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SPECIAL ISSUE

Can Cultural Differences Lead to Accidents? Team Cultural Differences and Sociotechnical System Operations

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Objective: I discuss cultural factors and how they may influence sociotechnical system operations. **Background:** Investigations of several major transportation accidents suggest that cultural factors may have played a role in the causes of the accidents. However, research has not fully addressed how cultural factors can influence sociotechnical systems. **Method:** I review literature on cultural differences in general and cultural factors in sociotechnical systems and discuss how these differences can affect team performance in sociotechnical systems. **Results:** Cultural differences have been observed in social and interpersonal dimensions and in cognitive and perceptual styles; these differences can affect multioperator team performance. **Conclusion:** Cultural factors may account for team errors in sociotechnical systems, most likely during high-workload, high-stress operational phases. However, much of the research on cultural factors has methodological and interpretive shortcomings that limit their applicability to sociotechnical systems. **Application:** Although some research has been conducted on the role of cultural differences on team performance in sociotechnical system operations, considerable work remains to be done before the effects of these differences can be fully understood. I propose a model that illustrates how culture can interact with sociotechnical system operations and suggest avenues of future research. Given methodological challenges in measuring cultural differences and team performance in sociotechnical system operations, research in these systems should use a variety of methodologies to better understand how culture can affect multioperator team performance in these systems.

INTRODUCTION

Sociotechnical systems are large, complex systems that generate electrical power, process chemicals, and transport people and cargo, among others. These systems have witnessed increased cultural interactions over the years, largely the result of the globalization of trade and commerce. Several major sociotechnical system accidents suggest that cultural factors, if not properly considered in system operations, may lead to breakdowns in team performance and, ultimately, to catastrophic accidents. Yet little research has been conducted to understand how cultural factors can affect the operations of such systems.

To understand the effects of culture in sociotechnical systems, I first define sociotechnical systems and then examine the role of teams in their operations. Because systems employ multioperator teams rather than single operators, I then examine the role of teams in sociotechnical systems. Thereafter, I discuss cultural factors and sociotechnical systems, focusing on two systems, marine and aviation, and propose a model that describes how cultural factors can affect team performance in system operations. Finally, I suggest research to help understand how cultural factors can influence sociotechnical system operations.

SOCIOTECHNICAL SYSTEMS

Sociotechnical systems interrelate *socio-* (of people and society) and *technical* (of machines and technology) elements to accomplish system objectives (Walker, Stanton, Salmon, & Jenkins, 2008). Operators must demonstrate both social and technical skills to be effective (see also Carayan, 2006). Social skills typically take the form of intrateam communication and

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coordination (Paris, Salas, & Cannon-Bowers, 1999), whereas technical skills require mastery of the relationship between system state and team actions sufficient to maintain situation awareness through all operating cycles (Endsley, 1995). Applying situation awareness to such systems typically involves (a) receiving and perceiving system information, (b) comprehending the perceived information regarding system operations, (c) projecting system status into the near future, and (d) selecting the response appropriate to the interpretation or assessment of the system state (G. A. Klein, 1993).

Because of their size, scope, and complexity, these systems typically require considerable operator training and expertise as well as systematic regulatory and/or company oversight. Much has been written about the operating environments of these systems. Orasanu and Connolly (1993), for example, cite eight factors often found in such systems, including (a) ill-structured problems, (b) uncertain dynamic environments, (c) time stress, and (d) high stakes. It is perhaps the latter features that distinguish sociotechnical systems from more simple ones. Component failure or team error can lead to catastrophic results, as illustrated by any number of past large-scale transportation accidents or military incidents (e.g., Wilson, Salas, Priest, & Andrews, 2007).

Multioperator teams rather than single operators are considered the "strategy of choice" in sociotechnical system operations (Salas, Cooke, & Rosen, 2008), because the complexity of tasks performed and the need for a range of skills, abilities, and experience can exceed the capabilities of individual operators. Workload in these systems can vary greatly through various operating phases, a function of the time available for task completion, operating phase, and external or internal conditions (Reiman & Oedewald, 2007). Multiple rather than single operators also allow tasks and duties to be delegated among team members during high-workload operational phases, reducing what could otherwise be intense individual workload.

Although much is known about cultural differences and about system operations, little is known about how cultural differences among team members can influence sociotechnical systems. An understanding of culture's effects on team performance is needed because of the increasing role of culturally heterogeneous teams in sociotechnical system operations. This study seeks to address this need, describe what is known about the influence of culture on sociotechnical system operations, and suggest avenues of research for researchers and practitioners.

Culture and Social-Interpersonal Factors

Culture incorporates the meaning, value system, and behavioral patterns that people with common characteristics share (Thomas, Au, & Ravlin, 2003). When applied to those who live in a particular region, it is referred to as national culture. Cultures vary not only across national borders but within them as well, forming subcultures. Within subcultures, norms can vary by demographic factors, such as age, education, and occupation (Schwartz, 1999). Subcultures associated with organizations or companies are referred to as organizational or corporate cultures (Schein, 1990, 1996). Cultural values and norms are evolutionary; they can change over time.

