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American and Chinese Personality Traits and Task Load in Simulated Flight Crews: Individual and Team Level Effects

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AMERICAN AND CHINESE PERSONALITY TRAITS AND TASK LOAD IN SIMULATED FLIGHT CREWS: INDIVIDUAL AND TEAM LEVEL EFFECTS

by

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ABSTRACT

AMERICAN AND CHINESE PERSONALITY TRAITS AND TASK LOAD IN SIMULATED FLIGHT CREWS: INDIVIDUAL AND TEAM LEVEL EFFECTS

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Understanding the impact of pilot interpersonal dynamics may be crucial for flight team success as well as the prevention of air crash disasters. Achieving optimum performance from flight teams requires limiting unnecessary pilot task load. This study examined American and Chinese simulated flight crews. Factors believed to affect cockpit interpersonal dynamics and subsequent crew task loads were pilot personality and nationality. Pilot personality, team personality elevation, team personality variability, and team nationality were analyzed for their potential impact on task load perceptions. Twenty-four American, 23 Chinese, and 23 mixed nationality two person teams were created and used for comparisons. Increasing level of openness to experience was found to significantly decrease pilot perceptions of task load at the individual level of analysis. American teams were found to experience significantly overall lower task load perceptions than Chinese teams. These findings may have implications for training and safety protocol for pilots. Limitations of this study and suggestions for future research are discussed.

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INTRODUCTION

Seldom does failure have such serious consequences as in aviation. Optimum performance is vital, and the risks pilots take can be tremendous. Technical knowledge and skills have been shown to be insufficient for guaranteeing effective flight team performance (Kanki, 1992). Because flight is inherently complex and demanding, increasing pilot demands or task load can be expected to decrease pilot proficiency. Achieving optimum performance from flight crews requires limiting unnecessary pilot task load.

Numerous factors affect pilot task load, but those directly related to the cockpit interpersonal environment are especially important. Personality may be one factor that affects pilots' perceptions of task load as well as flight crew dynamics. Additionally, as pilots and copilots may be from different countries, pilot nationality may also affect perceptions of task load. Understanding the impact of these factors may be crucial for flight team success as well as the prevention of aircraft accidents.

The research discussed here examined the influence of personality and nationality on perceptions of task load in American and Chinese simulated flight crews. Simulated flight crews faced a demanding and complex flight scenario that required them to work together as a team.

Task load

Task load is a subjective interpretation of many factors that combine to create an overall impression for the individual about a task experience. Coordination, motivation, communication, and training can all affect perceptions of task load, indicating that

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perceived task load is a consequence of the cognitive resources necessary for a task (Bowers, Braun, & Morgan, 1997). Human abilities are limited, and high levels of task load usually reduce performance (Urban, Bowers, Monday, & Morgan, 1995). Similarly, too little perceived task load may be related to boredom and equally as undesirable. This relationship conforms to the Yerkes-Dodson Law, which states that moderate arousal levels produce better performance than extremely high or low levels (Bowles, Ursin, & Picano, 2000). The interests of this study focus on the demanding side of this spectrum.

Although task load is commonly thought of as the amount of cognitive processing exerted during a task (Eggemeier, 1988), a complete conceptualization of task load must include more than mental demands. Task load also includes emotional demands, physical challenges, and stress levels an individual experiences while performing some task (Bowles et al., 2000). Born out of reactions like frustration or attitudes towards effort, these factors and the interpretation of these factors vary across people and time (Hart & Staveland, 1988).

Approximately 70 - 80% of commercial aviation accidents are the result of flight crew actions (Helmreich & Foushee, 1993; McFadden, 2002; Wiegmann & Shappell, 2001), suggesting that these teams experienced significant stressful task load challenges. Pilots may encounter numerous stressors during flight (Merritt & Helmreich, 1996). These stressors may become problematic when operational demands surpass the ability of pilots to cope physically or mentally with them (Bowles et al., 2000). Because flying consists of multiple tasks that must be coordinated, pilots must allocate their attention to a wide variety of duties, which can increase the number of stressors and heighten perceptions of task load (Mosier, Skitka, & Korte, 1994). Not surprisingly, piloting is one of the most stressful occupations (Bowles et al., 2000), and advances in flight automation have not removed all sources of stress (Billings, 1997).

Measuring Task Load

Evaluating flight crew task load may lead to insight for increasing performance and safety. For this study, the NASA-Task Load Index was used to evaluate flight crew task load. The TLX examines the experiences people have during diverse task circumstances (Hart & Staveland, 1988). Because a task involves the exertion of effort (task load) towards a goal, the study of this effort can be more important than the achievement of the goal itself; often more can be gained by examining the process than the outcome of an action. The ability to apply this measurement tool in comparing task load across a variety of situations and conditions, as well its ability to take into account both physical and mental evaluations, makes the TLX a very useful tool. A number of studies have looked at components of flight using the TLX (e.g., Bowles et al., 2000; Lee & Liu, 2003; Muller, Giesa, & Anders, 2001; Prinzell, Freeman, & Prinzel, 2005; Sohn & Jo, 2003).

The TLX score is derived from two general domains: (1) those that are related to the demands faced by the individual and (2) those that are related to interaction of an individual and the task. Three factors that are used to assess demands faced by the individual are mental demand, physical demand, and temporal demand. Three factors that are used to assess the interaction between individual and task are effort, performance evaluation and frustration level (Hart & Staveland, 1988).

Mental demand refers to the individual's perceptions of required exertion for deciding, remembering, or calculating (see Table 1). Physical demand pertains to how strenuous the activity is. Temporal demand concerns individual's feelings about being pressured for time. Effort is the personal evaluation of both mental and physical exertion considered necessary. Performance evaluation applies to an individual's assessment of

Table 1

NASA Task Load Index

TLX Factor	Description	Example of High Score
Demands of the Individual		
1) Mental Demand	individual's perceptions of the intellectual difficulty, complexity, and arduousness of the task	calculating a complex math problem
2) Physical Demand	amount of raw physical activity necessary	pushing and pulling several levers simultaneously
3) Temporal Demand	individual's feelings about pace of the task or felt pressure	working rapidly and outside of a comfort zone
Demands of the Interaction of The Individual and Task		
1) Effort	personal evaluation of both mental and physical exertion	having to work very hard to accomplish a task
2) Performance Evaluation	assessment of success in accomplishing task goals	being very successful in accomplishing goals
3) Frustration Level	self reports of insecurity, irritation, or stress	being irritated and annoyed

personal achievement of these goals. Frustration level represents insecurity, irritation, stress, and lack of gratification. All of the factors are evaluated from low to high except for performance evaluation, which looks at individual perspectives on success in terms of good to bad. Taken together they provide a more detailed assessment of task load than measuring perceptions of global task load (Hart & Staveland, 1988). Tasks for flight crews often require coordination with other crew members and thus require assessment of team task load as well as perceptions of task load at the individual level of analysis.

Teams and Team Task Load

A team consists of at least two individuals who engage in different tasks yet interact interdependently and adaptively in order to achieve a specific and shared goal (Brannick & Prince, 1997; Brannick, Roach, & Salas, 1993). Teamwork, the interaction of these individuals, refers to more than simply individuals coming together to accomplish their shared task. It refers to the process of interpersonal interactions required for achievement of some goal. This can include actions such as coordinating efforts, maintaining order, or communicating effectively and efficiently (Bowers, 1997; Liu, 2006; Prince, Ellis, Brannick, & Salas, 2007).

Teams play a central and increasing role in organizations because they contribute to organizational success (Bowers et al., 1998; Brannick & Prince, 1997). As a result of their effectiveness and versatility, teams are often used to perform intricate, taxing, and hazardous tasks, especially in military units and flight crews (Brannick & Prince, 1997; Cannon-Bower & Salas, 1998). Flight crews operate as a team in the cockpit.

