of some stressors while moderating the effects of others? This study includes a series of two experiments designed to address those questions.

HYPOTHESES

Many cognitive stressors have been shown to manipulate cognitive functions – heightening some and diminishing others – which would also lead to changes in team performance. Hypothesis 1 predicts that each stressor used in the two experiments will have unique effects upon team performance, positively or negatively. This study includes two experiments with two different stressors specifically because of the clear evidence that all stressors do not act the same.

H_1: Cognitive stressors will trigger changes in team performance.

In order to test the second step of the mediational model (Figure 7), the experiment needs to demonstrate that stresses targeting cognitive functions (e.g. increased task load) have emotional consequences. The models of stress proposed by Lazarus (1999) and Matthews et al (2002) both describe emotional components to the stress response, although in considerably different ways. Therefore:

H_2: Cognitive stressors will trigger changes in individual mood.

As demonstrated in several of the experiments detailed above, negative moods appear to disrupt multiple cognitive functions that in turn could negatively impact team task performance. Hypothesis 3 predicts that these experimental findings from the individual level will extend to the team level.

H_3: Negative mood among team members will result in diminished team task performance.

Prior experimental findings have shown how stressful conditions diminish the individual's perspective on team activity and disrupt an individual's ability to direct and regulate attention. The team emergency management tasks in these experiments rely on accurate situation assessment. This requires the ability for individuals to attend to and communicate about potential connections between events and emerging patterns of activity that may be suggestive of an organized attack or terrorist plot. Hypothesis four predicts that such skills will be diminished under stress.

> *H_4: Teams under high stress conditions will be less able to detect emerging patterns of activity in the simulated task environment.*

The mediating model portion of this research problem is addressed using the causal steps approach described by Baron and Kenny (1986). To demonstrate a mediating effect, these conditions must be satisfied: (1) there is a direct effect of the independent variable on the dependent variable [H_1], (2) the independent variable accounts for variation in the mediating variable [H_2], and (3) the mediating variable accounts for variation in the dependent variable [H_3]. A strong mediating effect is demonstrated when control of the mediating variable causes a significant reduction of the effect of the independent variable upon the dependent variable. Figure 9 restates the mediating model in terms of the first three hypotheses of this study.

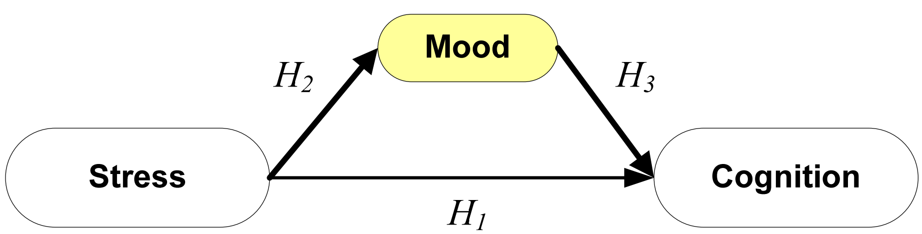


Figure 9: Mediating model in terms of the first three hypotheses

If mood is serving as a moderator of the effect of stress upon performance, however, then the interaction of stress and mood will show a significant effect upon team performance in some way. Mood and stress may also have main effects, though this is not required to prove the moderator hypothesis.

CHAPTER 5
NEOCITIES

The preceding chapters have reviewed the theoretical concepts and issues leading to the main research question and hypotheses of this study. This chapter describes NeoCITIES, the multi-user simulation used as the central testbed in this study. A brief overview of the NeoCITIES simulation is followed by a discussion of the extensions and upgrades made to the simulation to conduct the manipulations and measures required to test these hypotheses. NeoCITIES is a robust and complex simulation platform that merits a detailed review before proceeding in the next chapter to a full discussion of the research methodology for this study.

THE NEOCITIES SIMULATION

NeoCITIES is a scaled world simulation advancing from the original CITIES task: C^3 (command, control, and communication) Interactive Task for Identifying Emerging Situations (Wellens & Ergener, 1988). The NeoCITIES task is designed to mimic the situation assessment and resource allocation tasks of emergency crisis management teams. Teams of six are divided into three pairs (Police, Fire/EMS, and Hazardous Materials) to collectively address a custom-written series of emergency events requiring a range of responses and interactions within the team. The members of each pair have unique roles. One is the Information Manager (IM) who receives incoming information about the emergency events. The other is the Resource Manager (RM) who has control over the resources to respond to the event, as well as access to reports on the success or failure of those resources. As time passes, an event which is neglected or incorrectly addressed escalates in severity, which increases the number of resources required to bring that event under control. Furthermore, task scenarios can include complex underlying plots (e.g. an emerging terrorist attack) hidden among other disconnected events (e.g. trash can fire, domestic dispute, car accident, etc.).

To complete these tasks successfully, all six participants engage in data gathering, analysis, coordination, and communication activities which demand vigilance despite divided attention and frequent task switching. Performance is measured in the timeliness and accuracy of responses to individual events, as well as in the detection and interception of emerging underlying plots (McNeese et al., 2005).

A central server manages the roles and responsibilities of team members while monitoring and recording the actions and interactions of all participants. The server also computes multiple ongoing performance scores in real time, which provides feedback on the participants' performance. The recorded data include the time-stamped resource allocation activities, chat logs, and mouse and keyboard activity within the interface. This provides the researcher with a rich set of data to measure individual and group performance, knowledge transfer, and team cognition. The structure of the simulation allows for assessment of psychological measures or other self-reported data prior to, during, and following a NeoCITIES session.

The NeoCITIES simulation facilitates multiple methods of manipulating the participant's cognitive and emotional states. The scenarios driving NeoCITIES can be flexibly constructed to induce varying levels of workload, complexity, ambiguity, or time pressure. Built-in messaging mechanisms can present messages as manipulations at any time during the simulation. The components of the client software are modular in construction, allowing for ease in manipulating the effect of specific features, such as score polarity (see Derryberry & Reed, 1997, 2002).

NeoCITIES was developed as a Java-based client-server application. The first experimentally viable implementation of this simulation was NeoCITIES 1.3. This version was used in two dissertation studies conducted in 2006. Connors (2006) developed three intelligent group interface designs for NeoCITIES and tested them with multiple teams in a longitudinal study. Jones (2006), the principal architect of the NeoCITIES simulation, developed a decision aid based on fuzzy cognitive modeling and tested it in a scenario based on a terrorist attack. Both studies were conducted successfully, validating NeoCITIES as a stable platform for team-based experimentation.

EXTENDING THE NEOCITIES SIMULATION

Flexible Team Configuration

Upon review of the earlier studies, a number of issues were identified that required upgrades for NeoCITIES 1.4, the version used in this study. The first and foremost was that the server and client were hard-coded to run exclusively on a set of seven computers operating in the User Science and Engineering (USE) Lab in the College of IST at Penn State University. In order to run the simulation at any other location – even for a demonstration – revisions were required to configure teams and workstations independently.

The first part of the solution was to remove references to specific computers from the code and place them instead in an external file. Throughout the client and server code, all references to specific machines were pointed instead to a hash map which linked team roles to computer identities that were loaded from that configuration file at runtime. This simple text file listed an abbreviation for each role (e.g. PI for police information manager, HR for hazmat resource manager, and so on) and the machine name that was to play that role in the simulation.

Though this upgrade made the task of configuring teams relatively simple, even for a non-programmer, it was quickly determined that the task of configuring teams – especially a large number of teams – could and should be centralized. A new method was added to the client and server code which made a call over the internet to a web-based tool that acted as the front end of a database containing all of the information about which computers served which roles, and on which teams. The server identifies the computer making the call, determines its teammates from the database, and returns the appropriate configuration file for that computer. This new configuration arrangement allows for concurrent instantiations of NeoCITIES on an unlimited number of workstations on a network. The first successful implementation of this upgrade was for a half-day workshop for 36 middle-school girls simultaneously playing on six NeoCITIES simulations. The benefit to the experimenter is the ability to gather data from simultaneous NeoCITIES sessions, whereas before the simulation could only run one session at a time.

Figure 10: NeoCITIES in its first multisession test

Administration of the team configuration application was designed for operation by non-technical personnel. The operator logs on and simply assigns computers to teams via pull-down menus. The operator may also add or remove computers from the available pool. Thinking forward to future incarnations of NeoCITIES, this tool was not locked to the current NeoCITIES team structure (i.e. three dyads plus one server). Rather, the user is able to specify teams of any name and number of roles. The database and server code were designed in MySQL and PHP, respectively, both open standards which allowed for portability of this application to nearly any standard web server.

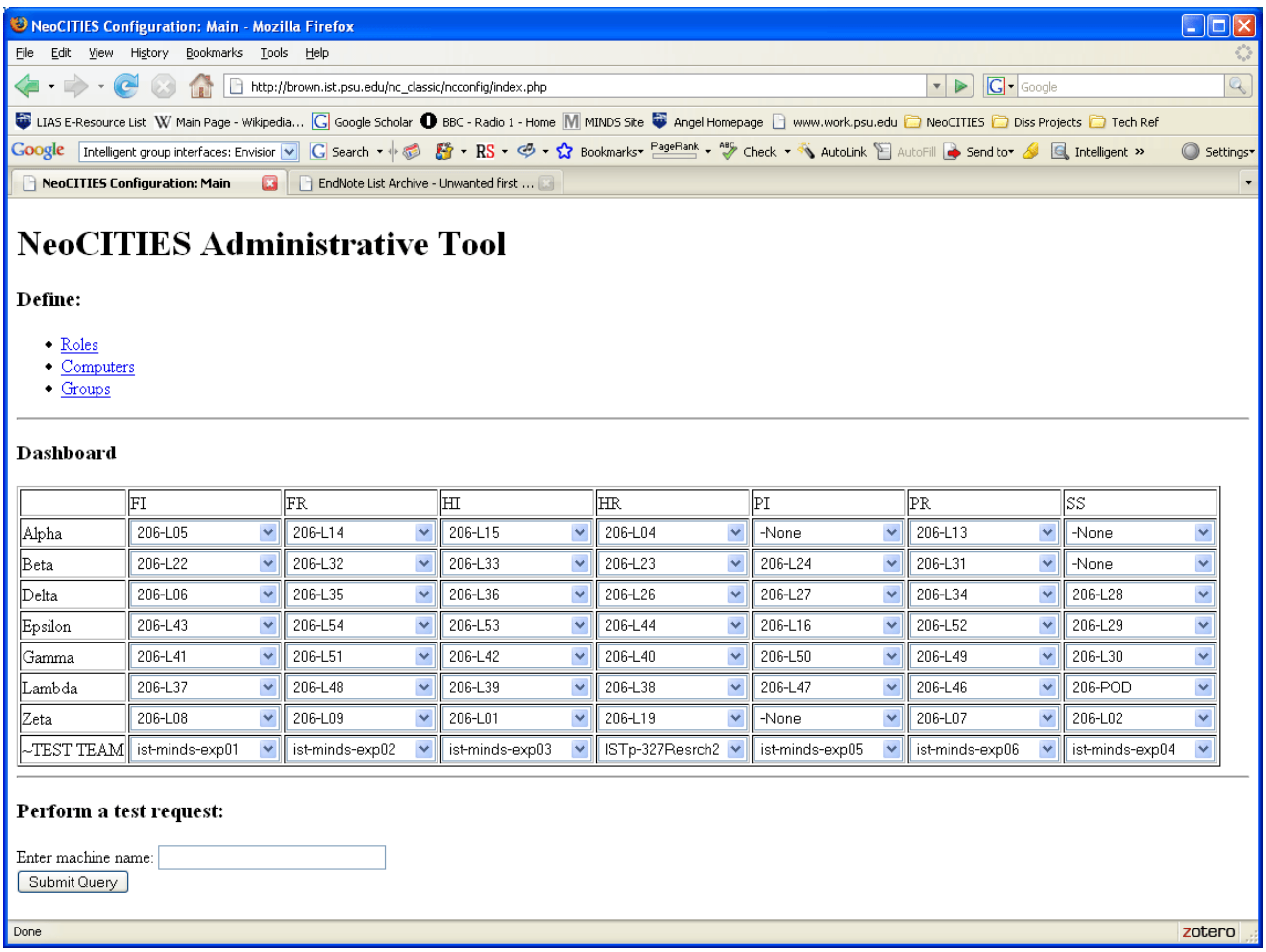


Figure 11: NeoCITIES online administration tool

Controlling Simulated Travel Time

Upon dispatching resources to an event, the resource manager experiences a pause before receiving on-site feedback about whether or not those resources were making progress. One potential stress manipulation was to extend that pause to increase the apparent travel time for the resources to arrive at the event. Originally, this travel time was six seconds (in real time, corresponding to several minutes of game time), which was short enough that participants always received feedback that was clearly associated with the action just taken. Lengthening the pause before revealing the status of events would prolong the uncertainty experienced by the participants. If lengthened long enough, waiting participants may also get involved in other tasks, such as a chat discussion or another incoming event. This would provide an additional cognitive challenge of paying attention to multiple overlapping events.

This pause before feedback was a fixed constant that could only be changed by recompiling the software. To fix this problem, a new runtime parameter was added to the client software which introduced a *traffic* variable. This variable acts as a multiplier to the original pause to simulate increased traffic in the city. Busy rush hour traffic might use a value of six to ten, while sedate traffic conditions at four in the morning might be between two and four. To ensure multitasking occurs, a value can be chosen which extends the pause to a time period longer than the pause between events. For example, a *traffic* value of five would produce a thirty second delay before receiving on-site feedback. If events are coming in every twenty seconds, a resource manager receiving two in a row would be busy attending to the second event while waiting for feedback from the first. Informal pretesting of this new function demonstrated that as the traffic delay got longer, participants took more time and made more errors associating feedback messages with the proper event.

User Interface Enhancements

The NeoCITIES user interface provides a set of tools for information visualization, critical analysis, and communication. Its composition was derived from a combination of elements in common to collaborative command-and-control systems and designed to be similar to common multi-player simulation games (as the most available subject pool consisted of undergraduate college students.)

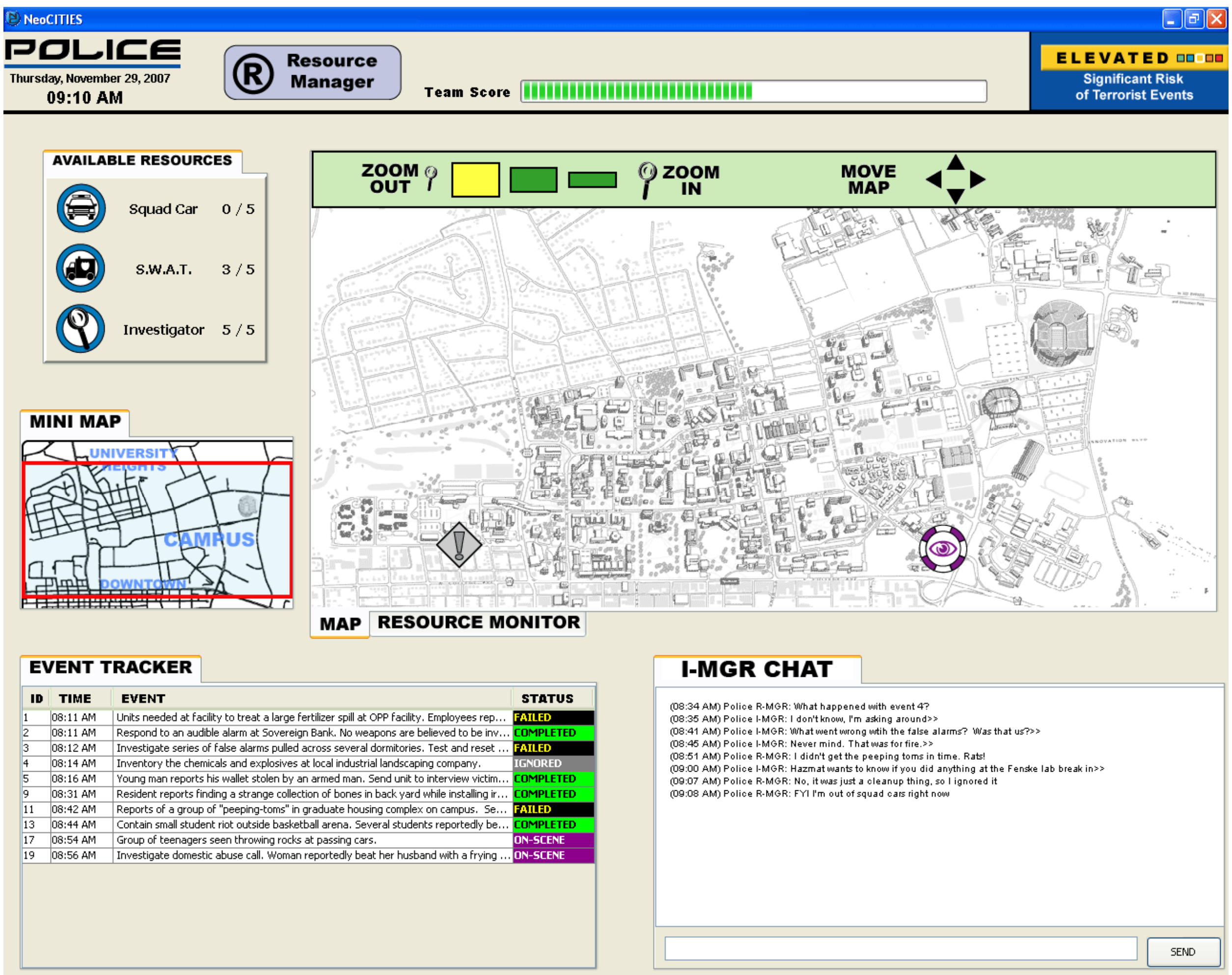


Figure 12: Screenshot of the NeoCITIES client interface

Several features of the user interface (UI) were identified that would benefit from additional design modifications. One issue regarded the event tracker, a table listing the time stamp, description, and status of each event. There was not enough room in the description column to contain more than the first few words of the event description which seemed to require frequent re-opening of events to re-read its details. This also made it difficult to quickly distinguish between similarly-worded events in the tracker. The root of this problem was that the status column had been made wide enough for the longest status message: “Resources Dispatched.” This was fixed simply by shortening the feedback message to “Dispatched” and decreasing the width of the status column accordingly. This provided a sizeable gain in width for that column.

A second UI issue appeared once the software was capable of running on computers of varying monitor sizes and resolutions. The NeoCITIES UI was configured to run exclusively at a resolution of 1280x1024. However, many laptop computers with non-standard screen proportions would typically have more screen available that the simulation required. Running NeoCITIES on these machines revealed that several of the UI elements were rendering in unattractive ways, though formerly this had not been an issue since the problem areas were outside of the available screen space. New adjustments to the UI containers ensured that the interface would look tidy and organized on any screen resolution. Additional minor cosmetic adjustments helped improve the overall look of the interface.

Preliminary testing of the traffic variable described above revealed problems when multiple dialog boxes would pop up and remain on the user’s screen. Formerly, it was rare for a user to leave one dialog box up long enough for another one to pop up in front of it as the time between events was quite long compared to the time between taking action and receiving feedback. However, once scenarios were designed to intentionally create a pile-up of messages and events for the user, this bug became very problematic.

Part of the system logic was to require users to take action on a dialog box (e.g. receiving a feedback message or an incoming event) before returning to use other parts of the UI, such as the map or chat features. When the pace of the simulation was fast enough for the user to be managing several events simultaneously, this would lead to apparent system lock-ups when one dialog box waiting for input would become occluded by one or more additional dialog boxes. The system would then be waiting indefinitely for the user to enter information on a dialog box that could no longer be seen or operated. To solve this matter, new logic was written so that new dialog boxes would wait in a queue to appear only after the currently visible one was closed. Other solutions were tested that employed more flexible UI elements, such as pop-up windows that could be repositioned and closed at will. However, tests showed that the server and clients could drift out of sync when the user addressed messages in the order of his or her choice, rather than the order in which the server had sent them.

Integrating Psychological Manipulations and Measures

Until this study, NeoCITIES had not been used to run experiments employing integrated psychological manipulations or measures. To date, only Connors (2006) employed a post-task online survey measure. Jones (2006) relied on a separate paper-and-pencil survey administered after the task. The current study required the administration of a different mood manipulation before every task as well as multiple self-reported measures before and after every NeoCITIES exposure. To reliably handle this complex experimental scenario, a new web-based system was developed to maintain and deliver all survey measures as well as manage the manipulations for each condition of the experiment.

The first layer of development was the creation of a MySQL database containing tables for every survey measure (e.g. STAI, SSSQ, PANAS, etc.). These tables contained the text of each question along with a unique identification number, scoring polarity (whether or not the question is reverse-coded), and any other necessary qualifiers, such as the categories or subscales the questions belonged to, as appropriate. By storing all questions in this way, all survey measures could be implemented simply with web page templates that only required specification of which table or tables to draw questions from, whether to filter the questions by category or subscale, whether to randomize the order of the questions, and how many points to use on the response scale (five point scales were the default). An additional table was designed to collect the responses from each participant during each session. This facilitated easy querying of response data from any individual or range of participants via custom query web pages.

One more table stored information on what experimental conditions were to run during the current session. At the beginning of an experimental session, each participant's workstation queried this table to determine which movie clips to use for the mood induction procedures and which NeoCITIES scenario files were going to be used in the simulation tasks. This allowed for central control, from the server side, of the experimental tasks and procedures in each session. Like the NeoCITIES team configuration tool described above, all of these server-side tools were built using PHP and MySQL for reusability and ready deployment on most any standard web server.

Development of the Chat Coding Measures

Holistic measurements of team cognition require more than aggregated task outcome measures (Cooke, Salas, Kiekel, & Bell, 2004). Similar task outcome measures can result from distinctly different group problem-solving activities due to within-group advantages and disadvantages in various team capacities, such as coordination, leadership, or shared memory. One team may fail a task due to a strongly persuasive leader who happens to be advocating an incorrect course of action. Another may similarly fail due to incoherent communication strategies. The challenge is figuring out why and how these failures happened.

Content analysis of communication data provides the experimenter with an effective means to explore the subtle "why" of team successes and failures. This is achieved by breaking down large bodies of complex qualitative information into more manageable forms which may be coded and quantified for comparison within or between groups (Smith, 2000). Simple measures of message quantity as well as complex analysis of message content provide useful details that can reveal individual and team behaviors that predict group task outcome. Communication data also serve as a dependent variable to explore how manipulations of task conditions (such as mood and stress) impact the style and frequency of team communication.

NeoCITIES provides several chat logs: one for the communication between the Information Manager and Resource Manager on each two-person team (Police, Fire/EMS, and Hazmat), and one for communications between all three Information Managers. The latter communication channel is primarily for discussion of which teams are responsible for responding to a given event. The IM/RM communication is largely comprised of messages pertaining to emergency responses still in progress. Note that since RMs cannot communicate with anyone except his or her IM, messages to other teams must be relayed through the IM. This communication structure permits the experimenter to observe the messages which transmit information from one point to another within the group – for example, from the Fire team's

Resource Manager to the Police team's Information Manager, via the Fire team's Information manager.

In this study, the coding scheme for the communications logs was adapted from one developed by Entin and Entin (2001) for the Adaptive Architectures for Command and Control (A2C2). This scheme individually records requests and transfers of information, action, and coordination, as well as acknowledgements such as "OK" or "got it." Ratios of anticipation are constructed by dividing the number of transfers by the number of requests in each category. This measure refers to how often one partner anticipates the other's need for information or action and sends a message to that effect without being prompted to do so. In other words, anticipation ratios describe the tendency for one partner to provide an answer without being asked a question.

The scheme used in this study was adapted from the original by changing the scale from a rate measurement (number of communications per minute) to a quantity of communications, as the duration of the sessions was constant in both experiments. An additional category was added for off-task communications such that all messages sent could be tallied and accounted for. For these measures to be reliable, the data must be analyzed and coded by two or more coders, whose agreement is measured in terms of inter-coder reliability. Coding instructions are contained in appendix B.

CHAPTER 6
RESEARCH METHODOLOGY

The previous chapter detailed the NeoCITIES simulation which figures prominently in the methodology applied in this study. Research situated team contexts takes many forms and often requires the use of methods practiced in multiple disciplines, including both quantitative and qualitative. This chapter begins with a brief review of common methodologies used in team research and the challenges faced by each. Simulated task environments, of which NeoCITIES is an example, are presented as an effective methodological approach that builds upon the strengths of multiple methods.

The remainder of this chapter describes the task, participants, and experimental design of this study in detail, including all of the manipulations and measures and how each one was conceived and implemented. The chapter concludes with the full procedure administered to the experimental participants during each experimental session.

Methodologies in Team Research

Small group research methods cover a range of within- and between-group processes. These include the formation, structure, and development of groups, as well as the social processes occurring within groups (such as leadership emergence or conflict behaviors), decision making, task performance, and external environmental events affecting all of these processes (see Kerr, Aronoff, & Messé, 2000; Weaver, Bowers, & Salas, 2001). The current study examines the impact of stressors and mood states as environmental factors on within-group communication, decision-making, and task performance.

Psychological research methods are often challenged to balance and manage experimental control and ecological validity. One shortcoming of psychological research conducted at the individual level is that it is often difficult to predict how the processes or behaviors of interest will actually manifest in the context of naturalistic interactions with one or more other individuals (researchers frequently point this out in the "future work" sections of journal articles). This is not to say that important findings continue to emerge by placing individual cognitive functions under the microscope (phenomena which may be termed *microcognition)*, but that the step from individual to group-level research is a necessary step toward research on cognition as it naturally occurs. Pietro Cacciabue and Erik Hollnagel coined the term *macrocognition* to refer to cognitive functions as they work together within and between individuals in naturalistic decision-making contexts (Cacciabue & Hollnagel, 1995).

