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ABSTRACT

THE EFFECT OF WORKLOAD ON INDIVIDUAL AND TEAM LEARNING, AFFECT, AND PERFORMANCE

By

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This experiment examined the relationships between workload on the one hand, and emotional arousal, learning, and performance on the other, among both individuals working alone and work teams. Through integrating various cognitive and motivational theories, I show that there is reason to believe that the relationships will vary across levels. Results indicated that the effect of workload on emotional arousal for individuals was moderated by neuroticism and extraversion, but in teams the effect was moderated by team structure and transactive learning. Workload was negatively related to learning in teams, and the effect persisted even when team workload decreased. In contrast, for individuals working alone, the effect of workload on learning was moderated by the individual's level of neuroticism. Previous workload had no direct effects of subsequent performance for individuals working alone, but was marginally positively related to subsequent speed of performance in teams.

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INTRODUCTION

In response to the increased use of team-based structures in organizations, research on team effectiveness has greatly expanded (Sanna & Parks, 1997). Two broad characteristics appear to be evident in recent teams research. First, there is a greater recognition that teams do not perform in isolation, but rather are embedded within larger organizations, and are themselves made up of smaller units (i.e., individual members). In this respect, teams engage in a dynamic interplay with both larger and smaller levels of analysis, affecting and being affected by both their members and their organizations (Arrow, McGrath, & Berdahl, 2000; Ilgen, Hollenbeck, Johnson, & Jundt, 2005). Second, whereas previous theory and research largely conceptualized teams as static entities engaging in single-cycle performance contexts, an emerging body of research examines teams in dynamic contexts that perform across time. This research has found that the past history of teams often reaches forward and affects their future processes and performance (Johnson et al., 2006; Moon et al., 2004).

The first characteristic is most evident in multi-level theory and research (Kozlowski & Klein, 2000). Although multi-level theories can take many forms, one of the most basic is the homologous model. Homologous models suggest that the relationships between constructs are isomorphic at more than one level of analysis. For example, Chen et al. (2002) found that the relationship between achievement motivation and performance was mediated by efficacy beliefs at both the individual and team levels. Tests of homology are critical in understanding organizational behavior, because they highlight the similarities and differences between phenomena at the individual, team, and organizational levels (House, Rousseau, & Thomashunt, 1995).

The second characteristic is evident in research that takes multiple measures of team processes and performance. Rather than examining phenomena with between-team designs, these studies examine within-team change over time. This research recognizes that "a group's activity (is) in part a function of its own past history" (Arrow, McGrath, & Berdahl, 2000, p. 29), often examining team performance in dynamic contexts. For example, Johnson et al. (2006) found that teams' past reward systems affected their future communication and performance, even after the reward system changed.

Drawing on both of these broad trends in teams research, this research tested a model of performance at the individual and team levels in a dynamic context. Specifically, in a laboratory setting, this experiment tested the effects of past workload on the subsequent performance of both teams and individuals working alone. I propose that although the relationship between past workload and subsequent performance is likely to be homologous across individual and team levels in terms of speed (or quantity), it is likely to vary in terms of accuracy (or quality). As will be shown, this is because the effect of workload on accuracy depends to a large extent upon learning, which operates differently at the individual and team levels. In contrast, I propose that the effect of workload on speed is largely a function of emotional arousal, which develops similarly across levels. Figure 1 graphically depicts the entire hypothesized model. I note that this figure is not a structural model, but rather a heuristic for examining the relationships between the various constructs.

Prior to describing the rationale for this model, boundary conditions must be established. First, the model assumes that veridical feedback is being provided on one's task performance, and thus does not apply in situations where no feedback, inaccurate feedback, or equivocal feedback is provided. Feedback is an important factor in influencing one's performance (Kluger & DeNisi, 1996). It may be provided by a supervisor, by coworkers, or may be derived from the task itself. Second, the model applies only in situations where workers have at least some degree of latitude over the way they perform their jobs. This applies both to the behaviors that the workers engage in, as well as the opportunity to make decisions regarding their work. Karasek's (1979) job demands/control theory (discussed in later parts of the manuscript) suggests that many of the effects of workload depend upon whether workers have some control over their jobs, and my model is expected to operate at the higher end of the control continuum. Third, the model is expected to apply in situations where the task is somewhat novel. The model suggests that learning is one of the mediators of the relationship between workload and performance, and therefore the task must be one that is not already well-learned. Fourth, the team portion of the model only applies to teams without well-established communication and coordination patterns. Previous research has established that teams with such patterns adapt more effectively to high-stress situations than teams without such patterns (Entin & Serfaty, 1999). Therefore, this model best applies to teams that are relatively new. Finally, the team portion of the model is also expected to apply only to teams that work together relatively regularly and have at least a moderate level of interdependence. It is not expected to apply to teams where the individuals typically work alone and only come together sporadically to discuss their work.

INDIVIDUAL WORKLOAD AND PERFORMANCE

Although the effect of workload on various outcomes has received consistent attention in the psychology literature for the past thirty years, it has become a particularly salient applied issue in recent years, due to downsizing, business expansion, and outsourcing (Schwartz, 2004). Both objective and subjective measures indicate that employee workloads have increased over the past few decades. According to the Economic Policy Institute, the average annual hours worked by Americans increased from 1,720 hours in 1973 to 1,898 hours in 1998 (Schor, 2002); an even more recent survey showed that 62% of workers said their workload had increased over the past six months, and more than half claimed their workload left them "overtired and overwhelmed" (Schwartz, 2004). Excessively high workloads can lead to stress-related health issues, including heart disease (Vahtera et al., 2004) and mental health problems (Ganster, Fox, & Dwyer, 2001). These health problems are harmful for the organization as well as the employee, as the organization incurs costs from increased employee sick leave (Westerlund et al., 2004) and may be legally liable for injury if they could have reasonably foreseen the risk ("The psychiatric injury liabilities of excessive workloads", 2005). Additionally, excessive workload may cause workers to commit errors; recent cases have included a medical center that failed to inform patients about the results of their cancer screening tests (Santora, 2005) and a train crash that caused the death of four people ("Dispatcher's errors caused fatal crash, NTSB rules", 1998).

Workload as a Construct

Workload is a deceptively complex construct. Although the word seems to be such an established part of the lexicon, it did not appear in most dictionaries until the

1970's (Huey, Wickens, & National Research Council Commission on Behavioral & Social Sciences & Education, 1993). At first blush, it appears to refer simply to how much work one has to do. It is not clear, however, whether this refers to objective workload or subjective perceptions of workload; whether the amount of work is simply quantitative or contains a qualitative dimension; or whether it is a characteristic of the job, the worker, or both. Indeed, theorists have had a difficult time both defining and agreeing upon the definition or workload. Huey et al. (1993, p. 54) note that "operational definitions (of workload) proposed by psychologists and engineers continue to disagree about its source(s), mechanism(s), consequence(s), and measurement." Of the related construct of mental workload, Xie and Salvendy (2000, p. 76) noted, "The simple fact is that nobody seems to know what mental workload is." Thus, I wade into turbulent waters as I discuss the construct of workload. First, I discuss what workload is and is not; then I distinguish it from the related concepts of job demands, job challenge, and job stress; and finally, I briefly discuss the two major lines of research that have dealt with workload.

What workload is and is not. The first issue that must be resolved is whether workload is an objective characteristic of the work environment, or a subjective perception of the worker. Shaw and Weekley (1985, p. 88) made the case for treating it as an objective characteristic by stating that managers "are, for the most part, limited to manipulating the objective characteristics of the work environment…." Several empirical studies have adopted this objective approach to workload, including ones where workload was experimentally manipulated in laboratory (Froggatt & Cotton, 1987; Perrewe & Ganster, 1989; Shaw & Weekley, 1985) and field settings (Parkes, 1995), as well as observed in naturalistic field settings (Hurst & Rose, 1978; Kakimoto, Nakamura, Tarui, Nagasawa, & et al., 1988; Rose & Fogg, 1993).

Other research has adopted a more subjective approach to workload. This research suggests that it is an individual's *perceptions* of workload, rather than the objective amount of work itself, that best represents the construct. This perspective is reflected in the work of Daniel Gopher, who defined workload as "the interaction between a person and a task" in the sense that people have different maximum capacities for handling different levels of work (Gopher & Donchin, 1986). Gopher likens workload to electrical current, in that current is a joint property of both the voltage supplied by the battery and the resistance provided by the circuit. Thus, two people may perceive objectively identical workloads differently, because they provide different "resistances" to their tasks. Empirical studies using subjective perceptions of workload have been conducted primarily in field settings (Greenglass, Burke, & Moore, 2003; Jacobs & Dodd, 2003; Markel & Frone, 1998; Spector, Dwyer, & Jex, 1988; Yeung, Genaidy, Deddens, & Sauter, 2005), although subjective perceptions of workload have also been used in laboratory settings (Fisher & Ford, 1998). Drawing upon this idea that both the demands of the task and the capacity of the individual determine workload, I view workload as an objective construct that is determined both by the objective demands of the task and the objective capacity of the individual. Empirically, however, it is difficult to determine an individual's workload capacity (particularly in non-physical tasks).

A second issue that must be resolved in the definition of the construct of workload is whether it is strictly quantitative or if it has a qualitative dimension as well. Most workload research has at least implicitly viewed workload as quantitative, as evidenced by the way the construct has been operationalized. The two most commonly used subjective measures of workload, the NASA Task Load Index (NASA-TLX; Hart & Staveland, 1988) and the Subjective Workload Assessment Technique (SWAT; Reid & Nygren, 1988) use items like, "How much time pressure did you feel due to the rate or pace at which the task occurred?" (NASA-TLX) and, "Often have spare time. Interruptions or overlap among activities occur infrequently or not at all" (SWAT). These representative items clearly tap into the idea that workload deals more with "how much" work one has to do rather than "what type" of work one is doing.

Far less research has examined workload as a qualitative construct. Shaw and Weekley (1985) discussed the concepts of "qualitative overload" and "qualitative underload." Qualitative overload exists when the individual cannot complete their tasks regardless of the amount of time they have to do them; qualitative underload exists when the tasks assigned to the individual are far below their ability, "such that the tasks are completed with boring ease" (p. 87). Because of its reference to ability, qualitative workload could also be conceptualized as a fit construct; one's qualitative workload is determined by how closely the nature of one's tasks matches one's ability. Although this is an intriguing concept that warrants further examination, it is beyond the scope of the current study. Therefore, in keeping with the vast majority of workload research, I view workload as solely quantitative, reflecting how much one has to do rather than what type of work one is doing.

Hence, with these two issues resolved, the definition of individual workload used in this study is *the degree to which the amount of work assigned to an individual is within that individual's capacity within the specified duration of time*. The definition also applies to the team level with "team" substituted for "individual." This is in keeping with at least one existing definition of team workload; Bowers, Braun, and Morgan (1997) defined team workload as "the relationship between the finite performance capacities of a team and the demands placed on the team by its performance environment." Thus, like Bowers et al. (1997), I assume that teams, like individuals, vary in their capacity for work. This capacity is likely not simply the sum of the individual team members' capacities, partly because teams are subject to process losses and gains (Steiner, 1972), but also because the type of tasks assigned to teams affects their capacity. For example, in conjunctive tasks, team performance is dependent upon the ability of the worst performing member, whereas in disjunctive tasks, team performance is dependent upon the ability of the best performing member. Therefore, team workload capacity depends upon the type of tasks facing the team in a way that is qualitatively different from the individual level. Nevertheless, the conceptualization of workload itself is isomorphic across levels.

Related constructs. Having defined workload, I now turn to distinguishing it from the related constructs of job demands, job challenge, and stress. The term *job demands* derives from Karasek's (1979) job demands/controls theory. In short, this theory holds that jobs vary meaningfully both in terms of the demands they place on the employee and the latitude (control) with which the employee can make decisions. According to this theory, jobs that are high in demands but low in control place a great deal of strain on the employee (high strain jobs); jobs that are high in demands and high in control (active jobs) lead to high productivity and high job satisfaction; job that are low in demands but high in control (low strain jobs) are relaxing and leisurely; and jobs that are low in demands and low in control (passive jobs) lead to apathetic behavior. In this theory, job demands refers specifically to psychological pressures on employees, of which workload is just one of many; Karasek suggests that job demands include "work load demands, conflicts or other stressors which place the individual in a motivated or energized state of 'stress'" (p. 287). Thus, job demands may be considered a superordinate category of job stressors that includes workload.

The construct of *job challenge* arose out of application of role theory to organizational settings (Berlew & Hall, 1966). The notion was that people are given high challenges early in their careers (or their employment in a particular organization), they will rise to the challenge and fill that role with all of its expectations for good performance. Moreover, job challenge had a carryover effect, such that high job challenge was associated with better performance later in one's career (e.g., Berlew & Hall, 1966; Orpen, 1974). As a construct, job challenge appears to be somewhat similar to job demands, in that the early literature on job challenge referred to "relatively demanding jobs" and "less demanding tasks" (Berlew & Hall, 1966). It does not, however, include the other informal stressful aspects of jobs (such as conflict) that characterize job demands; instead, job challenge appears to refer to the formal aspects of assigned work. In this respect, job challenge may also be considered to be a superordinate category that includes workload, but may also include other job characteristics. For example, a job challenge that may not involve greater amounts of work could be responsibility for major decisions or a major project.

Finally, workload must be distinguished from the general term *job stress*. These terms are closely linked in the research literature, as workload has often been considered to be a "job stressor" (Spector et al., 1988). Indeed, both inordinately high and inordinately low levels of workload can be stressful if they are sustained for long periods. Gaillard (1993) noted that because of this, the constructs often confound each other in empirical research. They are similar in that both are determined by demands of the environment and the capacity of the individual to meet them and that both result in the mobilization of energy to meet the environmental demands (Gaillard, 1993). Gaillard (1993) suggests that they are distinct, however, in three ways. First, the energy released to meet one's workload is constructive and focuses attention, whereas the energy released as a result of stress is destructive and distracting. Second, the energy activation caused by workload is limited to the time of meeting the load; in contrast, the energy released by stress tends to persist outside of the task situation in the form of generalized anxiety. Third, workload causes attention to be focused on the task, whereas stress causes attention to be focused on self-protection. Thus, although related, workload and job stress are distinct constructs; sustained inordinately high or low workload may lead to job stress, but so may many other factors, such as those discussed above under job demands and job challenge.

Lines of workload research. Workload research has generally followed two streams: one cognitive, and one motivational. The cognitive stream of research on workload derives primarily from the theoretical work of Kahneman (1973) and Gopher and colleagues (Gopher & Donchin, 1986). Kahneman's (1973) theory of mental effort suggests that people have limited attentional capacities and that they develop "allocation policies" based on their dispositions, momentary intentions, evaluation of the demands on their attention, and degree of arousal. This capacity model is structural in nature, in that it holds that a single cognitive mechanism processes information, and that when individuals have more than one possible stimulus to which they can attend, they must allocate their attention to only one of the stimuli. The competing demands for attention cause interference that exceeds individuals' available cognitive capacity. Although there is some debate in the cognitive psychology literature over whether the interference limits the *perception* of multiple stimuli or the *processing* of multiple streams of information (as well as whether there are single or multiple channels for processing information), the primary model of the theory has received considerable support (e.g., Kahneman, Ben-Ishai, & Lotan, 1973; Ninio & Kahneman, 1974).

Gopher and colleagues (Gopher & Donchin, 1986; Gopher & Koriat, 1999) explicitly integrated the concept of workload into attentional capacity theory. Indeed, they discussed the "close affinity between the literature concerned with workload and the literature that focuses on attention" (Gopher & Donchin, 1986, p. 4). The key element in Gopher's research is the "central processing mechanism" that determines where and how attention is allocated, and which information is processed. This notion is also addressed by Baddeley (2002), who referred to individuals' "executive control," where attention is shifted either automatically or in a controlled fashion between cognitive tasks.

The basic message of these theories is that when individuals' workload is within their attentional and information processing capacity, they can perform adequately, but when the central processing mechanism is overwhelmed by an inordinately high workload, attention is divided and overall performance declines. Empirical research has borne out this theoretical proposition in numerous arenas. Kahneman and colleagues found that the divided attention caused by high cognitive load was significantly related to the accident rate of bus drivers (Kahneman et al., 1973) and significantly reduced reaction time and increased errors of omission in an experimental task (Ninio & Kahneman, 1974). Aviation studies have consistently found that high cognitive demands reduce pilot performance, sometimes with tragic results (Tsang & Vidulich, 2003).

The motivational stream of research derives primarily from the work on burnout by Maslach and Jackson (1984). This theory is affective in nature and suggests that an inordinately high workload (among other antecedents) leads to three components of burnout: emotional exhaustion, depersonalization, and reduced personal accomplishment. Like the theories of attentional capacity, burnout theory also suggests that performance suffers under high workload, but differs in that it specifies the causal mechanism as being an affective, rather than a cognitive, state. This theory has been empirically studied less than attentional capacity theory, which arose during the cognitive revolution in psychology. Some suggest that we are currently undergoing an "affective revolution" in organizational behavior (Barsade, Brief, & Spataro, 2003), so it is likely that this theory will receive more attention in the future. The theory has been supported, however, in a handful of field studies with various samples like nurses (Greenglass et al., 2003), high school principals (Somech & Miassy-Maljak, 2003) bank employees and teachers (Houkes, Janssen, Jonge, & Nijhuis, 2001), and social workers (Himle, Jayaratne, & Thyness, 1991).

Long-term stress outcomes like burnout due to inordinately high workload, however, develop gradually over a long period of time (Ganster, Fox, & Dwyer, 2001). Thus, burnout theory does not lend itself to the types of laboratory studies that characterize the empirical testing of attentional capacity theory. Kinicki, McKee, and

Wade (1996) also note that these types of long-term outcomes are seldom assessed by organizational researchers, who tend to focus on stress outcomes that are more short-term. Ganster et al. (2001) made perhaps the only attempt in the organizational literature to draw a connection between short- and long-term stress outcomes when they showed that cortisol levels (a hormone related to stress) mediated the relationship between job demands and long-term health care costs.

This connection between short- and long-term outcomes of workload in the form of job demands may actually provide a way to link the dominant cognitive and motivational theories related to workload. I suggest that the elevated cortisol readings that Ganster et al. (2001) found in workers with high job demands were the result of a more general experience of emotional arousal, and that extended periods of high emotional arousal due to high workload lead to the experience of burnout.

Emotional Arousal

Emotional arousal refers to "how wide awake the organism is, of how ready it is to react" (Berlyne, 1960). Arousal captures the "continuum from slumber to activity" (Gopher & Donchin, 1986, p. 14). Schachter and Singer's (1962) cognition-arousal theory proposed that emotions are the product of two interrelated factors: physiological arousal and cognitions about the causes of that arousal. In their view, arousal determined the *intensity* of the emotion, while cognition determined the *quality* of that emotion. That is, people may feel aroused, but attribute that arousal to a specific emotion (e.g., anger, fear, excitement) based on their cognitions about what caused that arousal. Russell's (1980) and Larsen and Diener's (1985) circumplexes of emotion expanded upon this theory, suggesting that emotions can be placed in a two-dimensional space represented by hedonic tone and arousal. Positive (pleasant) emotions can be ones of high arousal (e.g., joy, excitement) or low arousal (peace, contentment). Similarly, negative (unpleasant) emotions can be of high arousal (fury, terror) or low arousal (sadness, despair). Early research established a "general" arousal factor involving both the reticular ascending activation system and the limbic system (Berlyne, 1964). Like most constructs in psychological research, it is a hypothetical construct in the sense that it cannot be measured directly, but only through its effects. Various studies have operationalized arousal by means of heart rate, blood pressure, electrodermal activity, and self-report measures.