Highly complex tasks and work environments require the division of responsibilities among team members (Urban et al., 1995). As a result, research often studies team process, team functioning, and team member performance rather than overall task outcomes (Brannick & Prince, 1997; Liu, 2006). Team process includes numerous factors. Liu (2006) created a summary of the many team process variables: giving/seeking feedback, monitoring, backup behaviors, communications, leadership, decision-making, adaptability, assertiveness, situational awareness, mission analysis, conflict resolution, team building, task load management, operational integrity, shared mental model, coordination, and team orientation. Specifically for aviation, Brannick and Prince (1997) identified key team process dimensions including communication, leadership, decision making, adaptability, assertiveness, situation awareness, and planning.

Team task load. Urban et al. (1995) found that teams with less hierarchical structures have less perceived task load. The findings of this study are important because the interdependence of team members moves the construct of task load from operating at the individual level of analysis to the team level of analysis. Working in a team requires additional effort beyond pursuing individual task goals. Engaging in additional tasks increases demands on limited cognitive resources (Pannebakker, Band, & Ridderinkhof, 2009). As such, even just two person teams may experience a higher task load than an individual engaging in the same task as a result of the added effort required to coordinate interdependent tasks among team members. Although team task load is a critical variable for team performance, little research has studied the relationship between individual and team task load. Because performance worsens as task load increases and task load is expected to increase within the team environment, a concern for team performance necessitates the use of task load analysis (Bowers et al., 1997; Brannick & Prince, 1997; Cannon-Bower, & Salas, 1997; Urban et al., 1995).

Flight crews are a two person team of particular importance, and they are the focus of the present study. As flight crews engage in challenging work where performance and safety are highly related, it is important to understand team task load. Team task load may be understood by examining flight team process and important factors that may affect that process, such as personality and nationality.

Personality

Teams can be comprised of members that share similar or different qualities. Milliken and Martins (1996) identified the different ways in which teams can be diverse: race, gender, ethnicity, age, skills, knowledge, cognitive processes, experience, and values. Although teams can vary in their heterogeneity, individuals tend to be happier, experience greater fit, and perform better when their dispositions align with team demands (Diener, Larsen, & Emmons, 1984; O'Reilly, Chatman, & Caldwell, 1991). When teams initially form, observable traits such as ethnicity are immediately apparent, whereas non-observable traits such as values become more significant over time (Staples & Zhao, 2006). One important way in which individuals can vary is in personality. Personality is "a set of relatively enduring behavioral and cognitive characteristics, traits, or predispositions that people take with them to different situations, contexts, and interactions with others, and that contribute to differences among individuals" (Matsumoto & Juang, 2004, p. 320). McCrae & Costa (1997) assert that the best framework for analyzing personality traits is the Five Factor Model (FFM) of personality.

In the FFM, personality traits are stable dispositions of individuals that have a biological basis and interact with life experiences. Traits are believed to be stable over time and unaffected by environmental factors (Hofstede & McCrae, 2004; Mooradian & Swan, 2006). First suggested by Thurstone (1934), the existence of five overarching personality traits was accurately identified by Norman (1963). McCrae and Costa (1985) developed and then refined what became the Revised NEO Personality Inventory (NEO-PI-R) to assess the FFM. This inventory has become the most researched and widely used measure used to assess personality. It uses six facets to analyze each of the five personality factors and eight items to assess each facet. The FFM has been positively related to job performance (Barrick & Mount, 1991), memory and learning skills (Matthews, 1999), effective personnel selection (De Fruyt & Mervielde, 1999), and team performance (Peeters, Van Tuijl, Rutte, & Reymen, 2006).

The FFM breaks personality into the following five factors: openness to experience or intellect, imagination, or culture (O), conscientiousness or will to achieve (C), extroversion or surgency (E), agreeableness versus antagonism (A), and neuroticism versus emotional stability (N) (McCrae & Costa, 1997). Openness to experience refers to the degree a person is imaginative and curious. Conscientiousness refers to the degree a person is self-disciplined and dutiful. Extroversion refers to the degree a person is social and seeks stimulation. Agreeableness refers to the degree a person is cooperative and compassionate. Neuroticism refers to the degree to which a person is anxious or emotionally unstable.

There has been wide support for the FFM across time and situations (e.g., Goldberg, 1993; Hofstede & McCrae, 2004; McCrae & Costa, 1996; O'Connor, 2002;

Ostendorf & Angleitner, 1992; Peeters, Van Tuijl, Rutte, & Reymen, 2006; Robertson & Callinan, 1998; Wiggins & Trapnell, 1997). The FFM has been shown to be consistent across samples, cultures, and ages (Albright, Malloy, Dong, Kenny, Fang, Winquist, & Yu, 1997; Hofstede & McCrae, 2004; Mastor, Jin, & Cooper, 2000; Mooradian & Swan, 2006). Relevant to this research, the FFM has been validated among Chinese people (McCrae, Costa, & Yik, 1996; Trull & Geary, 1997).

Matsumoto and Juang (2004) state that the development of personality traits is influenced both by biological predisposition and socialization in one's culture. The two assertions that the FFM can be applied to various cultures and that cultures, overall, differ in personality profiles, are not mutually exclusive statements. "Cultures studied are similar in that they share the same personality dimensions, even though they differ in where they fall along these dimensions [...] In most cases, the degree of individual variation is many times larger than the degree of difference between cultures" (Matsumoto & Juang, p. 327-8). Also, selective migration, reverse causation (Hofstede & McCrae, 2004), or large circles of heredity may be responsible for why certain groups of people differ from others in personality.

The FFM is a useful and universal structure for examining personality traits, but there is a wide range of variability across and within nations and cultures. These personality differences are expected to influence intercultural interactions. The implications of these personality interactions are particularly important to the work of teams.

Personality and teamwork. Driskell, Goodwin, Salas, and O'Shea (2006) reviewed the role of personality in teams and state that effective teamwork should result from team members who have higher openness to experience, conscientiousness, extroversion, and agreeableness but lower neuroticism. Driskell et al. make the case that, even if the entire factor is not helpful to teamwork, there are facets of the factor that may be important. An example might be the facet of dependability in the conscientiousness factor. Driskell et al. (p. 264) state that "Higher-level traits of emotional stability, extroversion, openness, agreeableness, and conscientiousness have all been related to team effectiveness at a broad level" (cf. Barrick, Stewart, Neubert, & Mount, 1998; Barry & Stewart, 1997; Hollenbeck et al., 2002; LePine, Hollenbeck, & Hedlund, 1997; Neuman & Wright, 1999). Higher levels of each factor (except for neuroticism) should be related to performance, and higher performance is usually associated with lower perceptions of task load.

According to Peeters et al. (2006), studying personality within teams consists of two aspects: trait elevation (mean level of trait) and trait variability. Elevation is the intensity of a trait. Variability is the extent to which a trait varies within a team. Peeters et al. (2006) conducted a meta-analysis of the effects of personality factors on team performance. They found that only elevation and variability of agreeableness and conscientiousness were found to have significant influences on team performance. These findings may have differed from those of Driskell et al. (2006) because of differences in the criterion used across the various studies for determining team success, the types of tasks evaluated, the team structures, participants, and measures used. Peeters et al. (2006) described the desirability of certain trait levels in teams. Each of the five personality factors from the FFM will be discussed individually in terms of predictions and findings reported by Peeters et al. (2006).

Peeters et al. (2006) predicted that elevation of openness would be positively related to team performance and that variability would not be related. The creativity and broadmindedness of team members who were high in openness were expected to enhance team members' abilities to expand ideas and innovatively solve problems (LePine, 2003). Peeters et al. did not find evidence to support these hypotheses. The non-significant findings of Peeters et al. are probably a result of mixing positive (Neuman, Wagner, & Christiansen, 1999) and negative (Van Vianen & De Dreu, 2001) influences of the same trait that cancel each other out. There are most likely conditional features of tasks and teams that determine the impact of a member's openness on team performance.