Considerable research has addressed cultural differences in general, with Hofstede's (e.g., 1980, 1991) work being particularly influential. Hofstede initially identified four dimensions that distinguish between cultures, labeled individualism-collectivism, power distance, masculinity-femininity, and uncertainty avoidance.

Individualism-collectivism refers to the degree to which individuals in a culture accept and pursue goals that are in their own best interests, as compared with those of the group to which they belong. *Power distance* is the extent to which people view and accept inequality within the distribution of power or status of their own groups and the degree to which people need or depend on superiors in the group. *Masculinity-femininity* refers to the degree to which people in a culture are assertive, ambitious, and competitive—considered masculine traits—as compared with caring and addressing interpersonal concerns—considered feminine. *Uncertainty avoidance* refers to the tolerance for ambiguity and the extent to which people in a culture feel comfortable in unstructured situations.

Hofstede later adapted an American personality inventory to the Chinese culture, identifying a fifth dimension that he added to the original four, labeled Confucian dynamism or long-term/short-term orientation (Hofstede and Bond, 1988). *Long-term orientation* reflects values such as thrift and perseverance, whereas *short-term orientation* reflects what Hofstede and McCrae (2004) refer to as "respect for tradition, fulfilling social obligations, and protecting one's 'face'" (p. 65), all values typically associated with Asian cultures.

Since Hofstede's initial work, others have conducted multicultural research based on the results of Likert-type surveys, as Hofstede did. Schwartz (1999), for example, derived seven "cultural values," including harmony, conservatism, hierarchy, mastery, egalitarianism, intellectual autonomy, and affective autonomy.

A comparative study of individuals in a variety of companies in 62 countries, the GLOBE (Global Leadership and Organizational Behavior Effectiveness) study, envisioned as a multiyear, multiphase endeavor, yielded nine cultural factors: power distance, uncertainty avoidance, and seven others (House, Hanges, Javidan, Dorfman, & Gupta, 2004). Critics of using Likert-type surveys in cultural research have cited shortcomings in the methodologies used in many of the studies and the inability of the derived cultural dimensions or factors to account for the complexities and subtleties that underlie cultural differences (e.g., Chen, 2008; Heine, Lehman, Peng, & Greenholtz, 2002; McSweeny, 2002).

Peng and Nisbett (1999) found differences in conflict avoidance and conflict resolution, with one culture tending to find a "middle ground" or a compromise between two conflicting positions when dealing with conflicts or conflicting situations and another tending to determine and support a position viewed as more correct. Peng and Nisbett considered the differences they observed to reflect differences in cognitive styles between cultures. Asian cultures relied on what Peng and Nisbett termed "dialectical thinking," whereas Westerns ones relied on formal and analytical logic.

Oetzel, Ting-Toomey, Masumoto, Yokochi, Pan, Takai, and Wilcox (2001) suggest that those from individualistic and low-power-distance cultures tend to address conflict directly, whereas those from collectivistic and high-power-distance cultures smooth over conflict. Markus, Kitayama, and VandenBos (1996) found differences in how cultures express emotion. In some cultures people believe that expressing emotion, particularly anger, is potentially disruptive to the social order, whereas in others, people view such expressions as within an individual's needs (see also Markus & Kitayama, 1998, 2003).

Cultural factors have been observed in the consideration of "face," a uniquely Asian concept that has no Western analog. It combines the sense of self-worth and identity with elements of social custom and status. Kang (2004) described face as the desire to behave according to aspects of the norms of the particular culture involved. In some cultures, social status—the hierarchical position of an individual in society—influences the perception of face (see also Oetzel et al., 2001). Jing, Lu, and Peng (2001) argue that power distance does not accurately describe the role of hierarchy in the Chinese culture. Instead, they propose a unique Chinese cultural factor that incorporates elements similar to face to explain the role of the leader in the culture.

Early (1989) found cultural differences in "social loafing," the tendency of individuals to exert less effort at the expense of others when working in a team. Those from individualistic cultures tend to exhibit more social loafing on a team task than did those from collectivistic ones. Karau and Hart (1998) found that social loafing decreases with team cohesiveness. Social loafing was reduced or eliminated in teams that had worked together for extended periods.

Culture and Cognitive-Perceptual Factors

Researchers have observed differences in perception and cognitive styles across cultures (e.g., Hong, Morris, Chieu, & Benet-Martinez, 2000; Ji, Peng, & Nisbett, 2000). Blais, Jack, Scheepers, Fiset, and Caldara (2008), for example, found that cultures differ in the way they look at faces, similar to cultural differences in the conception of face. That is, generally collectivistic cultures, which attend to the societal view of face, tend to focus on "holistic" features of the central facial region, whereas more individualistic cultures, which focus on specific features, tend to focus on the eyes (Hong et al., 2000).