Cognitive and social psychological research have extensively examined emotional arousal in a variety of domains, but organizational research has largely neglected the study of emotional arousal in favor of examining hedonic tone. This may be due in part to the methodological difficulties associated with assessing arousal levels in field studies, as well as being due to the factor analytic properties associated with the most commonly used scale for assessing emotions (PANAS; Watson, Clark, & Tellegen, 1988), which typically only shows two factors associated with positive and negative affect (the hedonic tone dimension of the circumplex)[1].

This neglect of arousal is unfortunate, because it figured prominently into both Kahneman's and Gopher's treatments of attentional capacity theory. As noted above, Kahneman (1973) suggested that arousal affects individuals' attention allocation policies. Indeed, Kahneman proposed that individuals' "arousal and capacity both increase or

[1] It should be noted that the emotional adjectives used in the PANAS tend to tap into aroused positive and negative emotions. For example, positive affect is measured with such adjectives as "excited" and "enthusiastic," and negative affect is measured with such adjectives as "scared" and "irritable." Thus, the PANAS differentiates between aroused positive affect and aroused negative affect.

decrease according to the changing demands of current activities" (p. 10). This is because people tend to exert more effort when they are emotionally aroused, which allows them to "pay more attention" to the task. In contrast, when people are in low states of arousal, they exert less effort in their tasks and, according to Kahneman, "*cannot* work as hard" (p. 14) as when they are more highly aroused. Thus, according to Kahneman, individuals' attentional capacities actually vary according to their degree of arousal, which is in part determined by the activities in which one is currently engaging. Although an individual's maximum *potential* capacity remains constant, their *momentary* capacity is determined by their level of arousal. Gopher and Donchin (1986) echoed this notion, suggesting that the relationship between workload and attention is in part determined by the *energy* available to individuals as a result of their arousal level.

Drawing on these rich theoretical traditions, I suggest that emotional arousal should have a positive linear relationship with workload; the higher the workload, the more aroused should be the affective state of individuals. Higher workloads provide more stimuli to which individuals can potentially direct their attention, which will naturally heighten individuals' arousal levels. As noted above in the discussion of the distinction between workload and job stress, both result in the mobilization of energy in response to environmental stimuli (Gaillard, 1993). In other words, both workload and job stress are emotionally arousing, preparing the body for action; the difference is that workload focuses attention on the task, whereas job stress focuses attention on self-protection.

The literature on job demands also supports this hypothesis. Karasek's (1979) job demands model suggests that the more demanding a job is, the more strain it places on the individual, which is manifested in aroused emotions such as anxiety or nervousness.

He found support for this relationship in large samples in both the U.S. and Sweden. Perrewe and Ganster (1989) found similar results when physiological indicators of arousal (heart rate and skin temperature) were regressed on job demands. Although, as noted above, job demands and workload are not identical constructs, they are sufficiently close to suggest that their relationship with arousal may be similar. Indeed, direct effects of objective quantitative workload on physiological arousal have been found in air traffic controllers (Hurst & Rose, 1978; Rose & Fogg, 1993), aircraft pilots and co-pilots (Kakimoto et al., 1988), manufacturing employees (Parker & Sprigg, 1999), and driving test examiners (Parkes, 1995).

H1: For individuals working alone, workload is positively related to emotional arousal.

Individual Learning

Decades of both educational and psychological research have examined the factors that influence learning, both in terms of knowledge acquisition and transfer of that knowledge (Mayer, 2004). A largely neglected area, however, has been the impact of workload on learning. This is not to say that the educational literature has entirely ignored workload, however. A number of studies have tested the hypothesis that workload was related to student evaluations of their instructors, generally finding that workload and evaluations were positively related, contrary to the proposed hypothesis (e.g., Marsh, 2001; Marsh & Roche, 2000).

Intuitively, workload is likely to affect learning, and two theories have been advanced that outline its effects. First, Karasek's updated dynamic model of job demands and control (Karasek & Theorell, 1990) suggests that the demands of a job affect not only strain, but also the degree to which the employee learns. Specifically, their "active learning hypothesis" suggests that jobs with high demands and high control lead to the most learning, whereas jobs with low demands and low control lead to the least learning (jobs with high demands/low control or low demands/high control lead to moderate levels of learning). This is because learning requires that the situation not be "unchallengingly simple (thus unimportant)" (p. 92), but rather be one that forces the individual to seek new knowledge or test new hypotheses. In jobs where demands are low, individuals do not have the opportunity to learn; such undemanding jobs may even be "associated with the reverse process of skill atrophy and unlearning" (p. 94). Several empirical studies have supported this hypothesis (Holman & Wall, 2002; Kauffeld, Jonas, & Frey, 2004; Parker & Sprigg, 1999; Taris & Feij, 2004; Vahtera, Pentti, & Uutela, 1996). Again, although job demands and workload are not identical constructs, their similarity warrants a test of the effect of workload on learning.

Second, Kahneman's (1973) theory of mental effort suggests that the effect of workload on learning could be mediated by arousal. If attentional capacity and arousal level covary as suggested by Kahneman and Gopher, higher workload should lead to both higher emotional arousal and higher attentional capacity. Kahneman (1973) discussed the notion of *processing resources*, which can determine whether a system fails to perform under high demands. The extent to which individuals are emotionally aroused, then, enhances their ability to process information. In their discussion of Kahneman's theory, Gopher and Donchin (1986) suggested that "the concept of *resources* is closely related to the concept of with *arousal*" (p. 14, italics in original), and failures of individuals to process information can be attributed at least in part to their arousal level.

This notion is not a new one. Berlyne's (1964) review suggested, "Among the internal factors that determine whether an organism is or is not in a state conducive to learning are apparently those that are classifiable as 'attentional,' including level of arousal" (p. 132). A certain level of arousal is a necessary (though not sufficient) condition for the processing of information involved in learning to take place. But how high must that arousal level be? The classic "Yerkes-Dodson law" (Yerkes & Dodson, 1908) suggested that there is an inverted U-shaped relationship between arousal and performance, with a moderate arousal level leading to the highest level of performance. Performance improves up to a point where the individual becomes overaroused, leading to a decline in performance.

McGrath (1976), however, called this theory into question, noting that (a) most studies have found no evidence of the downward slope of the curve at high levels of arousal; (b) the theory is incomplete in its explanation of the downward slope, relying on "the *assumption* of the right-hand side of the stress-performance curve" (p. 1360, italics in original); and (c) the theory specifies the inverted U only within-persons, and thus we cannot expect to detect it in between-person tests of the relationship. He proposed that tests of this relationship have been confounded with task difficulty; that is, studies that found performance decline at high levels of arousal did so only because the task was more difficult at these levels. When task difficulty is kept constant or statistically controlled, however, the relationship between arousal and performance is positive and linear.

Similarly, LePine, LePine, and Jackson (2004) noted that although the inverted U relationship has intuitive appeal, it has received very little empirical support. To clarify past inconsistent findings, they decomposed arousal into two types of stress: challenge stress—stress that is appraised as leading to future gains—and hindrance stress—stress that is appraised as hindering future gains. In a study of learning performance, they showed that challenge stress was linearly positively related to learning, whereas hindrance stress was negatively related to learning. Notably, for the purposes of this study, they suggested that workload leads to challenge stress: "For example, learners who experience stress associated with high workload and difficult learning content will exert more energy trying to learn because they believe that by doing so they will eventually come to understand and master the material" (p. 885). Interestingly, this mirrors the discussion above on how workload is distinguished from stress; both lead to the mobilization of energy, but only the energy mobilized by workload focuses attention on the task. LePine et al.'s (2004) conceptualization of hindrance stress is roughly equivalent to what Gaillard (1993) referred to generically as stress, which focuses attention on self-protection. Their conceptualization of challenge stress, however, refers to the constructive mobilization of energy that can arise due to an increased workload. Task demands that exceed an individual's capacity, however, could induce hindrance stress; this sort of inordinately high workload would be more likely to mobilize energy toward self-protection, rather than toward task performance or learning. Assuming the task demands do not exceed the individual's capacity, on the basis of this theory and empirical research, workload should be positively related to learning, and this effect should be mediated by emotional arousal.

H2: For individuals working alone, workload is positively related to learning.[2]

H3: For individuals working alone, emotional arousal mediates the effect of workload on learning.

To this point, I have only considered the effects of workload in static conditions; now I turn to consideration of how *changes* in workload affect performance. Although workloads that are inordinately high may hamper individual learning, it is not clear whether decreasing the workload will enable an individual to achieve higher performance or whether there will be residual effects of the previous workload. Conversely, the effects of increasing an individual's workload are not entirely clear, and may differ from maintaining a consistently high workload.

Several studies suggest that increases or decreases in an individual's workload may indeed affect their task performance. In a laboratory study that examined changes in workload at the task level, Campbell and Ilgen (1976) administered chess problems where participants had to make decisions of one, two, or three moves, and then subsequently presented participants with all three types of problems. Those who had just completed two- or three-move problems performed significantly better than participants who had completed one-move problems. Similarly, Taylor (1981) found that high prior task challenge was positively related to performance standards, task-related attitudes, and perceptions of skill competence. These studies suggest that there are carryover effects of previous job experiences (i.e., degree of previous challenge) on future performance. Notably, both of these studies examined changes in workload over a very short period of time (the duration of a laboratory session), but the phenomenon appears to apply not only

[2] As noted above, individuals do indeed have maximum potential capacities, and thus reach a limit where increases in workload cannot bring about any higher increases in learning. In most work settings (and in this research), this extreme high end of workload is not examined.

to the task level, but to the job level as well. Studies on job challenge have found that having high initial job challenge in one's career resulted in higher salary growth and performance (Berlew & Hall, 1966; Orpen, 1974, 1994), and job learning (Morrison & Brantner, 1992) many years later. Thus, workload may affect later performance and other outcomes over both short and long time periods, at both the task and job levels.

Neither attentional capacity theory nor burnout theory specifically address how changes in workload should affect performance, but perhaps I can extrapolate from them based on the results of the empirical studies cited above. A long tradition of research has demonstrated that performance is not a unidimensional construct, but rather consists of at least two dimensions. Drawing on a theory first articulated by Woodworth (1899) over 100 years ago, Beersma et al. (2003) and Johnson et al. (2006) showed that task performance is often best conceptualized along the dimensions of speed and accuracy. This roughly parallels the quantity/quality distinction made by others (e.g., Erez, 1990; Gilliland & Landis, 1992). Speed represents the rate at which people accomplish their tasks, but can also be measured by total output (i.e., faster individuals produce more than slower individuals). Accuracy represents the number of errors people make in the performance of their tasks, and is often conceptualized in terms of quality.

I first consider the effects of previous workload on speed of performance. The well-known "fight or flight" response to threat has often been viewed as a vestigial evolutionary adaptation in humans that is maladaptive in modern settings (Carruthers, 1981), but decades of research on both animals and humans have found that environmental stressors increase performance on a variety of tasks (Dienstbier, 1989). This research has outlined the physiological and neurological mechanisms responsible for the improved performance. Although these specific mechanisms are beyond the scope of this research, the general point is that environmental stressors serve to "toughen" people (and animals) so that they handle future stressors more readily. Dienstbier's (1989) model suggests that this is similar to the way that aerobic exercise increases body tolerance to physical stress; previous stressors act like "workouts" that toughen people and allow them to act more quickly and with more endurance when facing future stressors. Dienstbier (1989) also suggests that early experiences are vital in this process; although his neurological model addresses this in terms of aging, it may be that early experiences within a given context may have similar effects. That is, early difficult experiences of individuals in a job inure them to later experiences in that job.

Another line of research suggests that environmental stressors can actually speed up the functioning of the body's internal clock. Based on the idea that humans possess a "temporal pacemaker" that regulates individuals' perceptions and speed of activity, this research has shown that various stimuli cause changes in one's subjective perception of time (Treisman, Cook, Naish, & MacCrone, 1994). In a series of four studies, Penton-Voak, Edwards, Percival, and Wearden (1996) found that a mild environmental stimulus (audible clicks) caused individuals to overestimate the duration of subsequent gaps between stimuli (a series of tones independent from the clicks) by an average of 10% (and as high as 19%). Changes in body temperature have shown similar results, with rate of subjective time increasing by as much as 30% (Wearden & Penton-Voak, 1995). This phenomenon may underlie the perception of individuals under great stress that time slows down, causing them to perceive the events as happening in slow motion.

Taken together, these two lines of research suggest that the emotional arousal that accompanies higher workloads may actually increase individuals' subsequent speed of performance. First, based on Dienstbier's (1989) research, the higher previous workload could act as a form of exercise that allows individuals to respond more quickly in the future, and will increase their stamina to maintain higher levels of performance over time. Second, based on Treisman's temporal pacemaker notion, individuals with higher workloads should be likely to be faster in their subsequent performance due to the speeding up individuals' internal clocks. The magnitude of these effects is likely to be commensurate with both the previous workload itself, and with the duration of time that the individual worked under that workload. That is, very high previous workloads are likely to have greater effects on subsequent speed than only moderately high workloads. Similarly, operating under high workloads for longer periods of time is likely to exert an effect on speed for a longer subsequent period of time. For example, an individual who works under a high workload for only a short period of time will likely not have long-term improvement on speed.

H4: For individuals working alone, higher previous workload is associated with better subsequent speed of performance.

This hypothesis does not assume, however, that emotional arousal carries over into subsequent performance situations. Indeed, as noted above in the discussion on the distinction between stress and workload, the energy that is mobilized in response to workload dissipates after the task demand is met (Gaillard, 1993). Arousal is a transient state that comes and goes based on situational characteristics (Kahneman, 1973), and thus should only be affected by current workload. The effects of arousal, however, may be more permanent. First, as noted above, arousal is associated with the speed of individuals' temporal pacemakers. Highly aroused people tend to underestimate the amount of time that has passed, and this is associated with a faster pace of behavior (Brown & Boltz, 2002). Similarly, research on entrainment theory (McGrath, Kelly, & Machatka, 1984) has shown that people's rhythms of behavior can be set by external pacers, and furthermore, these rhythms can be relatively enduring even after the external pacers are no longer present. Thus, the speed with which people perform tasks because of the way their levels of arousal affect their temporal pacemakers is likely to carry over, even when the workload level has changed. Second, the "toughening" of individuals associated with the increased levels of arousal under conditions of high workload should also carry over to subsequent performance situations, in the same way that physical exercise strengthens the body for future physical tasks. In other words, individuals who have been exposed to high levels of workload should handle subsequent workloads more quickly and efficiently than individuals who have been exposed to low levels of workload. Thus, individuals' previous workload affects previous levels of arousal, which in turn affect subsequent speed of performance.

H5: For individuals working alone, the relationship between previous workload and subsequent speed is mediated by previous arousal.

Furthermore, previous workload should be associated with higher subsequent accuracy in individuals. Campbell and Ilgen (1976) explained their findings from the chess study on the basis of task skills; players who received the more difficult problems first had presumably developed more skills than those who had received the easy problems. Similarly, Morrison and Brantner's (1992) study of naval department heads found that the primary effect of prior job challenge was on learning knowledge and skills necessary to perform in future jobs. This is presumably because as I proposed above, people learn more under higher workloads than under lower workloads. As noted above, arousal is associated higher attentional capacity, which allows individuals to learn more. Although arousal and attentional capacity are both transient states, learning is more enduring. Learning from a previously high workload is likely to increase accuracy, then, because the development of job-related knowledge and skills should lead individuals to make fewer errors.

Although this explanation for why previous workload should be positively related to subsequent accuracy focuses on cognitive factors, one must consider whether motivational factors have a countervailing effect. Specifically, the concept of progressive mastery (Bandura & Jourden, 1991) that derives from social cognitive theory (Bandura, 1986) may be relevant here. Social cognitive theory holds that people self-regulate their effort based on their self-efficacy; when individuals believe that they are competent at performing their tasks, they set higher goals (Locke & Latham, 1990) for their performance than individuals who have less confidence in their ability to perform their tasks. As a specific application of social cognitive theory, the concept of progressive mastery suggests that individuals who progressively improve their performance (and upgrade their self-efficacy beliefs) will end up performing better overall than those with consistently high or low self-efficacy, and those who experience a decline in mastery.

Bandura and Jourden (1991) indeed found this effect. In an experimental setting, they manipulated feedback provided to the participants, such that some were given feedback that they consistently outperformed the other participants (superior capabilities); others were given feedback that they had consistently achieved average performance compared to the other participants (similar capabilities); others were given feedback where they were initially told that they were underperforming, then that they had achieved average performance, and finally that they had outperformed the other participants (progressive mastery); and others were given feedback that they initially outperformed the other participants, then that they had achieved average performance, and finally that they underperformed compared to the other participants (progressive decline). Those in the progressive mastery condition achieved higher overall performance than those in the other three conditions.

When applied to the concept of changing workloads, an initial interpretation of the phenomenon of progressive mastery could be that one should give people lighter workloads when they are initially learning a task, in order to allow them to improve their self-efficacy on their tasks. Later, one increases the workload when the individual has higher self-efficacy beliefs. This may, however, result in a condition more similar to the "superior capabilities" condition from Bandura and Jourden (1991): the individual may consistently maintain high self-efficacy beliefs over time, which was found to be associated with lower performance than those in the progressive mastery condition. In contrast, assigning high workloads early on and then reducing them later is likely to mimic the progressive mastery condition; individuals are likely to have low perceptions of self-efficacy under conditions of high workload, perhaps because they believe that the reason they cannot keep up with the workload demands is due to their low competence in the task. When workload is reduced, their self-efficacy beliefs are likely to increase, as they now feel capable of handling their current workload. Thus, the motivational effect of progressive mastery when shifting from conditions of high workload to low workload is likely to enhance the cognitive effect of task learning on subsequent accuracy.

H6: For individuals working alone, higher previous workload is associated with better subsequent accuracy of performance.

H7: For individuals working alone, the relationship between previous workload and subsequent accuracy is mediated by previous learning.

TEAM WORKLOAD AND PERFORMANCE

So far, this discussion has only considered the effect of workload on individual cognition, affect, and performance. A key question of multi-level theory (Kozlowski & Klein, 2000) is one of homology, or, "Do the relationships found at one level of analysis generalize to other levels?" In this case, then, the question may be whether teams or even higher levels of analysis (e.g., departments, organizations) also perform better overall when they have high previous workloads.

Examining phenomena at higher levels of analysis (e.g., teams), however, introduces greater levels of complexity due to the social relationships that are inherent within them. Individuals working alone do not need to coordinate their actions with others as much as those working in teams (Ilgen et al., 2005). Aside from the difficulties of coordinating their behaviors, teams must also coordinate their thoughts about their tasks. As Moreland, Argote, and Krishnan (1996, p. 58) note, "Information processing by groups requires socially shared cognition, that is, collaboration among members who seek to encode, interpret, and recall information together rather than apart." Additionally, recent research has suggested that team members also coordinate their emotional states with each other (i.e., emotional contagion; Barsade, 2002; Bartel & Saavedra, 2000). Thus, it appears that at the team level, as at the individual level, there are both cognitive and motivational approaches to the effects of workload on performance. The following section reviews the literature relevant to specific hypotheses regarding the effects of previous workload on teams.

Collective Arousal and Emotional Contagion

One approach to the study of workload at the team level that is motivational in nature is the theory of affect regulation (George, 2002). According to this theory, team members' emotions and moods are affected by their membership in the team, such that teams tend to converge in their affective states; these affective states in turn influence team member behavior. George (2002) suggests that affect is transmitted throughout teams in three ways, all of which appear to have relevance to the study of workload history.