It was predicted that elevation of conscientiousness would be positively related to team performance, and that variability would be negatively related. The hardworking and organized nature of team members who are high in conscientiousness was expected to be beneficial to task commitment (Barry & Stewart, 1997). Both hypotheses were supported. It is important to also note that Lepine (2003) found that high conscientiousness was related to worse performance, most likely because of hyper-focus on specific activities that detracted from overall task completion.

Peeters et al. (2006) predicted that elevation of extroversion would not be related to team performance because of mixed results from prior studies and that variability would be positively related. The dominant and positive nature of extroversion was expected to be beneficial to some extent, but findings showed no effect for either elevation or variability.

Peeters et al. (2006) predicted that elevation of agreeableness would be positively related to team performance; variability was expected to be negatively related. The friendly and altruistic manner of highly agreeable team members was expected to smooth conflict and open communication. Both hypotheses were supported by the meta-analysis.

Finally, Peeters et al. (2006) predicted that elevation of neuroticism would be negatively related to team performance and that variability would not be related. The relaxed and stable environment created by those low in neuroticism was expected to be related to positive team work performance. Additionally, it was assumed that the presence of even one emotionally unstable individual would have a significant impact on team performance. Meta-analytic findings did not support either hypothesis.

Although the findings of Peeters et al. (2006) suggest that any focus on perceptions of teamwork and personality should be limited to discussing conscientiousness and agreeableness, their review focused on team performance and did not examine team task load. Even though conclusive findings for the effects of team personality may not have been found for the context-relevant dependent variables of performance, personality variables may have direct effects on perceptions of task load. Said another way, the same personality-affecting-team-actions assumptions could be applied to other non-performance specific components of individual processes, such as perceptions of task load. Integrating the logic and findings of Peeters et al. (2006) and Driskell et al. (2006), predictions about the impact of personality on perceptions of team task load suggest the following hypotheses at the individual level of analysis:

H1: Openness will be negatively correlated to perceptions of task load.

H2: Conscientiousness will be negatively correlated to perceptions of task load.

H3: Extroversion will be negatively correlated to perceptions of task load.

H4: Agreeableness will be negatively correlated to perceptions of task load.

H5: Neuroticism will be positively correlated to perceptions of task load.

Hypotheses one through five assess the effects of individual personality traits on perceptions of task load. These effects are believed to occur independently of any personality influences other team members might exert on perceptions of task load. A multilevel analysis can examine both the individual and team level influences of factors. As will be shown in further detail later, this study employed a multi-level analysis approach. Since this type of analysis is also able to assess the impact of team members on individual processes, additional hypotheses represent this level of team influence. The following discussion provides a rationale for team level hypotheses.

Bowles et al. (2000) found that flight crews led by those who were active, warm, confident, competitive, and preferred challenges reported lower stress levels. They also found that high performing crews experienced less stress than low or moderately performing crews. Sohn and Jo (2003), using a Korean sample, found that concrete, realistic, and mechanically inclined individuals worked best together but not as well with other types. Also, those who were passionate, had a strong sense of responsibility, and tended to overlook details worked best with those who were creative, self-supported, and persistent. It was found that greater similarity between personality types reduces pilot perceived task load; more agreement between team member personalities is better.

Peeters et al. (2006) also commented on team homogeneity. Note that in the context of the present study, trait variability refers to how different members of a two person flight crew are from one another for a particular personality factor. Trait elevation refers to a particular individual or team score differing from overall mean personality trait scores. Peeters et al. found variability in conscientiousness and agreeableness to be negatively related to team performance. Performance is related to lower task load and vice versa. Similar traits should relate to similar task perceptions. Similar task perceptions should limit perceptions of task load. This indicates that variability would be positively related to task load.

An individual particularly high or low on a personality trait is likely to have a teammate that is closer to the average in trait elevation because of regression to the mean and the lesser probability that both individuals will be high on the trait. Success in some tasks may require only one individual to be highly conscientious or agreeable. Similarly, a team with even one individual with low conscientiousness or agreeableness would be expected to exhibit lower performance. Variability in both situations could be equal. One can infer from these findings that it may not only be the variability in conscientiousness or agreeableness that affects performance. The presence of individual team members having low levels of these traits may also influence team performance. This would indicate that one crew member low in these traits will experience increased perceptions of task load and, as a result, may hinder performance of other flight crew members and the team itself.

Peeters et al. (2006) predicted variability in openness would not be related to team performance. Although not affecting team performance, variability in team openness may still affect perceptions of task load. An individual very open to experience can be expected to be creative or highly adaptive, and, conversely, the less open an individual, the more rigid they appear. Teamwork can be expected to require creative solutions from team members. Team members with rigid perspectives would not be expected to help this process, and hindering teamwork would be expected to increase perceptions of task load. Thus, variability in openness should be positively related with perceptions of task load.

It was hypothesized by Peeters et al. (2006) that variability in neuroticism would have no effect on team performance, although the authors acknowledged that previous studies had mixed results. They predicted that a team with even one member who was high in neuroticism would have difficulty accomplishing its tasks because of this person's instability. Although findings were inconclusive for team performance, the presence of a highly unstable team member may still noticeably impact perceptions of task load. A highly neurotic individual may not significantly affect performance levels, but he or she may make an environment more taxing. Thus at the team level we expected to find that,

H6: Perceptions of task load would be lower the less varied and more elevated a team is for openness.

H7: Perceptions of task load will be lower the less varied and more elevated a team is for conscientiousness.

H8: Perceptions of task load will be lower the less varied and more elevated a team is for extroversion.

H9: Perceptions of task load will be lower the less varied and more elevated a team is for agreeableness.

H10: Perceptions of task load will be higher the more varied or more elevated a team is in neuroticism.

Nationality

Another way that teams can be heterogeneous is in the nationality of its members. National differences have been shown to affect approaches towards various aspects of teamwork (Salk & Brannen, 2000). Two national groups of particular importance to this study are American and Chinese.

Americans and Chinese differ in relation to teamwork on several dimensions. Americans and Chinese focus on different aspects of information, and Americans are more likely than Chinese to provide responses when prompted (Moore, 1998). Americans and Chinese also differ in cognitive factors such as field dependence and perceptions of control (Nisbett, Ji, & Peng, 2000) and recall interpretations of unobservable behaviors (Ji, Schwarz, & Nisbett, 2000), as well as aspects of teamwork, such as the impact of *guanxi*, a Chinese value describing the dynamism and importance of personalized relationship networks (Liu, 2006). These differences may be due to cultural values for power distance, individualism/collectivism, masculinity/femininity, and/or uncertainty avoidance (Hofstede, 1980). Although these cultural factors may influence team performance, they were not examined in my research.

Coordination and communication have been demonstrated to influence teamwork (Brannick & Prince, 1997; Liu, 2006). It has been shown that American and Chinese teams differ in their teamwork interactions, which contribute to possible challenges to coordination and communication (Moore, 1998). Subsequently, increases in communication uncertainty resulting from differing cultural perspectives may increase task load perceptions. The presence of these differences supports the idea that Americans and Chinese cockpit teams should have more difficulty working in mixed nationality teams than in single nationality teams. These challenges may come as a result of mismatches in communication styles and preferences. Thus,

> H11: Flight teams with members sharing the same national origin (culturally homogeneous teams, China or the USA) were expected to exhibit lower task load perceptions than flight teams comprised of members from both China and the USA (culturally heterogeneous teams).