Morris and Peng (1994) found that cultures differ in their attribution of cause, consistent with their individualistic or collectivistic orientation. Collectivist cultures attribute causality to the interaction of circumstances and individuals, whereas individualistic cultures attribute causality to the actions of the individuals themselves. Nisbett, Choi, Peng, and Norenzayan (2001) believe that cultures differ in their "tacit epistemologies" and "the nature of their cognitive processes" (p. 291). In their view, a given stimulus elicits different cognitive processes and cognitions in different cultures. "Indeed," they note,

> as some of the perceptual work we have reviewed indicates, the different focus of attention of Easterners and Westerners indicates that they may sometimes not be seeing the same stimulus situation at all—even when their heads are immobilized at a fixed distance away from a computer screen. (Nisbett et al., 2001, p. 306)

Nisbett and Norenzayan (2002) suggest that linguistic differences, as well as differences in ancient cultural philosophical orientations, account for cultural differences in cognition. They observed differences in the degree to which cultures (a) attend to objects rather than to the contexts in which the objects are located, (b) observe complexity in their environments and contradictions in causal elements, (c) categorize aspects of their environments according to formal logic or object similarities and relationships, and (d) attribute causality.

H. A. Klein (2005) contends that cultures differ cognitively on several dimensions. These include dialectical reasoning, viewing contradictory perspectives to select the single best as compared with seeking compromise; hypothetical thinking, imagining scenarios to examine the implications of plans versus reasoning on the basis of personal experience; time orientation, respecting and attending to traditions and customs versus focusing on long-term goals; and activity orientation, having work-related endeavors as a central focus of activities as compared with having interpersonal relationships as the focus.

Ambady and Bharucha (2009) suggest that social and cognitive differences between cultures may be reflected in differences in neural processing. Their review of the neuroscience literature, research that is admittedly preliminary, suggests that neural processes have evolved over time consistent with changes in culture. The brain, they theorize, has internalized and modified neural processing in ways that reflect cognitive differences between cultures. An overview of information on studies on cultural differences is presented in Table 1.

Implications for Sociotechnical Systems

Because there has been little research on the effects of cultural differences in sociotechnical system operations, researchers are limited in their ability to describe or predict how culture could influence these systems. Moreover, much of the research that has been applied to sociotechnical systems has relied extensively on attitude surveys, instruments that may not capture features unique to sociotechnical systems. Furthermore, the respondents completing these surveys had little in common with the technically oriented and team-based operators of sociotechnical systems. Most were college students, office workers, or elementary school teachers. The very potential of sociotechnical systems for intense time pressure and severe consequences from errors distinguishes system operators from the respondents of the bulk of cultural research. Thus, findings based on survey-based research may have limited applicability to sociotechnical system operations.

Of the cultural research applied to sociotechnical systems, Hofstede's has been cited the most. Researchers have applied Hofstede's dimensions to such systems or applications as commercial aviation (Merritt, 2000; Merritt & Helmreich, 1996), aviation accidents (Soeters & Boer, 2000), oil and gas industries (Mearns & Yule, 2009), and commercial shipping (Havold, 2007). However, these studies have been generally characterized by (a) comparisons between different culturally homogeneous groups rather than within culturally heterogeneous ones or between homogeneous and heterogeneous groups,

TABLE 1: Studies of Cultural Differences

Author(s) Identified	Year	Method	Participants/ Respondents	Differences
Ambady & Bharucha	2009	Literature review	—	Social, cognitive, neural
Blais, Jack, Scheepers, Fiset, & Caldara	2008	Experimental	College students	Perceptual
Early	1989	Experimental	Graduate students	Social-interpersonal
Gelfand, Nishii, & Raver	2006	Literature review	—	Social-interpersonal and "tightness-looseness"
Hofstede; Hofstede & Bond	1980, 1988	Likert-type survey	Office workers; undergrad students	Social-interpersonal
Hong, Morris, Chiu, & Benet-Martinez	2000	Experimental	High school and undergrad students	Cognitive-perceptual
House, Hanges, Javidan, Dorfman, & Gupta	2004	Likert-type survey	Office and other workers	Social/interpersonal
Ji, Peng, & Nisbett	2000	Experimental	Undergrad students	Social and perceptual
Kang	2004	Literature and personal familiarity with culture	—	Social-interpersonal
Karau & Hart	1998	Experimental	Undergrad students	Social loafing
Klein	2005	Literature review	—	Social-interpersonal and cognitive-perceptual
Markus & Kitayama	1998, 2003	Literature review	—	Social and personality
Markus, Kitayama, & VandenBos	1996	Literature review	—	Emotions
Morris & Peng	1994	Experimental	High school and grad students	Cognitive-perceptual
Nisbett, Choi, Peng, & Norenzayan	2001	Literature review	—	Cognitive-perceptual
Nisbett & Norenzayan	2002	Literature review	—	Cognitive-perceptual
Oetzel et al.	2001	Likert-type survey and open ended questionnaire	Undergrad students	Social-interpersonal
Peng & Nisbett	1999	Experimental	Undergrad and grad students	Cognitive styles
Schwartz	1999	Likert-type survey	Teachers; undergrad students	Social-interpersonal
Thomas	1999	Experimental	Undergrad students	Social-interpersonal
Watson, Kumar, & Michaelson	1993	Experimental	Undergrad students	Cultural differences and performance