In discussing their approach to research on macrocognitive processes using simulated environments, Brehmer and Dörner describe this methodological dilemma:

> "The root of these problems lies in the inability to handle *complexity*. In field research, there is often too much of it to allow for any more *definite* conclusions, and in laboratory research, there is usually too little complexity to allow for any *interesting* conclusions." (Brehmer & Dörner, 1993, p. 172)

To provide contrast to the controlled laboratory experiments detailed in the previous chapters, it is worth mentioning an example of field research on group decision making under stress. The TADMUS (Tactical Decision Making Under Stress) research program was a seven-year project launched by the U.S. Navy in response to the U.S.S. Vincennes accidental destruction of an Iranian airbus in 1989 – an accident ultimately attributed to human error resulting from insufficient technological, procedural, and administrative understanding of operators under stress in conflict scenarios. In addition to post-hoc analysis of the Vincennes incident itself, this research program utilized interviews and observation of Navy crews at work to better understand and define the decision environment and the stressors within that environment. The goals of this program were to develop principles of design for decision support systems and generate strategies for conducting simulations and training for decision making under stress.

The TADMUS report concludes with some lessons learned from the challenges of this research program (Salas, Cannon-Bowers, & Johnston, 1998). These suggest possible strategies for addressing the gulf between laboratory and field reseaerch:

- Do not underestimate the complexities of conducting meaningful field research.
- Do not be afraid of getting the users involved, but manage the process.
- Do not underestimate the value of data
- Be happy with small increments of progress; they eventually lead to the goal

SIMULATED TASK ENVIRONMENTS (STES)

The four points above provide a strong argument for the use of simulated task environments for detailed experimental research on group decision making under stress. STEs offer a potent blend of the strengths of field study and controlled laboratory experiments (Gray, 2002). The tasks and the environment provide ecological validity while the experimental conditions and manipulations can be carefully controlled and repeated. Finally, given a sufficient subject pool, STEs allow for an iterative and modular research process to explore detailed variations on a given theme.

A STE can be employed to create the illusion of stress without putting the subject in actual danger. This is a significant benefit given the ethical and legal constraints of experimentation on human subjects. In competitive sports or role-playing exercises, for example, participants caught up in the activity may perceive dangerous threats and experience great psychological stress. Yet to an outside observer (or even to the participants themselves, at another level of consciousness that is temporarily set aside), it is clear that these threats are not real, but simulated by the activity. An effective stress simulator, therefore, needs to be realistic and engaging enough to induce transportation into this insulated microcosm (Yates et al., 1995).

Gray (2002) defines a taxonomy of STEs which vary in complexity and fidelity. Scaled worlds are one variety of STE that balances these two parameters to simulate a subset of functions within a particular task environment. Which functions are included or removed depends on the specific research question. When implemented thoughtfully, scaled worlds are well suited for generalizing findings back to the original task environment. Rather than focus on the material properties of complexity and fidelity of a given STE, Gray proposes three evaluative dimensions drawn from the perspectives of the researcher (tractability), the task (correspondence), and the participant (engagement). *Tractability* describes how well the STE permits the researcher to manage the pursuit of a given research problem. Simple lab tasks are highly tractable, while complex hi-fidelity simulations can be difficult to assess and control. *Correspondence* refers to how the STE resembles the modeled domain. At one end of the spectrum, an F-16 flight simulator represents many aspects of one system. At the other end are lab experiments on one aspect found in many systems, such as memory retrieval or pattern recognition. Finally, *engagement* describes how seriously the participants take their experience in the STE. Engagement may come from many sources ranging from the sensory excitement of the simulated scenario to the compensation offered subjects for participating. Often engagement is enhanced by adding game-like features to the simulation, though a dull domain should not be simulated to be more engaging than it really is when vigilance or under-stimulation are the phenomena of interest in a study.

In two previous studies, NeoCITIES has been successfully implemented as a scaled world simulation (Connors, 2006; Jones, 2006). The simulation designers pursued high tractability by providing the experimenter with tight control over all aspects of the simulation including the initial training protocols, the characteristics and pace of the emergencies participants are tasked with managing, and the types of affordances and communication pathways offered to users in the interface. Each role in the simulation is defined to be distinct which allows the experimenter to carefully control the distribution of work across the team. In the interest of offering high correspondence to the emergency management domain, the simulation structure and underlying scenarios have been informed by *in situ* field observation and knowledge elicitation of 911 dispatch workers (Terrell, McNeese, & Jefferson, 2004). However, in order to maintain engagement, especially from participants who are typically university undergraduate students, the pace of the simulation is accelerated from ten to twenty-five times faster than real time (for example, events transpiring over 120 minutes in the city could be simulated during a ten minute experimental session). This accelerated temporal dimension resembles that used in similar types of popular simulation-based online multiplayer video games (Dickey, 2005).

TASK

In each condition, each six-person team ran the previously described NeoCITIES simulation (for detailed descriptions of the underlying functions and protocols of the NeoCITIES task see Connors, 2006). The members of each team are assigned to one of three pairs responsible for different types of emergency management: police, fire and hazmat. Each pair consists of two roles: an information manager (IM) and a resource manager (RM). Prior to the beginning of experimental trials, all participants receive role-specific training on how to operate the simulation and effectively perform their roles.

Participants perform the task isolated by dividers and therefore have to coordinate all action and communication exclusively through the NeoCITIES client software using a structured communication protocol and a text-based chat tool.

Figure 13: NeoCITIES Laboratory Workstations

During the simulation, the IMs all receive the same incoming information about emergency events and discuss via a chat panel which among their pairs should take action (often this requires discussion between all of the IMs). For example, a new event appears simultaneously on all three IMs displays describing a report that a burglar alarm had gone off in a chemistry lab on campus. The IM for the police team might quickly determine that her dyad should respond to this event, but the three IMs would also discuss whether or not the report suggested that the hazmat team should also send some resources. Those IMs that determine no action is necessary set the event aside by clicking the “Ignore” button.

If action is deemed necessary by a given IM, that IM uses a structured communication tool to pass the emergency report along to the RM along with a user-selected icon (from 24 available standard icons denoting common emergency events) and an optional text message used to convey additional information, when necessary, to the RM about the event.

The RM is the only member of the dyad with control to dispatch the appropriate resources to the event. Upon receipt of the structured communication from the IM described above, the RM has the option to dispatch one or more resources to the event or may opt to ignore the event if he or she believes the IM incorrectly accepted responsibility to manage the event. A chat panel permits discussion between the IM and RM to negotiate whether and how to respond to events. The RM does not know anything about any events other than the ones selected and passed along by the IM. The RMs can only communicate with their respective IMs.

Each RM has five units each of three different resources to utilize during the simulation. For example, the Hazmat RM has chemical clean-up trucks, bomb squads, and investigators available. There is a delay between the time resources are dispatched and the time they arrive on-scene, which is computed from a "traffic" constant set at run-time. Resources that are en-route, on scene, or returning from events are unavailable to be allocated to other events. This discourages over-allocation of resources. While five fire trucks can put out a fire faster than one, the RM is ill-advised to send all five to one event and have none available when another fire occurs. Once resources arrive on-scene, RMs receive an automatic report from the field pertaining to the success or failure of their actions. These messages indicate whether the resources sent were appropriate or in sufficient quantity to adequately resolve the emergency.

Depending upon the feedback received, additional communication and coordination with other teams may be necessary.

Table 1

Feedback messages received by resource managers

On-Scene Feedback Messages	Interpretation
"Unit(s) have arrived on-scene and report on-going progress. The situation will be resolved shortly."	RM dispatched the correct number of appropriate resources. Resources will return when the emergency is resolved.
"Units have arrived on-scene, but field commander reports that unnecessary personnel are present and currently inactive. However, progress is being made to resolve the situation."	RM dispatched more than the correct number of appropriate resources. Resources will return when the emergency is resolved.
"Unit(s) have arrived on-scene and report that progress is slow. Unit(s) have requested additional support from headquarters."	RM dispatched an insufficient quantity of the appropriate resource. Emergency is resolving too slowly. Resources will return when the emergency is fully resolved.
"Unit(s) have arrived on-scene, but do not have the capabilities to address the situation. Unit(s) have requested additional support from headquarters."	RM dispatched inappropriate resources to the event. Resources will return when the emergency is resolved.
"Unit(s) have arrived on-scene, but do not have the proper credentials to address this situation. Unit(s) are returning to headquarters."	This dyad is not required to respond to this event. Resources are returning immediately.

A scenario file containing a prewritten script controls the simulation during each exposure to the task. These scenario files contained ten minutes (experiment 1) or eight minutes (experiment 2) of emergency events to be released to the IMs at timed intervals. Each event was designed to be handled by only one dyad, however most were worded such that there was some ambiguity about whether an event was supposed to be dealt with by fire, police, or hazmat, or perhaps through collaboration between two or more. All of the events were selected from the scenario files previously tested and utilized in the prior two studies using NeoCITIES (Connors, 2006; Jones, 2006). Each scenario file was balanced such that each pair was required to deal with the same number of events and utilize the same total number of resources with approximately the same amount of time allowed to respond between events.

The score bar in each client's interface is set at 100% at the beginning of the simulation. The score bar reflects the accuracy and timeliness of each pair's responses to their respective events. All participants are asked to cooperate with each other and use the knowledge from their training to keep the score bars as high as possible (errors and delays gradually diminish the score). The simulation automatically closes at the end of the scenario.

PARTICIPANTS

Participants were drawn from a pool of undergraduate students enrolled in a junior-level human-computer interaction course as part of the curriculum in the College of Information Sciences and Technology at the Pennsylvania State University. Participation in the experiment was given in exchange for course credit.

EXPERIMENTAL DESIGN

Both experiments used a 2x2 within-subjects full-factorial design. The two independent variables were the level of stress (normal, high) and affective valence (sad, happy). The second experiment was conducted identically to the first with the stress manipulation changing from task load to performance pressure.

The condition sequence was changed each day as the time to configure conditions took longer than the time available between consecutive sessions. Teams visited the lab one at a time. No more than two groups visited the lab each day.

Table 2

Experimental Conditions

Condition	Stress	Mood
1	Normal	Sad
2	Normal	Happy
3	High	Sad
4	High	Happy

MANIPULATIONS AND MEASURES

The manipulations and measures implemented in this study are detailed in Table 3.

Table 3

Summary of independent and dependent variables

Independent Variables	Dependent Variables
Stress (manipulated): High task load or normal task load; high performance pressure or no performance pressure **Mood (manipulated):** Positive affective valence or negative affective valence	**Task Performance:** Dyad-level score based upon timeliness and accuracy of resource allocation responses **Communication type and frequencies:** Within-dyad messages coded according to communication types (acknowledgements, requests, or transfers of information, action, or coordination)

Independent Variables

Stress

Stress was manipulated in the first experiment using task load (normal or high) and in the second experiment using performance pressure (none or high). The same stress manipulation was applied to all six team members simultaneously. Low task load was provided with scenarios containing 18 events to be addressed in ten minutes. This task load was approximately equivalent to the load used in prior experiments which were testing tools under routine task conditions.

High task load was defined as scenarios containing 30 events to be addressed in ten minutes. This pace was determined to slightly exceed what an experienced user would be able to manage by ensuring that at least one new event would emerge for each dyad before the prior event could be fully addressed. Care was taken to avoid a task load so high that participants would "choke" under pressure and stop performing altogether.

The performance pressure stress manipulation used in the second experiment was partially adapted from the Trier Social Stress Test (Kirschbaum, Pirke, & Hellhammer, 1993). Subjects in the stressed condition were told at the beginning of the simulation that this particular trial had been randomly selected to be digitally monitored and recorded for evaluation by a panel of crisis management experts. Upon the launch of the simulation, two experimental monitors closely observed the participants by walking up and down the aisle behind the participants, pretending to make notes on clipboards. In addition, a monetary incentive of $150US was going to be awarded to the six-person team with the best overall score during the second experiment. The significance of this award was heavily emphasized at the beginning of the trials during the stress condition. To maintain this performance pressure further during the trial, participants were emphatically told that they needed to perform better at three minutes and seven minutes into the scenario. All scenarios in the second experiment had 18 events to be addressed in eight minutes, a pace slightly higher than the low-load condition in the first experiment.

Mood

Mood was manipulated by showing participants eight to ten minute happy or sad scenes from popular movies immediately prior to performing the NeoCITIES task. The happy and sad movie clips used in these experiments were selected from a larger pool through informal pretesting on lab personnel. Participants viewed a total of four clips in each experiment. This method has elicited the desired moods in several studies (e.g. Cavallo & Pinto, 2001; Van Tilburg & Vingerhoets, 2002; Wang et al., 2006). The same mood manipulation was applied simultaneously to all six team members. The happy manipulation actually has far less effect upon individuals than the sad manipulation. Most people enter a situation such as an experimental trial in a fairly happy mood (Diener & Diener, 1996), so there is not much room to make them happier. In that sense, the happy state is a control condition, while the sad state is the actual mood manipulation.

Table 4

Movies used for mood manipulations

Happy	Sad
Austin Powers: The Spy Who Shagged Me (Mike Myers, 1999) [two clips]	Forrest Gump (Robert Zemeckis, 1994)
Hitch (Kevin Bisch, 2005)	Terms of Endearment (James L. Brooks, 1983)
Play It Again, Sam (Woody Allen, 1972)	Titanic (James Cameron, 1997) [two clips]

Dependent Variables

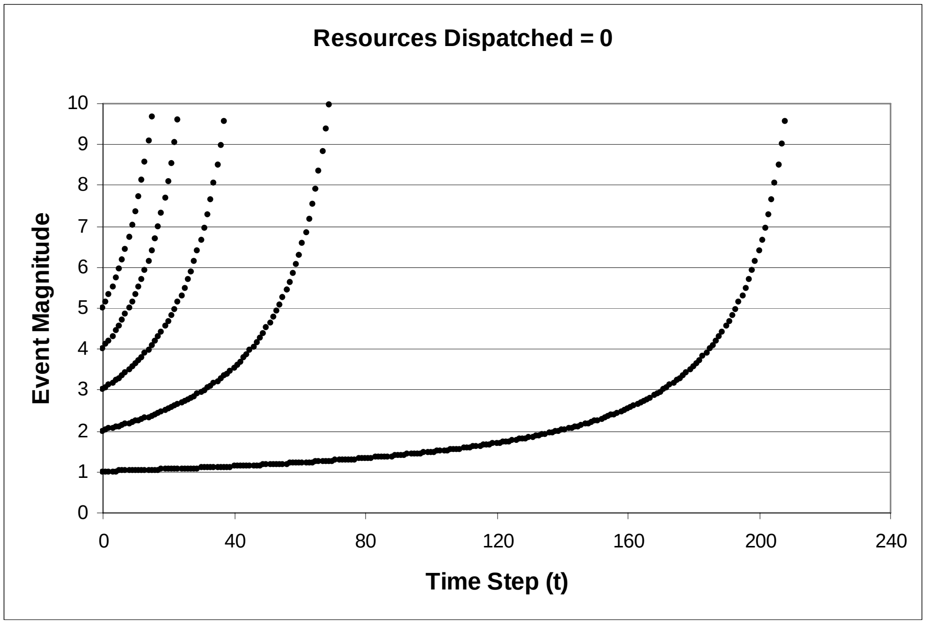
Task Performance

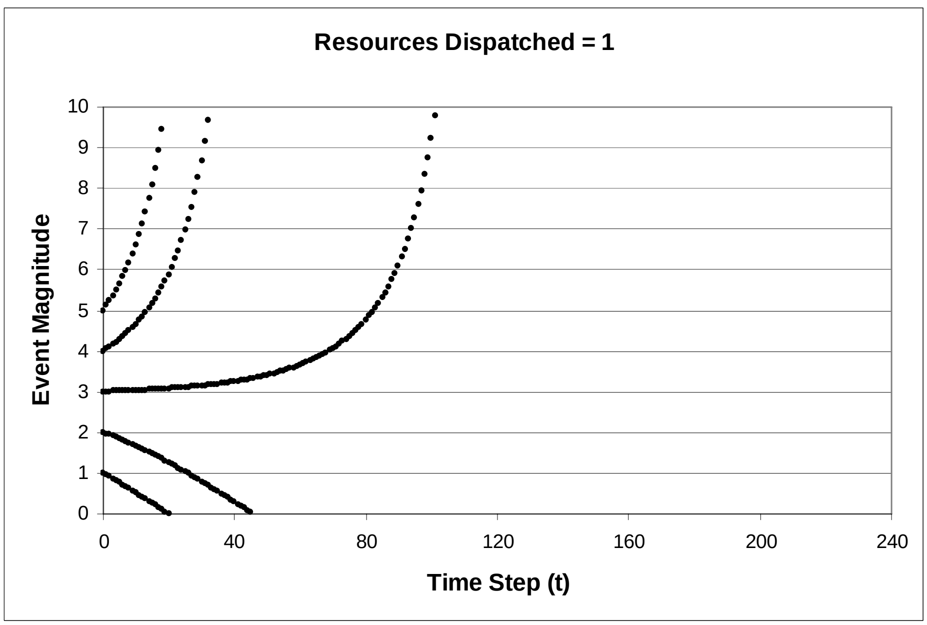
An overall task performance score for each dyad per session was calculated by aggregating per-event scores over the course of the scenario. This is the same formula used in the original CITIES experiments (Wellens & Ergener, 1988). The current magnitude for each event is recorded at each time step as a penalty. If the event magnitude continues to escalate beyond a preset threshold or if the event persists longer than a preset time limit, the event is declared a failure. On the other hand, once the appropriate resources arrive on scene ($R_{correct}$), the magnitude of the event will diminish at a rate proportionate to the quantity of resources correctly dispatched. Once the magnitude reaches zero, the event is considered to be successfully resolved.

$$M_t = a(M_{t-1}) + b(M_{t-1})^2 - c(R_{correct})$$

Equation 1: NeoCITIES event magnitude formula (Wellens & Ergener, 1988)

The event scores are recorded at each time step as M_t. The time when an event is dispatched to the clients is defined as $t = 0$. The first magnitude computed is M_1. The term $R_{correct}$ denotes the number of appropriate resources currently dispatched to the event (inappropriate resources have no effect in resolving the event). Each event is fired with an initial magnitude (M_0) that is proportional to the severity of the event. For example, for a wastebasket fire, the initial severity $M_0 = 1.25$, while for a multiple-car accident $M_0 = 3.00$. Over time, the magnitude of the event escalates until the proper resources arrive to address and begin to resolve the event. The general idea behind this model is that a wastebasket fire left unattended becomes an apartment fire, and if still unattended it can spread to many buildings, and so on. As the fire escalates, more resources are required to put that fire out. Ultimately, however, all the buildings burn down, so there is a maximum limit to the possible penalty. The graphs in Figure 14 show how event magnitudes change over time depending on how many resources are allocated to resolve them. Total penalty for an event is the area under the curve.


Resources Dispatched = 0
Event Magnitude
Time Step (t)
0
1
2
3
4
5
6
7
8
9
10
0
40
80
120
160
200
240


Resources Dispatched = 1
Event Magnitude
Time Step (t)
0
1
2
3
4
5
6
7
8
9
10
0
40
80
120
160
200
240

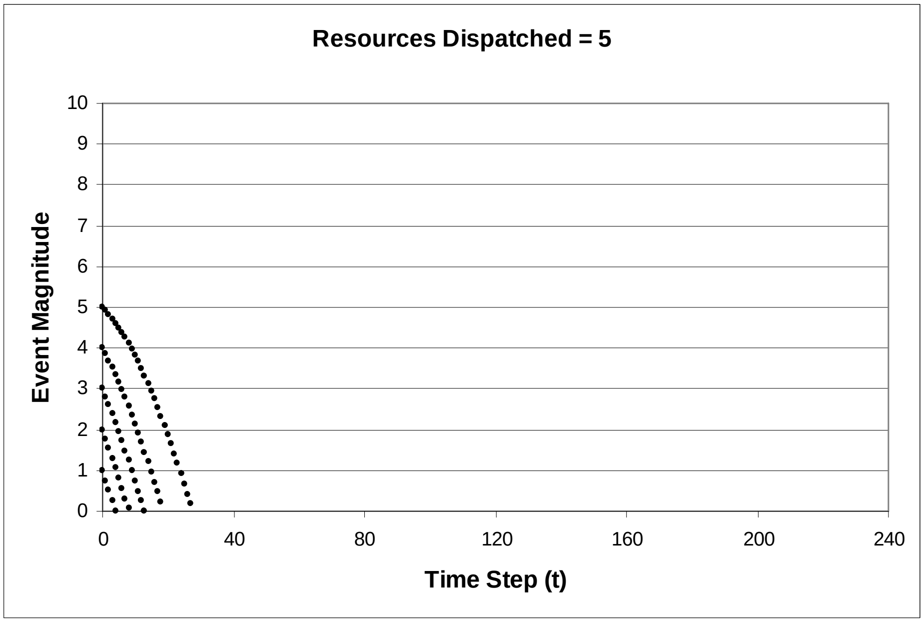


Figure 14: Event growth curves showing changes in event magnitudes over time given the allocation of 0, 1, or 5 resources to events of varying initial magnitude

The total penalty assigned to the dyad for that event (E_i) equals the sum of the event magnitude values (M_t) recorded during the lifetime of that event. This total penalty amount is then deducted from the dyad's score bar. Therefore, if an event is resolved with the proper resources very quickly, the penalty to that dyad's score is fairly small. If an emergency event is left to run out of control, however, the accumulated penalty can be very large. In this version of NeoCITIES, events fail when they increase in magnitude to the next higher integer (e.g. when an event of initial magnitude of 2 increases to a magnitude of 3).

Comparing the event scores for the magnitude 2 event in each of the three graphs above demonstrates the significant shifts in score depending on the operator's response. If the operator ignores the event ($R = 0$), the event reaches a magnitude of 3 by time step 36 and fails with a score of 80.40. If one resource is immediately dispatched, the event slowly resolves by time step 45 for a score of 50.66. If the operator dispatches 5 resources immediately, this excessive response resolves the event at time step 10 with a score of 9.38. Of course, this over-allocation of resources presents the risk of not having enough available for another imminent emergency.

Figure 15 shows a typical example of an event response. In this graph, an event of initial magnitude of 2 occurs at time step 0 ($M_0 = 2$). The operator does not address this event until time step 30, at which time two resources are dispatched. The magnitude begins to decrease at this point and reaches 0 at time step 66. At this point the event is successfully resolved, and the total score for the event is calculated as the area under the curve ($E_i = 131.68$).

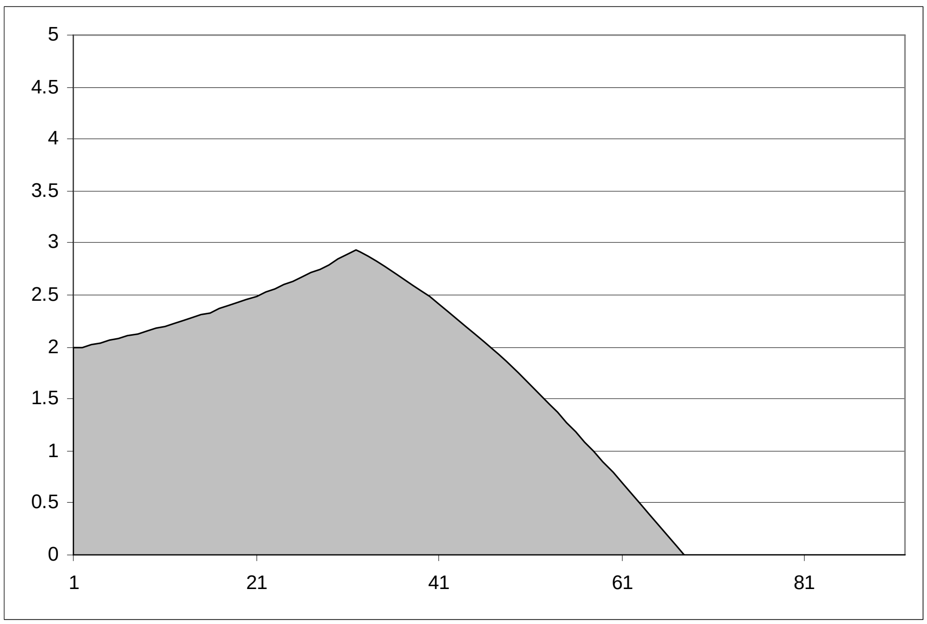


Figure 15: Example scoring for an event of intial magnitude of 2 addressed with 2 resources at time step 30

Each scenario has an initial maximum score S_{max} derived from the quantity and severity of events it contains. The final score for each dyad equals S_{max} minus the sum of the accumulated event penalties.

$$E_i = \sum_{t=0}^{t_{max}} M_t \qquad S_T = S_{max} - \sum_{i=1}^{I} E_i$$

Equation 2: Event score and final dyad score formulas

The calculations above refer to time in terms of *time-steps* in the simulation, not actual time in seconds or minutes. For example, time steps may be six seconds apart, each step representing one minute of simulation time. The scaling constants *a, b,* and *c* may be adjusted for different kinds of experimental scenarios. In this study, $a = 0.995$, $b = 0.0075$, and $c = 0.04995$. These constants and equations are the same as those used as measures in the C.I.T.I.E.S. game (Wellens & Ergener, 1988) which is NeoCITIES' progenitor. Two prior NeoCITIES experiments also used these scoring formulas as dependent measures (Connors, 2006; Jones, 2006).

Communication variables

The purpose of including measures of communication data is to try to find possible explanations for *why* stress or mood states cause changes in team performance. By detecting changes in communications types, patterns, or content, it may be possible to identify changes in attention or problem-solving styles at both the individual and team levels.

The communication variables computed for this study focused exclusively on within-dyad communications rather than between-dyad communications in order to directly compare the dyad-level performance score with the communication behaviors occurring at that level. The development of the chat coding scheme for NeoCITIES was described in chapter five (coding instructions are found in appendix B). The primary communication measures are described in Table 5.