First, a great deal of research has documented "emotional contagion" in groups, mobs, and crowds. Dating back at least as far as Le Bon (1895), social scientists have recognized that emotions can be "caught" from other group members in a quite primitive way. The general thinking on emotional contagion is that it is an automatic process that accompanies the deindividuation of members as they are absorbed into the group (Diener, Lusk, DeFour, & Flax, 1980). Members naturally mimic the emotional expressions of other group members, leading them to experience the emotions themselves. This effect has been documented not just in mob settings, but also in less affectively intense contexts, including workgroups (Barsade, 2002; Bartel & Saavedra, 2000).

Second, emotions may be transmitted through exposure to common tasks, outcomes, and events. Rather than emotions being passed from member to member, in this mechanism the emotions are generated in all of the team members by an outside source. For example, it a team is engaging in tedious work, feelings of boredom may develop throughout the entire team as a result of the work itself. This is also the primary thrust of Affective Events Theory (Weiss & Cropanzano, 1996): work-related events stimulate certain affective states, which in turn influence work-related judgments, affect-driven behaviors, and judgment-driven behaviors.

Third, emotions may be transmitted through vicarious processes. In this mode of transmission, team members observe the emotional expressions of their team members which can directly stimulate the same emotions in themselves through empathic processes. Although this process is similar to the more primitive emotional contagion process, vicarious transmission is usually more consciously engaged. George (2002) suggests that they are particularly distinct when it comes to the transmission of negative emotions. When negative emotions are transmitted through emotional contagion, team members are motivated to alleviate *their own* negative states; when negative emotions are transmitted through vicarious empathic processes, however, team members are motivated to alleviate *the other's* negative state.

This theory fits within the broader Input-Process-Output (I-P-O) model of group emotion outlined by Kelly and Barsade (2001). In their model, both affective context (e.g., organizational emotion norms, group emotion norms, group emotional history) and nonaffective context (intergroup relations, physical environment, technological conditions) act as inputs that impact both individual-level and group-level emotional processes. Like George (2002), Kelly and Barsade (2001) suggest that emotions converge within groups via processes like the ones mentioned above, giving rise to "group emotions (that) are phenomenologically experienced as real by group members" (p. 117). If group emotions are legitimate constructs, then, the question arises as to how similar they are to individual emotions. According to Morgeson and Hofmann (1999), collective constructs can be compared to individual-level constructs in terms of structure and function. If they are structurally similar, then the construction of the phenomenon is the same at both levels; if they are functionally similar, then the outcomes or effects of the phenomenon are the same at both levels. Group emotion, like individual emotion, is experienced *intra*personally by the group members; its transmission, however, is subject to the *inter*personal dynamics outlined above. Thus, group emotion is to some extent structurally dissimilar to individual emotion. Functionally, however, group emotion is likely to cause the same effects as individual emotion. Groups experiencing positive or negative emotions are likely to generate the same types of behavioral outcomes as individuals experiencing positive or negative emotions, as are groups experiencing varying levels of arousal likely to generate similar behaviors to individuals experiencing varying levels of arousal.

In terms of workload, the affective states generated from having varying levels of workload are likely to converge among team members via the processes outlined by George (2002) and Kelly and Barsade (2001). Team members may feel similar emotions as a result of their shared experiences, which converge further through primitive emotional contagion and vicarious empathy. Specifically, team members may experience similar levels of arousals due to high workloads, and these may converge further as they transmit this emotional experience to other members. Similarly, team members who experience boredom due to low workloads may transmit a different form of negative affect to other members. Thus, the relationship between workload and emotional arousal in teams should be similar to that in individuals; if the relationship differs at all, it should be stronger in teams, because team members' emotional states are likely to converge.

H8: For teams, workload is positively related to emotional arousal.

Similarly, the relationship between previous workload in teams and their subsequent speed is likely to take the same form as that found in individuals, because the constructs are functionally similar (Morgeson & Hofmann, 1999). That is, although individual and team workload differ in structure, they are likely to lead to a faster pace of behavior at both levels. The entrainment effect discussed above should affect teams (and other higher levels of analysis) in the same way that it affects individuals (Ancona & Chong, 1996). Indeed, this relationship may be stronger than that found in individuals, because teams develop norms of behavior (Bettenhausen & Murnighan, 1985) that are often mutually enforced (Barker, 1993). Thus, the pace of work that teams develop in their early experiences as a result of their previous emotional arousal becomes the teams' expectations for future behavior. When teams begin working at a fast pace due to high workload and high emotional arousal, this will carry over to their subsequent performance, even if their workload decreases. Conversely, teams that begin working slowly due to low previous workload are likely to struggle to speed up when their workload increases.

H9: For teams, higher previous workload is associated with better subsequent speed of performance.

H10: For teams, previous emotional arousal mediates the relationship between previous workload and subsequent speed.

Team Learning

The cognitive approach of the study of group phenomena derives from the social cognition movement (Fiore & Schooler, 2004), in the sense that it examines "those social processes... that relate to the acquisition, storage, transmission, manipulation and use of information for the purpose of creating a group-level intellective product" (Larson & Christensen, 1993, p. 6). This theoretical approach has outlined the effects of both shared and distributed cognition on the process and performance of work teams.

Interest in team-level information processing and learning has burgeoned in recent years and several theoretical models have appeared (Argote, Gruenfeld, & Naquin, 2001). Although a consensus model of team learning has not yet emerged, the theoretical and empirical treatments of the subject appear to agree that team learning is qualitatively different from individual learning. Interestingly, in outlining the unique characteristics of team-level learning, these conceptualizations draw upon individual-level models as a basis for understanding the similarities and differences between learning at each level (Hinsz, Tindale, & Vollrath, 1997). Unfortunately, because these models are based on individual-level cognition, they tend to ignore the social factors that affect learning at the team level. Argote, Gruenfeld, and Naquin (2001) suggested that when thinking about team learning, one must consider these social factors, examining team learning from a systems perspective. The actions of team members affect the team system whether or not they intend to, which can either help or inhibit team learning. In keeping with conceptualization, I suggest that team learning—like team-level emotional arousal—has both *intra*personal and *inter*personal elements, and thus differs in structure from individual-level cognition (Morgeson & Hofmann, 1999). As noted in Ellis et al.'s (2003, p. 822) empirical examination of team learning, "...teams can process information not only within, but also between the minds of team members." Unless information is transmitted between team members, true *team-level* learning does not take place.

Groups inevitably possess more knowledge together than any one team member does individually and thus possess an advantage over individuals (Argote et al., 2001). Indeed, in many cognitive activities, research has shown that teams perform better than individuals working alone. Teams tend to recall more information than individuals working alone (Hill, 1982; Hinsz, 1990), and tend to be more accurate in the information they recall (Hill, 1982). Teams also tend to perform better than individuals on induction tasks, where the goal is to find general principles or explanations (Laughlin, VanderStoep, & Hollingshead, 1991), and on general problem solving (Laughlin, Bonner, & Miner, 2002). As noted by Argote, Gruenfeld, and Naquin (2001, p. 377), however, the advantage that teams have over individuals "is dependent upon the degree to which the knowledge of individuals within the group can be effectively shared, or pooled, during group discussion."

Hinsz, Tindale, and Vollrath's (1997) review also noted the importance of communication—in terms of sharing information, ideas, and cognitive processes—to team level learning. In order to effectively learn at the team level, team members must communicate their ideas to the rest of the team. MacMillan, Entin, and Serfaty (2004, p. 61) call this "the hidden cost of team cognition," noting that communication between team members has no analogue at the individual level. Similarly, Larson and Christenson (1993, p. 12) note:

> Groups too must cope with the reality of limited cognitive resources—of the social as well as the individual variety. Consider, for example, the time and effort that group members have to devote to problem solving. These

are limited resources that, like attention, can be channeled in one direction or the other for the purpose of acquiring problem-relevant information.

Teams, like individuals, do not possess unlimited cognitive capacity, and their limited sets of social cognitive resources may be allocated to the task or to other factors that concern the team. In other words, team may choose to focus their cognitive resources on *taskwork*—their interactions with equipment, tools or systems—or on *teamwork*—their interactions with each other (Morgan, Salas, & Glickman, 1993). Although some teamwork is simply directed at the maintenance of the team as a social system (e.g., maintaining social order, providing social support), other teamwork serves to facilitate future taskwork (e.g., sharing information, observing others in order to better coordinate actions). In most situations, teams often switch their focus between these two, alternating between focusing on performing their task and attending to other team members.

In effect, then, working on a team is a dual-task paradigm where team members must do both taskwork and teamwork (Bowers et al., 1997). The dual-task paradigm has been utilized extensively in the workload literature, and it involves assigning individuals two tasks to perform simultaneously. In general, research has revealed that performance declines when individuals must switch their attention between two tasks, even when they are proficient in both; Navon and Gopher (1979) referred to this as "concurrence cost." Bowers, Braun, and Morgan (1997) suggested that when team members must constantly switch their attention between taskwork and teamwork, their performance in one or the other will decline.

The degree to which this decline in performance occurs is almost certainly dependent upon the team's level of workload. As task workload increases, the social cognitive resources of teams are increasingly taxed, inevitably resulting in a decline in performance on teamwork. Conversely, as workload decreases, teams have a surfeit of social cognitive resources and can reallocate more resources to teamwork. A wealth of empirical research supports this assertion. Bowers et al. (1998) reported the results of a study that found that flight crews in automated cockpits communicated more than flight crews in traditional cockpits. The explanation for this finding was that in the automated cockpit, crew members were able to devote more resources to communication, whereas in the traditional cockpit, crew members allocated those resources to performing their tasks. Entin and Serfaty (1999) found that teams that were given training on efficient communication strategies performed significantly better under high workload conditions than teams without such training. Similarly, Cannon-Bowers, Salas, Blickensderfer, & Bowers (1998) found that teams that were cross-trained performed better under high workload conditions than teams that were not cross-trained, because of "the more efficient communication strategy (i.e., volunteering more information) observed in cross-trained teams" (p. 99). Urban, Weaver, Bowers, & Rhodenizer (1996) found that teams under high workload communicated less and performed worse than teams under low workload.

These findings appear to hold not just for workload in general, but also for information load. Stasser and Titus (1987) found that only groups with low information load communicated unshared information with the group; groups with a high load of information tended to discuss only that information which was shared by all group members. Thus, despite the fact that high workload conditions provide more information to which team members can attend, they tend to limit their discussions to information that is already shared by other members of the team, rather than communicating information they hold uniquely.

As workload increases, then, teams have less time, effort, and attentional resources to devote to communicating with each other, and teamwork suffers. The effect, then, is that unlike at the individual level—where there is likely to be a positive relationship between workload and learning—the team level relationship between workload and learning should be attenuated, and may in fact be negative.

H11: For teams, the relationship between workload and learning is lower than the relationship for individuals working alone.

As with learning at the individual level, team learning is likely to have a carryover effect on the team's subsequent performance. Kozlowski, Gully, Nason, and Smith's (1999) model of team development suggests that there is a reciprocal causal relationship between team processes and performance, such that team processes at time t_n affect team performance at time t_n, and that this performance then becomes an input to team process at time t_{n+1}. Additionally, there is likely also a direct relationship between processes at time t_n and processes at time t_{n+1}, such that the team's interaction behaviors tend to become institutionalized. In the case of the current research, it is likely that the degree to which teams learn will affect not simply their current performance, but also their subsequent learning and performance.

As at the individual level, accuracy is the most likely dimension of performance to be affected by team learning. Although it is possible that the lack of learning will also slow teams down due to difficulties in coordination, the degree to which the team makes errors is more likely to be affected. This is because the extent to which members share what they have learned tends to reduce the number of errors made by the team (Edmondson, 1996). Taken together, I expect:

H12: For teams, higher previous workload is associated with lower subsequent accuracy.

H13: Team learning mediates the relationship between previous workload and subsequent accuracy.

MODERATORS OF THE EFFECTS OF WORKLOAD

To this point, I have only considered one influence on arousal, learning, and performance—that of the individual or team workload. In work settings, however, individuals and teams have multiple influences on their behavior, including characteristics employees bring to the job and aspects of their work environment. In this section, I propose that: (a) individual differences between employees—specifically, personality characteristics—act as moderators of the effect of workload at both the individual and team levels; and (b) structural characteristics—in terms of resource allocation and learning responsibilities, which exist only at levels higher than the individual—act as moderators of the effects of workload at the team level.

Personality

The study of personality has a long history in many areas of psychology, and has greatly informed research in organizational settings. The "Big Five" model of personality factors (Costa, Busch, Zonderman, & McCrae, 1986) has been a particularly fruitful avenue for assessing the effects of individual differences on various outcomes. In terms of personality effects on arousal and learning (and ultimately performance), both theory and prior empirical research suggest that extraversion and neuroticism, respectively, should show interactive effects with workload.

Extraversion. Along with Agreeableness, Extraversion has been considered to be an *interpersonal* personality trait; that is, it manifests itself in social situations (Wiggins & Pincus, 1992). In contrast, the other three traits in the five-factor model of personality—conscientiousness, neuroticism, and openness to experience—are generally considered to be *intrapsychic*; that is, their manifestations are not limited to social situations, but are also manifested when one is alone. This solely interpersonal characterization of extraversion, however, ignores a great deal of the rich theory and empirical work on this trait, much of which was focused on how Extraversion relates to emotional arousal.

Eysenck's (1967) three-factor theory of personality focused on the traits of extraversion, neuroticism, and psychoticism (which, according to Eysenck, is at least partially comprised of agreeableness and conscientiousness). More than anything else, Eysenck's theory is one of arousal, as he delineates how each of these traits is related to different arousal mechanisms. Extraversion, he proposed, is related to arousal through the reticulo-cortical system; neuroticism is related to arousal through the reticulo-limbic system; and psychoticism is related to arousal either through serotonin or dopamine (Eysenck, 1997). Although it is not the purpose of this paper to delve into neuropsychology, the point is that extraversion was proposed to be directly related to cortical arousal. The theory suggested that people high on extraversion seek external stimulation because they have lower baseline levels of arousal than those low on extraversion.

Empirical research, however, has generally not borne out this main effect theory of the effects of extraversion on arousal. Instead, tests of Eysenck's theory show that rather exerting a main effect, extraversion tends to show interactive effects with the arousing effects of the experimental task itself. For example, in his review of the literature on electroencephalographic (EEG) activity, Gale (1973) concluded that the effects of extraversion depended upon the arousal inducing properties of the testing environment. In testing environments that did not induce much arousal, extraversion exerted no effect on EEG readings; in testing environments that induced moderate arousal, however, those high on extraversion showed higher levels of EEG activity than those low on extraversion. Similarly, Mangan and Hookway (1988) found that those high in extraversion showed higher heart rates and electrodermal activity when viewing aversive film clips than those low in extraversion (but not when viewing neutral clips).

The picture that seems to be emerging is one of a person by situation interaction; in situations that are arousal inducing, people high in extraversion tend to become more aroused than those low in extraversion. In situations that are not very arousal inducing, extraversion appears to exert no effect. In the context of this study, then, I would expect extraversion to interact with workload, such that under low workload conditions, extraversion is unrelated to arousal, but under high workload conditions, extraversion and arousal are positively related.

This effect is likely to be homologous across levels. As Hofmann and Jones (2005) noted, the concept of personality refers to regularities in behavior; individuals tend to engage in routines or habits that are in keeping with their personality traits. They note that these sorts of behavioral regularities are just as observable in groups as they are in individuals, giving rise to "collective personality." They also note that collective personality is functionally isomorphic with individual personality; that is, individual and collective personality produce similar outcomes for individuals and teams, respectively. Although Hofmann and Jones (2005) suggest that collective personality is an emergent property that arises out of extended group interaction, a great deal of other research has shown that simply aggregating the individual personalities of group members is also a meaningful conceptualization of collective personality (e.g., Barrick, Stewart, Neubert, &

Mount, 1998; LePine, 2003; LePine, Hollenbeck, Ilgen, & Hedlund, 1997). These studies have shown that teams exhibit behaviors in keeping with the mean level of personality traits of the team members. Because the current research applies to teams that have not had extensive interaction (see the boundary conditions noted above), this latter compositional model is more appropriate. Thus, I suggest that team extraversion, assessed as the aggregation of individual team member Extraversion, will manifest the same types of behaviors as individual extraversion. The moderating effect of extraversion on the workload-arousal relationship, then, should be similar across levels of analysis.

H14: For both individuals and teams, extraversion moderates the effect of workload on arousal, such that the highest levels of arousal will be found in individuals and teams high in extraversion under conditions of high workload.

Neuroticism. Besides extraversion, neuroticism is the second personality trait that appears in both Eysenck's (1967) three-factor model and the currently popular five-factor model of personality (Costa et al., 1986). Although the term was popularized by Carl Jung, the concept had been considered at least as far back as the second century A.D., when the Greek physician Galen described the "four temperaments," with melancholics being described as "anxious" and "worried," and cholerics being described as "quickly roused" and "histrionic" (Eysenck, 1967, p. 35). Current descriptions of people who are high on neuroticism (or low on emotional stability) include adjectives such as frustrated, depressed, hopeless, and anxious (Barrick & Mount, 1991; Costa & McCrae, 1992).

Neuroticism is relevant to discussions of learning because of its anxiety component. M.W. Eysenck's (1981) theory of anxiety draws on attentional capacity theory in suggesting that the task-irrelevant information generated by anxiety competes with task-relevant information for cognitive attention. When individuals are in a state of anxiety, they use up cognitive resources by attending to the anxiety-provoking stimuli and their coping mechanisms for dealing with their anxiety. Consequently, fewer cognitive resources are available for processing task-relevant information. Because neuroticism is associated with higher reactivity to anxiety-producing stimuli (Eysenck, 1967), this should hamper the performance of people high in neuroticism under conditions of high workload.

Empirically, a few studies lend support to this notion at the individual level. Jensen (as discussed in Eysenck, 1967) found that learning was significantly predicted by an interaction between neuroticism and the rate at which the stimulus was presented. When the stimulus was presented at a relatively fast rate, those high in neuroticism made significantly more errors than those low in neuroticism. Presumably, the cognitive load associated with the rapid pace of presentation was anxiety-producing, and overtaxed the cognitive capacity of the neurotic participants. Interestingly, when the stimulus was presented at a relatively slow rate, those high in neuroticism made somewhat fewer errors. Similarly, Wallace and Newman (1998) found that women who were high in neuroticism were more impaired by a distractor stimulus than those who were low in neuroticism.

I expect, then, that neuroticism moderates the relationship between workload and learning. Although the proposed main effect of workload on learning is different at the individual (positive) and team (negative) levels, the moderating effect of neuroticism on the relationship should be similar. That is, because anxiety-producing stimuli overtax the cognitive resources of people who are high in neuroticism, individuals and teams that are high in neuroticism should learn less under conditions of high workload. For individuals, this should attenuate the positive correlation between workload and learning; for teams, this should strengthen the negative correlation between workload and learning.

H15: For both individuals and teams, neuroticism moderates the effect of workload on learning, such that individuals and teams high in neuroticism learn less under conditions of high workload than those low in neuroticism.

Structure

Because the effects of workload on teams involve interpersonal as well as individual dynamics, it is likely that the structure of the team exerts effects on the mediating processes discussed above and on team performance. Team structure refers to how the actions of the team members are formally coordinated (Hollenbeck et al., 2002). It can include horizontal elements—how tasks or resources are distributed within the team—or vertical elements—the team's hierarchical leadership or authority structure. In this study, I focus on the horizontal dimension, and suggest that the distribution of resources within the team should affect the team's emotional arousal, and distribution of responsibilities within the team should affect team learning.