(b) attribution of cultural dimensions after the fact to explain previously identified performance differences, and/or (c) assumptions regarding the efficacy of sociotechnical system moderators (e.g., training) without supporting evidence.

Nonetheless, given the findings of social-personal and cognitive-perceptual cultural differences, it can be suggested that sociotechnical team members differing on these factors may be more likely to commit errors than are those in culturally homogeneous teams. As Klein and Steele-Johnson (2007) note, "National differences in thinking and reasoning styles . . . create formidable barriers to understanding and collaboration" (p. 475). There is support for this assertion, although it is from research that was not conducted in sociotechnical system settings.

Thomas (1999) demonstrated that the greater the extent of cultural differences in critical social, cognitive, and perceptual dimensions, the more likely teams will commit errors in a cognitive task relative to more culturally homogeneous teams. Referring to what he termed "relative cultural distance," he observed that culturally homogeneous groups consistently outperformed heterogeneous ones in the same problem-solving task. Watson, Kumar, and Michaelson (1993) obtained similar differences in the performance of culturally heterogeneous and homogeneous teams. However, during a period of 17 weeks, as the culturally heterogeneous teams continued to work together, performance differences between the teams disappeared.

Gelfand, Nishii, and Raver (2006) contend that differences in the strength of cultural norms and the degree to which the group tolerates deviation from the norms affect performance between cultures. Tight norms allow little deviance by group members and are more likely to influence behavior than are loose norms. The dimension of tightness-looseness, they argue, is independent of other dimensions, such as individualism-collectivism.

H. A. Klein (2005) suggests that of Hofstede's dimensions, two—power distance and uncertainty avoidance—affect team performance. Because power distance affects the way subordinates view and defer to others on the team as a function of their perceived hierarchical status, it can be assumed that team members from high-power-distance cultures would differentially attend to inputs from colleagues according to their perceived status. Perception of power distance can also affect the willingness of team members to defer to their colleagues or supervisors in matters of system operations, even when deference may not be warranted.

Furthermore, because of the likelihood that systems will present ambiguous or conflicting cues, and what Orasanu and Connolly (1993) refer to as "ill-structured problems," uncertainty avoidance can be expected to directly affect sociotechnical system team performance. Those with high tolerance for ambiguity would be expected to respond more quickly and/or more appropriately to uncertain situations than would those from cultures with low tolerance for ambiguity.

Differences in cognitive and perceptual styles can affect team performance by leading to differences in the way operators perceive and comprehend system cues, differences that can affect situation awareness and subsequent decision making. Differences such as these, that interfere with team perception and interpretation of system cues, or can delay team response to cues, have the potential to cause breakdowns in team performance.

The literature suggests that team performance errors are more likely to be committed, and more likely to adversely affect system operations, during operational phases when workload and stress on operators are the highest. In lower-workload phases, operators can more effectively attend to system cues and monitor and respond to changes in system status, because there are fewer demands on their cognitive processes and more time available to attend to system operations (Urban, Weaver, Bowers, & Rhodenizer, 1996; Weaver, Bowers, & Salas, 2001; Woods & Patterson, 2001).

Cultural Research in the Marine System

Culturally heterogeneous teams are more likely to be found in systems that operate internationally, such as transportation, than in domestic ones, such as chemical processing. The marine and aviation systems, both of which operate internationally, have been the subject of more research on cultural interactions than most systems, although considerably more research has been conducted in the aviation than in the marine system. Both marine and aviation systems have also been the subject of official accident investigations that, although lacking in sample size and possessing other shortcomings for research purposes, nevertheless offer insights into multicultural team performance.

The marine transportation system consists of military, recreational, research, and other types of vessels and vessel operations. I focus here on international commercial operations, with vessels that traverse both oceans and local waterways, across international borders. When traversing foreign ports, commercial vessels are almost universally required to retain local harbor pilots to navigate or guide the vessels to and from berths and pilot stations. Captains or masters and other bridge crewmembers are expected to work together with the pilots, as a single team, to maneuver a vessel in narrow waterways, around other vessels and obstructions, while avoiding shallow water or other hazards.