Table 5

Team communication encoding measurements

Abbreviation	***Measure***	***Description***
	Overall Rate	
TC	Total Communications	Total number of communications in the session

	Communication Type	
IR	Information Request	Request for information
IT	Information Transfer	Transmission of information
AR	Action Request	Request for action
AT	Action Transfer	Statement of action taken or to be taken
CR	Coordination Request	Request to coordinate an action
CT	Coordination Transfer	Agreement to coordinate an action
ACK	Acknowledgements	Acknowledgements of the receipt of a communication, but without any specific message content (i.e. "OK")
INSIG	Insignificant Utterances	Task-irrelevant statements or chatter
	Communication Ratios	
OA	Overall Anticipation	Total communications transfers divided by total communications requests
IA	Information Anticipation	Information transfers divided by information requests
AA	Action Anticipation	Action transfers divided by action requests
CA	Coordination Anticipation	Coordination transfers divided by coordination requests

An additional category of communication measurement assessed the proportion of the chat log consisting of each type of communication. These were computed by dividing the number of each type of message by the total number of messages in the log. This provided variables indicating the percentage of the log consisting of information transfers (%IT), action requests (%AR), and so on. Lastly, a measure of on-task messages was computed by subtracting the insignificant utterances from the total communications (TC-INSIG)

Certain measures from this table are not relevant to within-dyad communication. When RMs receive a status report suggesting their dyad is not suited to handle an event, coordination requests (CR) may be made to their IMs to suggest to the other IMs that action by another dyad is necessary to resolve a certain event. Coordination transfers (CT), however, are exclusive to the domain of between-dyad communication. Therefore, CTs were not considered in this study, nor were the CA ratios.

Individual Difference Measures

The significant role of individual personality factors in reactions to stressors is acknowledged in nearly all models of stress. Though the effects of individual differences may not be reliable in subject pools as small as the one in thus study, failure to measure and account for those suggested by previous research posed a possible threat to the internal validity of the study. The literature reviewed in the preceding chapters identifies several individual differences that are particularly relevant in the context of the group decision making processes and conditions in this study: locus of control, tolerance of ambiguity, trait anxiety, neuroticism, and extraversion. Prior to the beginning of the experimental trials, all participants were administered the following survey measures:

Table 6

Control measures of individual differences

Measurement Instrument	**Measures Provided**
Myers-Briggs Type Indicator (Myers, McCaulley, Quenk, & Hammer, 1998)	Four-factor dichotomous personality type (administered by instructor in class)
International Personality Item Pool Representation of the NEO PI-R™ Five-factor personality inventory (Goldberg et al., 2006)	Continuous measures of extraversion, neuroticism, conscientiousness, agreeableness, and openness to experience
State-Trait Anxiety Inventory (STAI) Form X-2 (Spielberger, Gorsuch, & Lushene, 1970)	Trait anxiety index
Multiple Stimulus Types Ambiguity Tolerance (MSTAT-I) (McLain, 1993)	Tolerance of ambiguity index
Multidimensional Multiattributional Causality Scales (MMCS) (Lefcourt, 1981)	Internal and external locus of control indices
Basic demographics	Age and gender

Dyad-level measures of these individual differences were computed by averaging the values of the two dyad members. A gender mix variable was created to code whether dyads were male-male, male-female, or female-female.

Mood and Stress Measures

Immediately following the mood induction stimulus, participants completed a brief questionnaire (unrelated to the NeoCITIES task) that included items from the Positive and Negative Affectivity Scales (PANAS) (Watson et al., 1988), Short Stress State Questionnaire (SSSQ) (Helton, 2004), and Short-Form State Trait Anxiety Inventory (STAI) (Marteau & Bekker, 1992) in addition to questions about the content of the movie clip. These items were used to check for the effect of the mood manipulation. Immediately following the NeoCITIES task, participants completed another longer questionnaire that included a larger set of items from the three instruments listed above in addition to task-related questions about the participant's experience during the NeoCITIES simulation. These items checked for the effect of the stress manipulation and the persistence of the mood manipulation.

All questions on the two surveys mentioned above were answered on 5-point likert scales indicating agreement with statements (e.g. "I feel determined," "I am worried," "I feel this movie clip was sad") with responses ranging from "Not at all" to "Extremely." To prevent the survey instruments from becoming too long and fatiguing, a subset of questions from the each dimension of the SSSQ (engagement: six items; distress: five items; worry: five items) was selected as the most salient set of stress measures for these experiments. All of the survey items are reproduced in appendix A.

Additional task-related questions were utilized in experiment 2 to test the fourth hypothesis regarding the effects of stress on team processes, specifically the ability of the team to collectively detect patterns of activity from pieces of information distributed among each of its members. Prior to the second experiment, teams were told that sometimes there are connections between events in NeoCITIES, meaning that an event one pair is dealing with may cause another event for another pair, which again could cause yet another event. They were to be on alert to look closely at events and communicate with each other in order to find them when they occurred and describe them on a paper-and-pencil survey administered at the end of the task (this survey was not analyzed).

Each 18-event scenario had six connected events – two for each dyad to resolve (one third of the events per scenario were written to be interconnected). By holding the number of connected events constant in each scenario, variations in the attention to and reporting of such events could be attributed to the manipulations of stress or mood. Connected events were defined to be in close proximity on the map, have at least two keywords in common in the event description, and occur within a total span of six events. An example of connected events might be a break-in at a chemistry lab that would be addressed by the police. Some time later, however, the materials stolen in that incident would surface in another nearby event that requires the attention of the hazmat team. Resolving this second event successfully would require information gathered by police during the first event, so it benefits the hazmat team to a) recall that a potentially related event occurred earlier, and b) inquire of the police: “Didn’t you deal with a break-in at a chemistry lab a while ago? What happened with that?”

This hypothesis has communication and coordination dimensions which were tested with additional post-task questions. The experimenters constructed these questions by drawing from communication and cooperation-related parameters of teamwork frequently referred to in the stress literature. Examples of these include perceived levels of trust in communication, and confidence in information. The last two questions were designed to assess the perception of interconnected events as specifically defined for participants at the beginning of the experimental sessions. Participants indicated their agreement with the following statements added to the post-task surveys. These were answered on the same 5-point likert scale as the other self-report questions above.

EQUIPMENT

NeoCITIES is built on a Java-based server-client architecture. It currently runs exclusively on the Microsoft Windows platform. The server code runs on a separate computer from the client workstations. The NeoCITIES software does not require any specific hardware or software beyond what is commonly found on most desktop computers running Microsoft Windows: a keyboard and mouse, a monitor capable of displaying 1280x1024 pixels or higher, a web browser, the Java Runtime Engine (JRE) 1.5.02 or later, and a network connection. Training materials are presented to users in Microsoft PowerPoint format. The mood induction procedures as well as the assessments of stress and mood were administered online in a web browser prior to and following exposures to the NeoCITIES task. The launch and sequence of the mood inductions, NeoCITIES task, and survey instruments were automatically controlled by batch files.

The experiments were conducted in the User Science and Engineering Lab (314A IST Building) which houses a modular experimental space supporting six physically divided computer workstations (see Figure 13). Each client workstation contained a Dell Optiplex computer running Microsoft Windows XP Professional SP2 with a 17” flat-panel display, ethernet network connection, standard keyboard, optical 2-button mouse with scroll wheel, and stereo headset. The software installed on the computers included the Java Runtime Engine 1.5.02, Internet Explorer 7.0, Microsoft PowerPoint, and Adobe Flash Player 9.0. An additional Dell laptop computer running the same software ran the NeoCITIES server software from the experimental monitor’s position in the lab. Batch files ran from the experimenter’s workstation at the conclusion of each NeoCITIES task to gather all of the performance logs from the server and six clients and organize them on an external storage server.

PROCEDURES

An initial information session detailing participation requirements was performed during the first week of the semester. Participants were told that the experiments they were going to participate in were part of a joint effort by the College of Information Sciences and Technology, the College of Communications, the Department of Psychology, and the Department of Geography (all of which were, in fact, participating in various aspects of the current study) to conduct multiple unrelated experiments that all pertained to various aspects of “Individual Differences in Group Performance.” However, this statement was actually to provide a cover story for the mood induction procedure. Participants were told that they were participating in an experiment on visual communication and memory in which they would view a video clip and answer questions about it after waiting for ten to fifteen minutes. The experimenter would be using that waiting period to conduct the NeoCITIES experiment.

At that time participants were asked to read, sign, and return the IRB-mandated informed consent form. Each team was then asked to determine their availability for lab sessions;

assembly of the final schedule took approximately two weeks. Each group visited the lab at the same day and time for training and both experiments. Participants were randomly assigned to a dyad and role. Once assigned, each participant held the same position and computer workstation at each session during the experiment. In order to prevent repeated exposure from inducing boredom, subjects were reassigned to new roles within the team for the second experiment. While the task work of the Police, Fire, or Hazmat dyads are functionally equivalent, the changes in perspective (i.e role and resources in use) were intended to keep the simulation interesting and defer a loss of interest in the task.

Once the schedule was completed, teams visited the lab for a preliminary session that included the online administration of the personality survey measures and approximately 30-45 minutes of training on the NeoCITIES simulation. Training began with a self-paced PowerPoint-based tutorial customized for each role. It explained how the interface worked, what each participant's responsibilities were, and what to expect from their partner in the simulation. Once all participants completed the tutorial, the experimenter offered to answer any questions. Next, participants completed a brief scenario consisting of nine events at a slow place. Following this, participants could again ask any questions about operations or strategies within the simulation. Finally, participants went through a longer scenario consisting of twenty events, similar to what they would encounter in the actual experimental trials. Participants could then continue to ask questions if needed and then were dismissed. Participants were given the opportunity to review the training materials again prior to experiment 2.

For the active experimental sessions, participants were seated at the same workstation they had been trained at. Each logged into their workstation with a unique ID that ensured the self-reported data was automatically tracked with that individual's session. They were reminded that they would begin with the experiment on visual communication and memory and then proceed to the NeoCITIES experiment, returning again to the visual communication experiment at the end. Requiring participants to recall the movie clip after the NeoCITIES task is a technique that helps preserve the clip in working memory (and therefore maintains its emotional impact) during the task.

At the beginning of the session, participants put on their headphones and double-clicked an icon which launched the batch file that would automatically control each step of the experiment from that point on (screenshots of each page of the experimental session in sequence are in appendix C). At this point the experimenter sat at a desk at one end of the lab to discreetly monitor the experiment and control the NeoCITIES server. Participants first saw an introductory screen explaining the general instructions for the activities to follow. The next screen introduced the visual communications part of the study. After clicking "Begin" the mood manipulation movie clip began. At the conclusion of the movie clip, participants were presented with a short online survey that included questions about features from the movie clip and their current feelings at that moment (see appendix A). Questions about the movie provided cover for other items required for the mood manipulation check. Following the pre-task survey, participants received a score on their recall of features from the movie. This maintained the on-going thread of the visual communications study as separate from the NeoCITIES study. Responses to these questions were not analyzed. The NeoCITIES task immediately followed, lasting ten minutes (experiment 1) or eight minutes (experiment 2). Following the NeoCITIES task, participants completed a longer survey including questions about the NeoCITIES task and their feelings at that current moment (see appendix A). Participants were asked to wait after completing the survey until everyone had finished.

After a brief pause, the participants completed the second condition of the session. The cycle repeated with a second movie clip (opposite mood of the first), pre-task survey, NeoCITIES task (same stress condition as the first), post-task survey, and a final clip of a stand-up comedian that served two additional purposes. One was to provide an emotional “reset” to put participants back into a positive mood before leaving the session. The second was to present follow-up survey questions comparing the comedian clip to the happier of the two clips seen during the session. This reemphasized the requirement to preserve the movie clips in memory during the other tasks. Answers to these questions were not analyzed. After everyone had completed the final survey, participants were reminded of the date and time of their next lab session and were dismissed.

CHAPTER 7
RESULTS

This chapter details the results of the two experiments explained in the prior two chapters. The two experiments are reviewed in sequence, beginning with descriptive data about the participants and conduct of the experimental sessions, followed by the manipulation checks and main results. The main results sections first report on the analysis of task performance and results of the hypothesis tests, and then concludes with analysis of the communications data.

MANIPULATION CHECK ITEMS

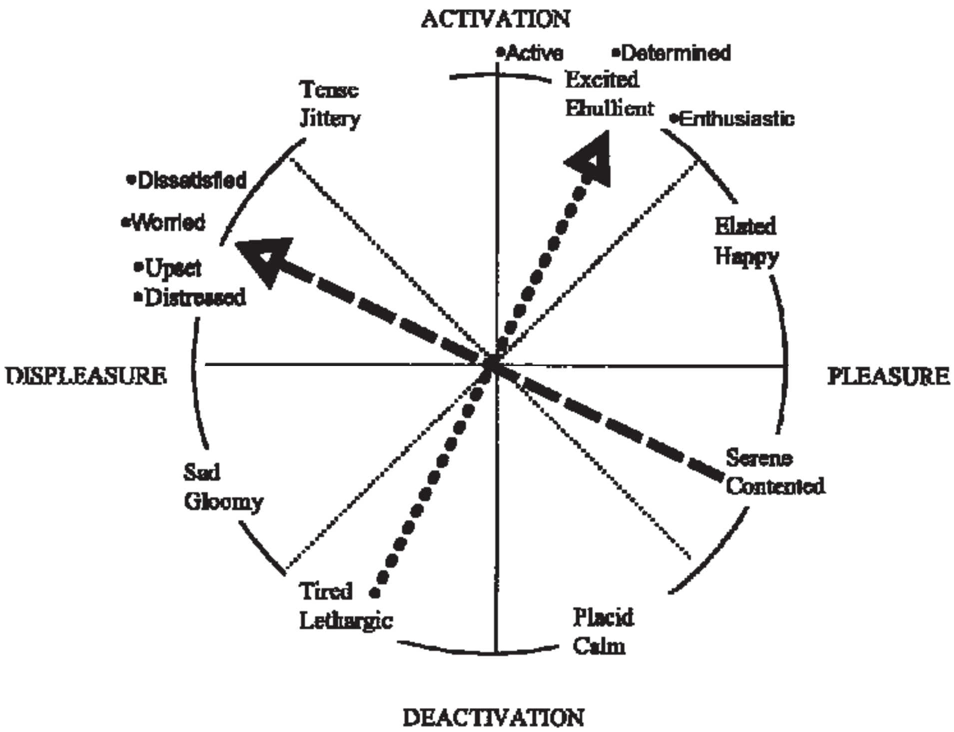
Principal components factor analyses (varimax rotation) were conducted on the pre- and post-NeoCITIES responses for each experiment (four analyses total). The scree plot for all four analyses suggested a three factor solution. Items were selected that loaded more than .60 on one factor without loading more than .40 on any other factor.

One factor containing three items from the positive affectivity scale of the PANAS (one item was also shared with the engagement scale of the SSSQ) was common to pre- and post-task surveys in both experiments: "I feel active" (PA, SSSQ-E), "I feel enthusiastic" (PA), and "I feel determined" (PA). This factor was named "PA/Engaged." A second factor appeared in the post-task survey in the second experiment with items from the negative affect scale of the PANAS, the State Trait Anxiety Inventory, and the distress scale of the SSSQ: "I feel upset" (STAI), "I am worried" (STAI), "I feel dissatisfied" (SSSQ-D), and "I feel distressed" (NA). The pre-task survey in experiment 2 had a six-item factor including the same four items. The post-task survey of experiment 1 had a five-item factor including three of those four items, and the pre-task survey had a nearly identical factor that did not quite meet the selection criteria. As no other items in the first experiment clearly formed meaningful pre- and post-task factors, this four-item factor was adopted for both experiments and named "NA/Anxious." All factors indicated adequate internal consistency. According to both Russell's model of core affect (Figure 4) and Watson and Tellegen's two-factor model of affect (Figure 5), these two measures are roughly orthogonal.

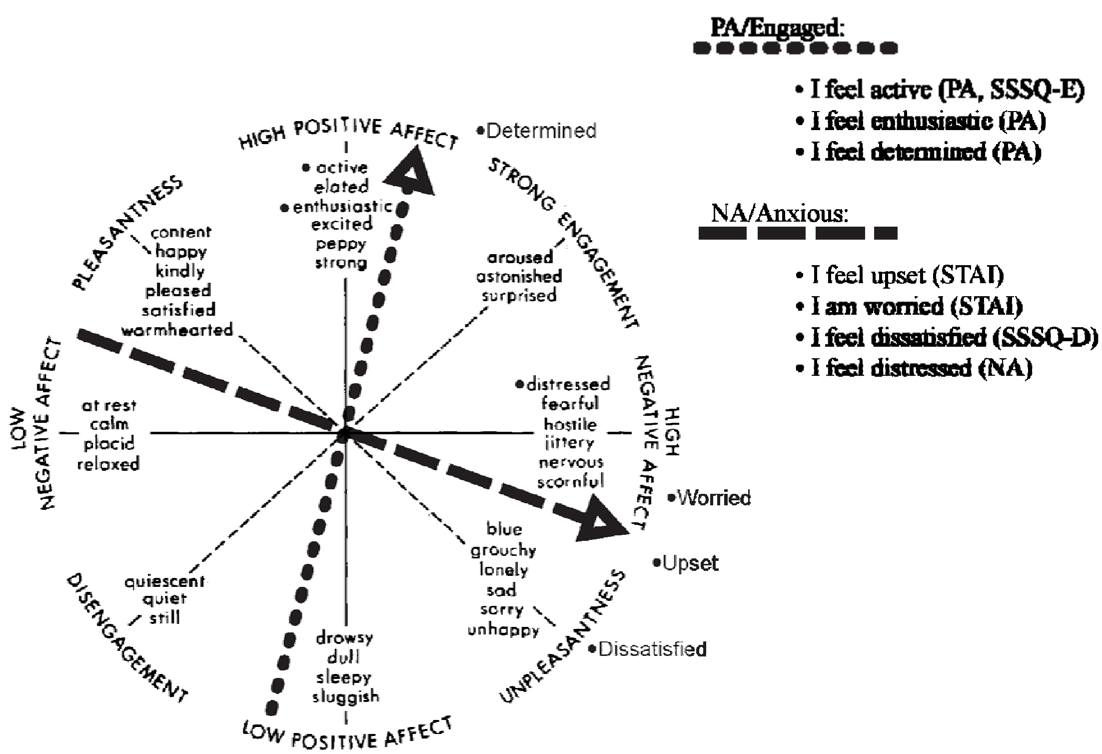
Table 7

Summary of manipulation check factors

	Experiment 1		***Experiment 2***	
	Pre-task	**Post-task**	**Pre-task**	**Post-task**
		PA/Engaged		
Cronbach's α	.79	.85	.86	.75
Mean	1.45	1.95	1.32	1.54
Standard Deviation	.91	.92	.77	.76
		NA/Anxious		
Cronbach's α	.72	.71	.77	.78
Mean	.49	.28	.37	.56
Standard Deviation	.62	.44	.48	.64



Model showing bi-polar positive and negative affect (Source: Russell, 2003)



Watson and Tellegen's two-factor model of affect (Source: Watson & Tellegen, 1985)

Figure 16: Overlay of affect measures on both models of affect

EXPERIMENT 1

Descriptive Data

Seven teams of six participants each divided into three dyads participated in the study. The unit of analysis for the dependent measures was the dyad ($N = 21$). Forty-three students ranging from 19 to 30 years old participated in the study. The average age of participants was 21.1 years ($SD = 1.98$). Thirty-nine were male and four were female. Forty-two of the participants were from the United States; one was from India.

The course instructor assigned the participants to groups of three to work on group projects for the duration of the semester. The experimenter created seven teams of six for the simulation by quasi-randomly combining two of these three-person groups based on which teams were able to schedule simultaneous time in the lab outside of class. The remaining student was a member of one of the groups for class projects and served as an alternate participant for the experiments. These groups stayed together for the duration of both experiments. The group cohesion found in real-world teams was mimicked as these teams maintained additional working contact outside of the experiments – in the classroom and on team projects.

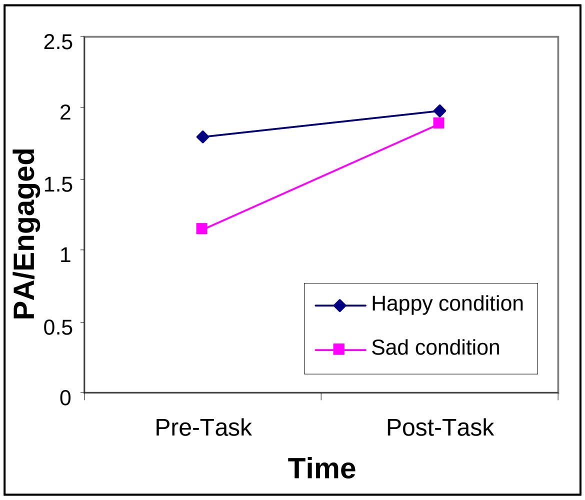
In the first experiment, one dyad was excluded from all four conditions for not following the experimenter's instructions. One additional dyad failed to report to the lab for one session (two conditions missed), though the simulation still ran with the two remaining dyads. This eliminated two additional data points from the no-stress condition of the first experiment.

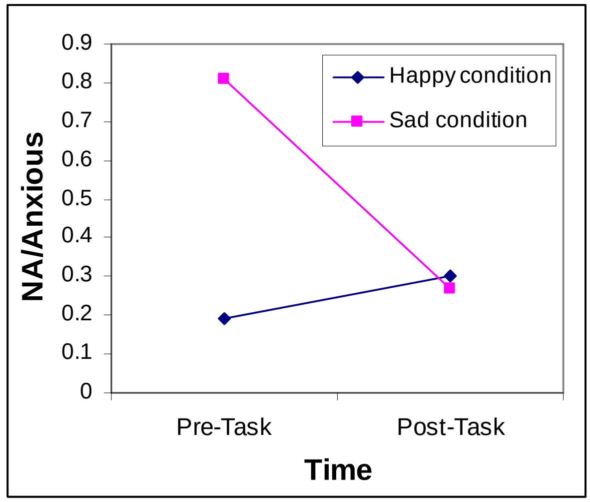
Manipulation Checks

The measures of self-reported stress and mood states were averaged across both members of each dyad to maintain all analysis at the dyad level. The effects of the mood manipulation were tested on all participants with a within-subjects analysis of variance (ANOVA) using the restricted maximum likelihood (REML) method. REML is a versatile approach for variance component estimation within models containing random effects, which in this case is to control for dyad ID in the within-subject measures across the four conditions. REML results feature attributes that differ in appearance from standard ANOVA analysis, including fractional degrees of freedom. Complete details on the REML method and the rationale for its use in this type of design are in Littell, Milliken, Stroup, Wolfinger, & Schabenberger (2006).

The two dependent variables tested were the self-reported *PA/Engaged* and *NA/Anxious* scales (defined in chapter 6) recorded immediately following the movie clip. There was a significant effect of mood on PA/Engaged, $F(1,56.98) = 45.53$, $p < .01$, $R^2 = .64$. Participants reported higher positive affect in the happy condition ($M = 1.80$, $SE = .12$) than in the sad condition ($M = 1.14$, $SE = .12$). There was also a significant effect of mood on the NA/Anxious variable, $F(1,57.14) = 91.30$, $p < .01$, $R^2 = .69$. Participants reported higher negative affect in the sad condition ($M = .81$, $SE = .07$) than in the happy condition ($M = .19$, $SE = .07$). Note, however, that the NA/Anxious measure was very low overall on a scale of zero to 4.

The differences between the post- and pre-task mood measurements were tested using the same technique to check for the persistence of the mood manipulation. In both cases, there was a significant result indicating that participants felt more negative affect and less positive affect after completing the task in the happy condition than the sad condition – just the opposite of what one might predict (*PA/Engaged:* $F(1,57.33) = 21.95$, $p < .01$, $R^2 = .48$; *NA/Anxious:* $F(1,56.69) = 74.45$, $p < .01$, $R^2 = .53$).





This reflected the fact that the mood manipulation appears to have worn off prematurely. Participants generally entered the experimental session in a good mood and did not become substantially happier after watching a happy movie clip. At the end of the task, their mood would remain roughly at the same level of happiness. This is a frequent problem with positive mood inductions (Westermann et al., 1996). The manipulation check above demonstrated that participants in the sad condition did indeed begin the task in a sad mood, but the pre-post change indicates participants returned to a good mood by the end of the task. Therefore, simply due to the effect of time passing, participants in the sad condition show a large improvement in mood following the task whereas participants in the happy condition show little or no change. As a result, to avoid this erroneous bias, only the post-task mood measures were used to assess changes in mood resulting from the task.

The differences between the post- and pre-task measurements of the three dimensions of the Short Stress State Questionnaire (SSSQ) were tested for the effect of the stress manipulation using the same analysis as above. The effect of stress on *sssq-engagement* approached significance, $F(1,58.77) = 3.31$, $p = .07$, $R^2 = .34$. Stressed participants reported lower engagement (*M* = .83, *SE* = .13) than non-stressed (*M* = 1.10, *SE* = .13). A significant effect was found on *sssq-worry*, $F(1,58.92) = 4.20$, $p < .05$, $R^2 = .03$. Participants under stress reported more worry (*M* = .19, *SE* = .08) than non-stressed participants (*M* = -.03, *SE* = .08), though this overall difference is quite small. No significant effect was found on *sssq-distress*.

Main Results

As a portion of this study was exploratory in nature, backward stepwise multiple regression was used to determine which individual difference measures had a significant impact upon dyad task performance[1] in addition to the Stress X Mood factorial model defined by the experimental design. Only when these factors are identified and controlled for can the hypotheses be reliably tested.

The individual differences identified in the literature (dyad age, gender mix, locus of control, tolerance of ambiguity, trait anxiety, neuroticism, conscientiousness, and extraversion; see Table 6) were analyzed for pairwise correlations to test for multicollinearity. Only neuroticism and trait anxiety showed a high enough degree of correlation ($r(82) = .66$, $p < .01$) to warrant exclusion of one of the terms; neuroticism was eliminated from the set prior to further analysis. These remaining factors were added to the model and removed one by one in order of the largest *p* values until the remaining terms showed $p < .10$. Gender mix, conscientiousness, and tolerance of ambiguity were the only individual difference measures remaining in the model. Gender mix was defined with three levels (male-male, male-female, and female-female), but as there were no female-female pairs in this study, this variable had only two levels. Conscientiousness and tolerance of ambiguity were continuous measures.