Resource allocation. Past research on the arousal hypothesis in the social facilitation literature has established that the mere presence of others increases arousal, particularly when one senses that one is being evaluated by others (Geen, 1991; Zajonc, 1965). One might expect, then, that individuals working in teams would show higher levels of arousal than individuals working alone. Subsequent research by Jackson and colleagues, however, has shown that being in groups can actually reduce arousal. Jackson and Latane (1981) found that when they had their participants perform on a stage, those who performed as part of the group felt significantly less stage fright—in the form of tension and nervousness—than those performing alone. Similarly, Jackson and Williams (1985) showed that people felt less pressure when working on an experimental task in groups rather than working alone. The causal mechanism underlying this effect is that people feel safer in groups if the other members of the group are facing the same threat or challenge. Interestingly, in a direct test of this effect versus the social facilitation effect, Jackson and Williams (1985) found that people felt the *most* pressure when they worked with just one other person—heightening the sense that they may be evaluated by their partner, as predicted by social facilitation theory, but the *least* when working in a group, as predicted by arousal reduction theory (Seta & Schkade, 1976).

Small group research has shown that groups vary in their entitativity, or the degree to which they constitute a group that is recognized by its members and outsiders (Campbell, 1958). For example, a group of people waiting in line for a bus is lower in entitativity than a formal work team. Similarly, research on team structure has demonstrated that teams vary in the degree to which they work together or separately. Teams that are structured functionally (rather than divisionally), are centralized in terms of decision-making authority, and/or are rewarded cooperatively engage in more interdependent behaviors (e.g., helping, information sharing) than teams that have the opposite structures (Johnson et al., in press). In essence, groups that are structured these ways are more interdependent and have a greater sense of possessing a common fate (Kramer & Brewer, 1984). Although the research on arousal reduction cited above compared individuals alone to individuals in groups, it may be that it applies to varying types of team structure.

In particular, the horizontal dimension of structure—in terms of resource allocation—is likely to affect the degree to which the arousal reduction effect applies. Members of teams that are structured functionally—possessing unique resources and thus having specialized areas of expertise—work more cooperatively with each other than members of teams that are structured divisionally—possessing the same set of resources as other members and being responsible for different areas of the team's task. This is because members of teams that are structured divisionally are not required to depend upon the other team members to accomplish tasks, because they already possess the full complement of resources to handle whatever tasks they face. In contrast, members of teams that are structured functionally must depend upon the other team members to accomplish the parts of the team's task that require resources that the individual team member does not possess (Hollenbeck, 2000).

I suggest that members of functionally-structured teams, then, are more likely to be subject to the arousal reduction effect than members of divisionally-structured teams. The members will have a greater sense that accomplishment of the team's task is jointly shared by the other members, and this will provide a sense of "safety in groups." Members of divisionally-structured teams, however, are more like "individuals working alone," (Hollenbeck, 2000), and thus are less likely to be affected by the arousal reduction effect.

H16: In teams, resource allocation structure moderates the relationship between workload and arousal, such that the positive relationship between workload and arousal is attenuated in functionally structured teams as compared to divisionally structured teams.

Transactive learning. As noted above, recent research has examined the importance of transactive memory for team performance. An unexamined notion, however, is the idea of *transactive learning*; just as teams can distribute their knowledge among team members, they also have the ability to distribute responsibility for learning among team members. I suggest that transactive learning may be a way to alleviate the problem of lower team accuracy following higher workloads. In their empirical study of team learning, Ellis et al. (2003) found that assigning members specialized roles within the team enhanced learning. Their explanation centered on how distributing cognitive information processing within the team enhances team performance because it takes better advantage of individual member cognition and enhances communication processes within the team (Hyatt & Ruddy, 1997; Stasser, Stewart, & Wittenbaum, 1995; Stewart & Stasser, 1995). Ellis et al. (2003) manipulated roles in terms of resource allocation, but it is likely that simply assigning responsibility for learning different aspects of the task could accomplish the same objective. By distributing responsibility for learning about their task, teams reduce the cognitive load on the individual members because the members are not attempting to learn all aspects of the task.

H17: In teams, transactive learning moderates the relationship between workload and learning, such that the negative relationship between workload and learning is attenuated when learning responsibilities are effectively distributed.

METHOD

Research Participants and Task

Four hundred forty-six undergraduate students in an upper-level management course at a large Midwestern university participated; 364 were arrayed into 91 four-person teams, and 82 participated as individuals working alone. The expected power for finding a population *r* of .30 is .82 for the team sample size, and .78 for the individual sample size ($p < .05$). Assuming main effects of this size and a two-way interaction accounting for 5% incremental variance, the power to detect this interaction was over .60 at these sample sizes. Participants signed up for a research session at their discretion, and were randomly assigned either to teams or to work as individuals within their session. Teams and individuals were also randomly assigned to conditions in which they participated in two 30-minute simulations. Students received course credit for participation, and they also had a chance to win a cash prize contingent upon their performance on the simulation.

Participants engaged in a dynamic and networked computer simulation. The simulation is a modified version of the Distributed Dynamic Decision-making (DDD) simulation developed for the Department of Defense for research and training (Miller, Young, Kleinman, & Serfaty, 1998). The version of the simulation used here was developed for teams of four members with little or no military experience (MSU-DDD).

Team task. The teams' mission in this simulation was to monitor air and ground space of a hypothetical geographic region, keeping unfriendly forces from moving into the restricted areas, while at the same time, allowing friendly forces to move about freely. Radar representations of these forces moving through the geographic space monitored by the team are known as "tracks." In monitoring the geographic space, each team member's base had radar capacities that covered only a portion of the area that needed to be monitored. Any track outside the radar range was invisible to the team members from their base. If the participants wished to determine the nature of a track outside this ring, they could launch a vehicle and move it near the track, or they could ask their teammates to share that information with them.

Each team member had control of four vehicles that could be launched and moved to different areas of the screen. In total, each team had control of four AWACS planes, four tanks, four helicopters, and four jets. Each of these vehicles varies in its capacities on four different dimensions: (a) range of vision, (b) speed of movement, (c) duration of operability, and (d) weapons capacity. The distribution of these vehicles varied according to the resource allocation structure manipulation, as noted below.

There were eight types of "standard tracks" that were known a priori to have specific characteristics, and these were taught in the training session prior to the start of the simulation. There were also four types of novel tracks, or "unknown tracks" that were not encountered during training. Thus, team members did not know whether the novel tracks were friendly or unfriendly, or what power was required to disable them if they are unfriendly. The team members were only able to learn the nature of these tracks via deductive trial and error experience. The teams' overall objective, then, was to disable enemy tracks as quickly as possible if they enter the restricted airspace, while avoiding the errors of disabling friendly tracks or wasting resources by attempting to engage tracks with less power than was required. Each team participated in two sessions on this simulation, which I will refer to as Game 1 and Game 2.

Individual task. Participants participating as individuals played a modified version of the team task, such that they defended one quadrant of the restricted area. Their track set was identical to the track set faced by individuals in one quadrant of the restricted area, and they possessed the same array of vehicles as those in the team version. Thus, the simulation was identical in all respects to the team game except one: they were completely responsible for their performance on the task (whereas in the team version, team members could pick up the slack for underperforming members).

Manipulations and Measures

Research design. The design of the team portion of the study was a 5 x 2 x 2 factorial design, with five levels of initial workload, two levels of resource allocation structure, and two levels of transactive learning, as outlined below. These manipulations were fully crossed, creating twenty cells with 4-5 teams in each cell. The individual portion of the study consisted of the five workload conditions only.

Workload. Workload was experimentally manipulated by adjusting the number of tracks faced by the teams/individuals in Game 1. Five levels of workload were introduced: (a) very high initial workload, where teams faced 140 tracks; (b) high initial workload, where teams faced 120 tracks; (c) moderate initial workload, where teams faced 100 tracks; low initial workload, where teams faced 80 tracks; and (e) very low initial workload, where teams faced 60 tracks. In Game 2, all teams faced 100 tracks. Those engaging in the individual task faced 35 tracks in the very high workload condition, 30 tracks in the high workload condition, 25 tracks in the moderate workload condition, 20 tracks in the low workload condition, and 15 tracks in the very low workload condition. In Game 2, all individuals faced 25 tracks. Although this manipulation created five distinct conditions, the increments between the conditions were equal, and there is a meaningful zero point; therefore, this manipulation was analyzed as a continuous variable.

As a manipulation check, perceptions of workload were measured with four items from the NASA Task Load Index (NASA-TLX; Hart & Staveland, 1988). Coefficient alpha was .73 for Game 1 and .84 for Game 2 in the individual portion of the study, and.76 for Game 1 and .84 for Game 2 in the team portion of the study. The results from this scale were compared with the objective levels of workload in Game 1, and the pattern of correlations between the workload manipulation and subjective workload varied between teams and individuals. These two variables showed a significant positive correlation in Game 1 for individuals (.34, $p < .01$), but not for teams (.08, *ns*). The pattern in Game 2 was the opposite, however; they showed a significant negative correlation for teams (-.28, $p < .01$), but not for individuals (.05, *ns*). The relationships found for individuals was expected, as workload was only manipulated in Game 1. For the teams, however, it appears that the *contrast* between the objective workloads in Games 1 and 2 drove their subjective perceptions of workload.

By employing both an objective manipulation and a subjective perception of workload, I was able to get at workload from multiple perspectives. As noted above, I view workload as a function of both the situation (the demands placed upon the individual) and the person (an individual's workload capacity). Because participants were randomly assigned to workload conditions, workload capacities should be equal across conditions. This means that the objective workload manipulation should still capture the person/situation conceptualization of workload (albeit with noise from randomization).

The subjective perception of workload provided by the NASA-TLX gets at the person/situation conceptualization more directly, but is subject to common method and source bias when examined with other self-report measures.

Resource allocation structure. Two levels of resource allocation structure were experimentally manipulated for the team portion of the study. Functionally structured team members were allocated all of one type of vehicle (four tanks, four jets, four helicopters, or four AWACs). Divisionally structured team members were allocated one of each vehicle type (each member had one tank, one jet, one helicopter, and one AWACs).

Transactive learning. Two levels of transactive learning were experimentally manipulated (treatment and control conditions) for the team portion of the study in Game 1. The treatment condition consisted of assigning each of the team members responsibility for learning the power of one of the four unknown tracks (discussed below under the learning measure). In the control condition, no such assignment was given.

Personality. Extraversion and neuroticism were measured with the NEO-PI-R, which assesses these personality factors with twelve items each. Coefficient alpha for extraversion was .86 in the individual portion of the study and .78 in the team portion of the study. Coefficient alpha for neuroticism was .85 for the individual portion of the study and .84 for the team portion.

Emotional arousal. Emotional arousal was measured in two ways. First, participants self reported arousal through the Current Mood Questionnaire developed by Feldman-Barrett and Russell (1998), which includes two statement measures and one adjective measure each for both the arousal and hedonic tone dimensions of affective states. The two statement measures are largely redundant, so only one was assessed. The arousal statement measure includes seven items on which participants indicate the degree to which they think the statement describes them: (a) "I'm full of energy and tension," (b) "I'm keyed up," (c) "I am stirred up," (d) "I'm feeling placid, low in energy" (reverse coded), (e) "My internal engine is running slow and smoothly" (reverse coded), (f) My body is in a quiet, still state" (reverse coded), and (g) "My mind and body are resting, near sleep" (reverse coded). Responses were given on a five-point scale from "Describes me not at all," to "Describes me very well." The arousal adjective scale contains six words on which participants indicate the degree to which they are feeling them at the moment: (a) aroused, (b) alert, (c) activated, (d) sleepy, (e) still, and (f) quiet. Reponses were given on a five-point scale from "Not at all" to "Extremely."

These measures showed good convergent validity with a previously validated semantic differential scale of emotional arousal from Russell and Mehrabian (1974), with zero-order correlations of .82, and .69 respectively in one study, and .64, and .65 in another. They also showed good discriminant validity from similar measures of hedonic tone, with zero-order correlations ranging from .00 to .26 (mean $r = .10$) across the two studies. These results have been replicated with similar findings across two samples (Yik, Russell, & Barrett, 1999). Neither the original study nor the replication provided reliability data in the form of coefficient alpha, but both showed high factor loadings on their intended factors and excellent fit in their structural equation models. Participants completed this questionnaire three times: when they first arrived at their laboratory session and after both games. Coefficient alpha for the statements measure was .86 at pregame, .90 after Game 1, and .92 after Game 2 in the individual portion of the study, and .84 at pregame, .81 after Game 1, and .86 after Game 2 in the team portion. Coefficient alpha for the adjectives scale was .65 at pregame, .85 after Game 1, and .80 after Game 2 for the individual portion of the study, and .70 at pregame, .74 after Game 1, and .73 after Game 2 for the team portion.

Second, arousal was assessed via the noninvasive Nellcor-200 heart rate monitor, which was attached by a clip to each participant's fingertip. In this simulation, only one hand is used for mouse operations, so the monitor was attached to the other hand. The monitor logged the participant's heart rate every five seconds.

The idea that emotions can be measured via physiological indicators dates as far back as William James (1884). The advantage of physiological indicators is that they bypass self-report measures, tapping into the physiological component of affective states. In particular, functions of the autonomic nervous system (ANS) such as heart rate, blood pressure, and finger temperature, have been commonly used as measures of emotion since the 1950's (Cacioppo, Klein, Berntson, & Hatfield, 1993). According to Levenson (1988, p. 40), the role of the ANS as an indicator of emotion is "the centerpiece of its evolutionary value in emotion." There has been some debate among emotion researchers as to whether ANS indicators can effectively discriminate among discrete emotions (i.e., anger vs. disgust, happiness vs. fear). Fortunately, for the purposes of this study, discriminating among discrete emotions was not necessary; instead, I only needed to measure the arousal dimension of emotional states. On this, emotion scholars largely agree that ANS measures are good indicators of arousal (e.g., "...the psychophysiology of emotion literature indicates that ANS measures are better indexes of the arousal dimension than of affective valence" (Guglielmi, 1999, p. 148); "Most measures of physiological reaction give direct indications only of the extent of arousal" (Cook & Selltiz, 1964, p. 53)).

Of the various ANS measures, heart rate is the most reliable measure of emotional arousal (Cacioppo et al., 1993; Guglielmi, 1999). Arena et al. (1983) showed high test-retest reliabilities of heart rate from week to week, with correlations of .66 while resting, and .53 and .79 under two stress conditions (performing mental arithmetic and imagining a stressful event). Additionally, they showed good test-retest reliabilities of change in heart rate (from resting to stress conditions), with correlations of .43 and .52, measured one week apart. Thayer (1970) showed a correlation of .33 between heart rate and self-reports of emotional activation, and concluded that heart rate and skin conductance were the two best physiological indicators of emotional arousal. Other studies have shown heart rate increases under experimentally-induced conditions of fear (Chessick, Bassan, & Shattan, 1966; Grossberg & Wilson, 1968; Tourangeau & Ellsworth, 1979) anger (Chessick et al., 1966; Frodi, 1978), and social anxiety (Knight & Borden, 1979), all of which are considered to be high-arousal emotions. Although these studies provide some evidence for the construct validity of heart rate as a measure of arousal, this evidence is certainly not overwhelming. Thus, an additional contribution of the present study was assessing the validity of heart rate as a measure of emotional arousal.

Because individual resting heart rates vary, studies using heart rate as a measure of arousal typically use the change score between resting heart rate and heart rate during the experimental manipulation. Difference scores, however, can be problematic because one cannot tell whether the effect is due to the starting or ending values (Edwards &

Parry, 1993). Therefore, the effects of workload on emotional arousal were analyzed through repeated measures regression (as noted below under Results).

Learning. Learning was assessed via a multiple-choice test, and participants completed this test three times: when they arrived at their laboratory session and after both games. The test consisted of two parts. First, it assessed the degree to which individuals and teams correctly identified the four types of novel tracks in terms of the power levels of each type of novel track. A similar measure was previously used on this task by Ellis et al. (2003; although they used behavioral measures rather than a knowledge test). Second, it quizzed teams on the best strategy for playing the game. I wrote four questions for this portion of the test, and tested them on seven people who were experts on the DDD simulation (current and former Research Assistants). All seven agreed on the correct answers for two of the items. Six agreed on the answer for the third item, and five agreed on the fourth. The intraclass correlation was over .99, indicating strong inter-rater agreement. The observed reliability of the test for the experiment was assessed using the Kuder-Richardson formula for dichotomously scored items. KR-20 on the pre-game test was .11, after Game 1 was .35, and after Game 2 was .38. The low reliability for the pregame test was expected, because participants guessed at the answers. The reliabilities after both games were considerably higher than the pregame test, but were still quite low. Therefore, I did not proceed with testing any of the learning hypotheses using this test.

Performance: Speed and Accuracy. Speed of performance was operationalized as a combination of attack speed and identification speed. Attack speed measures the elapsed time between when an enemy track enters the restricted area and when a team member engages it. Identification speed measures the elapsed time between when a track enters the screen and when a team member identifies it. The two variables were standardized and averaged to create the speed composite, which was obtained in both Game 1 and Game 2.

Accuracy of performance was operationalized as a combination of friendly fire errors and missed opportunities. Friendly fire errors reflect a count of the number of times a friendly track is disabled. Missed opportunities is a count of the number of times an enemy track is engaged, but the vehicle used to engage the track does not have enough power to disable it. Both of these variables represent errors made by the team, and were standardized and averaged to create the accuracy composite, which was also obtained in both Game 1 and Game 2.

Data Analysis

The research design in this study incorporated both within-units (individuals or teams) and between-units components. Workload, resource allocation structure, and transactive learning structure were between-units components, and time was a within-units component. Because of this mixed design, I utilized repeated measures regression to analyze the data. Repeated measures regression partitions the variance in the dependent variable into two orthogonal sources: variability between units, due to differences in overall performance, and variability within units, due to differences in time (Cohen & Cohen, 1983). Performance is then regressed onto the predictors, and the variance explained by the predictors is compared to the appropriate variance partition (either the between-units or within-units variance). This allows one to see how much of the appropriate variance component is explained by the predictors.

For example, workload was a between-units manipulation (i.e., each individual or team experiences only one sequence of workload), and thus any variance explained by workload should be compared to the between-units variance, rather than to the total variance in performance. Time was a within-units variable (i.e., each individual or team provides a measure of the mediators and dependent variables in both games). This analytical method also allows one to test interactions between within-units components with between-units components. Significant interactions would indicate support for contingencies, like the ones predicted. I note that this analysis is identical to one in which the measures for each game were treated as separate dependent variables, followed by a test of the difference between the regression coefficients. I chose repeated measures regression for parsimony and clarity of presentation.

RESULTS

Descriptive Statistics

Table 1 presents the means and standard deviations for all of the measured and manipulated variables. Examination of this table reveals that in terms of the pregame variables (personality, arousal, and knowledge), those who participated in the individual portion of the experiment were virtually identical to those who participated in the team portion of the experiment. They also did not differ in terms of their subjective perceptions of workload in either Game 1 or 2. In both games, however, those who worked in teams reported being significantly more emotionally aroused both in terms of the CMQ statements (Game 1: $M = 3.50$, $SD = .36$; Game 2: $M = 3.50$, $SD = .39$) and the CMQ adjectives (Game 1: $M = 3.38$, $SD = .37$; Game 2: $M = 3.31$, $SD = .39$) than those who worked alone (Game 1 statements: $M = 3.04$, $SD = .90$, $p < .01$; Game 2 statements: $M = 2.94$, $SD = .98$, $p < .01$; Game 1 adjectives: $M = 2.83$, $SD = .93$, $p < .01$; Game 2 adjectives: $M = 2.87$, $SD = .92$, $p < .01$). They were not significantly different, however, in terms of heart rate in either game. This may reflect the social facilitation hypothesis, that people are more aroused when interacting with others than when they are alone.