In this respect, the marine system is unique among sociotechnical systems. Pilots, usually unknown to vessel crewmembers, are likely to differ in culture and native language from the vessel crewmembers as well as in their respective experience in the particular waterway. Yet the pilots are expected to serve as fully functioning team members almost immediately on entering a vessel's bridge, during the highest workload phase of vessel operations, navigating in local waters. Nonetheless, the system appears to be robust, and pilot-involved accidents are infrequent.

Hetherington, Flin, and Mearns (2006) focused exclusively on operators in a review of shipping safety and marine accidents. They identified unique factors that played a role in those accidents, including bridge resource management and engine resource management, marine analogs to aviation's crew resource management. Hetherington et al. (2006) concluded that language and cultural issues affect vessel safety, primarily through breakdowns in communication and misunderstandings within the teams. Although the findings suggest an influence of culture on system operations, the authors did not distinguish between culture and language. Absent a methodology that distinguishes between language and culture, researchers are likely to be constrained in discriminating between the influence of one or the other on system operations.

Havold (2007) examined national cultures among crewmembers of Norwegian-flagged commercial vessels to determine whether nationality was related to vessel safety culture, or what he termed "safety orientation." He found that cultural differences between the crewmembers were consistent with several of Hofstede's dimensions. In addition, Havold found differences in the fatalism of the respondents and in factors that he termed "actions based on accidents," "work itself," and "espouses safety values."

The Transportation Safety Board of Canada (1995) examined 273 accidents of oceangoing vessels in Canadian waters that occurred between 1981 and 1992. The study focused exclusively on accidents involving pilots on internationally operating vessels, almost all of which involved multicultural operator teams. Two hundred of the accidents were determined to involve such issues as misunderstandings between pilots and captains or other bridge officers and misjudgments by pilots or captains. Follow-up interviews with both captains and pilots found that many attributed these misunderstandings to deficient language skills (French and English) of the vessel officers. However, some pilots also reported that "an increasing number of foreign masters consider the arrival of a pilot on board as a relief, a way to discharge some of their responsibilities, a chance to get some rest" (p. 6), suggesting an explicit cultural difference in social loafing.

A recent marine accident in the United States illustrates how cultural factors can influence social loafing in marine system operations. On November 7, 2007, in thick fog, the Hong Kong-registered container ship Cosco Busan struck the pier of a supporting tower of the San Francisco-Oakland Bay Bridge. The vessel's fuel tank was torn open, and more than 50,000 gallons of fuel oil spilled into San Francisco Bay as a result (National Transportation Safety Board, 2009). The vessel was under the navigational control of a local harbor pilot, a U.S. national with more than 26 years of experience in the San Francisco port. The pilot had been taking multiple prescription medications that degraded his cognitive skills and his ability to interpret electronic navigation data, effects that would have been unrecognizable to those working alongside him.

Investigators concluded that with the harbor pilot, the vessel's master or captain shared responsibility for the accident because he did not review with the pilot the intended vessel navigation plan from the Oakland berth to the San Francisco pilot station (the pilot boards a moving inbound vessel or disembarks from an outbound moving vessel at a pilot station outside the immediate port area) and did not effectively monitor the pilot's navigation of the vessel through the harbor. By the captain's admission, he deferred all navigation tasks to the pilot. The captain, a licensed mariner for more than 20 years and a captain for almost 10 years, was on his first voyage through San Francisco harbor.

The captain, who, like the other crewmembers, was a national of the People's Republic of China, interpreted the pilot's demeanor negatively when they first met. As he told investigators in an interview conducted through a translator,

> Normally as a captain I would welcome the pilot with my open arms, enthusiastic, and I would show my hospitality in offering him if he need any food or coffee or tea, et cetera. And then pilot came on board with a very cold face. Some of them just don't want to pay attention on us and some of them would not like to talk with us. . . . It seems the pilot coming on board was with cold face, doesn't want to talk. I don't know if he had a hard day before or because he was unhappy because I was a Chinese. (National Transportation Safety Board, 2009, pp. 67–68)

Several factors, either alone or in combination, likely account for the captain's minimal participation in harbor vessel navigation. Lacking any experience in the harbor, the captain may have simply deferred all navigation tasks to the pilot, the harbor expert. On the other hand, the captain's own explanation suggests that cultural factors played a role. His almost immediate focus on the pilot's face was consistent with Asian perceptual styles (Blais et al., 2008) and led him to limit his involvement with the pilot in a team task, vessel navigation.

Furthermore, his complete reliance on the pilot in navigating the vessel suggests a cultural difference in social loafing, consistent with the Transportation Safety Board of Canada's (1995) finding regarding a pilot's description of the role of non-Canadian captains in harbor navigation. Consequently, although noncultural factors cannot be excluded in accounting for the breakdown in the performance of the captain and pilot team, the circumstances of this accident suggest that cultural factors played a role.