The cockpit is host for many problematic communication interactions (Milanovich, Driskell, Stout, & Salas, 1998). As previously stated, although teamwork includes many behaviors, its primary focus is on coordination and communication (Brannick & Prince, 1997; Liu, 2006). Chinese teams favor clear hierarchical lines in interactions between team members (Conyne, Wilson, Tang, & Shi, 1999). Conversely, Anglo pilots believe in egalitarian discussion more than non-Anglo pilots (Helmreich & Merritt, 1998). These cultural differences may influence how American and Chinese subjects interact when serving as members of a flight crew since flying is a hierarchical task where the pilot is in a clearly superior position. As a result, cultural influences on Chinese teams may cause homogenous Chinese teams to have more communication difficulties than American teams. These communication difficulties should influence task load perceptions. These expected differences lead to the following hypothesis,

> H12: Homogeneous American flight teams were expected to exhibit lower task load perceptions than homogeneous Chinese flight teams.

METHOD

Participants and Procedure

This study was a secondary analysis of data gathered as part of a research project conducted for the National Aeronautics and Space Administration – Langley Research Center. This research is further described in Davis, Bryant, Tedrow, Liu, Selgrade, and Downey (2005). Participants were male undergraduate and graduate students from Old Dominion University, Eastern Virginia Medical School, and The College of William and Mary. There were 70 American participants from the United States and 70 Chinese participants from the People's Republic of China, Hong Kong, and Taiwan. Chinese participants averaged 7.9 years speaking English, spent an average of 2.26 years in the United States, and averaged 568.16, out of a possible 677, for the Test of English as a Foreign Language (TOEFL). Demographic information revealed that American participants had significantly more experience with simulation type activities $t(189) = 2.96, p < .05$.

All participants were at least 18 years of age. The total sample used in this secondary analysis consisted of 140 individuals assigned to 70 teams. In multilevel methodologies, the number of cases at the highest level offers the most statistical power, and the use of 70 teams exceeds or is on par with other research that has used hierarchical linear modeling. Compromise power analyses for ANCOVAs of one and two predictors, which are the design used in this study, show that a sample of 70 teams exceed 80% power for finding medium size effects.

Single and mixed culture two-person teams were created after individuals completed a flight training program and individual differences questionnaires. Each participant was trained to fly Microsoft Flight Simulator 2000 and had to pass a flight proficiency test before being assigned to teams. For each team the roles of pilot and copilot were randomly assigned. For the mixed-nationality teams, this process was counterbalanced to ensure that half of the teams had an American pilot and the other half a Chinese pilot. Twenty-four American only, 23 Chinese only, and a unique set of 23 mixed nationality teams were created and used for cross-cultural comparisons. These teams then completed a simulated flight scenario. This simulation included air-traffic control (ATC) communications as well as an engaging, demanding, and time-sensitive flight mission. Some Chinese-only teams did not speak to one another in English during the simulation. Transcripts describing simulation scenarios are described in Davis et al. (2005). At the conclusion of simulated flight, information on participant perceptions of task load was collected.

Training Program

Microsoft Flight Simulator Professional 2000 was used to deliver flight scenarios to subjects. In order to teach this program to subjects, six industrial/organizational psychology graduate students were trained in the use of this program and passed the Microsoft Flight Simulator 2000 proficiency test. These students then served as flight instructors who taught subjects how to fly the flight simulator.

Participants were taught how to fly a Cessna 182S airplane using lessons from the Microsoft Flight Simulator 2000 manual. Each subject received a training manual at the beginning of his training, and flight trainers used a script to ensure training consistency between instructors. Supplementary instructions were adapted from the Microsoft Flight Simulator 2000 Pilot's Handbook (1999) and included the use of a GPS navigational system, bad weather flight instructions, use of a flight computer to calculate fuel levels, proper use of air traffic control communications, and differentiation between pilot and copilot responsibilities. Trainer scripts and the training manual can be found in Davis et al. (2005).

Participants were administered a post-test that measured flight knowledge after the completion of training. If participants passed this flight knowledge test, they moved on to complete the flight scenario used as part of the experimental procedure. Participants completed their flight simulations while listening to tapes from simulated air traffic control recordings. Simulations had a flight time of approximately 35 minutes. Participants attempted to reach their flight destinations on time, despite challenging environmental and communication complications. A detailed description of the training procedures and flight scenarios is available in Davis et al. (2005).

Measures

At the onset of training, participants were given a list of Frequently Asked Questions (FAQs) addressing study requirements and providing experimenter contact information, a training manual, and a series of questionnaires that assessed individual differences. Participants were required to complete all questionnaires except the TLX in the research laboratory prior to completion of the experimental scenarios. The TLX was administered upon completion of the experimental scenarios.

NASA Task Load Index (TLX). The TLX is a multidimensional measure of subjective task load. Participants complete a series of ratings on six 20-point scales (mental demand, physical demand, temporal demand, performance, effort, and frustration level). A copy of the TLX is included in the Appendix. The TLX scoring procedure compares the six scales using paired comparison-derived weights to provide a unitary index of task load (Prinzell, Freeman, & Prinzel, 2005), although it is not necessary to conduct these pairwise comparisons (Moroney, Biers, Eggemeir, & Mitchell, 1992). Byers, Bittner, and Hill (1989) found highly correlated ($r = .96$) means and standard deviations between paired comparison data and non-pairwise data.

When an individual performs a task and then uses the TLX to evaluate that task, they rate the magnitude of each dimension. This is done by creating a score for each dimension on a 100 point scale. Participants mark on a 12-cm line with a title indicating the scale and bipolar descriptors at each end, such as low on one end and high on the other. No numerical values are present on the line, but values are assigned after the participant chooses a scale position from 1 to 100 (Hart & Staveland, 1988).

Hart and Staveland (1988) stated that test-retest reliability was .83 across a variety of measurement methods including verbal, paper/pencil, and computer methods. Also, according to Vitense, Jacko, and Emery (2003), the TLX measure is valid. The TLX measure produced results similar to those of other task load measurements (Hart & Staveland, 1988).

NEO-Personality Inventory-Revised. The NEO Personality Inventory-Revised (NEO-PI-R) was used to asses the five factor model of personality (Costa & McRae, 1992). The NEO-PI-R was purchased for this research and was used with permission. The five factors that were assessed are openness to experience (O), conscientiousness (C), extroversion (E), agreeableness (A), and neuroticism (N), also known as emotional stability. These five factors are comprised of 240 items organized into six subscales each. Participants indicate for each item the extent to which they strongly agree (one) or strongly disagree (five), with higher scores representing higher levels of the trait. According to Costa (1996), internal consistency of the measure (coefficient alpha) ranges from .56 to .92. A copy of the NEO-PI-R cannot be provided in the thesis without violating its copyright protection. The test can be obtained from Psychological Assessment Resources, Inc.

Team Level of Analysis. Additional scores were calculated to assess team level analyses pertaining to variability and elevation (average). The differences between team members' individual NEO-PI-R scores were used to determine team variability scores. The average of team members' individual NEO-PI-R scores were used to determine team average scores.

RESULTS

Analytic Strategy

Linear regression analysis and hierarchical linear modeling were used to examine the influence of personality and nationality on perceptions of task load. Task load was the criterion. Personality, team personality variability, team personality elevation, and nationality were entered as predictors. Task load was calculated as the sum of the six subscales of the TLX measure. For personality, a summary score of participants' subscales was used to create the five different factors of the FFM. Each of the five factors was added to the regression analysis independently.

For hypotheses concerning team process influence, hierarchical linear modeling (HLM) was used (Raudenbush & Bryk, 2002). Using the HLM framework, the TLX remained the criterion. Personality was used as a level 1 individual level variable while team trait variability was a level 2 grouping variable. Team trait elevation was assessed by examining group intercepts. Context effects were used to assess the influence of team variability and elevation on individual perceptions of task load. This analysis allowed groups to randomly differ on both variability and elevation.