Interestingly, they also did not differ significantly in terms of either of the learning variables in either game. This indicates that on this task at least, having the additional information provided by team members did not result in more learning than working alone. Also notable is the fact that in terms of both of the learning variables measured before they played the game, the participants achieved scores that would be expected by chance. This was expected, as they simply guessed at the answers to these questions, because they could not have known them without playing the game.

Table 2 presents the correlations of all of the measured and manipulated variables. Although some of the relationships are discussed below in testing the hypotheses, one other relationship bears mentioning. Despite random assignment, the workload manipulation correlated significantly with both neuroticism (.29, $p < .01$) and extraversion (-.25, $p < .05$) in teams. For individuals working alone, however, these relationships were not significant. The size of the correlations is due in part to the fact that aggregating the personality measures to the team level almost invariably reduces the standard error. The correlations prior to aggregation were .15 for workload and neuroticism, and -.13 for workload and extraversion; the significance levels were the same as with the aggregated variables. Neuroticism and extraversion did not correlate significantly with the other two manipulated team variables.

Hypothesis Testing

Hypothesis 1, which predicted a positive relationship between workload and emotional arousal in individuals in Game 1, was tested via repeated measures regression. The arousal measures were regressed on workload, time (baseline arousal measured when they arrive at their session, and after Game 1), and their interaction term. For the hypothesis to be supported, there would be a positive relationship between workload and arousal in Game 1, but no relationship with the baseline measure. Table 8 shows the results of this test. None of the arousal measures (CMQ statements, CMQ adjectives, or heart rate) were significantly affected by the workload manipulation, and thus Hypothesis 1 was not supported. Subjective workload, however, was significantly associated with both of the CMQ scales. When controlling for pregame arousal levels, the NASA-TLX scale was positively associated with both the CMQ statements scale ($\beta = .23$, $p < .05$) and the CMQ adjectives scale ($\beta = .27$, $p < .01$). Although these relationships may suffer from common method and source bias, the fact that pregame arousal levels were included in the regression equation lessens the concern about this bias. Any shared variance because of common source or method would presumably also be found in the self-report pregame measure as well, and thus would not be reflected in the relationship between subjective workload and Game 1 arousal.

Game 1 objective workload did, however, have an effect on Game 2 self-reported arousal. For the CMQ statements, controlling for pregame arousal, Game 1 workload exerted a negative effect on Game 2 arousal ($\beta = -.20$, $p = .05$), accounting for 4.1% of the variance. The implication seems to be that the contrast between the workload they experienced in Game 1 (which varied across conditions) and the workload they experienced in Game 2 (which was the same across conditions) created differing levels of arousal. Those who had higher workloads in Game 1 reported lower levels of arousal in Game 2 (when their workload decreased), whereas those who had lower workloads in Game 1 reported higher levels of arousal in Game 2 (when their workload increased). For the CMQ adjectives and heart rate, the coefficients were in the same direction, but were not statistically significant.

Hypothesis 2 predicted that there would be a positive relationship between workload and learning in individuals. This was also tested via repeated measures regression, and Table 13 also shows these results. As with arousal, workload did not significantly affect either of the learning variables; instead, time showed a positive main effect on the participants' identification of the unknown tracks ($\beta = .47$, $p < .01$). This was expected, as playing the game gave the participants a chance to identify the tracks (whereas they simply guessed at them prior to the game). I also examined the relationship between workload and learning by regressing Game 1 learning on the workload variable and its squared term (controlling for the baseline learning measure), in order to determine whether the relationship is best characterized as linear (as hypothesized) or quadratic (as predicted by the Yerkes-Dodson law). Neither workload nor its squared term exerted a significant effect on learning. Thus, neither Hypothesis 2 nor the Yerkes-Dodson law were supported in these data. Hypothesis 3 predicted that emotional arousal would mediate the relationship between previous workload and individual learning. Because workload was not significantly related to learning, Hypothesis 3 was not supported.

Hypothesis 4 predicted a positive relationship between previous workload (Game 1) and subsequent speed (Game 2) for individuals. I tested this both by examining the bivariate correlation and through repeated measures regression, where Game 2 performance was regressed on Game 1 workload, time (Game 1 or 2), and their interaction term. The bivariate correlation was not significant (-.12). As can be seen in Table 9, the interaction term of the repeated measures regression was significant, but this was due to the strong relationship between workload and speed in Game 1, and not due to a carryover effect of previous workload on subsequent speed. Thus, Hypothesis 4 was not supported. Hypothesis 5 predicted that emotional arousal mediates the relationship between previous workload and subsequent speed. Because the relationship between workload and subsequent speed was not significant, Hypothesis 5 was not supported.

Hypothesis 6 predicted a positive relationship between previous workload and subsequent accuracy in individuals. As with speed, the bivariate correlation was not significant (-.05), but the interaction term of the repeated measures regression equation was, as can be seen in Table 9. Again, this was due to the relationship between workload and accuracy in Game 1, and not due to a carryover effect of workload on subsequent accuracy. Thus, Hypothesis 6 was not supported. Interestingly, however, the bivariate correlation between subjective workload in Game 1 and accuracy in Game 2 were negatively related ($r = -.28$, $p < .05$). This means that individuals who perceived the workload to be high in Game 1 made more errors in Game 2 than those who perceived the workload in Game 1 to be low. Hypothesis 7, which predicted that individual learning mediates the relationship between previous workload and subsequent accuracy, was not supported, as neither the relationship between workload and learning, nor between workload and accuracy, was significant.

Hypothesis 8 predicted that workload is positively related to emotional arousal in teams, and like Hypothesis 1, was tested through repeated measures regression. As can be seen in Table 10, the interaction term was not significant for any of the emotional arousal measures, and thus Hypothesis 8 was not supported. As with the individuals working alone, however, subjective workload did have a significant effect on both the CMQ statements scale ($\beta = .41$, $p < .01$) and the CMQ adjectives scale ($\beta = .33$, $p < .01$), when controlling for pregame arousal levels. Again, the concern about common method and source bias is somewhat lessened because of the inclusion of the pregame scales in the regression equation.

Also similar to individuals working alone, Game 1 objective workload exerted an effect on Game 2 self-reported arousal. For the CMQ statements, the effect of Game 1 workload on Game 2 arousal was significant and negative when controlling for pregame arousal ($\beta = -.24$, $p < .05$), accounting for 4.6% of the variance. Again, this pattern held even when controlling for Game 1 arousal levels. For the CMQ adjectives, the effect was again in the same direction, but not significant. Again, this implies that the contrast between the workloads in Games 1 and 2 affected arousal levels. Despite the fact that all teams played the same workload in Game 2, teams that had higher workloads in Game 1 reported lower arousal levels in Game 2 (when their workload decreased), whereas teams that had lower workloads in Game 1 reported higher arousal levels in Game 2 (when their workload increased).

Hypothesis 9 predicted that teams will show a positive relationship between previous workload and subsequent speed. Like Hypotheses 4 and 6, I tested this both by examining the bivariate correlation and through repeated measures regression. The correlation was positive (.18) but did not reach traditional levels of statistical significance ($p = .10$). In the repeated measures regression equation, the interaction term was significant ($\beta = .35$, $p < .01$), and can be seen in Table 11. Figure 2 shows the nature of the interaction; there is a negative slope for workload and speed for Game 1, but a slight positive slope for Game 2. Because of the lack of bivariate significance, however, Hypothesis 9 was not supported. Hypothesis 10 predicted that emotional arousal mediates the relationship between previous workload and subsequent speed. Because the bivariate relationship between previous workload and subsequent speed was not significant, however, this hypothesis was not supported.

Hypothesis 11 predicted that teams will show an attenuated relationship between workload and learning. The bivariate correlation was significantly negative for identification of the unknown tracks (-.31, $p < .01$). Similarly, as can be seen in Table 12, the interaction term was significant in the repeated measures regression for identification of the unknown tracks ($\beta = -.56$, $p < .05$). Thus, Hypothesis 11 was supported. This finding for the unknown tracks is particularly interesting because the negative effect of workload on learning the values of the unknown tracks occurred despite the fact that the higher workloads provided more opportunities to learn the values of the unknown tracks. Each progressively higher workload condition had four more unknown tracks than the condition below it. Thus, the very high workload condition had sixteen more unknown tracks (one of each type) than the very low workload condition, yet they were much worse in determining the values of these tracks.

This team finding appeared to be different than the null finding for individuals working alone, so I tested the differences between the workload-learning correlations for teams and individuals. This test revealed, however, that the correlations were not significantly differently from each other ($p = .16$, two-tailed). Thus, the data do not support the notion that high workloads are harmful for team learning but not for individual learning.

Interestingly, the effect of workload on team learning continued to hold in Game 2. The bivariate correlation between Game 1 workload and Game 2 identification of the unknown tracks was -.20 ($p = .06$), and when controlling for pregame guesses of the unknown tracks, the effect was significant ($\beta = -.23$, $p < .05$). This implies that the higher the team's workload, the worse they were at determining the values of the unknown tracks, and this had a carryover effect into the future. Even though their workload declined, they were not able to make up for their previous lack of learning.

Hypothesis 12 predicted a negative relationship between previous workload and subsequent accuracy in teams. The bivariate correlation was not significant (-.02), nor was the interaction term of the repeated measures regression displayed in Table 11, and thus Hypothesis 12 was not supported. Hypothesis 13 predicted that team learning mediates the relationship between previous workload and subsequent accuracy, but because the relationship between previous workload and subsequent accuracy was not significant, this hypothesis was not supported.

Hypotheses 14 and 15 predicted that the personality traits of extraversion and neuroticism moderate the relationship between workload on the one hand, and arousal and learning on the other, at both the individual and team levels. These hypotheses were tested through moderated regression, where Game 1 arousal and learning (with pregame levels as a control) were regressed on workload and personality (at the team level, this was the mean level of the personality traits for the team), and their interaction terms. Tables 13 and 14 present the results of Hypothesis 14, which predicted that the highest levels of arousal would be found in individuals and teams high in Extraversion and under the highest levels of workload. For individuals working alone, extraversion did indeed moderate the effect of workload on emotional arousal for both the CMQ statements scale ($\beta = -2.22$, $p < .05$) and the CMQ adjectives scale ($\beta = -2.07$, $p < .05$). The nature of the interaction, however, was contrary to the hypothesis. As can be seen in Figure 3, which displays the results for the CMQ statements scale, it was a fully crossed interaction where the highest levels of emotional arousal were found in individuals high in Extraversion and low in workload, or low in extraversion and high in workload. Although not graphically displayed, the CMQ adjectives scale had the same interaction form. For teams, extraversion did not significantly moderate the effect of workload on any of the arousal measures. As a result, Hypothesis 14 was not supported.

Although it was not hypothesized, neuroticism also moderated the effect of workload on emotional arousal for individuals working alone. As with extraversion, neuroticism moderated the effect of workload on the CMQ statements scale ($\beta = -1.06$, $p < .05$) and the CMQ adjectives scale ($\beta = -1.10$, $p < .05$), but had no effect on heart rate ($\beta = .63$, *ns*). Figure 4 displays the results of the interaction for the CMQ statements scale, showing that at low levels of workload, neuroticism had no effect on emotional arousal. At high levels of workload, however, individuals low on neuroticism had higher levels of arousal than those who were high on neuroticism. Interestingly, the moderating effects of both extraversion and neuroticism carried over into Game 2 with almost identical patterns, despite the fact that the workload had changed.

Hypothesis 15 predicted that neuroticism moderates the relationship between workload and learning at both the individual and team levels, and the results of these tests are displayed in Tables 15 and 16. For individuals working alone, neuroticism exerted a negative main effect ($\beta = -.29$, $p < .05$), and also moderated the effect of workload on learning the unknown tracks ($\beta = -1.30$, $p < .05$). The pattern of the interaction for the unknown tracks is displayed in Figure 5 and is consistent with the hypothesis. For individuals high in neuroticism, workload exerted a negative effect on learning, and the lowest level of learning was for individuals who were high in neuroticism and had high workloads. Interestingly, workload exerted a positive effect on learning for individuals who were low in neuroticism. Thus, the main effect hypothesis that workload would be positively related to learning in individuals working alone, held only for those who were low in neuroticism. For teams, however, neuroticism did not significantly moderate the effect of workload on learning the unknown tracks. Thus, Hypothesis 15 was partially supported.

Hypothesis 16 predicted that resource allocation structure moderates the relationship between workload and emotional arousal in teams, and was tested through moderated regression. Table 17 displays the results of this test. The two-way interaction between workload and resource allocation was not significant for any of the arousal measures, and thus Hypothesis 16 was not supported.

Hypothesis 17 predicted that transactive learning moderates the relationship between workload and learning, and the results of this test are displayed in Table 18. As noted earlier, workload exerted a negative main effect on learning the unknown tracks. Structure also exerted a main effect, in that divisionally structured teams showed better learning than functionally structured teams. This is no doubt due to the fact that each team member in the divisional structure had all of the resources they needed to independently determine the values of the unknown tracks, whereas team members in the functionally structured teams had to depend on information from their team members to collectively determine the values of the unknown tracks. The two-way interaction between workload and structure was not significant for learning the unknown tracks, however, and therefore Hypothesis 17 was not supported.

Additional Post-hoc Analyses

Because few of the hypotheses were supported, I conducted additional post-hoc analyses to determine (a) whether support for the proposed model could be found in other operationalizations of the constructs, and (b) whether other non-hypothesized relationships could account for significant variance in the proposed mediators and dependent variables. Below, I describe these analyses, first for teams, and then for individuals working alone.

Teams. First, I examined different operationalizations of the dependent variables as captured by the simulation. Because I proposed that learning the unknown tracks would be affected by workload (and indeed it was for teams), I was able to separate parts of the dependent variables into whether or not they involved unknown tracks. It could be that rather than previous workload affecting total subsequent speed and accuracy, it could differentially affect speed and accuracy involving unknown tracks versus speed and accuracy involving known tracks.

For teams, workload had a direct negative effect on learning the unknown tracks. Therefore, one may expect that team accuracy toward the unknown tracks would be most affected by workload. I was able to separate friendly fire kills of unknown tracks and friendly fire kills of known tracks in order to test this. Repeated measures regression (with known and unknown being the repeated measure) revealed that this was indeed the case. As illustrated in Figure 6, previous workload greatly affected friendly fire kills of the unknown tracks, but had almost no effect on friendly fire kills of the known tracks.

Because I had proposed that learning would mediate the relationship between previous workload and subsequent accuracy, I tested this using learning the unknown tracks as the mediator and friendly fire kills of unknown tracks as the dependent variable. As noted in Table 5, workload and learning were significantly related ($r = -.31$, $p < .01$). Learning and subsequent friendly fire kills of unknown tracks were also significantly related ($r = -.36$, $p < .01$). With learning controlled, the effect of workload on subsequent friendly fire kills of unknown tracks dropped from .32 ($p < .01$) to .24 but remained significant ($p < .05$). Sobel's test revealed that these were significantly different (test statistic: 2.08, $p < .01$). Therefore, learning did not fully mediate, but appears to have partially mediated the effect of workload on subsequent accuracy with these operationalizations.

Neither of the variables used to compose the speed composite showed significant differences between the correlations of workload with known and unknown tracks, but a related variable did. *Good attacks* represents the total number of times the team successfully disabled an enemy track; as such it is a quantity of performance variable, and as noted above, quantity and speed are related performance factors. Although I expected the accuracy related to unknown tracks to be more affected by workload than the accuracy related to unknown tracks, I expected the opposite for speed/quantity. I had expected teams with higher previous workloads to be faster than teams with lower previous workloads. Because these teams did not learn the unknown tracks as well as teams with lower workloads, their advantage in quantity, then, should be more evident with the known tracks. That is, because teams with higher previous workloads did not learn the power levels of the unknown tracks, they would not be able to attack them quickly in the subsequent game. Thus, I would expect that they would attack more known tracks than teams that had lower workloads, but may not be different in their number of attacks on unknown tracks. Repeated measures regression revealed that this was indeed the case. As illustrated in Figure 7, workload was positively related to the number of good attacks of known tracks, but had no relationship with the number of attacks of unknown tracks.

Second, I examined possible relationships among other measured variables. These included both variables captured by the simulation and variables measured through self-report, and I examined both main effects and interactive effects with the measured personality variables. Workload had a significant main effect on a Game 2 self-report variable in teams. *Mental overload* (Campion & McClelland, 1993) in Game 2 was negatively related to previous workload ($r = -.35$, $p < .01$). This relationship reflects the contrast between the teams' workload in Game 1 and their workload in Game 2. Teams whose workload decreased reported lower levels of overload, and teams whose workload increased reported higher levels of overload. Notably, mental overload in Game 1 was also related to Game 1 workload ($r = .26$, $p < .05$).

I tested whether mental overload mediated the relationship between previous workload and subsequent good attacks of known tracks. Controlling for mental overload in Game 2, the beta for workload dropped to .14 (from .24) and became non-significant. Sobel's test also indicated that these were significantly different (test statistic: 2.11, $p < .05$). This indicates that mental overload at least partially mediated the effect of previous workload on subsequent quantity of performance.

Regarding personality variables, extraversion showed no interpretable main or interactive effects with workload on any team variables. Neuroticism did not show any significant main effects on team variables, but it did interact with workload in predicting Game 2 friendly fire kills in teams. The nature of the interaction was such that for teams low in neuroticism, previous workload had almost no effect on their subsequent friendly fire kills. For teams high in neuroticism, however, previous workload had a strong positive effect on their subsequent friendly fire kills. This is in keeping with the original model, which suggested that the teams that learned least would be those high in neuroticism with high workloads. Subsequently, one would expect that the low levels of learning would lead to lowest accuracy in Game 2. Although the learning hypothesis was not directly supported in the test (perhaps due to the strong main effect of workload on learning), the effect was evident in the teams' behavior in Game 2.

I also measured the other three factors of the "Big 5" model of personality: agreeableness, conscientiousness, and openness to experience. I had no theoretical reasons to test the effects of these factors on the mediators and dependent variables, but I did so purely for inductive reasons. Like extraversion, agreeableness yielded no significant main or interactive effects on team variables. Conscientiousness exerted a significant interactive effect with workload on one captured team variable in Game 2. Attack speed was one of the original variables comprising the speed composite. Workload had no effect on attack speed for teams high in conscientiousness, but was positively related to attack speed for teams low in conscientiousness. This may suggest that the proposed main effect of previous workload on subsequent speed is attenuated in teams high in conscientiousness. Because conscientiousness is associated with fulfilling one's responsibilities and duties (Costa & McCrae, 1992), it may be that highly conscientious teams work the same way regardless of their workload history.

Openness interacted with workload to predict the total number of times the team attacked tracks (these were not just "good" attacks as discussed above, but all attacks, including missed opportunities and friendly fire kills). This was a fully crossed interaction, such that teams high in openness that had low previous workloads, and teams low in openness that had previous workloads, showed the highest number of attacks in

Game 2. This may suggest that teams high in openness see increases in workload as a challenge to be met, and thus work harder than teams low in openness. This does not, however, result in an overall performance improvement, because although they are more productive (more attacks), they also make more mistakes (more friendly fire kills and missed opportunities). When their workload decreases, however, teams high in openness may lose interest and not work as hard as teams low in openness.