Cultural Research in the Aviation System

Aviation operations comprise many segments, such as military, recreational, agricultural, and commercial, which differ in complexity, type and extent of operator training and experience, operating procedures, and company or government oversight, among other factors. I focus primarily on commercial air transport, because most aviation cultural research has been carried out in this system and because it is the one most likely to involve intercultural interactions. Typically, such interactions occur when pilots fly into countries different from their own. Multinational cockpit crews are relatively uncommon within the world's commercial fleet, although they are present in some airlines.

Although marine systems routinely introduce cultural heterogeneity to vessel teams when harbor pilots guide the vessels in port, considerably more cultural research has been carried out in the aviation than in the marine system. Much of the research has applied the results of attitude surveys to aviation settings. For example, Merritt and Helmreich (1996) applied two of Hofstede's dimensions, individualism-collectivism and power distance, to Asian and American pilots and flight attendants in what they termed "cockpit management attitudes." Consistent with Hofstede's findings, Asian crewmembers were found to perceive greater differences between the authority of superiors and subordinates (i.e., between captains and first and second officers or between captains and flight attendants) and to recognize the need for greater crew harmony to support the captain than did their American counterparts. Conversely, American crewmembers believed that self-reliance and personal responsibility were more influential in contributing to effective crews than did the Asian crews.

Sherman, Helmreich, and Merritt (1997) surveyed pilots from 12 countries to determine their attitudes toward automation and automated aircraft, as highly automated, "fly-by-wire" air transport aircraft were being introduced into the worldwide fleet. A "consistent and substantial" relationship was found between pilots' attitudes toward automation and their nationalities. In particular, pilots from cultures scoring high on Hofstede's power distance dimension tended to prefer and use automation more than did pilots from cultures scoring lower on the dimension. The latter tended to see fewer differences between superiors and subordinates than did those who scored high. Merritt (2000) surveyed pilots from 19 countries to determine the extent to which Hofstede's initial four dimensions of culture could be replicated. The dimensions were replicated, although the findings differed somewhat from those of Hofstede's studies.

Li, Harris, and Chen (2007) compared the results of Human Factors Analysis and Classification System (HFACS) applications, a human error classification scheme (Shappell & Wiegmann, 1997, 2001), from a study of aircraft accidents in India (Gaur, 2005), the Republic of China (Li & Harris, 2005), and the United States (Wiegmann & Shappell, 2001). Significant differences between the accidents in the three countries were found in seven HFACS categories. However, although suggestive of cultural differences, the study had serious methodological flaws. Differences between the countries (and in the case of India, within the country) in the complexity of the operation, type of operation (military, commercial, and agricultural), level of government oversight, and extent of equipment sophistication and operator skill, among others, were not accounted for and, as a result, cannot be excluded as factors explaining the obtained differences.

Researchers also applied Hofstede's dimensions, after the fact, to explain previously observed differences in aviation accident rates. Soeters and Boer (2000) compared accident rates of 11 North Atlantic Treaty Organization (NATO) air forces from 1988 through 1992 and of 14 NATO air forces from 1991 through 1995 (data for 3 of the 14 air forces were unavailable in one interval). Accident rates correlated significantly with national scores on three of Hofstede's four dimensions.

Jing et al. (2001) compared aviation accidents in 59 countries in Asia-Australia, Europe, North America, Africa-Middle East, and South and Central America-Caribbean, across a combination of cultural factors identified by Hofstede and others. Power distance accounted for more than 50% of the variance in accident rates across the five regions. Because of the previously described limits to the generalizability of the initial attitude survey results, as well as the post hoc application of Hofstede's dimensions to the observed differences in accident rates, the findings of both Soeters and Boer (2000) and Jing et al. (2001) are only suggestive of cultural effects on aviation.

Helmreich (1994), Meshkati (2002), and Orasanu, Fischer, and Davison (1997) contend that cultural factors played a role in the 1990 accident of a Colombian aircraft in which the crew allowed the aircraft to exhaust its fuel and crash on approach to New York City (National Transportation Safety Board, 1991). The Colombian crew failed to unambiguously convey to the American air traffic controllers the urgency of their fuel state (the aircraft had been holding before approaching New York and was dangerously low on fuel when the crew initiated the first approach). Had the pilots declared an emergency, the controllers would have been required to expedite efforts to clear the airplane to land. Because the crew did not do so, the airplane was not given priority when it first entered New York airspace and instead was placed behind other aircraft in a queue lined up for the approach, despite the crew's awareness of their perilously low fuel state.

The captain and first officer communicated with each other in Spanish, whereas the first officer communicated with the U.S. air traffic controllers in English. The captain directed the first officer to declare an emergency to the controllers, but the first officer did not do so. Instead, he told the controllers, "I think we need priority" and "We're running out of fuel." Although language factors may have played a part in the communication breakdown between the Colombian first officer and the U.S. air traffic controllers, the similarity of the English word *emergency* with the Spanish word *emergencia* would argue against it.