Phases of Analysis and Explanation of Variables by Hypothesis

Phase 1: preliminary analysis establishing the use of HLM, i.e. that a multilevel effect exists in the data

<u>statistics:</u> random effects ANOVA

$y_{ij} = \gamma_{00} + \mu_{0j} + r_{ij}$

y_{ij}: individual task load score

γ_{00}: intercept (average of task load betas across all teams)

μ_{0j}: deviation of intercepts

τ_{00}: variance of μ_{0j}

r_{ij}: individual random error comparing predicted vs. observed task load

σ^2: variance of r_{ij}

λ: reliability of parameter variance relative to total variance of sample mean

ICC: proportion of total variance in task load that is attributed to variability among teams supporting existence of team level effect

Phase 2: analyzing level one variables associated with the individual level of analysis

hypotheses: Assessing the influence of personality on task load

H1: Openness will be negatively correlated to perceptions of task load.

H2: Conscientiousness will be negatively correlated to perceptions of task load.

H3: Extroversion will be negatively correlated to perceptions of task load.

H4: Agreeableness will be negatively correlated to perceptions of task load.

H5: Neuroticism will be positively correlated to perceptions of task load.

statistics: random effects ANCOVA for personality

$y_{ij} = \gamma_{00} + \gamma_{10} + \mu_{0j} + r_{ij}$

γ_{00}: grand mean of betas after controlling for covariate of γ_{10}

γ_{10}: grand mean for covariate of personality variable betas (single personality variable – other personality variables are not in equation; not random; slope is shared)

Phase 3: analyzing level two variables associated with the team level of analysis

hypotheses: team level personality variability and elevation will influence task load

H6: Perceptions of task load would be lower the less varied and more elevated a team is for openness.

H7: Perceptions of task load will be lower the less varied and more elevated a team is for conscientiousness.

H8: Perceptions of task load will be lower the less varied and more elevated a team is for extroversion.

H9: Perceptions of task load will be lower the less varied and more elevated a team is for agreeableness.

H10: Perceptions of task load will higher the more varied or more elevated a team is in neuroticism.

statistics: slopes and intercepts as outcomes model for assessing elevation and variability on personality

$y_{ij} = \gamma_{00} + \gamma_{10} + \gamma_{01} + \gamma_{02} + \mu_{0j} + r_{ij}$

$\gamma_{00:}$ grand mean after controlling for covariates of elevation and variability

$\gamma_{10:}$ grand mean for covariate of personality variable (not random; slope is shared)

$\gamma_{01:}$ grand mean for covariate betas of team elevation, a level 2 parameter

$\gamma_{02:}$ grand mean for covariate betas of team variability, a level 2 parameter

$\mu_{0j:}$ deviation of intercepts

$r_{ij:}$ individual random error comparing predicted vs. observed task load

Phase 4: team structure analysis including the potential influence of nationality

H11: Flight teams with members sharing the same national origin (culturally homogeneous teams, China or the USA) were expected to exhibit lower task load perceptions than flight teams comprised of members from both China and the USA (culturally heterogeneous teams).

statistics: regression of nationality composition with nationality dummy coded

H12: Homogeneous American flight teams were expected to exhibit lower task load perceptions than homogeneous Chinese flight teams.

statistics: regression on homogeneous American vs. Chinese teams

Data Preparation

Summary scores for TLX and personality were calculated. Team average and difference scores were computed for each personality variable. Team structure was coded 1 and 0 for same nationality and mixed nationality, respectively. American and Chinese participants were coded as 1 and 0, respectively. Both overall univariate and multivariate assumptions for random effects ANOVA as well as the eventual final model were met. For all variables descriptive statistics are presented in Table 2, and correlations are presented in Table 3.

Hierarchical Linear Modeling Preparation

A histogram of task load scores indicated that the dependent variable met necessary assumptions of normality. Boxplots of task load scores did not reveal any extreme outliers, indicating no need to remove any cases. Restricted maximum likelihood estimation was used for interpretations. The level 1 variables were grand mean centered. Level 2 variables of team variability and team elevation were also grand mean centered. Team similarity was not centered, as zero was a meaningful score. Error terms (r) are expected to be normally distributed with a mean of zero and a variance of σ^2. Grand mean deviations of μ are also expected to be normally distributed with a mean of zero but with variance of τ. This analysis used random intercepts; every team was allowed to have different average TLX scores, but the slopes were assumed and modeled to be fixed effects constant across all teams. As only k-1 (where k is the number of individuals within a group) random effects can be predicted, flight teams of two could only have random effects for γ_{00} (Raudenbush & Bryk, 2002).

Table 2

Descriptive Statistics

Variable	Mean	SD	N
Country of Origin	1.51	0.50	140
Team Type	1.69	0.47	140
TLX Total	341.96	80.46	140
Team TLX Average	341.96	61.24	140
Team TLX Difference	86.64	57.74	140
Openness to Experience	19.25	3.08	140
Conscientiousness	19.08	3.09	140
Extroversion	18.90	2.68	140
Agreeableness	18.56	2.33	140
Neuroticism	13.61	2.81	140
Openness to Experience Average	19.25	2.12	70
Conscientiousness Average	19.08	2.29	70
Extroversion Average	18.90	1.98	70
Agreeableness Average	18.57	1.74	70
Neuroticism Average	13.61	1.78	70
Openness to Experience Variability	3.70	2.53	70
Conscientiousness Variability	3.35	2.45	70
Extroversion Variability	2.96	2.05	70
Agreeableness Variability	2.54	1.77	70
Neuroticism Variability	3.52	2.53	70

Table 3

Correlations of Level 1 and 2 Variables

Var	1	2	3	4	5	6	7	8
1								
2	-.11							
3	.30*	-.24*						
4	.26*	-.42*	.43*					
5	-.06	-.33*	.19*	.06				
6	-.02	-.50*	.14	.30*	.23*			
7	.03	-.03	-.11	-.02	-.22*	-.09		
8	-.25*	.16	-.25*	-.13	.02	-.08	.02	
9	.09	-.03	.08	.10	-.01	.06	.07	.03
10	.01	-.14	.03	.04	.25*	.10	-.30*	-.01
11	-.11	.62*	-.13	-.18*	-.22*	-.35*	-.06	.16
12	.22*	-.12	.67*	.29*	.16	.10	-.16	-.22*
13	.26*	-.16	.27*	.72*	.04	.17*	-.03	-.12
14	-.13	-.17*	.14	.04	.77*	.23*	-.29*	.06
15	-.03	-.30*	.09	.17*	.24*	.73*	-.12	-.01
16	.06	-.07	.06	-.01	-.02	.09	.11	-.08
17	-.06	-.05	.10	-.04	-.17*	.10	-.18*	-.06
18	-.10	-.09	-.13	-.10	-.07	-.04	.05	-.11
19	.14	.11	.15	-.04	-.07	-.19*	-.07	-.08
20	-.04	.06	-.07	-.05	-.01	-.08	.02	.11

Note. * = $p < .05$ *(table continues)*

Table 3 Continued

Correlations of Level 1 and 2 Variables

Variable	10	11	12	13	14	15	16	17	18	19	20
1											
2											
3											
4											
5											
6											
7											
8											
9											
10	-.01										
11	.20*	-.23*									
12	-.27*	.04	-.19*								
13	-.15	.06	-.26*	.41*							
14	.08	.32*	-.28*	.21*	.05						
15	-.02	.14	-.48*	.14	.24*	.31*					
16	-.10	-.15	-.11	.09	-.01	-.03	.12				
17	-.08	-.21*	-.09	.15	-.06	-.22*	.14	.35*			
18	-.14	.07	-.15	-.20*	-.13	-.10	-.06	.38*	.28*		
19	-.10	-.17*	.17*	.23*	-.06	-.09	-.25*	.15	.21*	-.02	
20	.14	-.14	.10	-.10	-.07	-.01	-.11	.30*	.14	.33*	.20*

Note. * = $p < .05$

1. Country of Origin
2. Neuroticism
3. Openness to Experience
4. Extroversion
5. Agreeableness
6. Conscientiousness
7. Team Type
8. TLX Total
9. Team TLX Average
10. Team TLX Difference
11. Neuroticism Average
12. Openness to Experience Average
13. Extroversion Average
14. Agreeableness Average
15. Conscientiousness Average
16. Neuroticism Variability
17. Openness to Experience Variability
18. Extroversion Variability
19. Agreeableness Variability
20. Conscientiousness Variability

Preliminary Analysis

The random effects ANOVA design was the first model tested. This model assessed the independence of individuals. When independence is violated, an influence of group association establishes the use of hierarchical linear modeling. This model, looking only at group differences, was significant γ_{00} (69) = 338.75, $p < .05$, SE = 7.78, indicating that the grand mean of group task load was significantly different from zero. The deviance of these fixed effects, μ_{0j}, was significant at 39.79, $p < .05$, $\tau_{00} = 1583.48$. This indicates that there was significant variance in the intercepts of the teams, indicating a difference among teams in task load, thus confirming existence of an effect at the team level of analysis. This lack of independence warrants the use of multilevel modeling through HLM. Overall model error was acceptable; $r_{ij} = 73.75$, $\sigma^2 = 5439.46$. Model reliability, as measured by λ, was .368. Its deviance was 1624.82 at 2 parameters. For this unconditional model, the ICC indicated that 22.54% of variance in reported task load was due to team differences instead of individual differences.