Individuals working alone. Workload did not show any main effects on any of the captured or self-report Game 2 variables for individuals working alone. In terms of personality, however, neuroticism showed numerous main effects on captured individual variables captured in Game 2. Neuroticism was negatively related to the number of tracks identified ($r = -.28$, $p < .05$), the number of good attacks ($r = -.29$, $p < .05$), the number of launches ($r = -.25$, $p < .05$), and attack speed of unknown tracks ($r = -.32$, $p < .01$). It was also positively related to the number of missed opportunities ($r = .28$, $p < .05$). Taken as a whole, these indicate significantly worse performance by individuals high in neuroticism, as they were less productive overall, slower in attacking unknown tracks, and were more likely to attack tracks with assets that did not have enough power to disable them. As noted in Table 5, neuroticism also showed a negative effect on learning the unknown tracks ($r = -.27$, $p < .05$), which explained much of the variance in attack speed of the unknown tracks (the effect of neuroticism dropped to .21 and became non-significant when learning was controlled) and missed opportunities (dropped to .16 and became non-significant when learning was controlled). In terms of interactive effects, neuroticism showed no significant interactions with workload on any of the individual variables in Game 2.

Extraversion, agreeableness, and conscientiousness showed no interpretable main or interactive effects with workload on captured individual variables. Openness to experience, however, showed a number of significant main effects. Openness was positively related to the number of tracks identified ($r = .22$, $p < .05$) of good attacks ($r = .25$, $p < .05$), especially of the unknown tracks ($r = .34$, $p < .01$); and was negatively related to the number of missed opportunities ($r = -.29$, $p < .05$) and the number of times a track was disabled using more power than was needed (wastes; $r = -.23$, $p < .05$). Thus, people high on openness appear to have been better performers overall, as they were more productive, accurate, and efficient than those low on openness.

DISCUSSION

This research set out to test a model of the effects of previous workload on subsequent performance in teams and individuals. The results advance multi-level theory regarding the affective and cognitive processes that accompany varying levels of workload in both teams and individuals. This research demonstrated how a relevant past experience—their previous workload—affects future performance through individual and team thoughts and feelings as they perform their task. Thus, the research continues the current trend of not simply identifying which variables affect individual and team performance, but how and why they affect performance (Ilgen, Hollenbeck, Johnson, & Jundt, 2005). In this discussion, I first summarize the findings and limitations of the study, then proposed a revised theoretical model, and finally offer theoretical implications and practical applications of the study.

Findings for Individuals Working Alone

For individuals working alone, workload had no main effects on arousal, learning, or subsequent performance. Instead, the effect of workload on arousal and learning depended upon the personality traits of the individual. Individuals who were extraverts exhibited high levels of arousal under conditions of low workload, whereas individuals who were introverts exhibited high levels of arousal under conditions of high workload. These results appear to paint a more complex picture of the relationship between extraversion and arousal than that indicated by the theories of Hans Eysenck (1967), who suggested that extraverted people have lower baseline levels of arousal and are more affected by external stimuli. In the individual portion of this study, extraverts did not report significantly lower levels of arousal than introverts when they arrived at their experimental sessions (although this could be due to the stimulating effect of anticipation of participating in an experiment, which would have raised extraverts' baseline arousal levels). Then in what appears to contradict Eysenck's theory, extraverts did not become *more* aroused under conditions of high workload, but rather became *less* aroused, compared to those under conditions of low workload. In contrast, introverts became more aroused under conditions of high workload, and less aroused under conditions of low workload.

It must be noted that although much research has found support for Eysenck's extraversion-arousal theory, a number of published studies have not supported the theory. Matthews and Gilliland (1999) note that three factors in particular have accounted for the seemingly anomalous findings in this area. First, time of day has moderated the effect of extraversion on arousal, because extraverts tend to be more aroused in the evening than in the morning (Revelle et al., 1980). Although I found no time of day effects in these data, this could be because the range of workload was restricted in the morning and afternoon laboratory sessions, with only the evening sessions having the full range of workload. Second, there is some evidence that instead of extraversion leading to higher arousal under higher stimulus conditions, extraversion and arousal interact to predict performance. I also found no extraversion by arousal interactive effects in these data.

The third factor suggested by Matthews and Gilliland (1999) may provide the best post-hoc explanation for these unexpected results. The nature of the task and the laboratory setting in which the experiment took place may have affected arousal levels. The extraversion-arousal effect "is largely restricted to simple tasks requiring encoding of easily-perceived stimuli or to more complex tasks with a routine encoding component"

(Matthews & Gilliland, 1999, p. 610), but is not found in tasks that are attentionally demanding. The attentional demands of this simulation increased as workload increased, and the unknown tracks created additional demands that required more than "routine encoding." Therefore, this task may not have been simple enough to find the expected effect.

It may also be that extraverts are only emotionally aroused by external stimuli that involve interaction with other people. Due to space limitations, multiple participants in the individual portion of the study were sometimes working at computers in the same room. Under the low workload conditions, it is possible that the extraverts interacted with the other people in the room, which would have raised their arousal levels. Under the high workload conditions, however, the task was so demanding that they would not have had the time or cognitive resources to devote to interacting with the other participants, and thus would experience lower arousal levels. In contrast, the introverts reported higher arousal levels when the workload was higher, possibly because the individual nature of the task was more stimulating to them when it was more demanding.

Neuroticism also moderated the effect of workload on emotional arousal for individuals working alone, and again, it appears to be in contrast to Eysenck's (1967) theory. Eysenck proposed that people high on Neuroticism become more emotionally aroused by external stimuli than people low on Neuroticism. The results of this study, however, showed that people high in Neuroticism were *less* aroused under conditions of high workload than they were under conditions of low workload. In contrast, people low in Neuroticism were more aroused under conditions of high workload than they were under conditions of low workload.

Two post-hoc explanations may account for this unexpected finding. First, Eysenck (1994) postulated a protective mechanism he called "transmarginal inhibition" (TMI). TMI occurs when individuals reach high levels of stimulation; rather than continuing to become more aroused, increasing stimuli can actually cause people to become *less* aroused. This effect has been supported empirically (LeBlanc, Ducharme, & Thompson, 2004). It may be that the participants who were high in Neuroticism found the higher workload conditions too stimulating, which activated the TMI mechanism. Second, positive affect (PA) may be driving the finding. Although not reported above, I also measured positive and negative affect, and found a very strong correlation between PA and the CMQ statements scale (.48 at pretest, .74 after Game 1, and .69 after Game 2). Neuroticism moderated the effect of workload on PA in an almost identical pattern as the one found for arousal. It may be, then, that people high in Neuroticism simply found higher levels of workload unpleasant, and mentally disengaged from the task. In contrast, people low in Neuroticism found higher workloads to be more pleasant and arousing.

Neuroticism also moderated the effect of workload on learning, as hypothesized. Individuals who were low on Neuroticism learned more under conditions of high workload than under conditions of low workload, whereas those who were high in Neuroticism showed the opposite pattern. This is consistent with Eysenck's (1967) notion that that people high in Neuroticism are more reactive to anxiety-producing stimuli, and use up cognitive resources to cope with the anxiety rather than devoting them to learning. When individuals are low in neuroticism, however, they can take advantage of the additional information afforded by higher workloads, and learn more than when their workload is lower.

Findings for Teams

In contrast to its effect on individuals working alone, personality exerted almost no influence on team outcomes. Instead, workload exerted a negative main effect on team learning, regardless of the personality characteristics of the team. This supports the notion of team performance as a dual-task paradigm, where team members must attend both to taskwork and teamwork. When workload is high, teams cannot do both of these simultaneously, and teamwork is more likely than taskwork to suffer. Team learning is primarily a function of teamwork, because team members must attend to the information communicated by their teammates.

Communication among team members, however, suffers under conditions of high workload. Team members focus on their individual tasks—their taskwork—and neglect to either transmit or receive vital information that would help the team learn. This study revealed that teams under high workloads learned less than teams under low workloads. Even more troubling, this had a carryover effect such that teams facing initially high workloads did not "catch up" to the teams facing initially low workloads, even when their workload decreased. This may reflect communication norms that were developed early and carried over into the teams' later experiences. Teams under high workloads developed norms of low communication, and thus were hindered in their learning in the future.

Limitations

There are at least eight aspects of this study that limit its findings: four related to both the individual and team portions of the study, two specifically related to the individual portion of the study, and two specifically related to the team portion of the study. First, this study examined a limited range of workload. It is not clear what the results would be at more extreme levels of workload. For example, at inordinately high levels of workload may cause participants to simply give up and not even attempt to work at the task. I suspect that this would not be limited to laboratory tasks like the one in this study, but would also hold true in field settings. Employees who are assigned so much work that it is overwhelming may strike or otherwise walk off the job, knowing that they are not able to accomplish the workload assigned.

Second, this study examined a specific conceptualization of workload: an objective quantitative increase in the number of tasks assigned. As noted in the introduction, Shaw and Weekley (1985) have discussed the idea of workload having both quantitative and qualitative elements. It is unclear what the effects of previous workload would be on future performance if the workload changed qualitatively. A different type of work—rather than simply more or less of the same type of work—may yield different results than the ones found here.

Additionally, at least two factors limit the overall generalizability of the findings in this study. First, the experimental task is clearly not representative of all tasks teams undertake, and thus the findings may vary slightly for different tasks. The task has a great deal of both "mundane realism" and "psychological realism" (Berkowitz & Donnerstein, 1982), however, that enhances my confidence in the external validity of the findings. Mundane realism exists when a laboratory environment bears superficial similarity to a real-world task. The nature of this task—in terms of collecting information and making decisions using computer technology—is somewhat similar to military command-and-control settings and some civilian settings (e.g., air traffic control, emergency dispatch).

Psychological realism exists when a laboratory setting induces similar psychological states to real-world situations. Although the rewards for good performance and the consequences for errors were not as significant as in real work settings, the participants were generally highly engaged by the task and were visibly upset when they made errors.

Second, the sample consisted of undergraduate university students and thus may not be representative of the population of people in work settings. I note, however, that in many military settings, tasks like this are performed by lieutenants, who are approximately the same age as the participants in this study. Third, in this study participants performed over a short period of time. Thus, it is not clear whether the results would hold for individuals or teams that perform over longer periods. It may be that the negative effect of workload on learning found in teams would be lessened over time. On the other hand, however, it may be possible that if a team performed under a high workload over a longer period of time, the effect would be even greater. That is, as teams perform over long periods of time, they develop ingrained communication patterns that are resistant to change. Teams that had previously high workloads for a long period of time may not be able to overcome these patterns and may never learn effectively together.

Two aspects of the individual portion of this study greatly limit its findings. First, as noted above, participants in the individual portion of the study were in the same room with up to three other individuals who were also participating in the study. Although they were instructed to work on the task alone, it is possible that they shared information with each other about the task. Thus, participants could have acted as a de facto "team" and assisted each other with learning about the unknown tracks. This is somewhat unlikely, as participants in the individual portion of the study were instructed that their chance of winning a cash prize was dependent upon them being in the top half of all individual performers. Thus, assisting another participant would decrease their own chances of winning a prize. A more likely scenario is that participants may have simply chatted with each other but not provided assistance. Because the participants were all drawn from a pool of students in the same course, they may have known each other or talked with each other about course-related subjects. This may have affected their performance on the simulation in unpredictable ways.

Second, the individual simulation was constructed to mirror the team simulation as much as possible. Because of this, I left in all tracks that did not enter the quadrant of the restricted area that the participant was to defend. This allowed the individual participant to see the tracks in other quadrants in the same way that participants in the team portion of the study could see. This was to ensure that the task "looked" the same way to participants in the individual and team portions of the study. The downside of this was that participants in the individual portion of the study could send vehicles to the other quadrants and attack those tracks if they wished. They were specifically instructed not to do this and to only defend their own quadrant. Nevertheless, 73% of the participants did attack at least one target outside of their quadrant, with an average of 2.84 attacks in Game 1 and 3.44 attacks in Game 2. This was less than the amount for participants in teams for both Game 1 ($\mu = 4.76$) and Game 2 ($\mu = 6.65$), but in teams, the total number of tracks was not affected. That is, teams as a whole did not face more tracks when team members attacked tracks outside of their own quadrants. For individuals working alone, however, attacking tracks outside of their quadrants increased the total number of tracks they faced. Indeed, one participant attacked 25 tracks outside of his quadrant in Game 2, effectively doubling his workload. It is unclear what effect this had on the performance of individuals in the study.

· At least two factors limit the findings in the team portion of the study as well. First, personality was operationalized as the mean level of the team members' self-reported personalities. This operationalization is quite common in the teams literature (e.g., Barrick, Stewart, Neubert, & Mount, 1998; Boone et al., 2005; Ellis et al., 2003; LePine, 2003; Porter et al., 2003; Taggar, 2002), and Steiner (1972) advocated this approach for additive tasks like the one in this study. This aggregation method, however, is not without its critics. For example, Kozlowski and Klein (2000) suggested considering the *configuration* of individual personalities rather than simply taking the average of individual personalities. This method considers the statistical variance of individual personality scores in addition to the mean, and has been used by some (e.g., Barrick, Stewart, Neubert, & Mount, 1998; Boone et al., 2005). Testing the effects of personality variance, however, implies theoretical questions about the diversity of personalities in the team, which were not a focus of this study.

Additionally, Hofmann and Jones (2005) question whether team personality is a valid construct for short-term ad hoc teams like the ones in this study. They suggest that team personality is an emergent construct that develops as team members interact over extended periods of time. It is possible that personality has very different effects on team affect, learning, and performance for teams that have interacted enough for a true team personality to emerge.

Second, the task represented specific levels of task interdependence among the team members. The level of interdependence was partly a function of the simulation itself and partly a function of team structure. Teams in the functional structure were much more interdependent than teams in the divisional structure, because each team member did not have all of the assets necessary to disable every enemy track. Thus, certain team members had to rely on other members to disable enemy tracks in their quadrants of the restricted area. Nevertheless, it is not clear how other forms of task interdependence (e.g., sequential, pooled, reciprocal; Thompson, 1967), or other forms of team interdependence (e.g., goal interdependence, outcome interdependence; Wageman, 2001) would affect the results.

Post-hoc Inferences

On the basis of the hypothesis testing and additional post-hoc analyses, I revised the proposed model into one that appears to be more in keeping with the empirical results. Workload did not affect any of the outcomes in the individual portion of the study, and this may be due to the limitation mentioned above—that individuals attacked tracks outside of their quadrants and thus changed their workloads in unpredictable ways. Therefore, I am reluctant to develop a post-hoc theoretical model for individuals working alone on the basis of these null results. I do, however, offer a revision of my team model that is both grounded in theory and consistent with my empirical findings. This post-hoc model is illustrated in Figure 8; I note as well that it is not drastically different from the original team model I proposed.

One of the primary changes in the model is the reconceptualization of performance in terms of quantity and quality, rather than speed and accuracy. These dimensions are conceptually very similar, but these dimensions more precisely fit the empirical results. The quantity/quality distinction is well-established in organizational behavior/industrial-organizational psychology research (e.g., Anderson, 1947; Muscio, 1912; O'Hara, Johnson, & Beehr, 1985). Quality represents the degree of productivity on a task, and quality represents the extent to which errors are made on the task.

These dimensions are not entirely orthogonal; at the upper range of performance, one must sacrifice one of the dimensions in order to achieve higher performance in the other (Ilgen & Moore, 1987). This model, however, suggests that the dimensions can be pulled apart by previous workload, even at moderate performance levels. When their past workload has been high, teams will generally be highly productive but also make many errors. When their past workload has been low, however, teams will generally be less productive but will also make fewer errors.

The explanation for this phenomenon can be found in the two theoretical mediators: learning and mental overload. Team learning, as proposed in the original model, suffers under conditions of high workload because of the difficulty of communicating effectively under such conditions. When workload is high, teams cannot focus on both taskwork—what the team members must accomplish individually—and teamwork—what the team members must accomplish together. Team learning is particularly problematic under these conditions because it requires the team members to both share information they have gleaned and attend to information communicated by other team members. This "dual-task paradigm"—attempting to focus both on one's tasks and on communicating with teammates—is extremely difficult to accomplish under conditions of high workload, and team members will generally sacrifice communication in order to accomplish their individual taskwork. When workload is low, however, team members can accomplish both their individual taskwork and their collective teamwork.

Subsequent performance quality is a function of previous learning. When teams under conditions of low workload learn about their task and the environment in which they are operating, they can convert this knowledge into better quality in the future. They learn how to avoid mistakes on their tasks, and thus reduce their errors in the future. Teams under high workload conditions, however, do not learn about their task and environment, and thus are more likely to make errors in the future.

Mental overload is new to my model, but it has been examined in previous workload research as "mental workload" or just "mental load." Mental workload concerns "the cost of mental operations, and the constraints that are imposed by these costs on the ability of a performer to cope with the demands of a task that he or she is given to perform" (Gopher, 2000, p. 197). More simply, it is "the amount of mental effort needed to perform a task" (Brown & Boltz, 2002, p. 600). Mental workload has been found to be negatively related to such outcomes as test performance (Croizet et al., 2004), driving performance (Recarte & Nunes, 2003), and flight performance (Hardy & Parasuraman, 1997).

In this model, however, the concern is not so much on the effects of workload on concurrent mental overload, but with the effects of *previous* workload on *subsequent* mental overload. Although team workload should affect concurrent mental overload (and indeed it did in these data), the effect is stronger after the team's workload has changed. Increases in workload lead to higher levels of mental overload, and decreases in workload lead to lower levels of mental overload. In effect, the team members' degree of mental overload is more affected by the *contrast* between their previous workload and their current workload than by the raw level of workload. The team members get used to a certain workload level, and establish their work patterns and interaction routines on the basis of that level of workload. When the workload changes, these patterns and routines are disrupted. If the workload increases, the team is overwhelmed and cannot be as productive. In this way, low previous workload leads to higher subsequent mental overload, which in turn leads to lower performance quantity. If the workload decreases, however, team members have less work to which they need to devote their cognitive resources, and hence experience less mental overload. They can continue working at the highly productive pace from their previously high workload, and thus maintain high performance quantity.

The relationships between previous team workload on the one hand, and learning, mental overload, quality and quantity of performance on the other, are moderated by another new construct in my model: *task novelty*. Previous research has examined the effects of task novelty on attentional processes (e.g., Ball & Zuckerman, 1992) with the idea that people pay more attention to novel stimuli than to stimuli to which they have become habituated. My use of the term, however, does not carry the connotation of a novel task being more interesting than a familiar one; rather, task novelty simply captures the degree to which a task presents learning opportunities to the team. Novel tasks, then, are tasks that are not well-learned by the team, and as the team learns about a novel task, they make fewer errors (improve their performance quality). A task that is familiar to the team, however, presents few learning opportunities; the team cannot learn much more about the task and thus cannot reduce their error rate any further.

Thus, task novelty moderates the relationship between workload and learning, in that teams can learn a great deal about novel tasks but not about familiar ones. The interactive effect of workload and task novelty on learning would be represented by a flat slope when tasks are familiar (workload has little effect because there is little to be learned), and a negative slope when the task is novel (higher workloads lead to less learning). In turn, the relationship between previous workload and subsequent performance quality would take the same form: no relationship for familiar tasks, but a negative slope for novel tasks. This was represented in the data in this study by the relationship between previous workload and friendly fire kills. Teams that had high previous workloads committed more friendly fire kills of unknown (novel) tracks than teams with low workloads, but there was no relationship between previous workload and friendly fire kills of known (familiar) tracks.