Helmreich (1994) suggests that the high power distance of the Colombian culture explains the first officer's reluctance to seek clarification from the captain regarding an emergency declaration. Orasanu et al. (1997) attributes to cultural factors the crew's reluctance to request assistance in obtaining fuel from U.S. dispatchers, even after being informed that they might have to hold before reaching their destination. Meshkati (2002) believes that the crewmembers' desire to avoid uncertainty might have made them reluctant to discuss alternatives to their plan to land in New York. Although the pilots' communication errors may have been influenced by cultural influences, other explanations, such as the crew's unfamiliarity with U.S. dispatch offices, a reluctance to divert to an airport with which the airline did not have prearranged fueling and passenger handling procedures, and poor "airmanship" skills in their inability to relate expected holding times to anticipated fuel needs, could also account for their performance errors.

By contrast, a 1977 aviation accident offers few explanations other than culture to account for the breakdown in team performance. A Japanese cargo aircraft en route to Tokyo crashed shortly after takeoff from Anchorage, Alaska, killing the three crewmembers and two cargo handlers on board (National Transportation Safety Board, 1979).

Investigators determined that the captain was intoxicated—postmortem analysis showed a blood alcohol level of 0.29%—causing obvious performance decrements (a U.S. driver with a blood alcohol level of 0.08% is considered to be legally intoxicated). The captain's intoxication was sufficiently manifest that the driver who took the crew to the airport from their hotel informed his dispatcher of the captain's behavior. The dispatcher notified the airline's Anchorage office, but no further action was taken. Cockpit voice recorder data showed that neither the first nor the second officer remarked about the captain's intoxication, and neither attempted to deter the captain from controlling the airplane.

The captain was a U.S. national, age 53, whereas the first officer and the flight engineer, both Japanese, were ages 31 and 35, respectively. The reluctance of the two junior crewmembers to confront the captain, and their inaction in the face of his control of the aircraft, can be attributed to their reluctance to humiliate the captain. This is because an affront to the captain's "face" would have resulted by their suggesting to the captain, their superior, that he delegate the takeoff to the first officer, a junior crewmember (e.g., Kang, 2004; Oetzel et al., 2001). The circumstances of this accident suggest few factors other than culture that can adequately explain the failure of the junior crewmembers to prevent the captain from taking control of the aircraft, even at the cost of an accident.

The Cosco Busan marine accident and the Anchorage aviation accident share some characteristics. Critical operator performance was degraded by the use of alcohol in one and prescription drugs in the other, although in the Cosco Busan accident, the degradation was subtle and undetectable to others. In both accidents, the crewmembers who failed to properly respond to deficiencies in team member performance were members of a single cultural group and the impaired operator the "outsider." Their failure to coordinate team objectives in operating the aircraft and vessel led to a breakdown in team performance, which led to accidents. An overview of information on studies on cultural differences in sociotechnical systems is presented in Table 2.

DISCUSSION

Culture's Effects on Team Performance

The findings of the present study provide insight into how cultural differences can affect sociotechnical system operations. Culturally heterogeneous teams, in which team members differ in sufficient degree in critical social and/or cognitive dimensions, will be more likely to commit errors than would culturally homogeneous teams. These errors are more likely to

TABLE 2: Studies of Cultural Differences in Sociotechnical Systems

Author(s)	Year	Method	System	Findings
Havold	2007	Likert-type survey	Marine	Consistent with Hofstede
Helmreich	1994	Literature review	Aviation	Hofstede's dimensions could explain cause of an accident
Hetherington, Flin, & Mearns	2006	Literature review	Marine	Not applicable
Jing, Lu, & Peng	2001	Literature review	Aviation	National differences relate to differences in accident rates
Klein & Steele-Johnson	2007	Exploratory study of training effectiveness	Military	Training may moderate cultural differences in cognitive and social factors
Li, Harris, & Chen	2007	Accident rates of three countries compared using HFACS to explain differences	Aviation	National differences accounted for differences in accident rates
Merritt	2000	Likert-type survey	Aviation	Consistent with Hofstede
Merritt & Helmreich	1996	Likert-type survey	Aviation	Consistent with Hofstede
Meshkati	2002	Literature review	Aviation	Hofstede's dimensions could explain cause of an accident
National Transportation Safety Board (NTSB)	1979	Accident investigation	Aviation	Not applicable
NTSB	1991	Accident investigation	Aviation	Not applicable
NTSB	2009	Accident investigation	Marine	Not applicable
Orasanu, Fischer, & Davison	1997	Literature review	Aviation	Hofstede's dimensions could explain cause of an accident
Sherman, Helmreich, & Merritt	1997	Likert-type survey	Aviation	Pilot views on automation consistent with Hofstede
Soeters & Boer	2000	Applied previous findings to account for accident rate differences	Aviation	Consistent with Hofstede
Transportation Safety Board of Canada	1995	Safety study	Marine	Not applicable