Model Development: Level 1 Predictors

Measures of personality were included in a hierarchical linear model as level 1 predictors. Each of the five personality variables was assessed as covariates in individual ANCOVA (covariate of team averages) models to yield specific interpretations. Personality variables were examined as level one predictors instead of OLS regression predictors because this technique more accurately decomposes total error since individuals were nested in teams.

The effect of openness to experience was evaluated as γ_{10}. This effect was significant at $\gamma_{10}(138) = -6.24$, $p < .05$, *SE* = 2.10, indicating that for every one unit of increase in openness to experience there was a significant decrease in perceptions of task load by 6.24 points. This result confirmed Hypothesis 1. All other level 1 variables of individual scores of personality, including conscientiousness, extroversion, agreeableness, and neuroticism, were not found to be significant predictors of task load perceptions. Results of these analyses are presented in Table 4.

Further Model Development: Level 2 Predictors

Level two variables of team variability and team elevation for each personality variable were each entered as individual slopes and intercepts as outcomes in hierarchical linear models. Each of these models, one for each personality variable, contained a variable for team personality elevation and variability. For each model, both elevation and variability evaluated the fixed effect coefficient, standard error, degrees of freedom, reliability, and level of significance. No predictor for either elevation or variability of personality was significant. These results indicate that perceptions of task load were not significantly affected by the interaction of pilot personality traits at the team level of analysis. Results of these analyses are presented in Table 4.

Team Structure Analysis

Homogeneity of team nationality was not found to be a significant predictor of task load perceptions, $\beta = 3.48$, $t(138) = 0.23$, *ns*; $R^2 = 0.00$, $F(1, 138) = 0.05$, *ns*. However, type of nationally homogeneous team was found to have a significant influence on perceptions of task load, $\beta = -40.93$, $t(138) = -2.97$, $p < .05$; $R^2 = 0.06$, $F(1, 138) = 8.83$, $p < .05$. American teams ($M = 318.29$, $SD = 87.48$) experienced significantly lower task load perceptions throughout the flight simulation than did Chinese teams ($M = 359.21$, $SD = 74.98$), thus confirming Hypothesis 12.

Table 4

Hierarchical Linear Modeling Results for Personality Effects on Task Load Perceptions

Variable	γ	S.E.	t-ratio	n	df
Level 1: Random Effects ANCOVAS					
Openness	-6.24*	2.10	-2.97	140	138
Conscientiousness	-2.77	2.27	-1.15	140	138
Extroversion	-3.61	2.66	-1.36	140	138
Agreeableness	-0.01	3.22	-0.01	140	138
Neuroticism	4.14	2.37	1.75	140	138
Level 2: Slopes and Intercepts as Outcomes					
Openness					
Elevation	-3.14	4.55	-0.70	70	67
Variability	-0.99	3.20	-0.31	70	67
Conscientiousness					
Elevation	4.24	4.81	0.88	70	67
Variability	3.80	2.88	1.32	70	67
Extroversion					
Elevation	-3.26	4.30	-0.76	70	67
Variability	-4.73	4.87	-0.97	70	67
Agreeableness					
Elevation	5.06	5.49	0.92	70	67
Variability	-3.58	4.43	-0.81	70	67
Neuroticism					
Elevation	4.32	5.13	0.84	70	67
Variability	-1.97	3.06	-0.65	70	67

Note. * = $p < .05$

Team Level Post Hoc Analyses

Following analyses based on total TLX scores, exploratory post hoc analyses were conducted on the subscales of the TLX. Although not as prominent in research as the total TLX score, a few studies have put emphasis on the subscales of the TLX (e.g., Shinohara, Miura, & Usui, 2002; Tomporowski, 2006). Subscales of the TLX may be useful for evaluating more specific demands of the flight task. The six subscales (mental, physical, temporal, effort, performance, and frustration) were assessed as criteria in hierarchical linear model analyses.

Only four of the evaluated coefficients achieved significance. Results are presented in Tables 5 through 10. Team elevation of both extroversion and openness was found to significantly decrease perceptions of mental workload; the more extroverted or open the team, the less demanding the flight task was perceived as being (Table 5). The team elevation of openness was also significantly related to lower perceptions of physical demands (Table 6). Finally, lowered individual neuroticism was related to significantly lower perceptions of temporal demands (Table 7).

Table 5

Hierarchical Linear Modeling Results for Personality Effects on Perceptions of the Mental Subscale of Task Load

Mental Component	γ	S.E.	t-ratio	n	df
Level 1: Random Effects ANCOVAS					
Openness	0.11	0.50	0.22	140	138
Conscientiousness	-0.01	0.55	-0.03	140	138
Extroversion	0.10	0.52	0.18	140	138
Agreeableness	-0.15	0.56	-0.27	140	138
Neuroticism	1.07	0.60	1.80	140	138
Level 2: Slopes and Intercepts as Outcomes					
Openness					
Elevation	-2.50*	1.07	-2.33	70	66
Variability	0.09	0.60	0.15	70	66
Conscientiousness					
Elevation	-0.01	1.12	-0.01	70	66
Variability	0.66	0.65	1.03	70	66
Extroversion					
Elevation	-3.01*	1.41	-2.13	70	66
Variability	-0.44	0.84	-0.52	70	66
Agreeableness					
Elevation	0.47	1.88	0.25	70	66
Variability	-0.18	1.12	-0.16	70	66
Neuroticism					
Elevation	0.65	1.37	0.47	70	66
Variability	-0.39	0.70	-0.56	70	66

Note. * = $p < .05$

Table 6

Hierarchical Linear Modeling Results for Personality Effects on Perceptions of the Physical Subscale of Task Load

Physical Component	γ	S.E.	t-ratio	n	df
Level 1: Random Effects ANCOVAS					
Openness	-0.11	0.72	0.16	140	138
Conscientiousness	-0.75	0.79	-0.95	140	138
Extroversion	0.76	0.86	0.88	140	138
Agreeableness	0.86	0.92	0.94	140	138
Neuroticism	-0.33	0.86	-0.38	140	138
Level 2: Slopes and Intercepts as Outcomes					
Openness					
Elevation	-4.93*	1.59	-3.11	70	66
Variability	-1.27	0.96	-1.32	70	66
Conscientiousness					
Elevation	0.56	1.41	0.40	70	66
Variability	-0.25	0.82	-0.31	70	66
Extroversion					
Elevation	-3.82	1.94	-1.97	70	66
Variability	0.57	1.15	0.49	70	66
Agreeableness					
Elevation	0.07	1.90	0.04	70	66
Variability	-1.01	1.15	-1.14	70	66
Neuroticism					
Elevation	2.46	1.74	1.42	70	66
Variability	0.06	1.13	0.05	70	66