Task novelty is also likely to moderate the relationships on the bottom half of my model: the relationships of previous workload with mental overload and performance quantity. I was not able to test the first of these relationships with the current data because I only had a global measure of mental overload, but I was able to test the second (performance quantity). Teams that had high previous workloads had more good attacks of known (familiar) tracks than teams that had low previous workloads; for the unknown (novel) tracks, however, there was no relationship between workload and good attacks. The notion here is that teams under high workloads carry over their high rate of productivity only if they are familiar with the task; when they have to work on novel tasks, however, they cannot be as productive because they are not certain how to go about the task.

Previous workload and task novelty are also likely to show an interactive effect on mental workload. As noted above, when teams experience a decrease in workload, they also experience lower levels of mental overload. If the team is facing a novel task, however, their levels of mental workload are likely to be higher than if they are facing a familiar task. The stress of having to perform a novel task is likely to negate the effect of their previous workload. Thus, the nature of the interaction should be that previous workload has a negative effect on mental workload for familiar tasks, but no relationship for novel tasks.

Theoretical Implications

This study extends personality, affect, and teams research. In terms of personality, this experiment demonstrated that two personality characteristics—extraversion and neuroticism—interact with workload to affect both individuals' emotional arousal and learning. Consistent with Mischel and Shoda's (1995) cognitive-affective personality system (CAPS), this study revealed that these personality characteristics did not exert a deterministic main effect on emotions and learning. Instead, there was a person by situation interactions in terms of people's responses to varying levels of workload. This appears to be the kind of "if…then" dynamic Mischel and Shoda (1995) suggested, in that personality traits have differential effects depending upon the situation.

The study also found disconfirming evidence for Eysenck's (1967) theory of the arousing effects of personality. Eysenck proposed that extraversion and neuroticism (and a third trait he termed "psychoticism") are related to emotional arousal. Specifically, he suggested that people high in extraversion and neuroticism are more affected by stimulating situations than people who are low on these traits. This study found, however, that people high on these traits showed *negative* relationships between workload and emotional arousal, whereas people low on these traits showed positive relationships. Although this finding may be due to characteristics of the task and the experimental environment, it at least suggests that the relationship between the traits and arousal is more complex than Eysenck proposed. It may be that extraverts are only sensitive to stimulating *social* situations, rather than to stimulating situations in general. Introverts, on the other hand, may be more sensitive to stimulating non-social situations, like the one in the individual portion of this study. People high in Neuroticism may be affected by stressful situations by disengaging from the task and decreasing their arousal levels, whereas people low in neuroticism see these situations as a challenge and increase their arousal levels accordingly.

In terms of team structure, as noted by Hollenbeck et al. (2002), it is important to match individuals to structure (internal fit), and structure to the environment (external fit). Although this research did not directly examine internal fit, it did examine external fit in terms of matching structure to workload demands. Extending the research on resource allocation structures, this study examined the notion that distributing resources among team members in a functional manner reduces the emotional arousal of the team under conditions of high workload. As noted above, however, the results indicated that this was only true when combined with another manipulation. Thus, it does not appear that functional structures are necessarily associated with lower arousal levels.

Extending the transactive memory literature in teams by examining the concept of transactive learning, the experiment tested a simple method for overcoming the negative effects of high workload on team learning through the assignment of responsibility for learning about different aspects of the task. On the assumption that this would distribute the cognitive load throughout the team and thus effectively reduce the load on any individual team member, I expected that these teams would learn more effectively than teams where learning responsibility was not distributed. The results did not support this for teams as a whole, but a post-hoc analysis of specific responses by team members revealed that the manipulation did have some significant effects. Thus, the notion that teams can learn more effectively by distributing responsibility for learning among the team members may bear more examination.

In terms of affect, two findings from this study may have implications for theory. First, although arousal and hedonic tone have been conceptualized as somewhat distinct dimensions of affect (Russell, 1980), these data showed a strong correlation between measures of these dimensions. This casts doubt either on the dimensional perspective or on the construct validity of the measures. Second, although previous research has found heart rate to be a valid measure of emotional arousal, this study found that heart rate was not related to the self-report measures of arousal, nor was it affected by any of the experimental manipulations. It is possible that the sedentary nature of the task (sitting at a computer) contributed to the null effects, but other seemingly sedentary tasks have found heart rate effects (e.g., Arena et al., 1983). At the very least, the results of this study suggest that heart rate may not be a construct valid measure of arousal across types of tasks.

Practical Applications

Two practical applications are evident from the results that may provide information for managers on how much of a workload to assign to new individuals and teams. For teams, if learning about the task is an important and desired outcome, managers would be advised to give teams low early workloads. This would allow the teams to take the extra time and cognitive resources needed for communicating information to each other that will enable them to learn about their task. The evidence from this study suggests that high workloads negatively affect teams in a lasting manner, such that they are not able to learn well even when their workload decreases. Starting with a low workload may be particularly critical for teams that have just formed, like the teams in this study. Previous research on entrainment in teams (Ancona & Chong, 1996) has suggested found that teams establish norms of communication that carry over and affect their future performance (Johnson et al. 2006; Moon et al., 2004). Thus, if newly formed teams start out with a high workload, they may develop communication norms that are inadequate for effective team learning.

For individuals who are working alone, however, the amount of workload a manager should assign depends upon the personality of the employee. Specifically, managers would be advised to ascertain the level of neuroticism of their employees prior to assigning new tasks. Employees that are low in neuroticism appear to be engaged by high workloads (as evidenced by their emotional arousal levels) and learn well due to the increased information available. Employees that are high in neuroticism, however, appear to disengage from the task and do not learn well when workload is high. For these employees, lower workloads may be advisable until they gain mastery on the task.

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APPENDIX

Table 1. Means and standard deviations.

		Teams		Individuals	
		M	*SD*	*M*	*SD*
	1. Workload	3.03	1.46	2.99	1.45
	2. Team structure	.51	.50	-	-
	3. Transactive learning	.53	.50	-	-
	4. Neuroticism	2.46	.29	2.55	.62
	5. Extraversion	3.70	.25	3.70	.57
Pregame	6. CMQ statements	2.89	.38	2.86	.79
	7. CMQ adjectives	2.67	.33	2.60	.69
	8. Heart rate	75.53	6.55	75.50	8.80
	9. Unknown tracks	1.06	.65	.93	.80
Game 1	10. NASA-TLX	3.05	.43	3.01	.76
	11. CMQ statements	3.50	.36	3.04	.90
	12. CMQ adjectives	3.38	.37	2.83	.93
	13. Heart rate	76.14	6.10	74.64	9.39
	14. Unknown tracks	2.44	1.05	2.23	1.44
	15. Speed	.00	.94	.00	.90
	16. Accuracy	.00	.83	.00	.85
Game 2	17. NASA-TLX	2.93	.45	2.92	.86
	18. CMQ statements	3.50	.39	2.94	.98
	19. CMQ adjectives	3.31	.39	2.87	.92
	20. Heart rate	75.15	5.87	73.71	9.47
	21. Unknown tracks	3.03	.88	2.80	1.43
	22. Speed	.00	.87	.00	.84
	23. Accuracy	.00	.85	.00	.79

Individual N = 82; team N = 91.

Table 2. Intercorrelations between experimental manipulations and pregame measures.

	1	2	3	4	5	6	7	8	9
1. Objective workload		–	–	-.08	-.03	-.02	-.04	.03	.02
2. Team structure	.01		–	–	–	–	–	–	–
3. Transactive learning	.02	-.06		–	–	–	–	–	–
4. Neuroticism	.29**	.02	.02		-.49**	.01	-.15	.21†	-.30*
5. Extraversion	-.25*	.12	.07	-.35**		.02	.16	.00	.15
6. Emotional arousal (statements)	-.12	-.10	-.02	.07	.24*		.71**	-.14	.11
7. Emotional arousal (adjectives)	-.19†	.05	-.04	.09	.16	.58**		-.17	.14
8. Heart rate	.03	.14	.17	.17	-.21†	.09	.14		-.10
9. Learning	.00	-.10	-.15	.01	.07	.04	-.12	-.03	

Individuals are above the diagonal; teams are below the diagonal. Individual N = 82; team N = 91.
* $p < .05$; ** $p < .01$; † $p < .10$

Table 3. Intercorrelations between Game 1 measures.

	10	11	12	13	14	15	16
10. Subjective workload		.27*	.36**	.11	-.09	-.19†	-.24*
11. Emotional arousal (statements)	.44**		.83**	.11	.21†	.05	.23*
12. Emotional arousal (adjectives)	.36**	.79**		.08	.21†	.07	.18
13. Heart rate	-.01	.12	.00		.08	.07	-.04
14. Learning	.11	.21*	.22*	-.05		.15	.40**
15. Speed	-.11	.06	.16	-.19†	.48**		.32**
16. Accuracy	.10	-.01	.10	-.06	.23*	.29**	

Individuals are above the diagonal; teams are below the diagonal. Individual N = 82; team N = 91.
* $p < .05$; ** $p < .01$; † $p < .10$

Table 4. Intercorrelations between Game 2 measures.

	19	20	21	22	23	24	25
17. Subjective workload		.35**	.39**	.04	-.20	-.07	-.19†
18. Emotional arousal (statements)	.40**		.87**	.17	.24†	.23*	.28*
19. Emotional arousal (adjectives)	.36**	.79**		.11	.29*	.12	.22†
20. Heart rate	.00	.17	-.01		-.04	.12	.12
21. Learning	.07	.29**	.29**	-.01		-.01	.46**
22. Speed	-.17	.03	.08	.00	.34**		.12
23. Accuracy	-.02	.19†	.28**	.05	.60**	.30**	

Individuals are above the diagonal; teams are below the diagonal. Individual N = 82; team N = 91.
* $p < .05$; ** $p < .01$; † $p < .10$

Table 5. Correlations between experimental manipulations, pregame measures, and Game 1 measures.

Pregame → / Game 1 ↓	Objective workload	Team structure	Transactive learning	Neurot-icism	Extra-version	Emot. arousal (stmts.)	Emot. arousal (adjs.)	Heart rate	Learning
Subjective workload	.34** (.08)	(-.06)	(.16)	.08 (.23*)	.06 (.19†)	.08 (.12)	.19† (.14)	.13 (-.01)	-.06 (.04)
Emotional arousal (stmts.)	.00 (-.05)	(.08)	(.12)	-.30** (.18†)	.18 (-.02)	.45** (.26*)	.40** (.21*)	-.01 (.11)	.32* (-.14)
Emotional arousal (adjs.)	-.07 (-.13)	(-.02)	(.19†)	-.25* (.07)	.09 (.01)	.40** (.13)	.52** (.21*)	-.03 (.02)	.31* (-.18)
Heart rate	-.03 (.04)	(.16)	(.14)	.14 (.18)	.04 (-.17)	-.12 (.13)	-.21 (.16)	.87** (.93**)	.10 (-.04)
Learning	-.04 (-.31**)	(.27*)	(.04)	-.27* (-.07)	.10 (.05)	-.04 (.05)	.00 (-.01)	-.15 (-.03)	.28† (.14)
Verbal comm.	(-.16)	(.18†)	(.01)	(-.13)	(.10)	(-.06)	(-.07)	(-.01)	(-.07)
Electronic comm.	(.34**)	(-.66**)	(.05)	(.02)	(-.20†)	(-.05)	(-.16)	(-.09)	(.00)
Speed	-.55** (-.81**)	(.13)	(-.09)	-.05 (-.30)	-.06 (.13)	-.18 (-.07)	-.05 (-.10)	.02 (-.20†)	.15 (.06)
Accuracy	-.27* (-.26*)	(-.45**)	(.09)	-.15 (-.05)	.01 (-.09)	.02 (-.07)	.12 (-.24)	-.10 (-.02)	.19 (.12)

Individual correlations are before the parentheses; team correlations are in the parentheses. Individual N = 82; team N = 91.
* $p < .05$; ** $p < .01$; † $p < .10$

Table 6. Correlations between experimental manipulations, pregame measures, and Game 2 measures.

Pregame → / Game 2 ↓	Objective workload	Team structure	Transactive learning	Neurot-icism	Extra-version	Emot. arousal (stmts.)	Emot. arousal (adjs.)	Heart rate	Learning
Subjective workload	.05 (-.28**)	(-.08)	(.11)	-.04 (.21*)	.14 (.25*)	.14 (.26*)	.23* (.30**)	.07 (-.04)	-.07 (-.02)
Emotional arousal (stmts.)	-.21† (-.25*)	(.03)	(.11)	-.15 (-.05)	.11 (.10)	.37** (.13)	.39** (.20†)	.03 (.20†)	.32* (-.06)
Emotional arousal (adjs.)	-.14 (-.21†)	(.00)	(.16)	-.23* (-.18)	.13 (.17)	.39** (.08)	.47** (.21*)	-.03 (.04)	.30* (.00)
Heart rate	-.04 (.04)	(.20†)	(.13)	.15 (.16)	-.01 (-.14)	-.07 (.12)	-.18 (.14)	.84** (.92**)	.07 (-.09)
Learning	-.10 (-.20†)	(.01)	(.04)	-.33** (-.12)	.25* (.01)	.08 (-.03)	.15 (-.06)	-.25† (-.01)	.23 (.23*)
Verbal comm.	(.13)	(-.15)	(.05)	(.04)	(.01)	(-.01)	(-.08)	(.13)	(-.18)
Electronic comm.	(.03)	(-.64**)	(.00)	(-.09)	(-.11)	(.00)	(-.13)	(-.21†)	(.00)
Speed	-.12 (.18)	(.31**)	(.01)	.02 (.00)	-.03 (-.16)	-.02 (-.23*)	.05 (-.18)	.05 (-.08)	.23 (.14)
Accuracy	-.05 (-.02)	(-.20†)	(.18†)	-.24* (-.04)	.22† (.07)	.18 (-.13)	.12 (-.18†)	-.08 (.01)	.27† (.20†)

Individual correlations are before the parentheses; team correlations are in the parentheses. Individual N = 82; team N = 91.
* $p < .05$; ** $p < .01$; † $p < .10$

Table 7. Correlations between Game 1 measures and Game 2 measures.

Game 2 ↓ / Game 1 →	Subjective workload	Emot. arousal (stmts.)	Emot. arousal (adjs.)	Heart rate	Learning	Verbal comm	Electronic comm	Speed	Accuracy
Subjective workload	.65** (.57**)	.25* (.31**)	.36** (.37**)	.09 (.01)	-.15 (.05)	(.00)	(-.06)	-.03 (.09)	-.19† (.14)
Emotional arousal (stmts.)	.23* (.17)	.80** (.62**)	.82** (.61**)	.16 (.16)	.19 (.14)	(.06)	(-.02)	.15 (.14)	.25* (.08)
Emotional arousal (adjs.)	.27* (.20†)	.72** (.49**)	.84** (.66**)	.11 (-.01)	.23† (.14)	(.19†)	(-.02)	.06 (.12)	.15 (.14)
Heart rate	.06 (-.08)	.09 (.11)	.09 (-.01)	.97** (.97**)	.11 (-.02)	(.11)	(-.16)	.06 (-.15)	-.02 (-.05)
Learning	-.14 (.14)	.23† (.22*)	.28* (.29**)	-.07 (-.02)	.65** (.67**)	(.23*)	(.05)	.00 (.31**)	.34** (.35**)
Verbal comm.	(-.09)	(.03)	(.09)	(.16)	(-.32**)	(.21*)	(.11)	(-.25*)	(.00)
Electronic comm.	(.09)	(.07)	(.15)	(-.23*)	(-.18†)	(.07)	(.79)	(.00)	(.36**)
Speed	.06 (.04)	.24* (.15)	.22† (.16)	.13 (-.01)	.16 (.33**)	(.33**)	(-.05)	.53** (.22*)	.23* (.13)
Accuracy	-.28* (.08)	.27* (.12)	.18 (.22*)	.08 (.04)	.48** (.35**)	(.24*)	(.11)	.07 (.12)	.61** (.44**)

Individual correlations are before the parentheses; team correlations are in the parentheses. Individual N = 82; team N = 91.
* $p < .05$; ** $p < .01$; † $p < .10$

Table 8. Repeated measures regression of proposed mediators on workload and time for individuals working alone in Game 1.

	CMQ statements		CMQ adjectives		Heart rate		Learning	
	Step 1	Step 2	Step 1	Step 2	Step 1	Step 2	Step 1	Step 2
Workload	-.01	-.03	-.05	.00	.00	.09	-.02	.06
Game	.10	.09	.14	.18	-.05	.01	.47**	.52**
Workload x game		.03		-.07		-.11		-.10
F	.88	.01	1.86	.06	.16	.13	15.04**	.08
ΔR^2	.01	.00	.02	.00	.00	.00	.22	.00

N = 82.
** $p < .01$ (two-tailed)

Table 9. Repeated measures regression of performance dimensions on workload and time for individuals working alone.

	Speed		Accuracy	
	Step 1	Step 2	Step 1	Step 2
Workload	-.34**	-1.03**	-.16*	-.51*
Time	.00	-.48**	.00	-.24
Workload x time		.86**		.43
F	10.14**	9.56**	2.08	2.11
ΔR^2	.12	.05	.03	.01

N = 82.
* $p < .05$ (two-tailed)
** $p < .01$ (two-tailed)

Table 10. Repeated measures regression of emotional arousal indicators on workload and game for teams in Game 1.

	CMQ statements			CMQ adjectives			Heart rate		
	Step 1	Step 2	Step 3	Step 1	Step 2	Step 3	Step 1	Step 2	Step 3
Game	.64**	.64**	.45**	.71**	.71**	.62**	.05	.05	.05
Workload		-.07	-.14		-.11†	-.14		.03	.01
Structure		-.01	-.23		.01	.07		.17†	.15
Transactive learning		.04	-.13		.06	-.18		.18*	.24
Workload x game			.10			.04			.03
Structure x game			.24			-.06			.02
Transactive learning x game			.18			.27			-.07
F	121.51**	.57	.87	184.52**	1.91	.90	.38	3.06†	.03
ΔR^2	.40	.01	.01	.51	.02	.01	.00	.06	.00

N = 91.
† $p < .10$ (two-tailed)
* $p < .05$ (two-tailed)
** $p < .01$ (two-tailed)

Table 11. Repeated measures regression of performance dimensions on workload and time for teams.

	Speed			Accuracy		
	Step 1	Step 2	Step 3	Step 1	Step 2	Step 3
Game	.00	.00	-1.19**	.00	.00	-.43*
Workload		-.32**	-1.87**		-.15*	-.53*
Structure		.21**	-.10		-.32**	-.71**
Transactive learning		-.02	-.07		.13	.00
Workload x game			1.95**			.47
Structure x game			.34			.42
Transactive learning x game			.07			.15
F	.00	10.06**	25.70**	.00	9.23**	2.18
ΔR^2	.00	.15	.27	.00	.14	.03

N = 91.
* $p < .05$ (two-tailed)
** $p < .01$ (two-tailed)

Table 12. Repeated measures regression of learning indicators on workload and game for teams in Game 1.

	Learning		
	Step 1	Step 2	Step 3
Game	.62**	.62**	.68**
Workload		-.15*	.29
Structure		.10	-.38
Transactive learning		-.01	-.24
Workload x game			-.56*
Structure x game			.53*
Transactive learning x game			.25
F	104.62**	3.15*	5.23**
ΔR^2	.38	.03	.05

N = 91.
* $p < .05$ (two-tailed)
** $p < .01$ (two-tailed)

Table 13. Moderated regression of Game 1 emotional arousal on workload and personality for individuals working alone.