[1] The task performance measure was squared for a normal distribution in experiment 1. Back-transformed means appear in parentheses after the analyzed means in the results tables.

During experimental trials, teams were observed to perform better during the second task of each session. Indeed, a one-way ANOVA revealed a significant effect for task order indicating that participants performed significantly better on the second task of each experimental session, $F(1,57.15) = 15.12$, $p < .01$, $R^2 = .38$. Therefore, task order was also entered into the model as a covariate.

Dyad Task Performance

Following the regression analysis, the dyad task performance variable was tested using a 2 (Stress: none, high) X 2 (Mood: happy, sad) factorial within-subjects ANCOVA (REML method) using task order (first, second), gender mix (male-male, male-female), conscientiousness, and tolerance of ambiguity as covariates. There was a significant main effect for the stress manipulation, $F(1,18.45) = 7.31$, $p < .05$. Participants performed worse in the high stress condition (*M* = 1371.66 (37.04), *SE* = 78.40) than in the no stress condition (*M* = 1567.07 (39.59), *SE* = 79.07). There was no main effect for mood, nor was there any significant interaction between mood and stress.

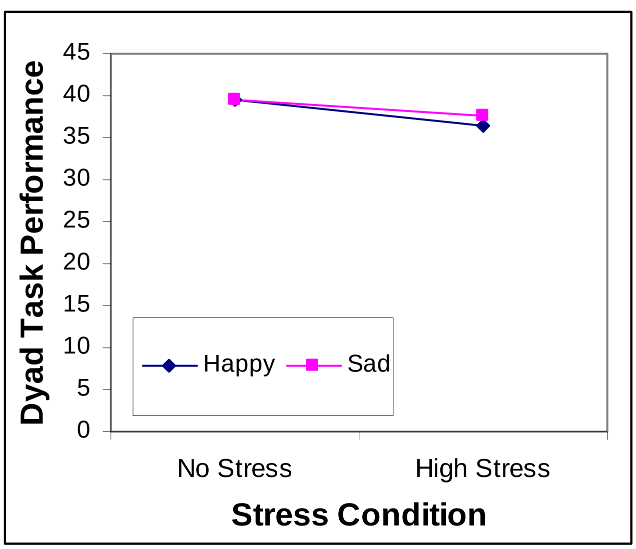


Figure 17: Mood X Stress interaction for task performance in experiment 1

Table 8

Mood X Stress interaction for task performance in experiment 1

	No Stress			High Stress		
Mood	***N***	***M***	***SE***	***N***	***M***	***SE***
Happy Mood	19	1566.21 (39.58)	94.34	20	1328.80 (36.45)	92.98
Sad Mood	19	1567.93 (39.60)	94.34	20	1414.52 (37.61)	92.98

Back-transformed means appear in parentheses

The model confirmed that task order had a very significant effect, $F(1,18.42) = 12.70$, $p < .01$. Participants performed considerably better on the second task (M = 1614.58 (40.18), SE = 80.95) than on the first (M = 1324.15 (36.39), SE = 80.95). Gender mix also showed a significant result, $F(1,15.63) = 4.78$, $p < .05$, with male-female dyads performing worse (M = 1310.98 (36.21), SE = 131.93) than male-male dyads (M = 1627.75 (40.35), SE = 53.72). Lastly, conscientiousness revealed a positive correlation with performance which approached significance, $B = 5.96$, $t(18.01) = 2.07$, $p = .054$.

Testing of Hypotheses

The first three hypotheses were designed to determine whether mood mediated the effect of stress upon performance. Hypothesis 1 predicted the main effect of stress upon performance which was confirmed above. This shows there is an effect of stress to be mediated.

Hypothesis 2 predicted that cognitive stressors would trigger changes in individual mood, as assessed by the two mood measures, *PA/Engaged* and *NA/Anxious*. A one-way within-subjects ANOVA (REML method) showed that stress had a significant effect on negative affectivity, $F(1,58.16) = 4.99$, $p < .05$, $R^2 = .37$, with stressed participants rating higher NA/Anxious (M =

.35, *SE* = .05) than non-stressed participants (*M* = .22, *SE* = .05). This was also true for the effect of stress upon the PA/Engaged measure, $F(1,57.43) = 4.68$, $p < .05$, $R^2 = .75$. Participants rated lower on this measure when in the stressed condition (*M* = 1.83, *SE* = .15) than in the non-stressed condition (*M* = 2.03, *SE* = .15). This supports the second hypothesis that stress also has an effect upon the participant's mood as assessed by both mood measurements.

Next, hypothesis 3 predicted that a negative mood among participants would result in diminished team task performance. This was tested using a within-subjects (REML method) regression analysis between each of the mood measures (one at a time) and performance, controlling for stress. The analysis of NA/Anxious showed an effect to diminish task performance which approached significance, $B = -339.93$, $t(54.24) = 1.93$, $p = .06$. This regression also showed that the formerly significant effect of stress was no longer significant, $B = -72.00$, $t(17.33) = 1.62$, $p > .10$, which demonstrates that negative affect mediated the effect of stress upon performance. The analysis of the PA/Engaged variable, however, showed no correlation between positive affect and performance. The main effect of stress remained significant ($F(1,17.89) = 5.71$, $p < .05$). This affect variable does not show the hypothesized mediating effect.

Hypothesis 4 was not tested until the second experiment.

Dyad Communications

Communication logs for each IM-RM pair were analyzed by two coders according to the coding scheme described in appendix B. The two coders' ratings were highly correlated, $r(894) =$

.97, $p < .01$. The logs recording messages between the three IMs were not analyzed for this study.[2] The two coders' total counts for each message type were averaged for each log.

The communication variables were examined using a 2 (Stress: none, high) X 2 (Mood: happy, sad) within-subjects ANOVA (REML method). The individual differences included in the performance model have only been cited with regard to task performance and were not included in the communication models.

Only one main effect was identified among the communications variables. Stress showed an effect approaching significance on the percentage of messages that were information requests (%IR), $F(1,10.51) = 4.17$, $p = .07$. A greater proportion of information requests were made under stress ($M = -1.69$ (.18), $SE = .15$) than in the non-stressed condition ($M = -1.98$ (.14), $SE = .13$). An interaction between stress and mood was observed on the percentage of information transfers (%IT), $F(1,15.9) = 5.31$, $p < .05$. Participants in the happy condition dedicated significantly more of their communication efforts toward information transfers when under stress than in the non-stressed condition, while participants in the sad condition did the opposite, showing a marginal decrease in %IT in the stressed condition. Post-hoc analysis using Tukey's HSD "Honestly Significantly Different" (HSD) test with an alpha of 0.05, however, revealed no significant differences between the test means.

[2] Dyad performance scores were squared to achieve a normal distribution. Most of the aggregate communication measures (TC, TC-INSIG, OA, IA, AA, %IR, %AR, %CR, %ACK, and %INSIG) were log-transformed for a normal distribution. %AT was log-transformed and then cubed; %IT required no transformation. Back-transformed means appear in parentheses after the analyzed means.

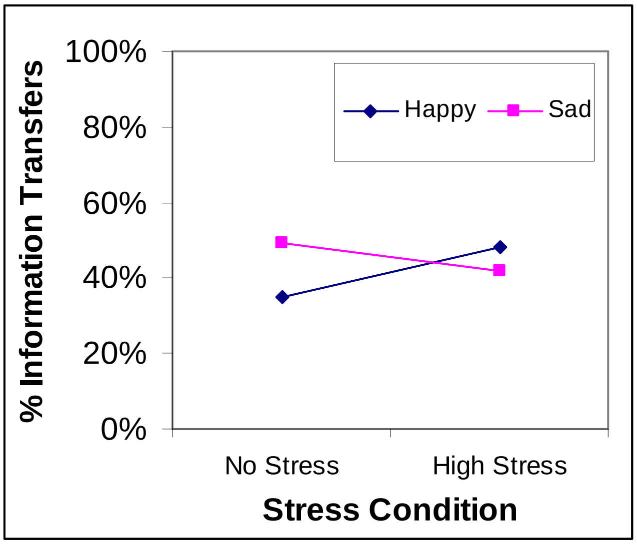


Figure 18: Mood X Stress interaction for %IT

Table 9

Mood X Stress interaction for %IT

	No Stress		High Stress	
Mood	*M*	*SE*	*M*	*SE*
Happy Mood	.35	.05	.48	.04
Sad Mood	.49	.05	.42	.04

Means did not significantly differ per Tukey's HSD, α = .050

An interaction between mood and stress, also approaching significance, was observed on the total communications variable (TC), $F(1, 8.54) = 4.20$, $p = .07$. Participants in the happy condition sent fewer messages under stress, while participants in the sad condition sent more under stress. Tukey's HSD again revealed no significant differences between means.

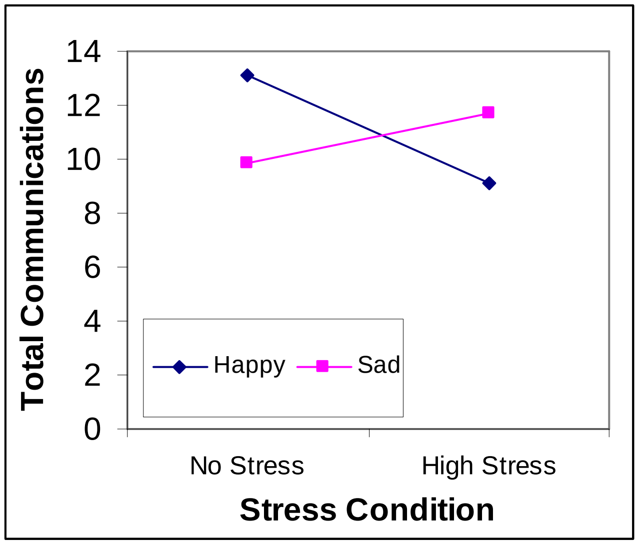


Figure 19: Mood X Stress interaction for total communications

Table 10

Mood X Stress interaction for total communications

	No Stress		High Stress	
Mood	*M*	*SE*	*M*	*SE*
Happy Mood	2.57 (13.10)	.22	2.21 (9.12)	.19
Sad Mood	2.28 (9.82)	.22	2.46 (11.73)	.19

Back-transformed means appear in parentheses.
Means did not significantly differ per Tukey's HSD, $\alpha = .050$

EXPERIMENT 2

Changes from experiment 1

The same teams from experiment 1 participated in experiment 2. Each member was assigned a new role within the team. Resource managers became information managers and vice versa. Each member was assigned to a new dyad (fire, police, hazmat) such that each was working with a new partner. Each team retrained on NeoCITIES in their new roles for 30 minutes.

The task load stressor was replaced with the performance pressure stressor specified in chapter 6. The mood manipulation and the format of the experimental sessions remained the same as the first experiment. The seven additional questions regarding perceived connections between events and coordination between teammates (see chapter 6) were added to the post-task surveys.

Descriptive Data

All 42 participants arrived on time and followed instructions for each session in the second experiment, so no data points had to be eliminated. Communication and self-reported measures were aggregated and transformed using the same methods as experiment 1 (unlike experiment 1, the task performance measure did not require any transformation). The learning effect between the first and second tasks per session found in experiment 1 had leveled off in experiment 2.

Manipulation Checks

As in experiment 1, the measures of self-reported stress and mood states were averaged across both members of each dyad to maintain all analysis at the dyad level. The mood and stress manipulations were tested using the same analyses from experiment 1. For the mood measures immediately following the movie, *PA/Engaged* and *NA/Anxiety* both showed a significant effect. Participants rated higher on the PA/Engaged measure in the happy condition (M = 1.42, SE = .09) than in the sad condition (M = 1.22, SE = .09), $F(1,62) = 5.52$, $p < .05$, $R^2 = .52$. Participants likewise reported lower on the NA/Anxious measure in the happy condition (M = .29, SE = .06) than in the sad condition (M = .45, SE = .06), $F(1,62) = 6.44$, $p < .05$, $R^2 = .41$. As in experiment

1, post- and pre-task comparisons of these mood measures indicated that the mood manipulations did not persist through the conclusion of the task.

None of the three measures of the SSSQ stress instrument showed a significant result for the stress manipulation. This suggests that the performance pressure stressor used in this experiment was not perceived as stressful, unlike the task load stressor which was perceived as stressful by participants on two of the three dimensions of the SSSQ.

Main results

As in experiment 1, backward stepwise multiple regression was performed upon the main factorial model and the individual difference measures to see which factors had a significant impact on performance in the context of the performance pressure stressor. Factors were again removed one at a time in order of the largest p values until the remaining terms showed $p < .10$. In this experiment, gender mix ($F(1,76) = 4.35$, $p < .05$), locus of control ($F(1,76) = 3.39$, $p = .07$), trait anxiety ($F(1,76) = 3.86$, $p = .05$), and conscientiousness ($F(1,76) = 9.83$, $p < .01$) remained as factors in the model. Gender mix again had two levels (male-male and male-female) and the other three covariates were continuous measures.

Dyad Task Performance

Dyad task performance was once again tested using a 2 (Stress: none, high) X 2 (Mood: happy, sad) factorial within-subjects ANCOVA (REML method) using gender mix (male-male, male-female), locus of control, trait anxiety, and conscientiousness as covariates. There was a significant main effect for the stressor, $F(1,19.91) = 6.40$, $p < .05$. In this case, participants performed better under the performance pressure stressor ($M = 31.33$, $SE = 1.46$) than under no stress ($M = 28.18$, $SE = 1.46$). There was also a significant interaction between mood and stress, ($F(1,20) = 6.54$, $p < .05$). Participants in the happy conditions performed much better in the stress condition (performance pressure applied) than in the non-stressed condition (no pressure applied), while participants in the sad conditions performed slightly worse in the stress condition than in the non-stressed condition. Post-hoc analysis using Tukey's HSD showed that the mean from the happy/stress condition significantly differed from the mean for the happy/no-stress condition.

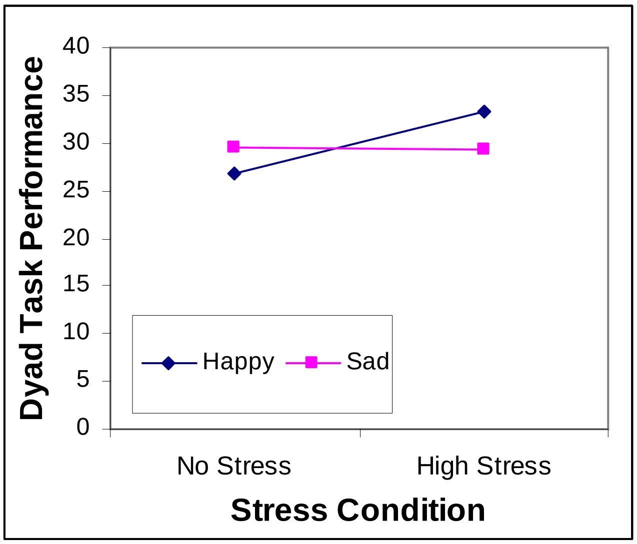


Figure 20: Mood X Stress interaction for task performance in experiment 2

Table 11

Mood X Stress interaction for task performance in experiment 2

	No Stress			High Stress		
Mood	***N***	***M***	***SE***	***N***	***M***	***SE***
Happy Mood	21	26.82_a	1.83	21	33.26_b	1.83
Sad Mood	21	29.54_{ab}	1.83	21	29.40_{ab}	1.83

Means not sharing a letter differ significantly at $\alpha = .050$

The only additional factor showing a significant effect in the model was conscientiousness which showed a negative correlation with performance, $B = -.12$, $t(16.6) = 2.35$, $p < .05$.

Testing of Hypotheses

Hypothesis 1 predicting the main effect of stress on performance was confirmed above, though with the opposite effect as experiment 1. In this case, performance pressure led to an increase in task performance.

Hypothesis 2 was not supported in this experiment. One-way within-subjects ANOVAs (REML method) showed that there was no significant effect of the stress manipulation on either the *PA/Engaged* or *NA/Anxious* mood measurement. Hypothesis 3 was also not supported. Within-subjects regression analysis (REML method) revealed that neither mood measurement showed any significant correlation with task performance. The main effect of stress remained in both analyses. Therefore, there appears to be no mediating effect of mood in this experiment.

Hypothesis 4 predicted that teams in the stressed conditions would be less able to detect emerging patterns of activity that require communication and coordination between team members. This was tested using the *Cooperation* and *Connections* measures defined in chapter 6.

Principal components factor analyses (varimax rotation) were conducted on these measures to determine a factor structure. The scree plot suggested a three factor solution. Items were selected that loaded more than .60 on one factor without loading more than .40 on any other factor.

Table 12

Factor structure of the post-task assessments

Question	Cooperation	Connections	Uncertainty
I felt like I knew what other teams were doing during the simulation.	.57	.48	-.10
I was unsure about how to communicate with other teams.	-.19	-.06	**.67**
I frequently felt like I was being ignored.	**-.81**	.05	.15
My teammates were highly cooperative in resolving events.	**.91**	-.03	.04
I felt like I needed more information to make correct decisions.	.07	-.04	**.81**
I think there were connections between some of the events. I think each team had a part in resolving some related events.	-.03	**.88**	.01
I did not see any connections between events. All of these events happened independently of each other.	-.02	**-.88**	.13

Loadings exceeding .60 with no other factor loading more than .40 are in bold.

Three two-item factors resulted from the analysis. The first, dubbed *cooperation*, contained two questions measuring the perceived level of cooperation within the team: "I frequently felt like I was being ignored" and "My teammates were highly cooperative in resolving events." These were inversely correlated, $r(166) = -.60$, $p < .01$. The second factor, named *connections*, contained items measuring the perceived interconnectedness of events within the team: “I think there were connections between some of the events. I think each team had a part in resolving some related events.” and “I did not see any connections between events. All of these events happened independently of each other.” These were inversely correlated as well, $r(166) = -.64$, $p < .01$. The third factor, *uncertainty*, contained the items “I was unsure about how to communicate with other teams” and “I felt like I needed more information to make correct decisions.” These two were only weakly correlated, $r(166) = .11$, $p > .10$, so this factor was not used for analysis.

One-way within-subjects ANOVAs (REML method) did not support this fourth hypothesis, however, as the stress manipulation had no significant effect on either measure. However, once stress was eliminated as a predictor of perceived event connections and cooperation processes, additional analyses were performed to test whether mood was possibly a significant predictor of either. Two within-subjects regression analyses (REML method) were performed using PA/Engaged and NA/Anxious as the independent variables, using *cooperation* as the dependent variable in the first, and *connections* in the second. The analysis of cooperation showed a significant inverse correlation between NA/Anxious and cooperation $B = -.42$, $t(68.96) = 2.74$, $p < .01$. There was no significant effect of PA/Engaged on perceived cooperation. The analysis of connections showed a significant positive correlation between PA/Engaged and connections $B = .67$, $t(75.46) = 3.20$, $p < .01$. There was no significant effect of NA/Anxious on perceived connections between events. Though hypothesis four was not supported as originally conceived, these two findings reveal unique affective influences upon specific perceptions of team processes.

Dyad Communications

Communications logs for each IM-RM pair were analyzed by the same two coders as experiment 1. The ratings were again highly correlated, $r(894) = .96$, $p < .01$. These variables were examined using the same 2 (Stress: none, high) X 2 (Mood: happy, sad) within subjects ANOVA (REML method) as experiment 1.

Stress showed a main effect on the total number of communications (TC) sent within each dyad, $F(1,19.85) = 4.66$, $p < .05$. Participants sent more messages per session in the stressed condition than in the non-stressed condition. This effect was more pronounced after removing off-task messages from the total, (TC-INSIG) $F(1,19.7) = 5.98$, $p < .05$. There was also a significant effect of stress on the percentage of acknowledgement messages sent (%ACK), $F(1,14.68) = 7.11$, $p < .05$. Participants dedicated more of their messages toward acknowledging other messages in the stressed condition than in the non-stressed condition. Stress also significantly curtailed the proportion of off-task remarks made in the chat (%INSIG), $F(1,12.23) = 14.05$, $p < .01$. Participants sent a far smaller proportion of off-task statements under stress than in the non-stressed condition. These results are summarized in Table 13.

Table 13

Summary of analysis of variance for communication variables

	No Stress		High Stress	
Communication Variable	***M***	***SE***	***M***	***SE***
Total Communications (TC)	6.19 (12.03)	.61	7.13 (14.45)	.60
Total on-task communications (TC-INSIG)	5.21 (9.80)	.62	6.59 (13.02)	.60
Proportion of acknowledgments (%ACK)	-2.27 (.10)	.13	-1.91 (.15)	.12
Proportion of insignificant messages (%INSIG)	-1.53 (.22)	.24	-2.34 (.10)	.22

Back-transformed means appear in parentheses.

Only one main effect for mood was identified. The percentage of action requests (%AR) dropped significantly in the sad mood conditions (*M* = -2.95 (.05), *SE* = .14) as compared to the happy condition (*M* = -2.40 (.09), *SE* = .14), $F(1,9.14) = 10.36$, $p < .05$.

An interaction approaching significance between mood and stress was found for information anticipation, $F(1,16.78) = 3.50$, $p = .08$. In the stressed condition, participants in happy and sad mood appeared to anticipate their partner's information needs roughly equally. However, in the non-stressed condition, happy participants rated noticeably higher on information anticipation than sad participants.

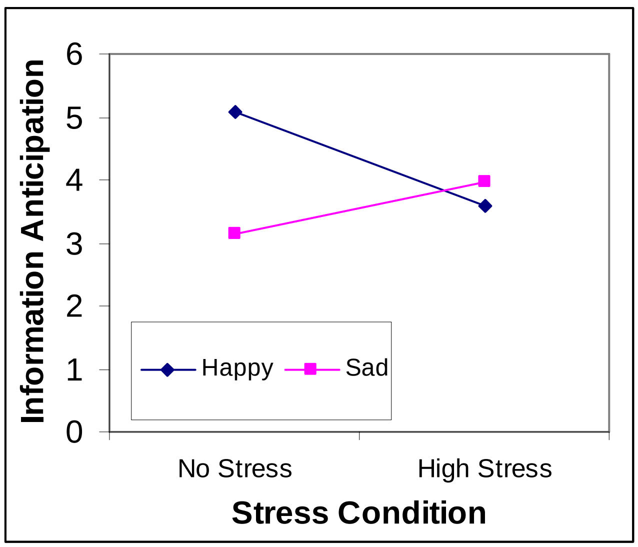


Figure 21: Mood X Stress interaction for information anticipation

Table 14

Mood X Stress interaction for information anticipation

	No Stress		High Stress	
Mood	***M***	***SE***	***M***	***SE***
Happy Mood	1.62 (5.07)	.17	1.28 (3.59)	.14
Sad Mood	1.15 (3.15)	.15	1.38 (3.97)	.16

Back-transformed means appear in parentheses.
Means did not significantly differ per Tukey's HSD, α = .050

CHAPTER 8
DISCUSSION

This chapter discusses the theoretical and practical implications of the results detailed in the previous chapter. Both experiments in this study were identical in most respects except for the stress manipulation employed. The change in stressors provided two distinct cases for testing the hypotheses of this study and comparing the changes in performance and communication behaviors among the teams. Each experiment is reviewed in terms of the key variables of interest and the proposed hypotheses. A summary of these experiments reviews the efficacy and limitations of the manipulations, measures, and methods used during this study. This is followed by a discussion of the contributions of this work and plans for future research. This chapter concludes with an exploration of the practical implications of these results.

EXPERIMENT ONE

The first experiment used the stressor of task overload. This might be considered a standard exemplar from Lazarus' transactional model of stress: in the high-stress condition, the amount of work exceeded the individual's ability to respond (and was perceived as such by participants). According to the manipulation check, participants perceived this manipulation as stressful according to the motivational (less engaged) and cognitive (more worried) dimensions of the SSSQ instrument, but not the affective dimension (distress). For the type of tasks involved in the NeoCITIES simulation, the increased worry is sensible. Participants would be increasingly concerned about their ability to keep up as events piled on faster than they could be resolved. The decrease in engagement, however, suggests that the task load may have seemed insurmountable and therefore decreased the participants' willingness to act. It is likely they cared less about engaging with the specific details of the events than simply going through the motions as quickly as possible. This could imply that the task load was higher than necessary in the stress condition. A somewhat less aggressive task load may have maintained or even enhanced engagement.

The loss of engagement under the task overload condition may also result from the fact that the course credit received by the participants was not tied to success or failure on the task. Once the task got harder than a certain level, many participants may have lost interest in investing energy into the task when no reward was at stake. Instances of clear disinterest were observed during the first experiment which provided additional rationale for a monetary incentive as part of the performance pressure stressor in the second experiment.

Support for Hypotheses in Experiment 1

Table 15

Summary of hypotheses supported in experiment 1

Hypothesis	Supported
1) Stress impacts performance	Supported
2) Stress changes mood	Supported for both *PA/Engaged* and *NA/Anxious*
3) Mood impacts performance	Marginally supported for *NA/Anxious* measure
4) Stress diminishes detection of emergent activity	Not tested

The task overload manipulation had a significantly negative impact on task performance, which confirmed hypothesis 1 that stressful experiences can impact task performance. Hypothesis 1 was deliberately non-directional in anticipation of unique results for each stressor. The profile afforded by the SSSQ aids in characterizing each stressor for that purpose. Thus, the particular effects observed with this stressor may extend to other stressors that increase worry, decrease engagement, and have little impact on distress.

Task overload had significant effects on both affective measures, *PA/Engaged* and *NA/Anxious*, confirming hypothesis 2 that the experience of stress has emotional outcomes. Again, this non-directional hypothesis anticipated that different stressors would have diverse emotional outcomes. In fact, this very point is the crux of the proposed mediational model: that instances of eustress and distress (that is, enhanced or diminished performance) can be explained by the positive or negative emotional outcomes of a given stressful situation. It is important to point out that the distress dimension of the SSSQ (specifically, the subset of its questions used in this study) did *not* reveal an affective impact of the stress manipulation. It can be concluded that the PA and NA scales developed specifically for this study were more sensitive than that particular dimension of the generalized SSSQ instrument as used here.