Note. * = $p < .05$

Table 7

Hierarchical Linear Modeling Results for Personality Effects on Perceptions of the Temporal Subscale of Task Load

Temporal Component	γ	S.E.	t-ratio	n	df
Level 1: Random Effects ANCOVAS					
Openness	-0.20	0.49	-0.41	140	138
Conscientiousness	-0.28	0.49	-0.57	140	138
Extroversion	0.04	0.62	0.07	140	138
Agreeableness	0.85	0.54	1.55	140	138
Neuroticism	1.40*	0.56	2.50	140	138
Level 2: Slopes and Intercepts as Outcomes					
Openness					
Elevation	-2.06	1.25	-1.65	70	66
Variability	0.02	0.71	0.03	70	66
Conscientiousness					
Elevation	0.14	1.34	0.10	70	66
Variability	0.53	0.72	0.75	70	66
Extroversion					
Elevation	-2.84	1.52	-1.86	70	66
Variability	0.61	0.79	0.78	70	66
Agreeableness					
Elevation	0.51	2.31	0.22	70	66
Variability	-1.22	1.28	-0.96	70	66
Neuroticism					
Elevation	0.87	1.54	0.57	70	66
Variability	-0.54	0.82	-0.66	70	66

Note. * = $p < .05$

Table 8

Hierarchical Linear Modeling Results for Personality Effects on Perceptions of the Performance Subscale of Task Load

Performance Component	γ	S.E.	t-ratio	n	df
Level 1: Random Effects ANCOVAS					
Openness	0.07	0.63	0.10	140	138
Conscientiousness	0.75	0.63	1.20	140	138
Extroversion	0.29	0.85	0.34	140	138
Agreeableness	-0.35	0.82	-0.43	140	138
Neuroticism	-1.02	0.78	-1.32	140	138
Level 2: Slopes and Intercepts as Outcomes					
Openness					
Elevation	-1.74	1.56	-1.11	70	66
Variability	1.05	0.84	1.25	70	66
Conscientiousness					
Elevation	-0.41	1.64	-0.25	70	66
Variability	0.39	0.94	0.42	70	66
Extroversion					
Elevation	-0.88	2.25	-0.39	70	66
Variability	-2.15	1.15	-1.86	70	66
Agreeableness					
Elevation	-2.94	1.92	-1.53	70	66
Variability	-0.07	1.25	-0.05	70	66
Neuroticism					
Elevation	-1.61	1.71	-0.94	70	66
Variability	-0.60	0.93	-0.64	70	66

Note. * = $p < .05$

Table 9

Hierarchical Linear Modeling Results for Personality Effects on Perceptions of the Effort Subscale of Task Load

Effort Component	γ	S.E.	t-ratio	n	df
Level 1: Random Effects ANCOVAS					
Openness	0.07	0.67	0.11	140	138
Conscientiousness	-0.10	0.62	-0.16	140	138
Extroversion	-0.38	0.80	-0.47	140	138
Agreeableness	0.43	0.74	0.58	140	138
Neuroticism	1.37	0.75	1.83	140	138
Level 2: Slopes and Intercepts as Outcomes					
Openness					
Elevation	-1.60	1.49	-1.05	70	66
Variability	0.13	0.75	0.17	70	66
Conscientiousness					
Elevation	1.54	1.41	1.09	70	66
Variability	0.70	0.69	1.01	70	66
Extroversion					
Elevation	-2.49	1.61	-1.54	70	66
Variability	-0.76	0.89	-0.85	70	66
Agreeableness					
Elevation	1.01	1.57	0.65	70	66
Variability	-0.02	1.21	-0.01	70	66
Neuroticism					
Elevation	-0.32	1.77	-0.18	70	66
Variability	-0.51	0.94	-0.54	70	66

Note. * = $p < .05$

Table 10

Hierarchical Linear Modeling Results for Personality Effects on Perceptions of the Frustration Subscale of Task Load

Frustration Component	γ	S.E.	t-ratio	n	df
Level 1: Random Effects ANCOVAS					
Openness	-0.48	0.61	-0.78	140	138
Conscientiousness	-0.79	0.59	-1.35	140	138
Extroversion	-0.24	0.56	-0.43	140	138
Agreeableness	-0.11	0.83	-0.14	140	138
Neuroticism	0.66	0.57	1.17	140	138
Level 2: Slopes and Intercepts as Outcomes					
Openness					
Elevation	-2.08	1.53	-1.36	70	66
Variability	-0.82	0.80	-1.03	70	66
Conscientiousness					
Elevation	1.37	1.68	0.82	70	66
Variability	1.26	0.80	1.57	70	66
Extroversion					
Elevation	-2.14	1.63	-1.31	70	66
Variability	0.99	0.86	1.16	70	66
Agreeableness					
Elevation	0.95	1.82	0.52	70	66
Variability	0.80	1.17	0.69	70	66
Neuroticism					
Elevation	-1.19	1.65	-0.72	70	66
Variability	-0.26	0.72	-0.36	70	66

Note. * = $p < .05$

DISCUSSION

Flight can be a very hazardous activity, and pilot performance and safety are important areas of focus. Unfortunately, technical knowledge and skills are not enough to ensure flight effectiveness (Foushee,1984; Kanki, 1992). Many factors can affect a pilot's environment and subsequent performance. "Because the cockpit crew is a highly structured small group, a number of socio-psychological, personality, and group process variables are relevant to crew effectiveness" (Foushee, 1984, p. 885). Although numerous factors affect pilot task load, those directly related to the cockpit interpersonal environment were of particular interest

Flight crews operate as a team in the cockpit. As such, the cockpit is host for many problematic communication interactions (Milanovich, Driskell, Stout, & Salas, 1998). Cockpit coordination accounts for a large component of flight team performance (Stout, Salas, & Carson, 2002). Because flying consists of multiple tasks that must be coordinated, pilots must allocate their attention to a wide variety of duties, (Mosier, Skitka, & Korte, 1994). The dynamic interaction of flight tasks and intra-cockpit coordination may increase the number of stressors, affecting both the structural and functional capacity limitations of pilots (Mosier, Skitka, & Korte, 1994; Pannebakker, Band, & Ridderinkhof, 2009). "Performance on demanding tasks is known to be limited by temporal overlap with other demanding tasks" (Pannebakker, Band, & Ridderinkhof, 2009, p. 447).

Examining the impact of these demanding and overlapping tasks in relation to pilot attributes was the focus of this study. It was believed that evaluating flight crew task load might lead to insight for increasing performance and safety. These relationships were investigated through evaluations of pilot perceived task load. Since higher task load is generally believed to relate to lower performance, achieving optimum performance from flight teams requires limiting unnecessary pilot task load. Although team task load is a critical variable for team performance, little research has studied the relationship between individual and team task load. This study was designed to examine how personality or nationality could have negative effects on flight team performance and safety as indicated by higher perceptions of task load.

Assumptions and Propositions

This study examined if nationality and personality variables affected a pilot's perceptions of task load. Previous research has included a focus on personality existing at the individual level while other previous research has linked elevated levels of personality traits to team performance (Barrick, Stewart, Neubert, & Mount, 1998; Peeters et al., 2006). This study analyzed personality at both the individual and team level of analysis. In addition to individual personality, the effect of team personality was also believed to affect perceptions of task load. According to Peeters et al. (2006), studying personality within teams consists of two aspects: trait elevation (mean level of trait) and trait variability. Connections between team performance and the elevation and personality of team members have been reported in past research (Neuman, Wagner, & Christiansen, 1999). Peeters et al. conducted a meta-analysis of the findings, and complexities, of personality variables and teams. In this study, both elevation and variability were assumed to be variables that affected perceptions of task load at the team level and were included in hierarchical models as such.