	CMQ statements				CMQ adjectives				Heart rate			
	Step 1	Step 2	Step 3	Step 4	Step 1	Step 2	Step 3	Step 4	Step 1	Step 2	Step 3	Step 4
Pregame levels	.45**	.45**	.46**	.42**	.52**	.52**	.50**	.45**	.87**	.88**	.89**	.88**
Workload		.01	-.02	3.06**		-.04	-.06	2.90*		-.06	-.06	-.43
Extraversion			.02	.69*			-.10	.52			.02	-.04
Neuroticism			-.29*	.21			-.23*	.28			-.04	-.84
Workload x extraversion				-2.22*				-2.07*				.37
Workload x neuroticism				-1.06*				-1.10*				.63
F	2.80**	.00	4.98**	3.97*	29.55**	.20	2.17	3.71*	23.89**	.98	.50	.20
ΔR^2	.21	.00	.09	.07	.27	.00	.04	.06	.76	.00	.00	.00

N = 82.
* $p < .05$ (two-tailed)
** $p < .01$ (two-tailed)

Table 14. Moderated regression of Game 1 emotional arousal on workload and personality for teams.

	CMQ statements				CMQ adjectives				Heart rate			
	Step 1	Step 2	Step 3	Step 4	Step 1	Step 2	Step 3	Step 4	Step 1	Step 2	Step 3	Step 4
Pregame levels	.26*	.26*	.25*	.29**	.21*	.19	.18	.22	.93**	.93**	.94**	.94**
Workload		-.02	-.08	2.54		-.09	-.13	2.14		.02	.02	-.16
Extraversion			-.04	.08			-.02	.11			.04	.06
Neuroticism			.17	.65*			.08	.46			.03	-.05
Workload x extraversion				-.77				-.80				-.12
Workload x neuroticism				-2.02				-1.59				.34
F	6.49*	.04	1.56	1.82	4.07*	.79	.36	1.06	525.89**	.16	.58	.40
ΔR^2	.07	.00	.03	.04	.04	.01	.01	.02	.87	.00	.00	.00

N = 82.
* $p < .05$ (two-tailed)
** $p < .01$ (two-tailed)

Table 15. Moderated regression of Game 1 learning on workload and personality for individuals working alone.

	Learning		
	Step 1	Step 2	Step 3
Workload	-.04	-.05	.83
Extraversion		-.04	-.10
Neuroticism		-.29*	.35
Workload x extraversion			.25
Workload x neuroticism			-1.30*
F	.09	2.43	2.88
ΔR^2	.00	.07	.08

N = 82.
* $p < .05$ (two-tailed)

Table 16. Moderated regression of Game 1 learning on workload and personality for teams.

	Learning		
	Step 1	Step 2	Step 3
Workload	-.31**	-.32**	.76
Extraversion		-.02	.04
Neuroticism		.01	.19
Workload x extraversion			-.39
Workload x neuroticism			-.75
F	9.51**	.04	.26
ΔR^2	.10	.00	.01

N = 91.
** $p < .01$ (two-tailed)

Table 17. Moderated regression of emotional arousal indicators on manipulations for teams.

	CMQ statements				CMQ adjectives				Heart rate			
	Step 1	Step 2	Step 3	Step 4	Step 1	Step 2	Step 3	Step 4	Step 1	Step 2	Step 3	Step 4
Pregame levels	.26*	.27**	.27*	.27**	.21*	.20	.20	.20	.93**	.93**	.94**	.94**
Workload		-.02	-.05	.27		-.10	-.10	.18		.02	-.04	-.03
Structure		.12	-.02	.58		-.02	-.22	.30		.04	-.09	-.08
Transactive learning		.13	.47	1.05**		.20	.40	.91**		-.01	-.06	-.04
Workload x structure			.32	-.42			.26	-.40			.11	.10
Workload x transactive learning			-.26	-.99**			-.24	-.88*			.01	.00
Structure x transactive learning			-.22	- 1.19**			-.01	-.87*			.05	.04
Workload x structure x transactive learning				1.14**				1.00*				.02
F	6.49*	.90	1.33	7.35**	4.07*	1.53	.60	5.41*	525.8 9**	.37	.52	.01
ΔR^2	.07	.03	.04	.07	.04	.05	.02	.06	.87	.00	.00	.00

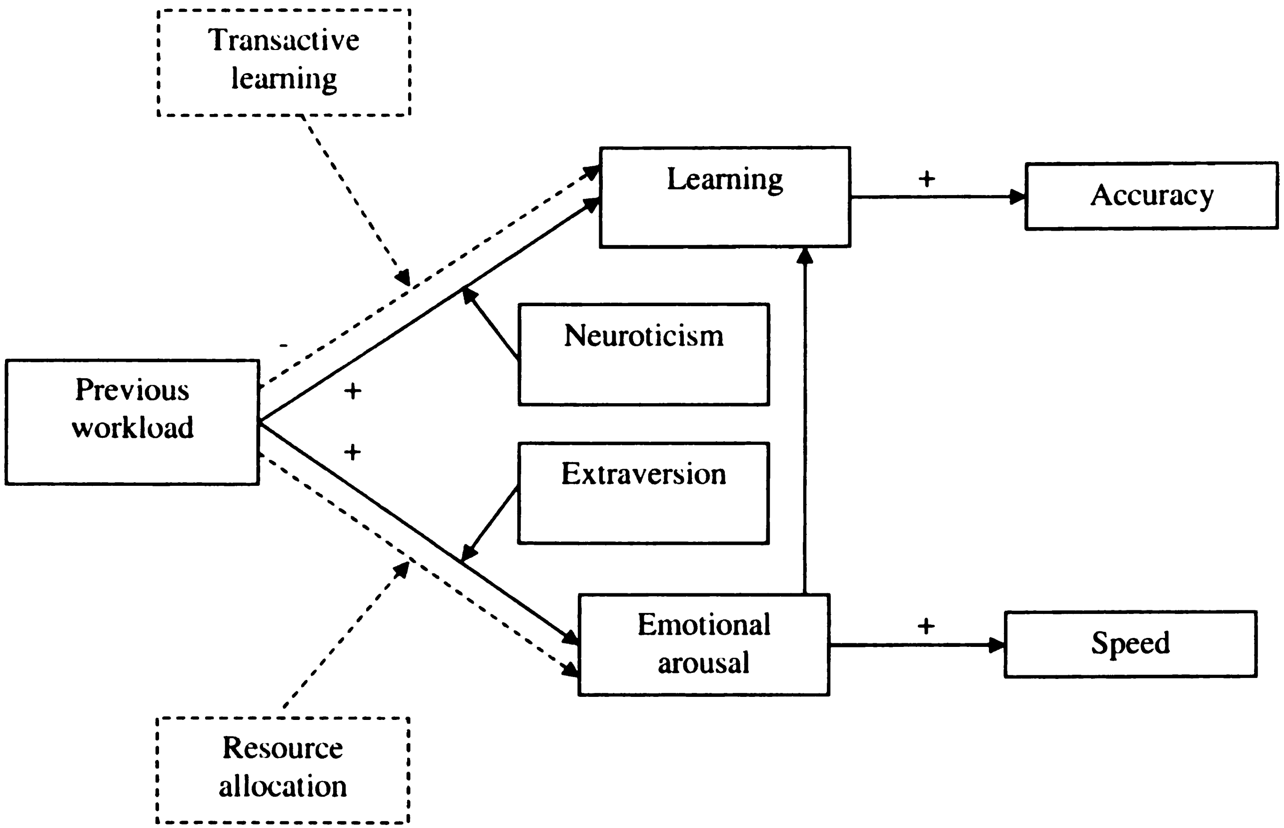
N = 91.
* $p < .05$ (two-tailed)
** $p < .01$ (two-tailed)

Table 18. Moderated regression of learning indicators on manipulations for teams.

	Learning		
	Step 1	Step 2	Step 3
Workload	-.31**	-.34**	-.39†
Structure	.27**	.09	-.01
Transactive learning	.06	.07	.01
Workload x structure		.17	.30
Workload x transactive learning		-.11	.00
Structure x transactive learning		.07	.23
Workload x structure x transactive learning			-.19
F	5.93**	.29	.19
ΔR^2	.17	.01	.00

N = 91.
† $p < .10$ (two-tailed)
** $p < .01$ (two-tailed)

Figure 1. Hypothesized model.



Dashed lines indicate constructs and relationships only hypothesized at the team level.

Figure 2. Interactive effects of workload and time on speed of performance.

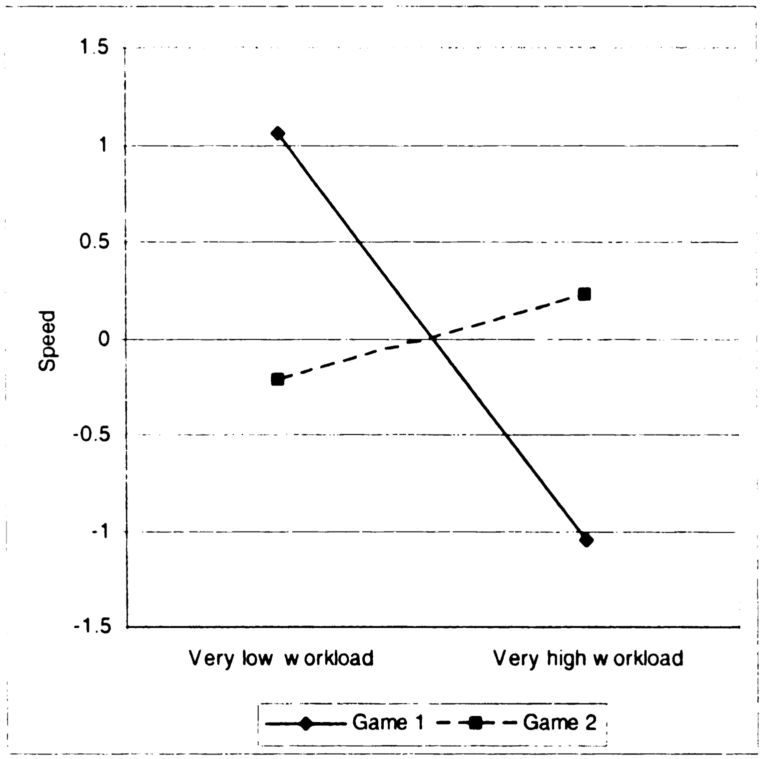
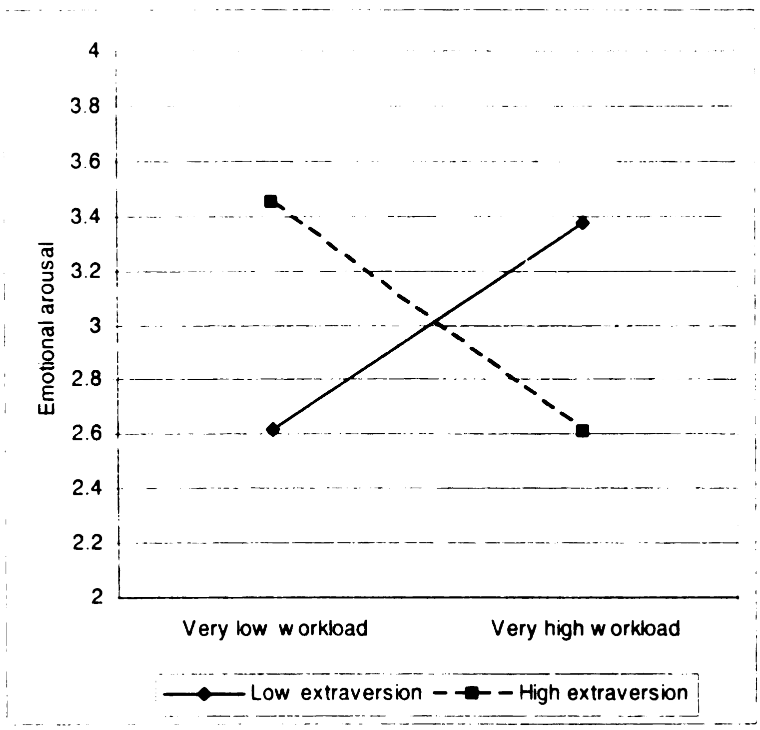
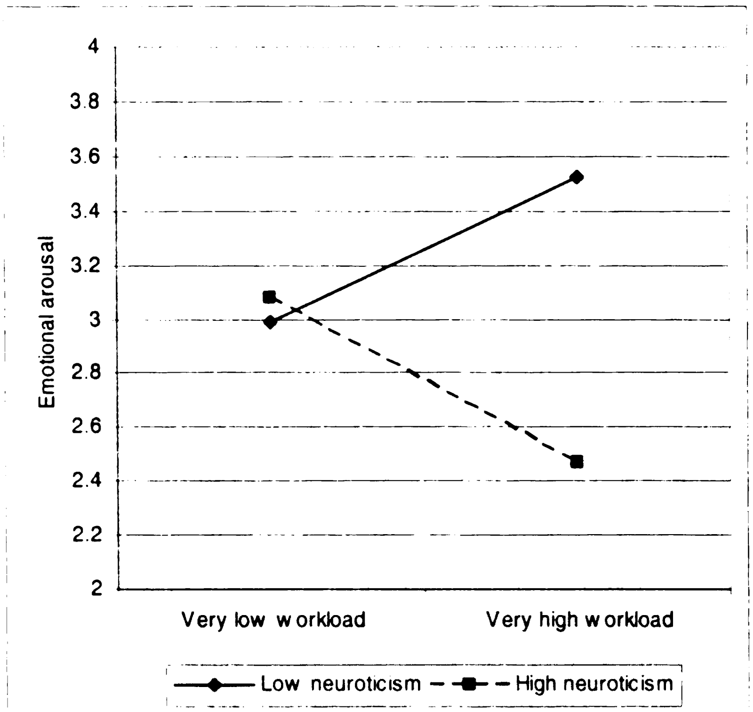


Figure 3. Interactive effects of workload and Extraversion on individual emotional arousal.



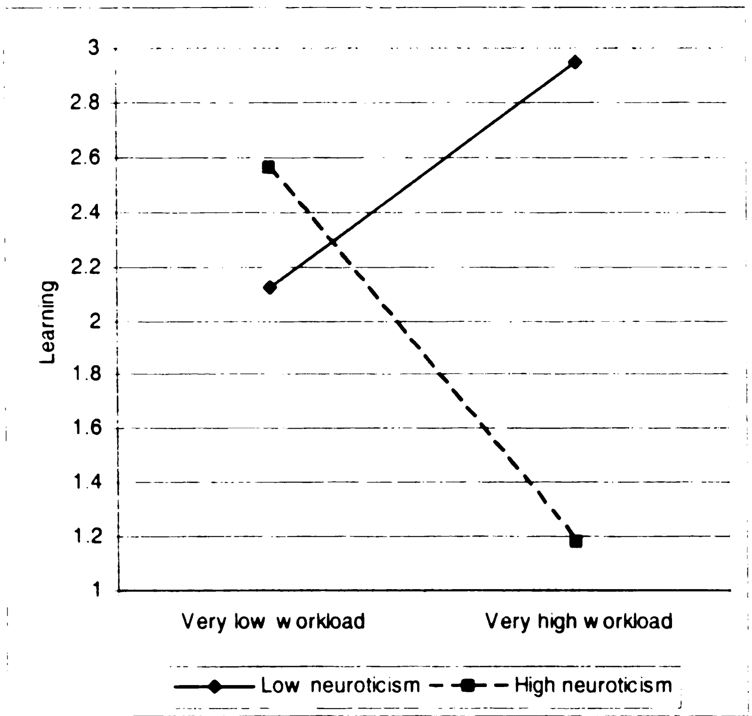
Extraversion is plotted 1 SD above and below the mean.

Figure 4. Interactive effects of workload and Neuroticism on individual emotional arousal.



Neuroticism is plotted 1 SD above and below the mean.

Figure 5. Interactive effects of workload and Neuroticism on individual learning.



Neuroticism is plotted 1 SD above and below the mean.

Figure 6. Interaction of workload and type of track on friendly fire kills in teams.

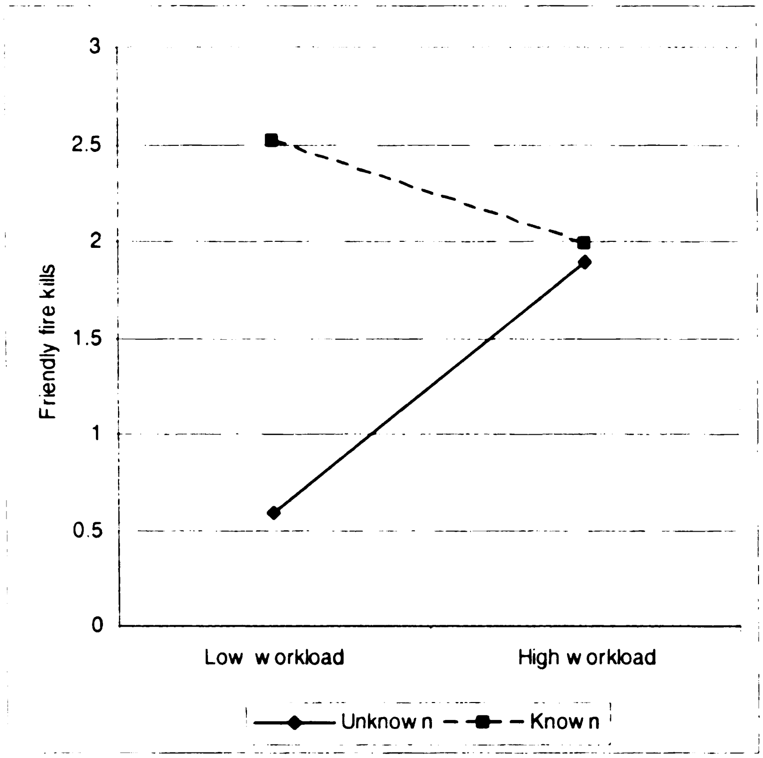


Figure 7. Interaction of workload and type of track on good attacks in teams.

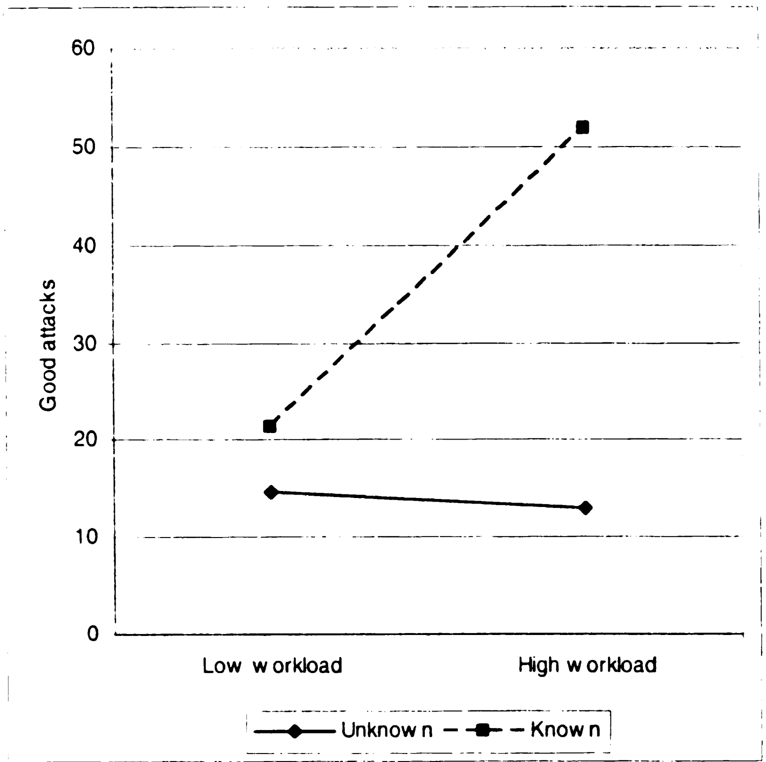


Figure 8. Post-hoc team model.