The mood manipulation was clearly successful in placing participants in significantly different moods prior to the beginning of the task. While no main effect of the mood manipulation was observed on performance, the NA/Anxiety measure at the conclusion of the task was indeed inversely correlated with performance and very nearly approached significance (p = .0586). This failure to achieve significance unfortunately did not support hypothesis 3 that negative mood would diminish performance. The detrimental effects of negative affect on performance in individual-level cognitive tasks are well documented, so it is highly probable that similar effects are at work in group-level tasks such as the NeoCITIES simulation. On the other hand, even though participants were physically isolated and exposed to the mood and stress manipulations individually, group-level effects such as social facilitation (Zajonc, 1965) or others could be moderating or normalizing the within-group stress and emotional reactions. Therefore, a repeated study with an increase in participants would be necessary to see if significance increases, or if this effect is indeed a marginal one.

The most likely explanation for the absence of a main effect for the mood manipulation is that the effect wore off before the post-task survey. Effect persistence has been an issue in other studies employing similar mood induction procedures (Westermann et al., 1996). Many of those studies, however, generally involve simple individual tasks, whereas these experiments employed complexity, interactivity, and multiple performers, any of which could have profoundly diminished the effect of the mood manipulation. The point at which the effect wore off, and at what rate, however, remains a mystery given only pre- and post-task measurements to work from. Had additional measurements been taken during the simulation, using EMA or psychophysiological methods, more could be known about the persistence of the mood manipulation in this task context. Psychophysiological measures have provided valuable insights into the subjective experience of interactive environments (e.g. Sundar & Kalyanaraman, 2004; Sundar & Wagner, 2002). Perhaps a creative solution can be found for a continuous mood induction of some sort that participants are exposed to *during* the task, rather than only beforehand.

The observed effect of post-task mood on performance, however, implies that other factors in addition to (or indeed contrary to) the mood manipulation induced negative affect and anxiety, even in the positive mood condition. These other phenomena may have included dysfunctional team interactions, task underperformance, frustration with the software, or other factors external to the experiment (having a bad day, arriving at the experiment after a difficult exam, etc.). In fact, given that no main effect for the mood manipulation was found in either study, if the within-task activities were stimulating a measurably diverse range of moods, then the mood manipulation may have been unnecessary to test the hypotheses of this study.

Despite the lack of support for hypothesis 3, the main effect of the task load stressor was eliminated by controlling for mood, meeting three of the four conditions necessary for demonstrating the mediating model suggested in Figure 7. Task overload caused an increase in negative affect, which possibly led to diminished task performance. The impact of negative affect on cognitive task performance itself is nothing new, which again suggests that the mediation effect may have occurred despite the lack of strong support for hypothesis. This result suggests that it was not actually the stress itself that diminished the timeliness and accuracy of the resource allocation responses, but rather the affective consequences of the stressful experience. Specifically, it was *negative affect* which was significant in this case, which is consistent with the notion of hedonic asymmetry – that negative affect generally has much stronger and more persistent effects than positive affect. As seen in Figure 22 below, stress is correlated with mood such that when stress increases, so does negative affect and anxiety. As that increases, task performance decreases.

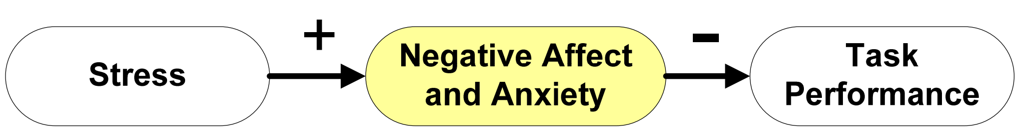


Figure 22: Mood mediating the effect of stress upon task performance

The covariates included in the model shed additional light onto the factors at work in this experiment. The learning effect observed on the first experiment was to be expected and was an unfortunate logistic consequence of having the teams complete two conditions in each experimental session. Noting that it leveled off by the second experiment, future studies now have a benchmark for how much exposure to the NeoCITIES task before participants develop and retain measurable task expertise.

The positive effect of the conscientiousness trait is not surprising in a task requiring effective team interactions. Within the five-factor model from which this measure is derived, conscientiousness is defined as the opposite of undirectedness or impulsivity. Conscientious dyads would be described as careful, deliberate, fair, and cautious, as opposed to careless, unstable, playful, and disorganized. To successfully allocate limited resources to resolve somewhat ambiguous emergencies, especially for these participants who were quite new to the job of emergency management, it is sensible to expect that more cautious and organized individuals would engage in more discussion and be more open to input and joint problem-solving than impulsive individuals, who would make judgments and take action without too much concern for due process. Given that each member of the dyad possesses unique powers and information that must be combined to perform the task, in addition to each member being accountable to the other, the conscientiousness is likely to lead to more success than impulsivity.

Lastly, it is difficult to make too much of the gender-mix effect with only four mixed-gender dyads compared to 17 all-male dyads. Additional studies with more balanced groupings of all three possible gender pairs would be necessary to better explain a) why male-female dyads performed so much worse than all-male dyads, and b) where all-female dyads would rank overall in a task environment such as NeoCITIES. However, possible explanations may be drawn from other studies that have shown that college-age males value and trust other males more than females in technological contexts (e.g. Joshi & Schmidt, 2006; Williams, Ogletree, Woodburn, &

Raffeld, 1993) and act more competitively than cooperatively in mixed-gender pairs (Valenzuela & Raghubir, 2007).

Chat behavior

The results of the chat analysis provided some additional information about the changes in teamwork behaviors under the different conditions. These results also provide some hints about the technological or procedural interventions that would be of aid in these stressful circumstances.

The increase in the proportion of information requests under stress is interesting and helps identify specific cognitive processes affected by the stress manipulation. Information requests are typically retrospective and analytical. A high proportion of such statements suggests that the dyad was engaging in high amounts of sensemaking behavior: "What did you send to event number 5?" or "Do you know why we failed on that car crash event?" Such behavior points to difficulty in attending to the details of multiple events and effectively holding them in memory. In the stress condition, participants had to repeatedly shift their attention from the current task to either a new incoming task or a chat message from their partner. This challenge to attention may be interfering with the process of forming memories by limiting the amount of attention allotted to each event. It may also be directly impacting memory formation by interrupting the processes of consolidating and storing information after an event (Mendl, 1999). These all suggest that tools enhancing transactive memory (Wegner, 1986) would be of great use in distributed problem solving environments like that simulated in NeoCITIES.

The significant interaction between mood and stress on the proportion of information transfers reveals a trend extending the sensemaking behavior just described. In this case, only happy participants showed an increased proportion of information transfers under stress (presumably in partial response to the increase in information requests), while sad participants did not. However, the interaction between mood and stress on the total amount of communication suggests that sad participants were sending *more* messages overall under stress while happy participants sent fewer. This indicates that sad participants under stress, rather than dwelling on the retrospective sensemaking messages, may have been sending more of the other more immediate categories of messages: *action* ("you do this" or "I'm doing this") and *coordination* ("find someone to do this"). These findings point to a local "right now" focus induced by the sad mood. This corresponds to similar findings in which individuals in sad moods pay more attention to the trees than the forest (Derryberry & Reed, 1998; Gasper & Clore, 2002), but in this case that phenomenon is only occurring under stress. Since happy participants were sending fewer messages under stress than sad participants, this implies that happy participants sustained a sense that the task was proceeding acceptably (i.e. no extra effort necessary), as predicted by the affect-as-information perspective and demonstrated in experiments on mood and problem solving strategies (Gasper, 2003).

EXPERIMENT TWO

Experiment 2 was designed to replicate and extend experiment 1 by replacing the task load stressor with performance pressure and introducing additional dependent measures regarding perceived coordination and communication. This stressor did not register any significant changes in any of the three dimensions of the SSSQ. This was somewhat surprising as performance pressure has been successfully employed in other experiments in a similar fashion, by convincing participants in one way or another that they had to perform well and were being carefully monitored and evaluated (e.g. Baumeister, 1984; Beilock et al., 2004; Butler &

Baumeister, 1998). The chat logs repeatedly showed statements that the teams were effortfully pursuing the goals laid out by the performance pressure stressor: “Let’s not fail this time!” and “Let’s see if we can do a little better this time.”

However, instantiation of the performance pressure stressor in this experiment was intended to bend, but not break (i.e. “choke”) the participants’ ability to succeed. It is conceivable that only when the pressure is great enough to induce “choking” that participants would begin to rate the task as stressful on one or more of the SSSQ dimensions.

Returning for a moment to the multiple stress definitions described in chapter 2, it is clear that this stressor did not fulfill the definition prescribed by the commonly adopted transactional model. Participants do not appear to have appraised the demands of the situation as outstripping their ability to respond. Further pretesting of this complex stressor may have produced more powerful results.

On the other hand, regardless of how it was perceived, the performance pressure manipulation in this experiment did have a clearly measurable effect on task performance. Participants were motivated to a significantly higher level of timeliness and accuracy in the resource allocation tasks. This result accords with a definition of stress that extends Selye’s concept of homeostasis mentioned previously which considers an event stressful “if it puts pressure on the individual to perform more accurately or faster or differently from his normal mode” (Solley, 1969, p. 1). Of course, it would be dangerous to begin suggesting that anything that changes an individual’s performance is a stressor, yet in this case it seems clear that the improvement in task performance is directly in response to the increased sense that it was very important to achieve highly. Recall that all of the other task characteristics (load, complexity, etc.) remained constant in all conditions.

Support for Hypotheses in Experiment 2

Table 16

Support of hypotheses in experiment 2

Hypothesis	Supported
1) Stress impacts performance	Supported
2) Stress changes mood	Not supported
3) Mood impacts performance	Not supported
4) Stress diminishes detection of emergent activity	Not supported; mood measures *are* correlated with measures of cooperation and connectedness of events

Even though the performance pressure stressor was not perceived as stressful, it did induce a change in task performance, showing that hypothesis 1 was supported in this second experiment. This stressor did not induce any significant change in either affect measure, nor did either affect measure show any significant correlation with performance, eliminating any support for hypotheses 2 and 3, respectively, as well as any mediating effect as seen in experiment 1. The mood manipulation was just as strong as the first experiment, though, and the interaction between the mood and stress manipulations pointed out an interesting complication with the application of the performance pressure stressor.

In this experiment, the pressure was applied on the entire group which had to work together and perform well in order to receive the monetary incentive. Therefore, the effects of this stressor would be much less significant upon an individual team member who did not care much for the team's success or who did not believe he or she had much ability or access to make a substantial difference. In contrast, an individual-level performance pressure stressor could place personal responsibility for the team's performance upon each participant (e.g. "Only your score will determine the maximum score your team can receive."). Of course, in a task involving group communication such a premise would be impossible to maintain.

A broad team perspective is not only a good predictor of team performance, but also a factor that significantly mediates the effect of stress upon team performance (Driskell et al., 1999). The interaction between mood and stress seen in this experiment adds a new twist to their finding by suggesting that the participants in sad moods lose team perspective (that is, return to a local focus and deal with their own problems without attending to those of their teammates) and therefore were not motivated to support their team. Only the happy participants showed a significant jump in performance as a result of the motivation provided by performance pressure, while the sad participants performed about the same in both high and low stress conditions. Driskell et al. concluded that stress diminished team perspective which in turn diminished performance; this study adds that *negative affect* also diminishes team perspective, of course with the same consequences on performance. By drawing from the mediating effects observed in experiment 1, it is proposed that the diminished team perspective Driskell et al. observed was actually caused by the emotional consequences of their stress stimuli (auditory distraction, task load, and time pressure). That is, those stressors (similar to those used in experiment 1 of this study) increased negative affect, which diminished team perspective (as witnessed in experiment 2 of this study), which decreased team task performance.

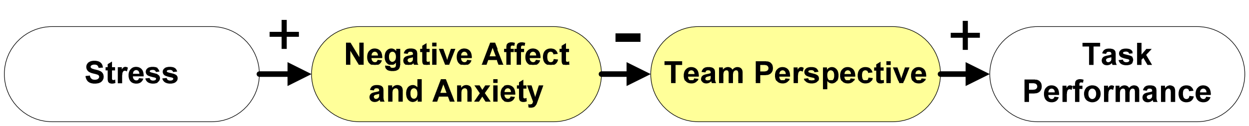


Figure 23: Possible doubly mediated relationship between stress and performance

An alternative argument for this interaction would be the common finding that positive moods show a coping role in managing stress. Indeed, emotion-focused forms of coping allow for cognitive reappraisals of threats and can help change the meaning of a stressful transaction for the better (Lazarus & Folkman, 1984). However, given that the performance pressure stressor was not measurably perceived as a threat according to any dimensions of the SSSQ, it appears that there would be no threat for participants to reappraise. The argument above regarding the diminished team perspective seems much more fitting in this experiment.

Returning to the two proposed models regarding stress, mood, and performance, mood was not observed to mediate the effect of stress upon performance in this experiment. Rather, manipulated mood has *moderated* the effect of a stressor upon task performance by producing different stress responses for happy and sad individuals. The moderator relationship between these concepts is shown in the model in figure 8.

The only covariate with a significant effect in this experiment was conscientiousness, but this time it was negatively correlated with performance – the opposite finding of experiment 1. Fast-acting and impulsive teams performed better than mindful, orderly ones. The most likely cause of this change is the accumulated task experience participants had by the time they began the second experiment. While novice decision makers tend to use orderly and consensus-based techniques (and successfully, as seen in experiment 1), experienced decision makers are able to recognize cues in a scenario and immediately jump to the correct course of action, a process known as recognition-primed decision making (RPD) (Klein, 1993). These less conscientious individuals are more likely to have adopted RPD strategies for making decisions by the second experiment, while more conscientious ones continued to tend toward more orderly and deliberate, but slower, decision making methods.

In a task like NeoCITIES where performance is directly related to the speed at which teams make correct resource allocation decisions, the advantages of RPD strategies are clear. Much of RPD research investigates the actions of individual decision makers. This experiment reveals RPD occurring at a group level, as this task requires the actions of two individuals in distinct roles to jointly make these decisions quickly and accurately. Further studies along this thread may expand RPD theory at the group level which is still a developing field (e.g. Hayne et al., 2005). Additionally, as decisions are frequently made by teams rather than individuals in the complex domains addressed by this research, more knowledge about team RPD will help develop useful decision aids that can accommodate these disorderly-yet-effective strategies in team decision making.

Hypothesis 4 attempted to explore one of the core goals of distributed command and control systems, which is to facilitate synchronous (and asynchronous) situation assessment and decision making tasks by multiple individuals with different locations, knowledge, access, and abilities. The system must visually and conceptually help bring about a common operational picture (McNeese et al., 2006), otherwise evidence of a complex emerging plot would simply be anomalous pieces of knowledge distributed across multiple individuals who have little reason to think that those pieces could belong to a single puzzle. It was disappointing to find that stress did not affect either of the measures developed to capture the participants' awareness of these events as well as their perception of cooperation within their team. However, the correlations between these two measures and the two mood measures that were found after additional analysis proved to be very intriguing findings.

The inverse correlation between perceived cooperation and the NA/Anxious measure shows that participants who exited the task with high levels of negative affect and anxiety also felt that there were low levels of cooperation within their team. It is impossible to determine whether one caused the other as both measures were attained from post-task surveys. Those who finished the task with feelings of high positive affect and engagement also reported sensing more connections between events (recall that the quantity of connected events per scenario was constant). The analysis is unable to show whether those in happy moods had an exaggerated sense of connections between events. That is, the elevated mood states may have led them to see connections that were not actually present. Again, whether one caused the other would be very interesting to know, but cannot be determined from this experiment.

It is particularly interesting that each of these two teamwork measures correlated to one affective measure and not the other. This attests to the discriminant validity of the two mood measures developed for this study; recall that they appear as orthogonal factors in both models of affect. It also points out that perceived connections and coordination are associated with distinct affective dimensions.

Without any ability to assess causes and effects, the most one could argue from these two results is that the feeling of cooperation within a team is associated with feelings of contentedness, calm, and being relaxed, whereas uncooperative experiences are associated with feeling upset, distressed, hostile, and nervous. Additionally, the feelings of being excited, enthusiastic, active, and strong, are associated with the discovery of many connections between events, while teams reporting feeling tired, dull, sluggish, and lethargic do not share this perception.

Chat Behavior

Several of the effects seen on the chat variables are most likely explained by a heightened task-focus resulting from the performance pressure stressor. Under stress, participants communicated significantly more with each other overall, the proportion of acknowledgements sent in response to each others messages raised to 15% from 10%, and the proportion of off-task remarks dropped sharply from 22% to 10%. Several of the chat logs in the stress condition began with calls for increased task-focused communication, such as “I say we announce what we are doing so we know each thing is being taken care of” and “To get the best score let’s each say who gets what event.”

The interaction between mood and stress on information anticipation shows a tendency toward a convergence of behavior under the task focusing effect of performance pressure. Without stress, happy participants were noticeably more likely to send information transfers without waiting for information requests than sad participants. This could again be evidence of sad mood diminishing team perspective. Sad individuals simply were not motivated to address their teammates’ concerns until prompted to and would not speak until spoken to. The interaction between mood and stress showed that these differences in behavior converged under the stress condition. The performance pressure stressor overwhelmed the mood effect such that information anticipation became approximately the same for both happy and sad participants. This begins to indicate the scale of some of these effects and helps identify which among them may be too minor to worry about under the stressful conditions that are of primary concern. In this case, it is clear that a minor difference in behavior based on a mood state becomes negligible when the rubber hits the road.

The drop in the proportion of action requests from 9% to 5% in the sad mood condition returns to the diminished team perspective discussed previously. Sad participants were more likely to concern themselves with their own tasks – a manifestation of "I'll do my job and you do yours." A sad participant noticing an event that requires attention by another team member would be more likely to leave it up to that member to find out about it, rather than make the effort to bring it to that member's attention. Not only does this provide additional confirmation of the affective influences on team perspective, but it strongly recommends that distributed command and control systems actively maintain positive linkages between team members. Without reaffirming team cohesion, especially during frustrating or anxious conditions, diminishing team perspective will gradually render useless the collaborative functions the system is designed to provide.

SUMMARY OF RESULTS

The proposed mediation of stress by mood was nearly demonstrated in experiment 1, but additional studies are necessary to determine a) if this effect really does occur, and b) if so, why is stress mediated by negative affect and anxiety but not positive affect and engagement? The task load stressor itself significantly impacted both mood measures, but only the former suggested the mediational relationship. If nothing else, this result attests to the discriminant validity of the two mood measures and provides additional evidence that positive and negative affectivity are *not* bipolar constructs (though in many cases they are found to behave that way).

Since the two experiments were identical in nearly all respects, excepting the stress manipulation, the substantial differences in the results of the two experiments are most likely attributed to characteristics unique to each stressor. If the performance pressure stressor may be considered a stressor, despite the fact that it was not perceived as such by the participants, then affect appears to mediate the effect of stress on performance for some stressors while moderating the effects of others. On the other hand, if the performance pressure manipulation was not extreme enough to truly induce significant stress, then an additional study with performance pressure applied high enough to cause "choking" among participants is necessary to begin to explore how broadly the mediational model may be applied. In fact, it would be wise to repeat the experiment with a range of stressors, from physical ones like extremes of heat or noise, to physiological ones such as sleep deprivation, to task-related ones like task ambiguity, and team-based ones such as personality conflicts.

The SSSQ instrument, which captures the impacts of stress across multiple distinct dimensions, performed usefully as a discriminatory measure of how individuals appraise potentially stressful situations. It not only reveals whether or not a situation was stressful, as do many task-specific or ad-hoc measures used in other studies (e.g. Braunstein-Bercovitz et al., 2001), but it indicates *how* a particular situation was appraised as stressful. The appraisals revealed by this instrument have provided descriptive profiles of various stressful situations in this experiment and others (Helton, Fields, & Thoreson, 2005; Helton & Garland, 2006). Profiles mapped to particular cognitive and emotional outcomes of stressful experiences could help develop a model describing how these parameters of multiple stressful experience impact real-world macrocognitive tasks. This would be a significant contribution on top of the array of known microcognitive impacts of stress.

There were no main effects on performance from the mood manipulation in either experiment, yet the mood states measured post-task *were* significantly correlated with performance. This indicates that within-task activities had persistent and task-relevant emotional impacts, and these impacts were, in some cases, significantly correlated with performance. So was the mood manipulation really necessary? According to the theory of affect-as-information, the levels-of-focus hypothesis states that the emotional impact of the manipulation should not affect task performance to the extent that individuals realize that the induced mood is not task relevant. As administered, the movie stimulus was purportedly not relevant to the task at hand (participants were told it was part of another study not related to NeoCITIES), yet it did show some significant impacts, especially the interaction seen in the second experiment in which the induced mood diminished team perspective.

This begs the question of whether there would have been a main effect for the mood manipulation if it had been designed and described to participants as task- or context-relevant. A study using an off-the-shelf PC-based combat game used two war films as task-relevant stress stimuli: one highly graphic, the other a documentary. Participants watching the graphic (stressful) stimuli showed a significantly higher motivation to succeed and greater mission success than participants who watched the documentary (Morris et al., 2004). Should task relevance be deemed necessary for future NeoCITIES trials, mood manipulations could use both documentary (neutral) and dramatized (happy or sad) accounts of emergency responses to events such as the 9/11 attacks or hurricane Katrina.

Few conclusions can be drawn overall from the inclusion of the individual differences variables in this study. In general, finding significant results in studies on individual differences requires far greater numbers of participants than this study provided. Several of the measures suggested by the literature do appear to be relevant to the domain and tasks of the NeoCITIES simulation, as evidenced by the factor analysis used to determine which measures to include in the models for each experiment. Gender mix, tolerance of ambiguity, locus of control, trait anxiety, and conscientiousness all made it into the model in either experiment 1 or 2. Conscientiousness was the only one to figure in both experiments, though its impact seems to interact with task experience. Participants in experiment one, though fully trained on the task, were essentially novices and made decisions as novices often do – carefully and considerately. Conscientious dyads appeared to succeed by making accurate decisions, though their more impulsive colleagues may have made *faster* (but inaccurate) decisions. By the second experiment, all participants had greater experience with the NeoCITIES task which was evidenced by their ability to make accurate decisions with less deliberation (if that was the dyad's tendency), and therefore resolve the emergencies more quickly.

Even though few of the individual difference measures demonstrated significant effects in this study, it is still recommended to observe and control for their influence, especially in exploratory studies such as this one. While traits such as neuroticism, extraversion, or tolerance of ambiguity held clear connections to the NeoCITIES task and conditions of the experiment, the conscientiousness finding was unexpected. In fact, its inclusion in the study was simply due to the fact that it came along with the others in the five-factor personality model assessment instrument (IPIP-NEO). The conflict observed between conscientiousness and group-level RPD is a compelling finding that would have gone unnoticed without having made the effort to gather these trait measures.

LIMITATIONS

Several issues in the design and conduct of these experiments pose certain limitations to the results. The last within-subjects experiment using NeoCITIES had such difficulty scheduling teams of six undergraduate students to come to the lab – and actually having them all show up – that the decision to have teams complete two conditions per visit was reluctantly made. The resulting task learning effect was expected, though, and addressed to an extent by counterbalancing conditions to the extent made possible by the experimental setup. It was relieving to see the effect had leveled off by the second experiment. With professional or otherwise more invested participants (such as emergency management personnel), such shortcuts would be less necessary. An alternative would be to redesign these experiments with longer one-shot sessions, three to four hours long, first training participants to a sufficient experience level and then administering all four conditions in counterbalanced order. However, fatigue may become an issue just as troublesome as the learning effect. It may also become difficult to effectively manipulate so many mood and stress states during one contiguous session.

Effect persistence is a concern with all mood induction procedures, and this experiment was no exception. As previously discussed, the mood manipulations were successful throughout both experiments to the extent that participants reliably entered the NeoCITIES task in the desired mood state. However, the effect wore off by the time the post-task surveys were administered in both experiments. The post-task mood measurements revealed that there were significant correlations between stress, moods, and task performance, but the antecedents of those moods are unclear. More study is required to elicit the emotional reactions occurring within an individual’s experience in the NeoCITIES simulation.

Undergraduate college students are often the most available subject pool for research such as this, but rarely does their manner or motivation resemble members of the domain of interest – in this case, emergency dispatch workers. The participant pool in this study was predominantly 21 year old Caucasian males who were participating for course credit. Very few women or persons of other races were represented. The chat transcripts occasionally revealed that some participants were not taking the experiment seriously (e.g. "ive been drinking tequilla all afternoon" and "let's not submit anything n just loose…" [*copied verbatim*]).

On the other hand, these teams were engaged in group work in the lab and the classroom for the duration of the semester, which stimulated team cohesion. Leveraging this advantage further, these were all junior-level students in the same major, so most of the students were likely to have at least some familiarity with their teammates prior to the study. Overall, these are highly desirable characteristics of cohesive teams that are not usually found in the most common subject pool in university research, which is the one-shot extra credit crowd who want to get it over with and go home.

There has yet to be any formal analysis of the task difficulty in NeoCITIES according to a standardized measure, such as NASA TLX or similar instruments. Therefore it is difficult to say with certainty that the characteristics of these NeoCITIES scenarios resemble those in other studies or domains simply because they have only been compared relative to other NeoCITIES scenarios. Studies of this sort, whether testing tool efficacy or individual behaviors, benefit from better measurement and control of the task difficulty (Greitzer & Allwein, 2005). The task pace and load for the scenarios used in these experiments were calibrated in comparison to scenarios utilized in prior experiments, which were calibrated via informal pretesting. Therefore it is not yet clear how different scenario parameters such as pace, complexity, or ambiguity come together to form tasks of greater or lesser difficulty. More research is required on the craft of scenario development to better understand and quantify these parameters. This is not only to provide better control over the stimuli provided by the scenarios but also to be able to compare studies using the NeoCITIES task with others implementing analogous tasks.

CONTRIBUTIONS

The foremost theoretical contribution of this study is the evidence found for a mediating effect of mood on the relationship between stress and team task performance. Though continued research is necessary to test this discovery in more detail, it was the suspicion of this very phenomenon that served as the launching point for this program of study. To have found even partial evidence for it is very gratifying.