In addition to personality, nationality of team members was another factor believed to influence pilot perceptions of task load. In particular, this study was interested in American and Chinese pilots. National differences have been shown to affect approaches towards various aspects of teamwork (Salk & Brannen, 2000). Moore (1998) indicated that American and Chinese teams can have communication and coordination difficulties because of differences in their teamwork interactions. Potential nationality differences were also cited by Conyne et al. (1999) as well as Helmerich and Merritt (1998). As a result of these previous research findings, it was hypothesized that Americans and Chinese cockpit teams would have more difficulty working in mixed nationality teams than in single nationality teams. Furthermore, it was also hypothesized that cultural influences within Chinese teams would cause homogenous Chinese teams to have more communication difficulties than American teams.

Measures and Analysis

In this study, simulated flight crews faced a demanding and complex flight scenario that required participants to work as a piloting team. Both heterogeneous and homogenous teams in terms of American and Chinese nationality were created. The NEO-PI-R (Costa & McRae, 1992) was used to assess participant personality, and the NASA-TLX (Hart and Staveland, 1988) was used to analyze subjective perceptions of task load from various challenges of the flight simulation scenario.

Moynihan & Peterson (2001) suggest that a contingent configuration approach be used for assessing the mix of traits with a group in order to more accurately predict team performance. Such an approach takes into account the context of the group efforts and seeks to examine the effects caused by the interaction of team member personalities.

Other studies examining the dynamics of personality and teams have used correlations and regressions in their analysis. To search for more descriptive results as well as include elements of contextual influences, this study used linear regression analysis and hierarchical linear modeling to examine the effects of personality and nationality on perceptions of task load. In these analyses, task load was the dependent variable, and personality, team personality variability, team personality elevation, and nationality were examined as predictors. This use of multilevel modeling may serve as the most significant contribution of this study, providing a framework for addressing variables such as personality at both the individual and group level.

Findings and Implications

Although previous research by Peeters et al. (2006) and Driskell et al. (2006) supported hypotheses that individual personality, team personality elevation, and team personality variability would significantly influence perceptions of pilot task load, results only partially supported the hypotheses. For pilot personality, this study found that a pilot's openness to experience influenced task workload perceptions. Increasing levels of openness to experience were found to significantly decrease pilot perceptions of task load. These findings may have implications on training and safety protocol for pilots. The creativity and broadmindedness of an individual with high openness to experience (LePine, 2003) may have helped these individuals to take a more positive attitude of curiosity towards their flight simulation. This attitude may have reduced stress or perceptions of task load. Flight teams may benefit from selecting pilots with high levels of openness. The lowered perceptions of workload for these individuals may enhance performance. Enhanced performance may increase the safety of pilots and crew members.

This study also found evidence supporting the influence of nationality on flight team performance. American teams were found to experience significantly lower task load perceptions than Chinese teams. This effect might have occurred because, on average, Americans are better at team tasks, may be more likely to exhibit positive intrapersonal characteristics, may simply be more familiar with this type of task, or are not hindered by any potential language barriers that may have existed in the simulation. As a result of likely associations to particular cultural norms and preferences which may inhibit certain aspects of communication and coordination beneficial to the cockpit environment, the Chinese pilots may experience task load challenges.

Finally, the results of post hoc analyses may provide further insight. It is important to note that the large number of post hoc analyses warrant caution as no correction for type I error was used; however fewer significant results were found than could be expected by chance. In these post hoc analyses, the potential value of openness for pilots was additionally supported by its significant influence, in terms of team elevation, on lowering perceptions of mental and physical demands. Again, creativity and broadmindedness likely contribute positively to the challenging interpersonal mental and physical demands of flight (LePine, 2003). In addition, post hoc analyses indicated that higher team extroversion significantly lowered perceptions of mental demands. This effect is likely the result of the positive influence that occurs from having a highly communicative team as more communication is likely to decrease the calculations or other complex thought processes that might otherwise be done individually (Brannick &

Prince, 1997; Liu, 2006). Finally, post hoc analyses showed that lower individual levels of neuroticism significantly decreased perceptions of temporal demand (Peeters et al., 2006). These results indicate that an individual's mental stability helps with reducing perceptions of situational pressure.

Limitations

The first limitation of this study is that flight scenarios were simulated with non-pilots. As indicated by Mosier, Skitka, and Korte (1994), flying consists of multiple coordinated tasks across various duties that all require attention and can cause stress. All stressors could be expected to be more apparent in real flight situations. Real flight situations with actual pilots may cause stress and teamwork situations to be far more intense, interactive, and meaningful. Said another way, a potential limitation may be the ability to generalize findings produced in a laboratory simulation to those that could be produced in a field observation of real flight.

Despite this concern for the relevance of simulations, research has supported their applicability. Campbell (1986) posited that effectively generalizing the findings of laboratory studies to field environments may mean applying conclusions, officially recognizing some phenomenon, or justifying a certain practice within an operational setting. With this conceptualization, and from a review of research on simulations, Campbell concluded that the "lab versus field distinction is not a very useful one. Research studies do not fit cleanly into these two categories [...] the message is clear: the data do not support the belief that lab studies produce different results than field studies" (pp. 275-276). Specifically concerning flight simulators, "A flight simulator environment rather realistically imitates actual tasks and pilot performance in aviation. Therefore, laboratory experiments and simulators have frequently been used in studies on cognitive load and mental stress, as cognitive processes can be examined in these environments without intervening physical factors" (Hannula et al., 2008, p. 1164).

The significant findings associated with openness to experience may have been more related to the subjects' perceptions of novelty of the simulation task than the actual actions associated with flight. Other simulation environments might have helped to limit the impact of the new experience and bring out the components of team coordination. In such scenarios the influence of personality and nationality may be much more prominent.

Differences between Chinese and American participants may have had a significant influence on understanding of the task used for task load perception assessments. Chinese participants may have been at a disadvantage in an American flight simulation program at an American university that used English instructions, American trainers, and American interfaces.

Future Research

This study found evidence supporting the influence of nationality on flight team performance. Future research should examine what specific components of nationality differences have the most impact on pilots and the piloting environment. It should also examine how such nationality-linked influences relate to coordination between members from places other than America or China. Examining such questions should continue to be explored through multilevel modeling.

This study also found evidence supporting the likelihood of a pilot's openness to experience as being a beneficial factor to flight task performance. Future studies should examine what components of this dimension of personality are most beneficial to the flight environment and training for that environment. As Moynihan and Peterson (2001) stated, "optimal configurations of all traits are likely to depend on both the trait and the context in which the group operates" (p. 354).

A significant challenge this study encountered was finding research connecting team performance to the NASA Task Load Index. There is little literature describing the dynamics of how working in a team affects individual perceptions of task load or how a team's collective perceptions of task load should be analyzed. Future studies should examine these relationships.

Undoubtedly, a number of things will keep researchers from being able to draw universally applicable conclusions about personality and teams. Such challenging influences are likely to be the contextual nature of performance, the mutually existing beneficial and detrimental components of a specific personality trait, the influence of non-personality factors (such as nationality), or the changing communication and coordination needs of realistic scenarios. Regardless of such challenges, examining various components of personality, such as elevation and variability, may still be useful. Future research should continue to employ multi-level analyses to more accurately reflect the role of teams on individual performance.

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APPENDIX

NASA-TLX TASK LOAD MEASURE

Please complete this quick survey regarding the task load you experiences during the flight simulation. Task load is split up among Mental Demand, Physical Demand, Temporal Demand, Performance, Efforts and Frustration Level. These six aspects of task load are defined on the sheet. Please note that all scales go continuously from low to high except performance, which goes form good to poor. Please place a mark anywhere along the scale.

Demand	Items
MENTAL DEMAND	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
PHYSICAL DEMAND	How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
TEMPORAL DEMAND	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
EFFORT	How successful do you think you were? How hard did you have to work (mentally and physically) to accomplish your level of performance?
PERFORMANCE	How successful do you think you were in accomplishing the goals set by the experimenter or yourself? How satisfied were you with your performance in accomplishing these goals?
FRUSTRATION LEVEL	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

VITA

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