Another theoretical contribution is empirical measurement of the differences in the individual perception and impact upon task performance of two stressors common to the domains of team decision making under stress: task load and performance pressure. This is only scratching the surface of what remains to be tested, however. Not only are there many more relevant stressors to explore, but the two employed in this study require recalibration and further testing. This study only tested the presence and absence of two stressors at a one preset level each; the impacts of the same stressors at higher or lower levels are still unknown.

This study began by holding no opinion about whether positive and negative affectivity were bipolar or not. As it turned out, two scales emerged from the study which appeared to be orthogonal on Watson and Tellegen's two-factor model (which would be expected) as well as Russell's bipolar model (which was a surprise). It is beyond the scope of this dissertation to enter into the ongoing fray of the bipolarity-of-affect debate, but multiple results found in both experiments demonstrate that these two scales were independently measuring qualitatively different ranges of emotions. Additional studies could be conducted solely with the purpose of refining these scales for assessing emotional reactions in other complex tasks.

A practical contribution of this study is the development of an experimental platform supporting rapid development of materials for testing new hypotheses regarding team-based problem solving. All of the systems designed and integrated for this study, including delivery of stimuli and tasks, administration of measures, and collection of data, can all be readily reconfigured to explore new research questions in the domain of team cognition. Open-source and platform-independent software options were chosen whenever possible with the explicit desire to enable this platform to be deployed with the fewest restrictions on computing resources. The goal was to develop a framework to lift NeoCITIES from its captivity in the lab of its origin and permit its free deployment in multiple sites, simultaneously, by non-technical operators. This goal was achieved.

In this study, the system gracefully supported interchangeable mood and stress manipulations while collecting and backing up data with bullet-proof reliability (not a single data point was lost due to experimenter error). The timing and structure of the experimental sessions were consistent and continuous from start to finish with little intervention required by the experimenter. Where possible, transitions from one phase to the next were automated and synchronized. These features all aimed to eliminate as much inconsistency, complexity, and uncertainty as possible from the challenging task of running multiple-subject experiments.

Lastly, the chat logs collected in this study provided a wealth of information previously unrecorded in NeoCITIES experiments. On the surface, these logs seemed to contain mostly trivial and off-task messages as one might expect from undergraduate college students. However, after analysis, they revealed clear demonstrations of focused problem solving and sensemaking behaviors. The analysis also showed how the mood and stress manipulations altered how individuals interacted within their teams. The data collection and coding techniques developed for this study are an additional contribution to future studies on teams using NeoCITIES and similar simulations.

FUTURE WORK

The successor to NeoCITIES 1.4 has been in development for approximately 18 months and is about to enter usability testing. NeoCITIES 2.0 maintains the Java-based server engine of its predecessor, but is redeployed as a Web application. The Java client has been completely replaced with a new user interface designed in Adobe Flex, a cross-platform and open-source rich internet application platform based on the ubiquitous Flash player. The client is accessed via any Web browser on any device with the free Flash plugin installed (this means virtually all desktop and portable computers). Therefore, no software is installed on the client end; the client simply visits a URL to connect to the simulation. The end-user experience is guaranteed to be uniform regardless of which browser or operating system is in use. This eliminates the need for programmers to develop multiple solutions for multiple platforms, which allows for that energy to be expended instead in more innovative directions.

Development in Flex permits the rapid prototyping of rich visualization methods and novel tools for communication and collaboration. In development now are tools for graphically annotated chat (which allows users to share shapes drawn on their personal map with other users by attaching the shape to a chat message) and selective map layering options drawing from powerful geographic information systems (GIS). Upcoming experiments will test the efficacy of these tools individually and in combination with each other. This Web-based task can be easily integrated into the experimental platform designed for the current study to explore the interactions of mood and stress with such tools. Does annotated chat mitigate the effects of a time pressure stressor on team performance? Does the utilization of layer filtering options change under different mood states? These questions and more can be pursued by integrating the new NeoCITIES task with the current experimental platform.

The communications variables derived from the chat data provided valuable insight into the team processes involved in the NeoCITIES task. However, these variables were only used as dependent measures in these experiments. It is quite possible that certain communication behaviors could predict task successes or failures. Therefore, additional data analysis will be performed soon to determine which, if any, communication variables are correlated with performance. If any such relationships are found, continued analysis may reveal whether any of these communication measures mediate the effects of stress upon performance. An oversimplified example for demonstration's sake might be that a time pressure stressor would appear to be decreasing performance. A possible mediating relationship could be that the stressor was causing a drop in the number of messages sent and the decreased communication was causing the drop in performance. This is an exciting prospect for secondary analysis of this study's data.

This study evaluated all variables at the dyad level. The scores were achieved by the work of both individuals in the dyad; there is no individual score in this version of NeoCITIES.

The individual differences measures and individually reported mood and stress measurements were averaged to create dyad-level measures in the analysis. However, there are multiple levels of analysis of interest in this research including individual, small group (dyad), and large group (team). There are individual-level performance variables that were not analyzed in this experiment. These include logs of the different types of errors committed which are unique to each role within the dyad. Analysis of these errors may help distinguish each individual's contribution to the dyad's performance.

Coming from the other direction, hierarchical linear modeling is a method for understanding the effect of group membership upon individual group members. For example, such analysis is used to measure the efficacy of school testing methods when individual measurements (students) are nested in groups (classrooms), which could also be nested at another level (schools). Students in different classrooms with different teachers cannot all be directly compared without accounting for the effect the teacher has on the population of his or her classroom. Likewise, in this study, since the teams worked together all semester long both in the classroom and the lab, it is highly reasonable to believe that there could be a significant group-level effect that explains some of the variation between measurements of dyads taken in the lab. This type of analysis is complex and requires high numbers of individuals and groups to arrive at significant results. However, the relevance of such multilevel analyses cannot be ignored in the context of team-based tasks where group membership is a significant factor and individual members have unique contributions toward common goals. Future studies will aim for opportunities to incorporate these analytic techniques.

Lastly, another method in which to study the effects of individual traits and characteristics is to use them for assignment to conditions in experiments like the ones just completed. For example, teams of high trait anxious individuals could be compared to teams of low trait anxiety. Alternatively, teams could be deliberately composed of high and low pairs (i.e. extraverted information managers and introverted resources managers) to see whether some traits balance out between the two, or whether complete dysfunction ensues. This method provides a more direct route to assessing the roles of individual differences, but the fact remains that, in general, the odds are that most real teams will have a random helping of these traits. However, certain job descriptions attract certain personality types. What would a battery of personality profiles reveal about the typical employees of an emergency dispatch center? Are there particular traits that are either helping or hindering teamwork in these contexts? It is these questions that could be addressed by using individual differences as a selection technique.

PRACTICAL APPLICATIONS

The findings of this study provide a more detailed explanation of the collective relationships between specific components of stress, mood, and performance than is evident from previous research on these components in isolation. Further exploration of these results, particularly in experiments applying these same manipulations against specific tools or problem solving methods, may also point toward procedural or technological interventions for addressing these phenomena in real-world contexts.

In organizational contexts, when the specific mechanisms by which stress affects performance are identified, there are five approaches for applying these findings (Yates et al., 1995):

1. Eliminate or weaken the stressor.

2. Reduce stress reactions by system operators.
3. Select operators who are resistant or immune to the stressor
4. Train operators to function effectively under stress.
5. Stress-proof the system by designing features and procedures that achieve system goals despite the stress upon system operators.

Each of these approaches has its advantages and disadvantages. Approaches 1 and 2 are among the most commonly used: identify and remove the stressor from the environment, and/or diminish the impact of the stressor upon operators. Approach 3 is challenging from a human-resources perspective, given the limitations of an available pool of candidates, as well as the difficulty and expense in accurately assessing a potential hire's reactions to the anticipated stressors. Approach 4 has found support in the use of preparatory information (Inzana, Driskell, Salas, & Johnston, 1996) and stress inoculation training (Saunders, Driskell, Johnston, & Salas, 1996). The latter is a method analogous to inoculations against a disease, pre-exposing operators to anticipated stressors in order to build up a resistance to them. Approach 5 takes a human factors perspective to develop and test specific design interventions that increase the stress-immunity of the system. To be effective, this approach requires fine-grained analysis, as provided by this study, of the unique interactions between stressors, affective states, and cognitive processes.

In this study, certain findings point directly to design guidelines for addressing some of the changes in user behavior observed under these different mood and stress conditions. The effect of negative affect diminishing team perspective indicates that system designers need to make sure collaborative systems reemphasize the existence and activities of other team members *especially* when task conditions are at their worst. The challenges observed in attending to and recalling information under stress *as a group* point to the need for tools supporting shared memory and the exchange of knowledge from the working memory of one team member to another.

Further developments in these areas have multiple practical applications for collaborative systems. In the context of CSCW for real-time problem solving, individuals are generally required to devote their attention to a locally focused task (such as analyzing an image or sending a message) while also attending to global details of situational awareness (such as position or status of other team members, or incoming information). Armed with knowledge of how certain characteristics of working environments (such as stressors) can disrupt these macrocognitive tasks, developers can design tools that address those problems. As an example, one study assessing how transparency levels permitted simultaneous foreground and background attention demonstrated limited success (Harrison, Kurtenbach, & Vicente, 1995). Future practical developments are likely to come from a combination of novel technological approaches with improved understandings of the interactions between stressful environments, individual emotions, and distributed cognition.

Applications of these findings will prove valuable to many command and control contexts, including emergency management centers, air traffic control, entities such as the Department of Homeland Security (DHS) who are responsible for managing complex terrorist or humanitarian crises, and the Department of Defense (DOD) C^4ISR infrastructure (Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconaissance).

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APPENDIX A: SURVEY ITEMS

PRE-TASK SURVEY

The pre-task survey contained questions regarding the visual communications portion of the study (i.e. watching the movie clips). Section 1 of this survey contained four movie-specific questions. Section 2 contained self-report mood and stress items. All questions were presented in a randomized order. The forms below are not formatted exactly as they appeared on screen to participants (see screenshots in Appendix C).

Section 1

This section consists of a number of specific questions about the movie. Read each statement and then select the correct answer.

Why was winning the ticket the best thing that happened to Jack?	☐ He had never travelled before ☐ He got to meet Rose ☐ He escaped from his family ☐ He was getting a fresh start
Jack tells Rose she will die an old woman in her:	☐ Rocking chair ☐ Sleep ☐ Home ☐ Bed
Why are the rowers instructed to be careful with their oars?	☐ To not make too much noise ☐ To go very slowly ☐ To not splash too much ☐ To not hit the bodies
Jack tells Rose that the delay in their rescue is because:	☐ They are getting the boats organized ☐ There weren't enough boats ☐ The boats aren't big enough ☐ The boats move too slowly

Section 2

Read each statement and then select the most appropriate answer to indicate how you feel **right now**, at the **present moment**. Do not spend too much time on any one statement. Use the following scale to indicate your answers:

1. Very slightly or not at all
2. A little
3. Moderately
4. Quite a bit
5. Extremely

	1 Not at all	**2** A little	**3** Moderately	**4** Quite a bit	**5** Extremely
I feel upset	☐	☐	☐	☐	☐
I feel concerned about the impression I am making	☐	☐	☐	☐	☐
I feel this movie clip was funny	☐	☐	☐	☐	☐
I am relaxed	☐	☐	☐	☐	☐
I feel sad	☐	☐	☐	☐	☐
I feel distressed	☐	☐	☐	☐	☐
I feel jittery	☐	☐	☐	☐	☐
I feel dissatisfied	☐	☐	☐	☐	☐
	1 Not at all	**2** A little	**3** Moderately	**4** Quite a bit	**5** Extremely
I am worried	☐	☐	☐	☐	☐
I feel this movie clip was boring	☐	☐	☐	☐	☐
I feel this movie clip was stimulating	☐	☐	☐	☐	☐
I feel determined	☐	☐	☐	☐	☐
I feel enthusiastic	☐	☐	☐	☐	☐
I feel this movie clip was sad	☐	☐	☐	☐	☐
I feel active	☐	☐	☐	☐	☐

Click Here to Continue

Please be patient. It may take up to 60 seconds before the next page appears.

POST-TASK SURVEY

The post-task survey contained questions regarding the experience of the NeoCITIES simulation. Section 1 of this survey contained self-report mood and stress items. Section 2 contained task-specific questions (i.e. perceived communication, coordination). All questions were presented in a randomized order.

Section 1

Read each statement and then select the most appropriate answer to indicate how you feel **right now**, at the **present moment**. Do not spend too much time on any one statement. Use the following scale to indicate your answers:

1. Very slightly or not at all
2. A little
3. Moderately
4. Quite a bit
5. Extremely

	1 Not at all	**2** A little	**3** Moderately	**4** Quite a bit	**5** Extremely
I feel distressed	☐	☐	☐	☐	☐
I feel determined	☐	☐	☐	☐	☐
I feel I am performing well on these tasks	☐	☐	☐	☐	☐
I feel confident about my abilities	☐	☐	☐	☐	☐
I am tense	☐	☐	☐	☐	☐
I feel alert	☐	☐	☐	☐	☐
I am motivated to do these tasks	☐	☐	☐	☐	☐
I feel dissatisfied	☐	☐	☐	☐	☐
I feel sad	☐	☐	☐	☐	☐
I feel calm	☐	☐	☐	☐	☐
	1 Not at all	**2** A little	**3** Moderately	**4** Quite a bit	**5** Extremely
I feel upset	☐	☐	☐	☐	☐
I feel concerned about the impression I am making	☐	☐	☐	☐	☐

I feel content	☐	☐	☐	☐	☐
I feel irritable	☐	☐	☐	☐	☐
I am trying to figure myself out	☐	☐	☐	☐	☐
I feel annoyed	☐	☐	☐	☐	☐
I feel jittery	☐	☐	☐	☐	☐
I thought about how I would feel if I were told how I performed	☐	☐	☐	☐	☐
I feel active	☐	☐	☐	☐	☐
I feel angry	☐	☐	☐	☐	☐
	1 Not at all	**2** A little	**3** Moderately	**4** Quite a bit	**5** Extremely
I am relaxed	☐	☐	☐	☐	☐
I feel self-conscious	☐	☐	☐	☐	☐
I feel enthusiastic	☐	☐	☐	☐	☐
I am worried	☐	☐	☐	☐	☐
Generally, I feel in control of things	☐	☐	☐	☐	☐
I am worried about what other people think of me	☐	☐	☐	☐	☐
	1 Not at all	**2** A little	**3** Moderately	**4** Quite a bit	**5** Extremely

Section 2

This section consists of a number of specific questions about your experience **today** with the NeoCITIES simulation you just completed. Read each statement and then select your response.

	Strongly Disagree	**Disagree**	**Neither Agree nor Disagree**	**Agree**	**Strongly Agree**
I felt like I knew what other teams were doing during the simulation	☐	☐	☐	☐	☐
I was unsure about how to communicate with other teams	☐	☐	☐	☐	☐
I felt like I needed more information to make correct	☐	☐	☐	☐	☐

decisions					
I did not see any connections between events. All of these events happened independently of each other.					
My teammates were highly cooperative in resolving events					
I frequently felt like I was being ignored					
I think there were connections between some of the events. I think each team had a part in resolving some related events.					
	Strongly Disagree	**Disagree**	**Neither Agree nor Disagree**	**Agree**	**Strongly Agree**

STOP - Complete the paper questionnaire now.
Wait for everyone to finish before you continue.

Click Here to Continue

Please be patient. It may take up to 60 seconds before the next page appears.

WRAP-UP SURVEY

The wrap-up survey concluded the experiment following the stand-up comic clip. This simply provided cover for showing this last clip which was actually intended to "reset" the participant's mood back to a happy state before leaving the lab. The questions were to be answered in comparison to the "happy" movie clip of the session (in the example below, this was the second movie).

Section 1

Using the different adjectives listed below, indicate how much you think this last clip differed from the second clip you watched.

Compared to the second movie you watched, was *the last clip you watched* ***more*** *or* ***less****:*

	Much less	**A little less**	**About the same**	**A little more**	**Much more**
Unpredictable					
Exciting					

Silly	☐	☐	☐	☐	☐
Interesting	☐	☐	☐	☐	☐
Dull	☐	☐	☐	☐	☐
Happy	☐	☐	☐	☐	☐
Depressing	☐	☐	☐	☐	☐
Serious	☐	☐	☐	☐	☐
	Much less	**A little less**	**About the same**	**A little more**	**Much more**

Click Here to Continue

Please be patient. It may take up to 60 seconds before the next page appears.

APPENDIX B: CODING PROCEDURE FOR NEOCITIES CHAT LOGS

For each team/condition there will be a tally for:

- All three IMs combined (one file)
- Each IM/RM pair (three files)

1. Browse all of the chat files first to get a feel for the team's communication style
2. Code all MergedIMChat.txt first for all sessions
3. Code each RM chat log (*rm_chatlog.txt*) next. The rm_chatlog file is the same in both the IM and RM folder, so use the one in the IM folder for convenience and consistency.
    a. These are often short, or empty (i.e. IM and RM did not chat)
    b. Final result is a tally for each IM/RM pair

Complete all 8 conditions for a team before moving on to the next team

Put everything in one Excel file. use chat coding template.xls and SAVE AS… using "chat coding - [coder's last name].xls" as the file name. E.g. "chat coding – pfaff.xls"

CODES

	Measure	Description
	Overall Rate	
TC	Total Communications	Total number of communications in the session
	Communication Type	
IR	Information Request	Request for information
IT	Information Transfer	Transmission of information
AR	Action Request	Request for action
AT	Action Transfer	Statement of action taken or to be taken
CR	Coordination Request	Request to coordinate an action
CT	Coordination Transfer	Agreement to coordinate an action
ACK	Acknowledgements	Acknowledgements of the receipt of a communication, but without any specific message content (i.e. "OK")
INSIG	Insignificant Utterances	Task-irrelevant statements or chatter

These codes have been adapted and extended from those described in: Entin, E. E., & Entin, E. B. (2001). Measures for Evaluation of Team Processes and Performance in Experiments and Exercises. *Proceedings of the 6th International Command and Control Research and Technology Symposium, Annapolis, Maryland June*, 19-21, p.8.

CODING RULES

There are three primary classes of communications in NeoCITIES: Information, Action, and Coordination. Each class has two types: Request or Transfer. Other communications fall into the categories of Acknowledgements or Insignificant Utterances.

Chat discussions between IMs tend to revolve around the coordination of which dyad(s) are responsible for which events. IM-RM chat usually involves the actions in response to specific events and the status of dyad resources. Events are usually referred to in chat by their ID number or time-stamp, but sometimes by their subject or location (e.g. "the big car crash").

Information

"Information" refers to statements expressing or inquiring about of the status of events in the city or the activities of the participants in the simulation. Information requests and transfers are analytical in nature, and sometimes retrospective – discussing what has taken place for a given event. Statements classified as "information" do not include discuss coordination or statements of actions (to be) taken. It is often difficult to distinguish whether a statement is requesting information or requesting coordination, so the surrounding context should be used as a guide.

In simple scenarios with straightforward events, there are usually few information requests or transfers. Rather, the subjects discuss coordinating responsibility and taking action on events. However, in complex scenarios with ill-defined events or puzzles to solve, there will generally be many more exchanges of information.

IR – requesting information from other team member(s), but NOT about which team is taking responsibility for an event (that would be a CR in question form).

`(08:39 AM) Police I-MGR: Is hazmat sending a bomb unit to 4?`	***IR***
`(08:40 AM) Hazmat I-MGR: No, we haven't done anything on 4.`	***IT***
-- which could be followed by --	
`(08:41 AM) Police I-MGR: Hazmat needs to take care of 4`	***CR***
-- or --	
`(08:41 AM) Police I-MGR: Hazmat – send a bomb unit to 4!`	***AR***

Examples:
"Is anything happening yet?"
"How did we fail 25, police?"
"What do you think about the firearms one?"
[If this last statement is in reference to a current event and is asking for discussion about who should take the firearms event, then it is a CR. On the other hand, if it is in reference to an event that happened some time ago, and the requester is asking about its status or outcome, then it is an IR.]

IT – statements containing general information not directly related to taking responsibility for an event (which would be a CT) or taking a particular action (which would be an AT). These might include justifications or rationale for actions, but not a statement of action taken. Often these are in response to an IR.

Examples:
"EMT wasn't needed for 12"
"Because 5 is a bomb event."
"Fumes are not fire related"
"Lots of poisonings going on."

Coordination

"Coordination" refers to the delegation or acceptance of responsibility to manage an event in the simulation. These exchanges are usually between IMs. A CR may ask an IM's dyad to take responsibility for handling an event, or may begin a discussion among all three IMs about who should handle the event.

CR – specifically assigning responsibility for an event to another dyad (police, fire, hazmat) or asking that members determine which team should handle an event. Between IMs, this is usually in the form of "police to 14" or "hazmat on 3?" or "who is taking 12?" "Hazmat 3?" is often how IMs will state a CR, which would then be followed by a CT from Hazmat: "We're on 3."

Stated by an RM to an IM, this is more like "this isn't our event, fire should take it instead" (CR from RM to IM)

Examples:
"Police to 14"
"Fire on 10?"
"Who is taking 12?"
"Who transports ammunition?"
[If this last statement is made among IMs in the context of an event just fired requiring the transportation of ammunition, then it is a CR referring to the event by activity, rather than by ID number or time stamp. If it is a discussion between an IM and RM about what kind of resource transports ammunition, then it is an IR.]

CT – a statement of agreement to manage a given event. Coordination is a high-level administrative activity and does not include statements about specific actions to be taken. This type of statement is exclusive to IMs. Sometimes CTs are hard to distinguish from ACKs, but the communication style of the group usually makes it clear how an agreement to coordinate is made. A key distinction is that a CT must include a specific reference back to the event being coordinated. "On it" only states receipt of the CR. Even though the agreement to coordinate is implied, because there is no reference back to the initial request, such a statement is an ACK.

Note in the example below that each CT makes reference to the specific event being accepted. Some teams might simply use "got it" or "on it" in response to a CR. The context makes it clear that the statement is an agreement to coordinate the event just mentioned, but because the message does not include any substantive information (event ID, time stamp, or action), then it is classified as an ACK.

Examples:

`(08:56 AM) Hazmat I-MGR: police needed at 8:53`	***CR***
`(08:59 AM) Police I-MGR: on it...8:53`	***CT***
`(09:01 AM) Police I-MGR: hazmat at 8:58`	***CR***
`(09:03 AM) Hazmat I-MGR: dispatched at 8:58`	***CT***
`(09:03 AM) Fire I-MGR: Police for 9:03`	***CR***
`(09:04 AM) Police I-MGR: On it.`	***ACK***
`(09:06 AM) Hazmat I-MGR: police for 9:06 ?`	***CR***
`(09:07 AM) Fire I-MGR: No, 9:06 is Fire.`	***CT***

```
(09:07 AM) Hazmat I-MGR: Ok.                                   ACK
```

Note that in the next to last line that even though the Fire I-MGR did not explicitly say “I’m taking it,” it is implied when he indicates that his team is responsible for the event. The same words – “No, 9:06 is Fire” coming from the Hazmat or Police I-MGR would be a CT.

Action

“Action” refers to ground-level activities, usually discussed between IMs and RMs. Exchanges involve dispatching specific resource(s) to events. Asking for a fire investigator to be sent is an AR, while asking the Fire/EMS team to handle an event is a CR.

Often a team and a resource may be referred to similarly. For example, “EMS to 13” may mean “The fire/ems team should deal with 13” (CR) or “The fire team should send an EMS unit to 13” (AR). When in doubt, if it is an exchange between IMs, code it as a CR. If it is an exchange between IM-RM, code it as an AR.

AR – specifically asking another member to take a particular action (“send a chem truck”), rather than “Hazmat team, you take this event” (which is a CR). Sometimes IMs may instruct other IMs to tell their RM to send a specific resource – this is an AR. Often IMs will prompt their RM to send a specific resource via the “Send to IM” dialogue box, so there are often few ARs from IM to RM.

AT – Agreement to send a resource to a given event. Usually this is a statement to an IM from an RM, as the RMs are the only ones with the authority to take action on events (i.e. dispatch resources). Typical statements: “Sent three trucks to the coal fire.” “Sent two investigators.”

Acknowledgments (ACK)

ACK lines include agreements or receipt of info “OK” “yep” and “yeah,” as well as more substantial agreements like “seems like it” or “yeah, probably was” that do not, on their own, constitute an AR or CR. Even if the context seems to indicate an “OK” is serving as another message (such as an CT), if the message does not include any reference to other tangible message information (event ID, event description) then it is only an ACK.

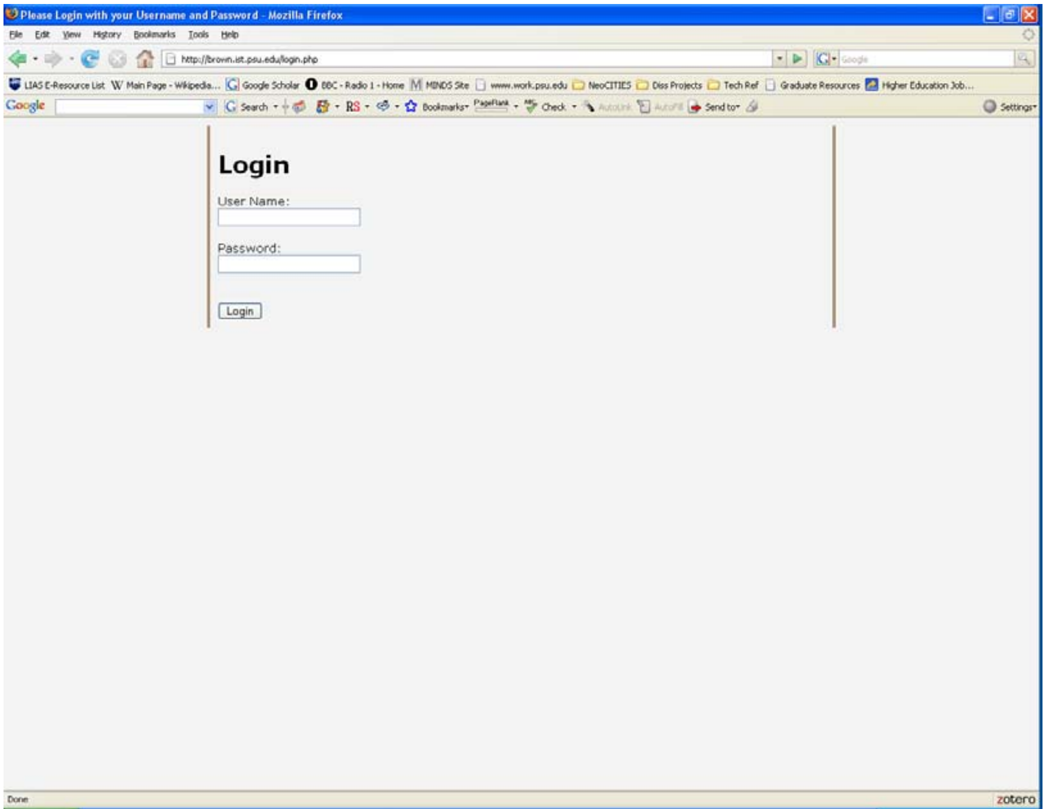
Insignificant statements (INSIG)

Insignificant statements are those that don’t really contribute to the tasks at hand. An exchange like “I wish there were a sudoku option” “yes, me too” would be insignificant. Asides like “sorry” (referring to a typo) or “Woohoo!” exclamations are also insignificant. The reason for coding such lines is that they all should be included in the total amount of communication occurring. On-task message counts can be isolated by subtracting INSIG from TC.

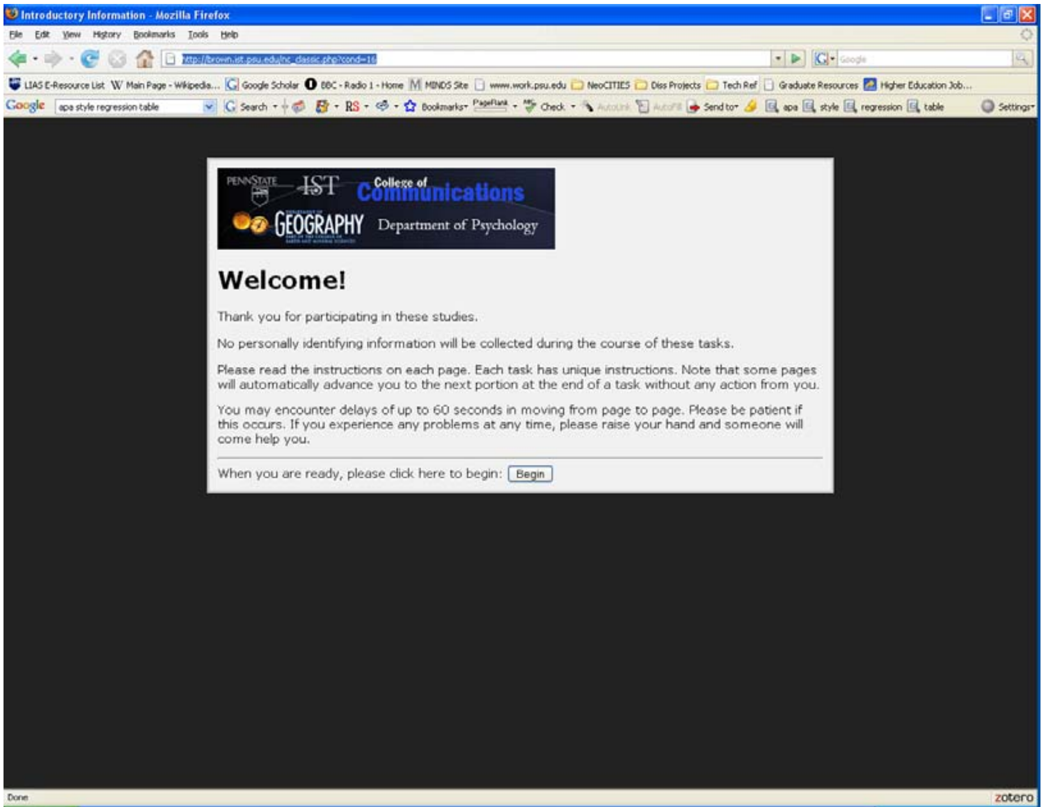
Participants may discuss the simulation itself, which is considered an on-task message. An exchange like “How are we failing on 4 things?” (IR); “Good question” (ACK); “I’m so confused on this” (IT) should not be coded as INSIG.

APPENDIX C: STIMULUS SCREENSHOTS

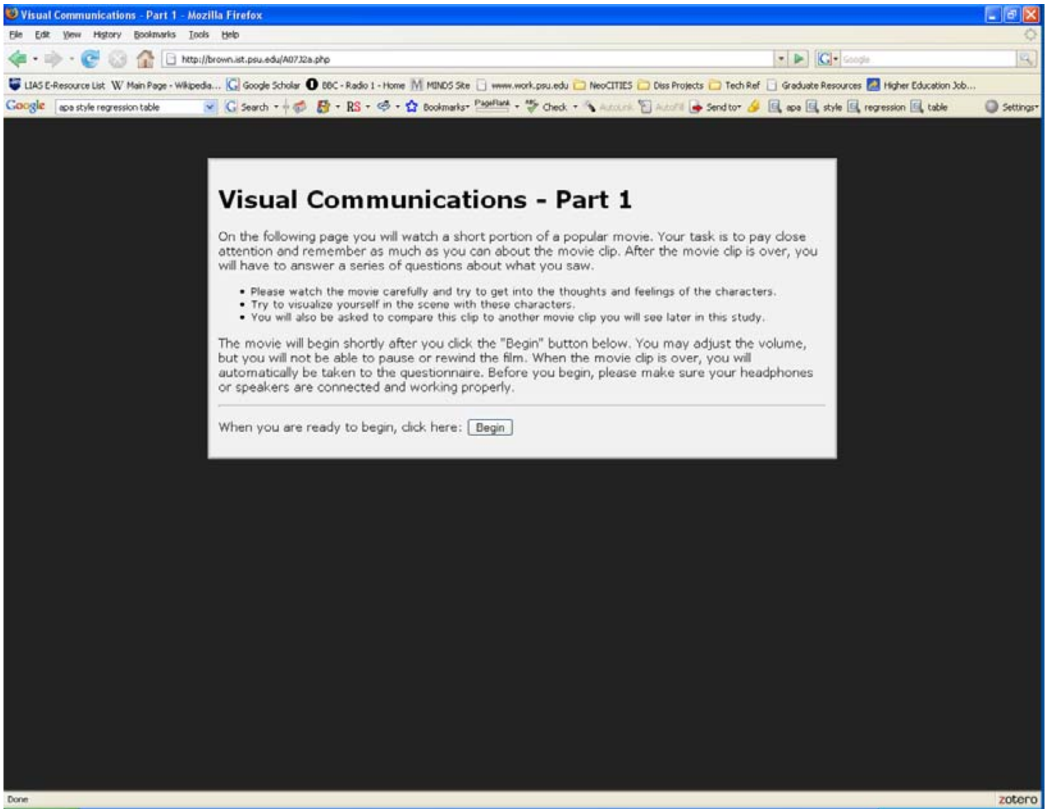
Participants logged in with a personal user ID and password to begin the experiment. This ensured the data collected was properly ascribed to each participant:



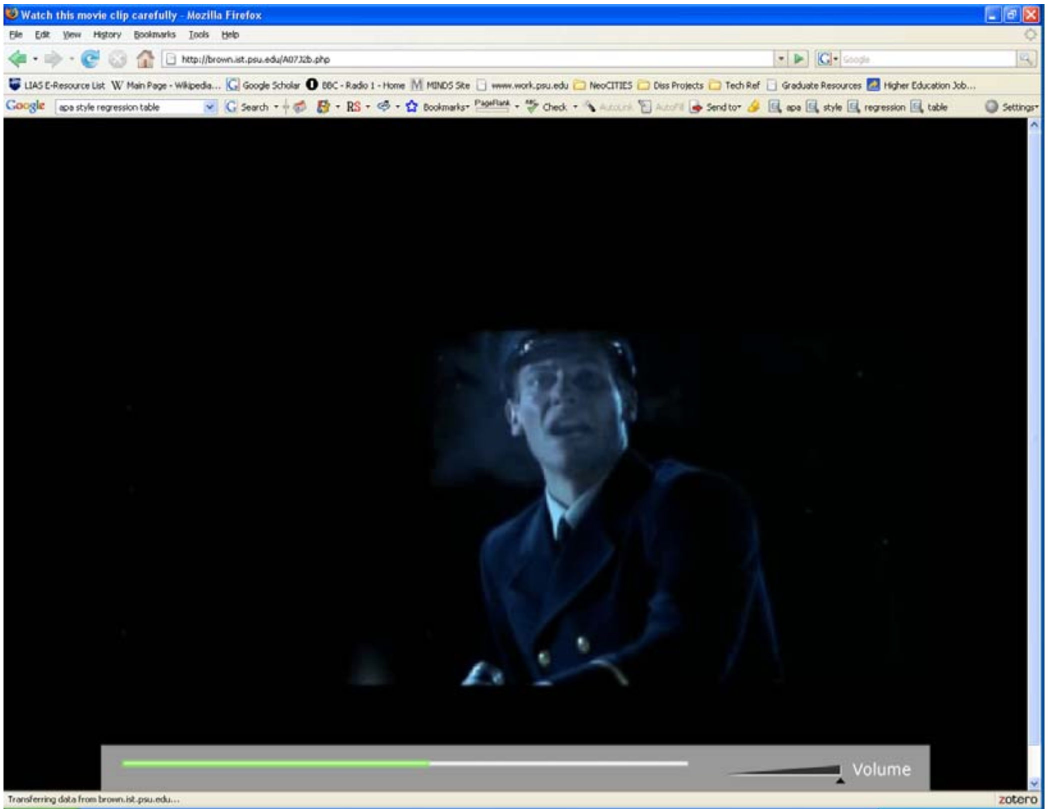
Upon login, participants were greeted with the following screen explaining the instructions for the experiment:



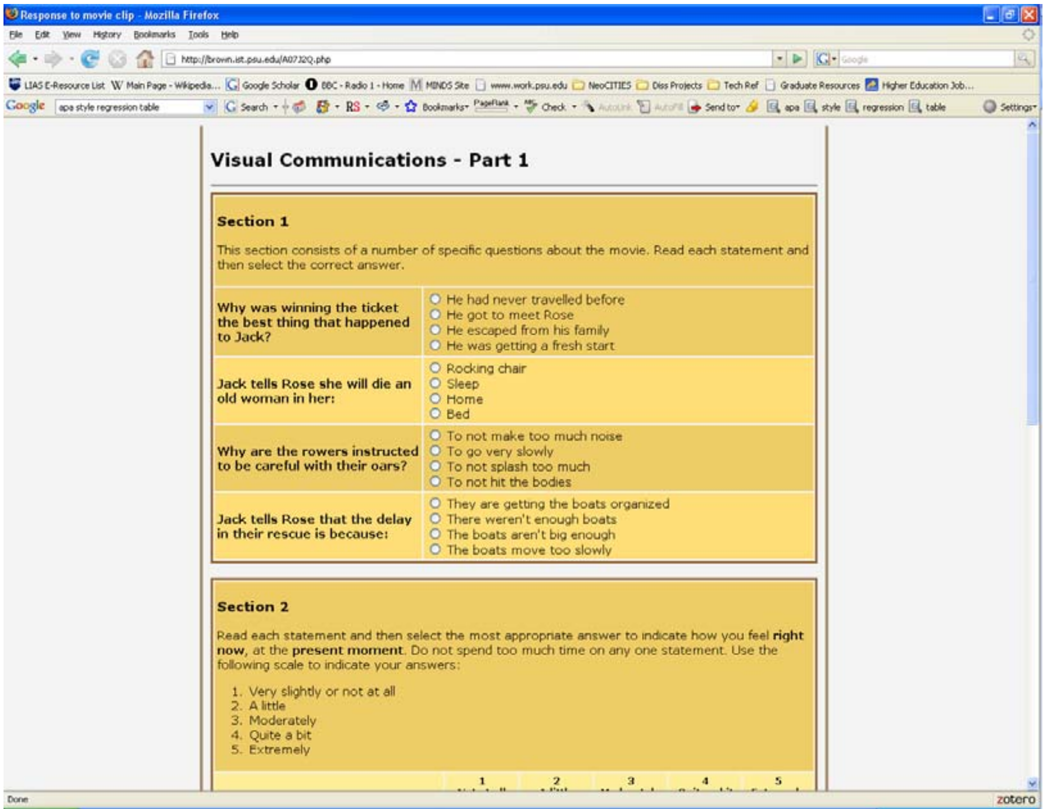
The pre-task mood manipulation was encapsulated as an unrelated study on visual communication. This was introduced with this page:



The movie was presented in a screen with no controls to pause, scan, or restart the movie. Participants could adjust the volume if needed.



The movie was followed by a survey testing recall of features from the movie (section 1) and self-reported mood and stress measures (section 2):


Response to movie clip - Mozilla Firefox

Visual Communications - Part 1

Section 1

This section consists of a number of specific questions about the movie. Read each statement and then select the correct answer.

Why was winning the ticket the best thing that happened to Jack?	○ He had never travelled before ○ He got to meet Rose ○ He escaped from his family ○ He was getting a fresh start
Jack tells Rose she will die an old woman in her:	○ Rocking chair ○ Sleep ○ Home ○ Bed
Why are the rowers instructed to be careful with their oars?	○ To not make too much noise ○ To go very slowly ○ To not splash too much ○ To not hit the bodies
Jack tells Rose that the delay in their rescue is because:	○ They are getting the boats organized ○ There weren't enough boats ○ The boats aren't big enough ○ The boats move too slowly

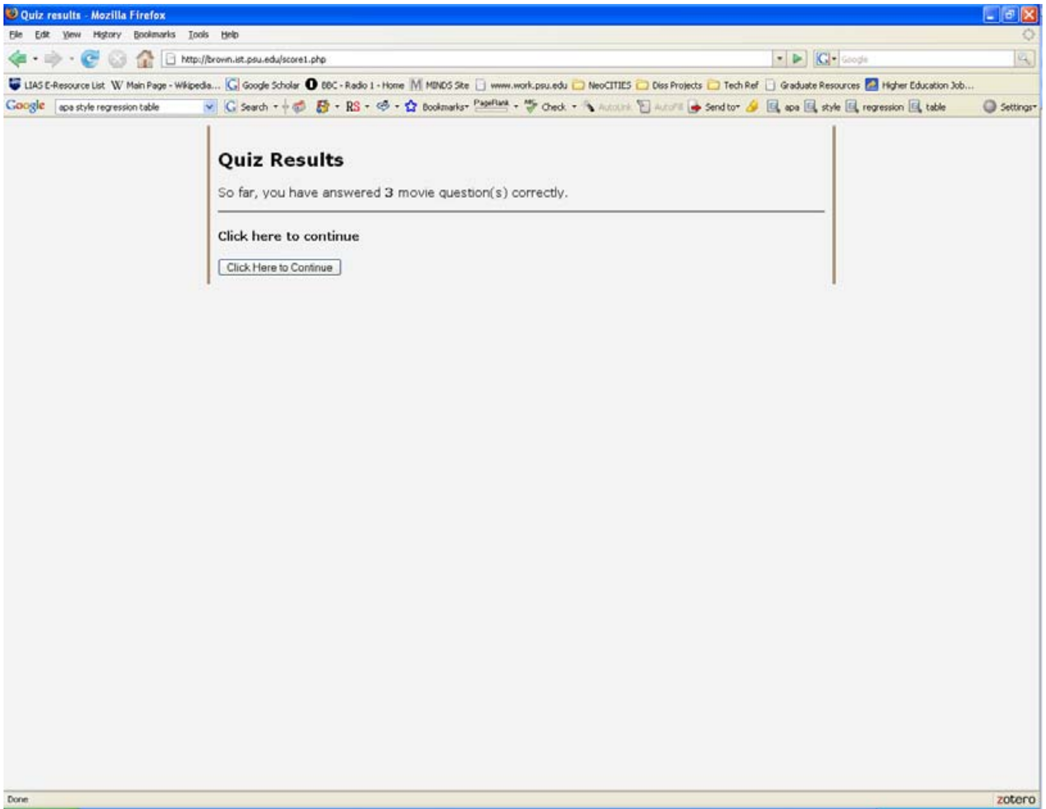
Section 2

Read each statement and then select the most appropriate answer to indicate how you feel **right now**, at the **present moment**. Do not spend too much time on any one statement. Use the following scale to indicate your answers:

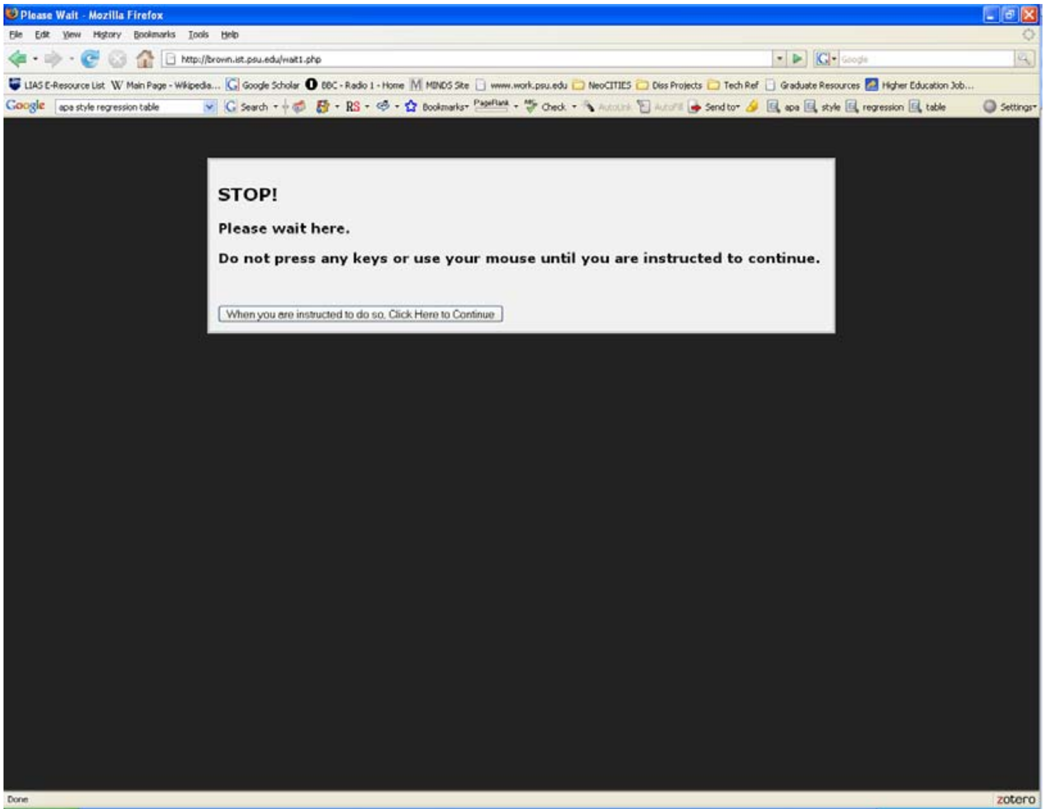
1. Very slightly or not at all
2. A little
3. Moderately
4. Quite a bit
5. Extremely

1 2 3 4 5

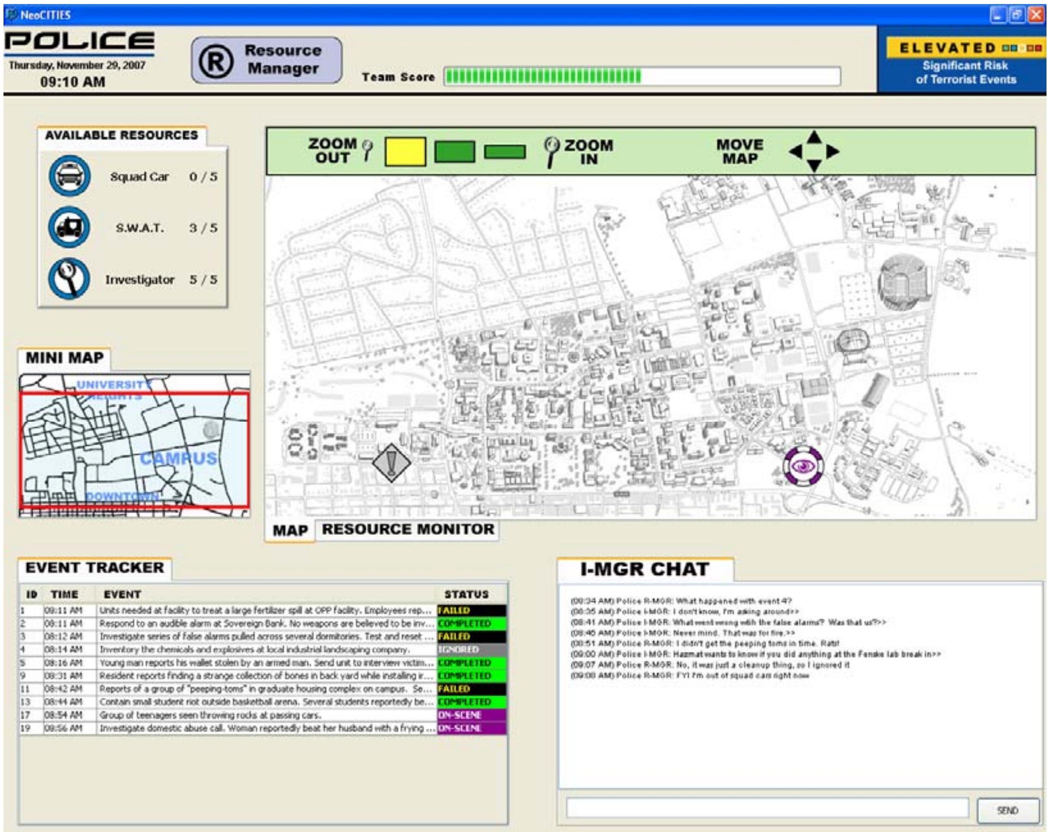
Following the pre-task survey, participants received a score on their recall of features from the movie. This maintained the on-going thread of the visual communications study as separate from the NeoCITIES study:



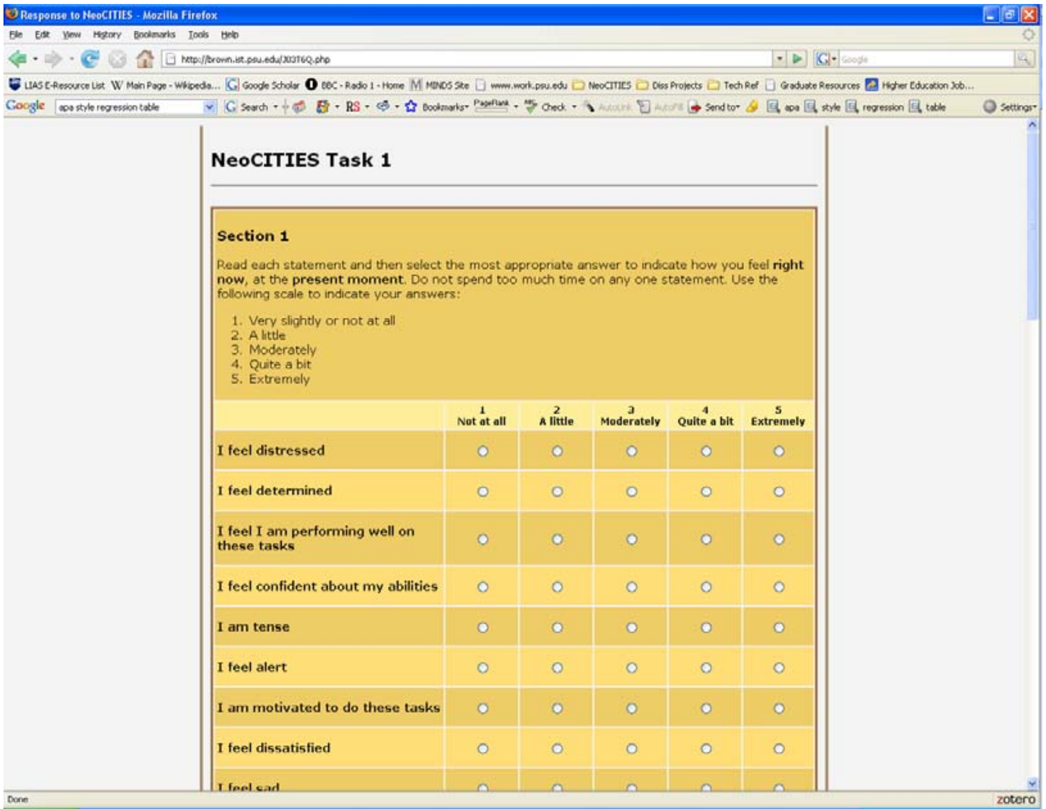
All participants were instructed to stop and wait until the experimental monitor instructed them to proceed. The monitor waited until all participants had completed the survey questions and arrived at this screen before instructing participants to begin the NeoCITIES task:



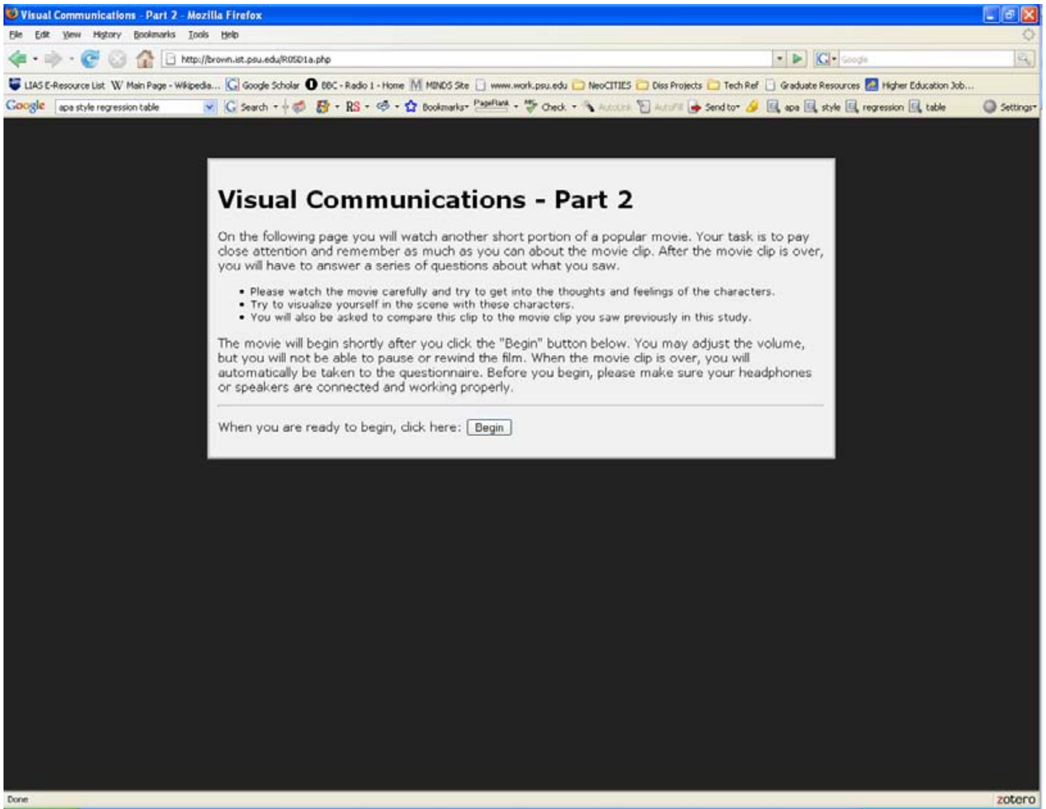
At this point, participants began the NeoCITIES simulation:



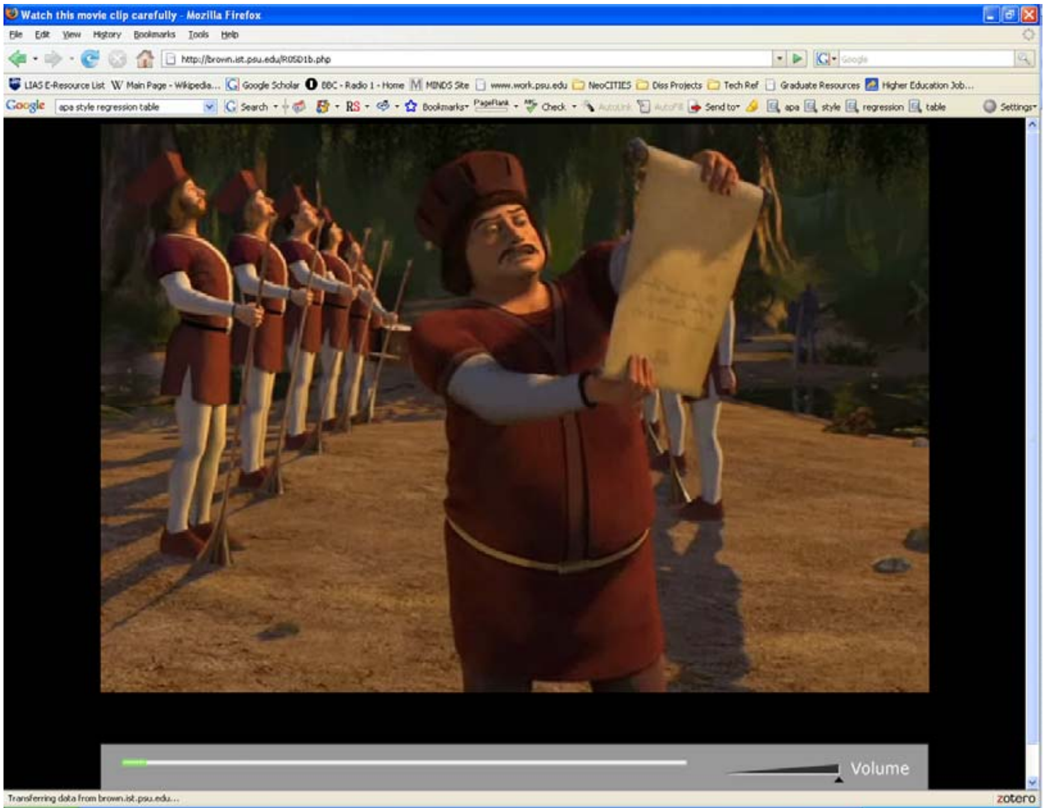
At the conclusion of the NeoCITIES task, participants arrived at this screen to answer self-report mood and stress items:



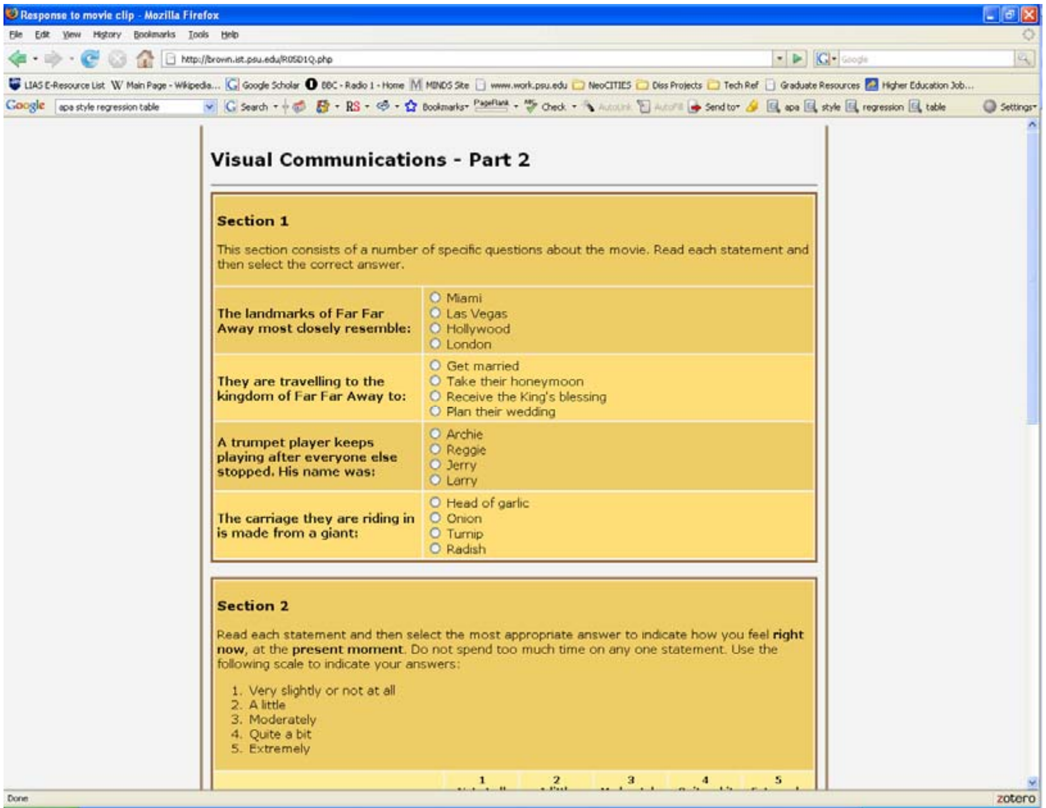
The cycle repeated with exposure to the second condition of the session. This was identical to the first except for the mood manipulation which was the opposite mood of the first condition:



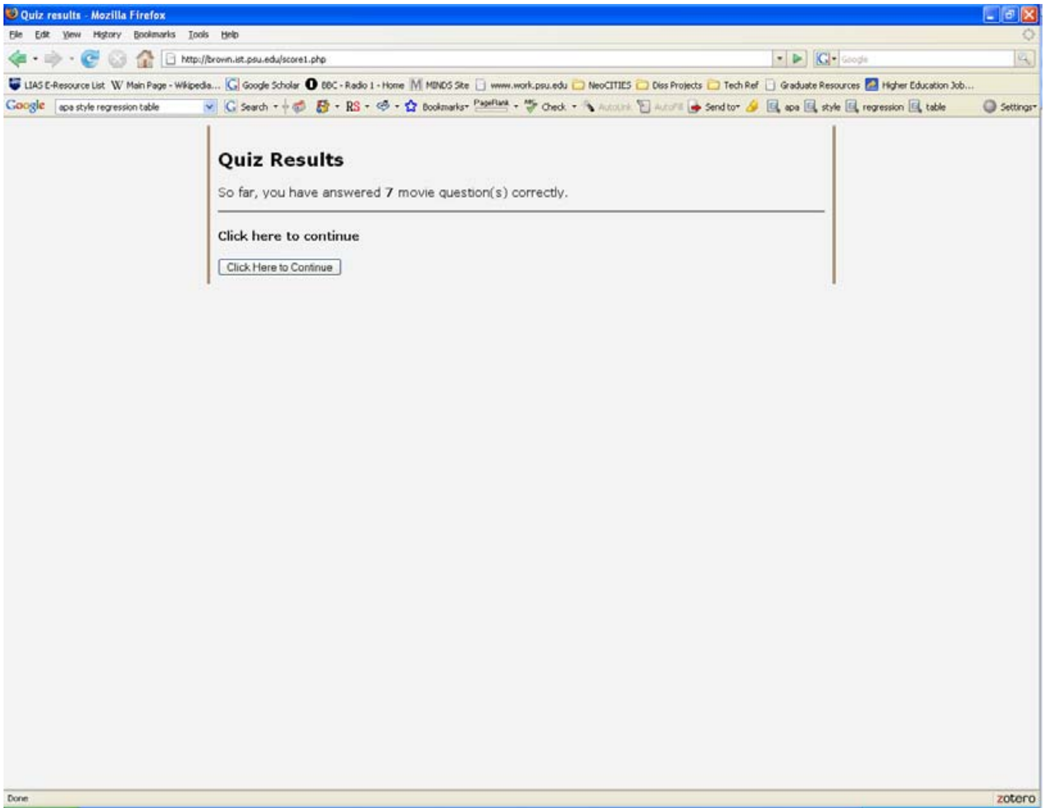
The second mood manipulation movie clip:



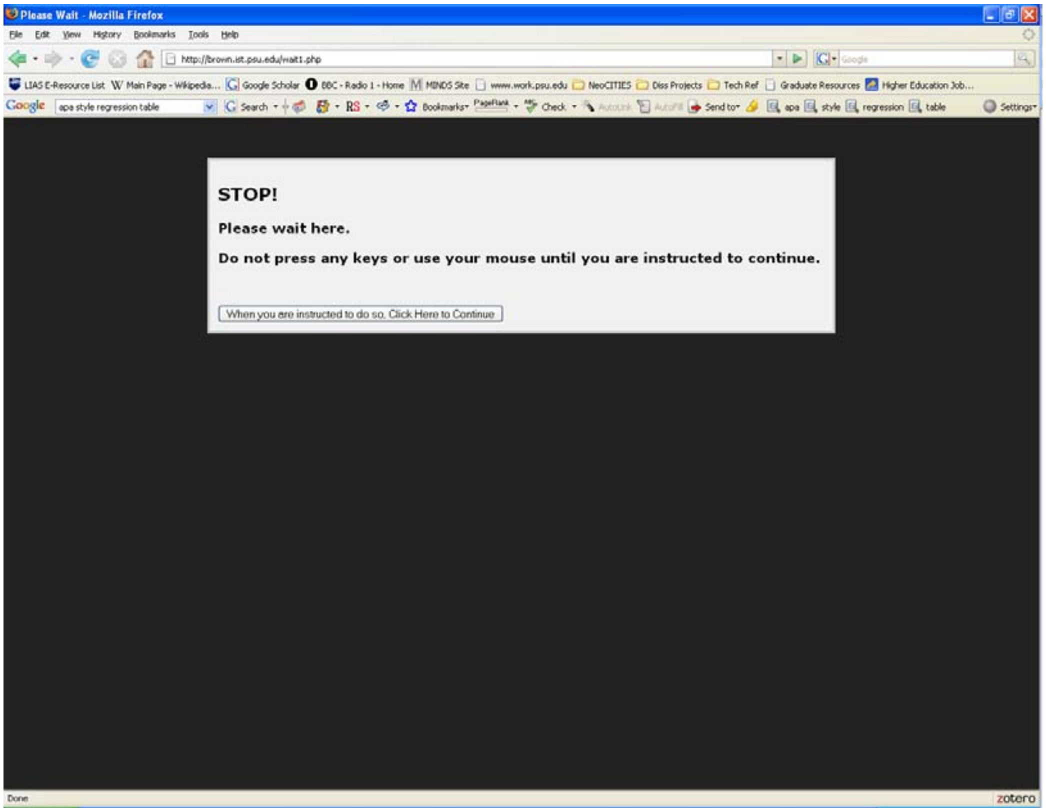
Pre-task survey for the second condition:



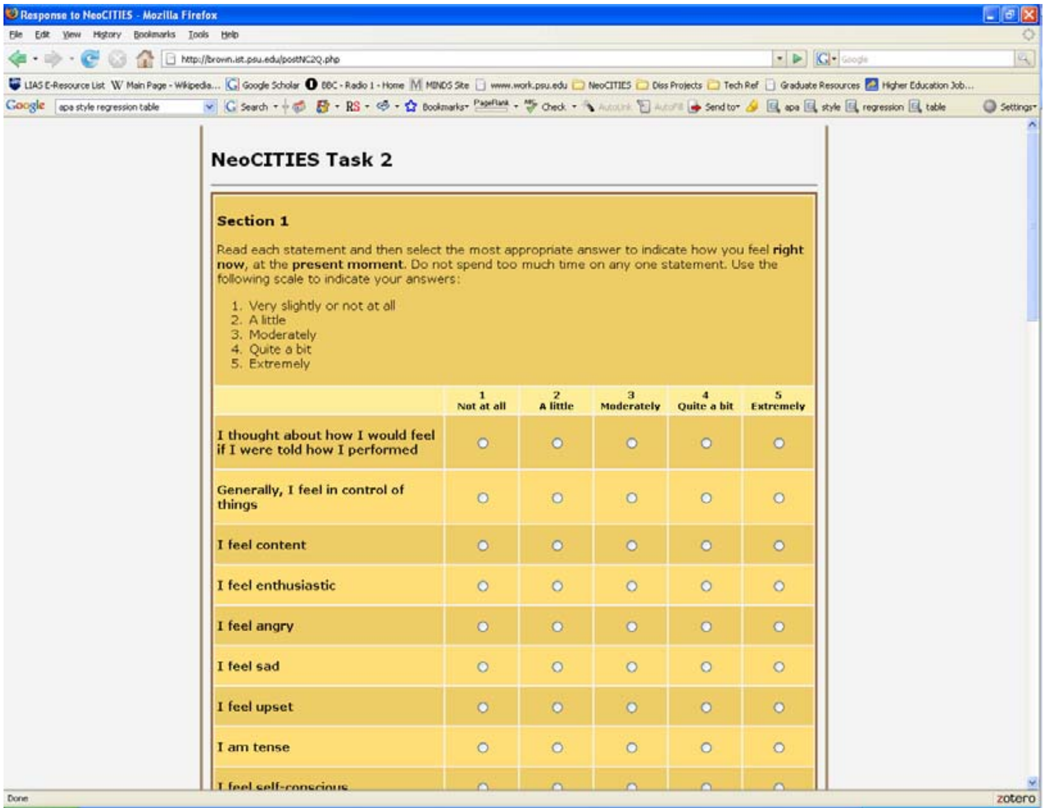
Score report for the second condition:



Pause before beginning the second NeoCITIES task:



Post-task survey following the second NeoCITIES task:



NeoCITIES Task 2

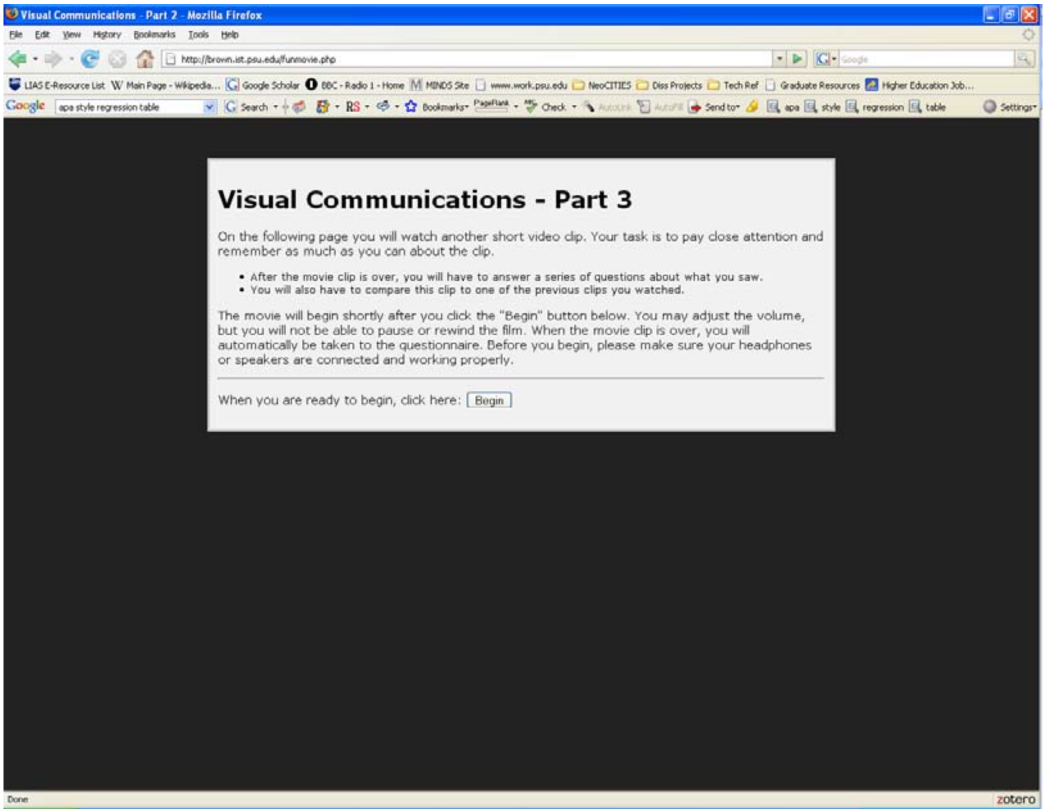
Section 1

Read each statement and then select the most appropriate answer to indicate how you feel **right now**, at the **present moment**. Do not spend too much time on any one statement. Use the following scale to indicate your answers:

1. Very slightly or not at all
2. A little
3. Moderately
4. Quite a bit
5. Extremely

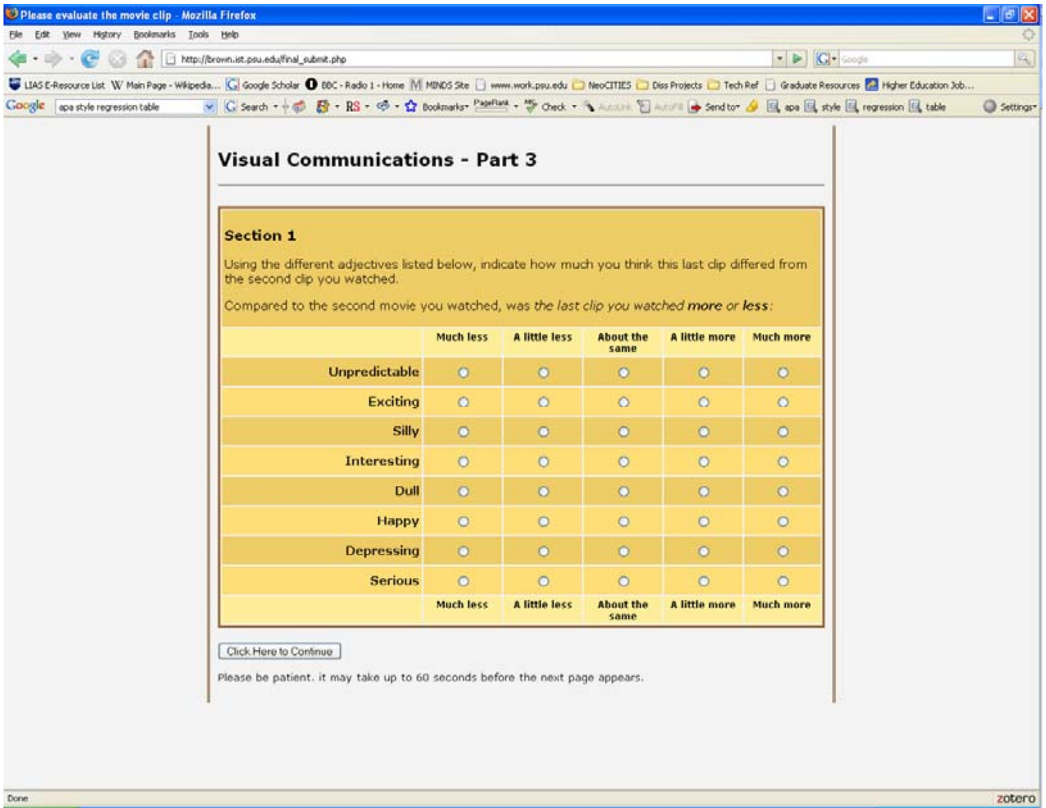
	1 Not at all	2 A little	3 Moderately	4 Quite a bit	5 Extremely
I thought about how I would feel if I were told how I performed	○	○	○	○	○
Generally, I feel in control of things	○	○	○	○	○
I feel content	○	○	○	○	○
I feel enthusiastic	○	○	○	○	○
I feel angry	○	○	○	○	○
I feel sad	○	○	○	○	○
I feel upset	○	○	○	○	○
I am tense	○	○	○	○	○
I feel self-conscious	○	○	○	○	○

Final mood manipulation stage to “reset” participants’ moods in the event that the last mood was a sad clip:

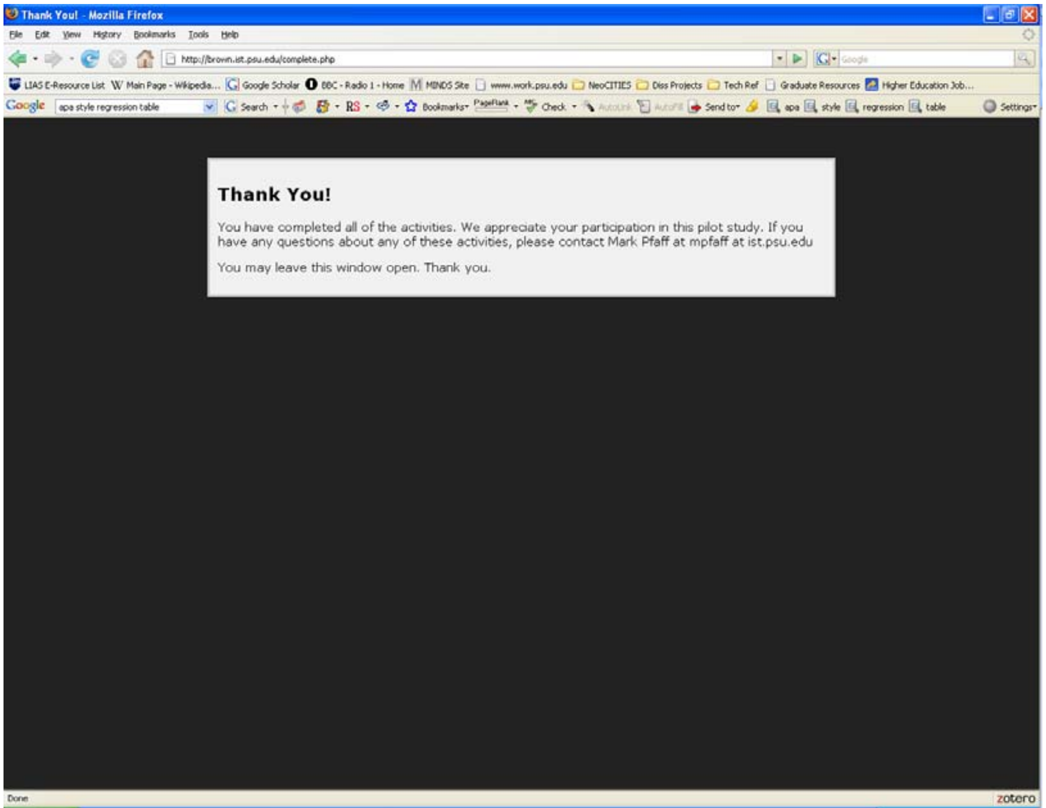


This final clip was always a stand-up comic:

Final questions presented to continue the ongoing thread of the visual communication study:



Closing screen before participants were dismissed:



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Refereed Papers:

Krakowiak, K. M., Lacayo, A., Pfaff, M. (2007). The puzzling effects of multitasking in online environments. *93rd Annual Convention of the National Communication Association* (NCA 2007), Chicago, IL, November 2007. [Winner of Scholar-to-Scholar Best Overall Display Award]

Ahern, L., Pfaff, M., Rutter, P., & Johnson, C. (2007). Media bias in the eye of the beholder: Issue importance, issue support and political identity. *90th Annual Convention of the Association for Education in Journalism and Mass Communication,* (AEJMC 2007), Washington, D.C., August 2007.

Zhu, S., Abraham, J., Paul, S., Reddy, M., Yen, J., Pfaff, M., DeFlitch, D. (2007). R-CAST-MED: Applying intelligent agents to support emergency medical decision making teams. *11th Conference on Artificial Intelligence in Medicine,* (AIME 2007), Amsterdam, The Netherlands, July 2007.

McNeese, M., Pfaff, M., Connors, E., Obieta, J., Terrell, I., & Friedenberg, M. (2006). Multiple vantage points of the common operational picture: Supporting complex teamwork. *50th Annual Meeting of the Human Factors and Ergonomics Society,* (HFES 2006), San Francisco, CA, October 2006.