Note. HFACS = Human Factors Analysis and Classification System. Hofstede refers to Hofstede (1980, 1991), Hofstede and Bond (1988), and/or Hofstede and McCrae (2004).

be committed during high-stress system operational phases than during routine ones (Salas, Rosen, & King, 2007; Weaver et al., 2001; Woods & Patterson, 2001). The Cosco Busan marine (National Transportation Safety Board, 2009) and the Anchorage airline accidents (National Transportation Safety Board, 1979) illustrate how cultural differences can influence team communication, coordination, and decision making in the respective systems. In both accidents, the breakdown in team performance occurred during the phases of highest workload: port navigation in restricted visibility in the former accident and takeoff in the latter.

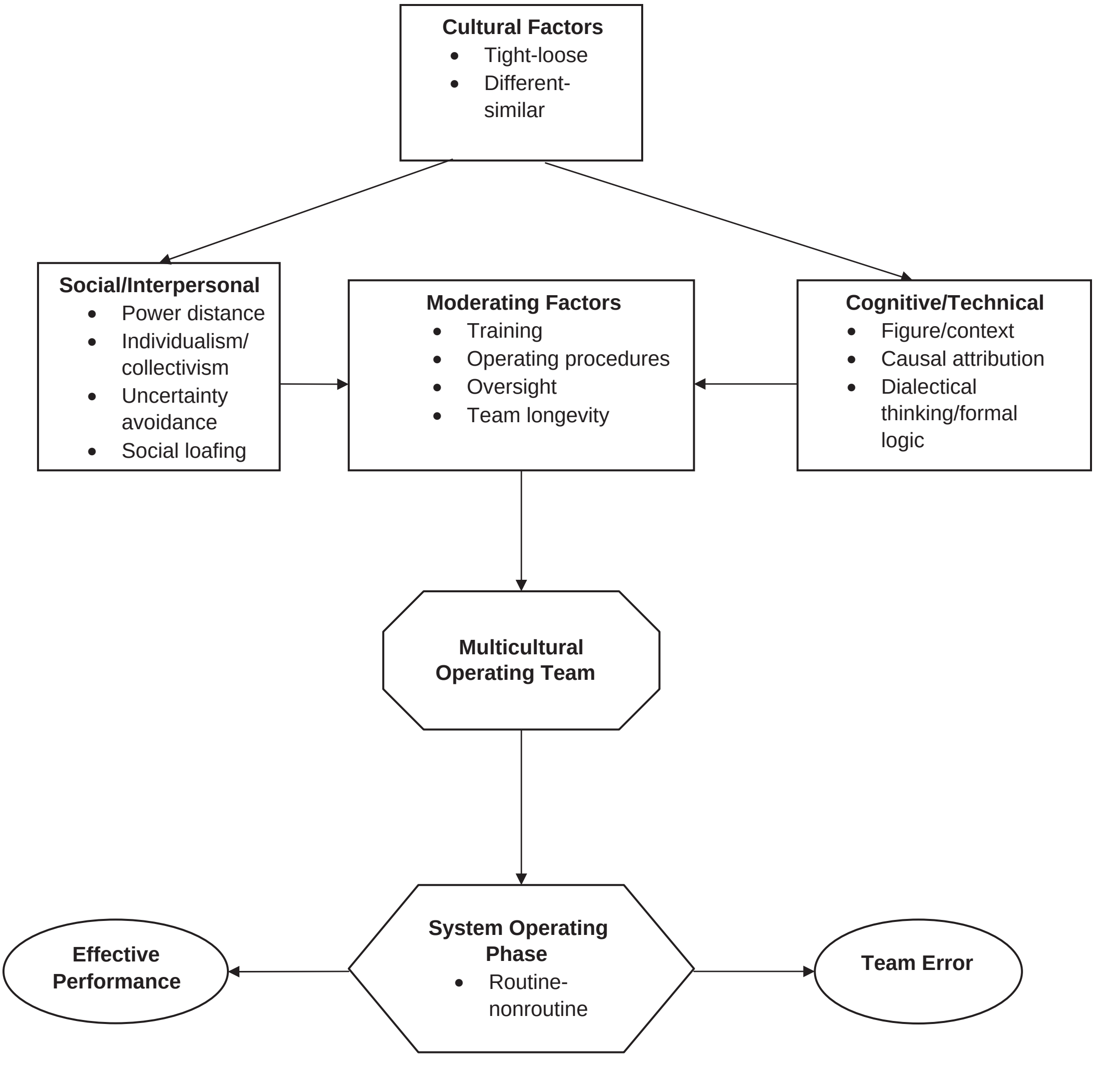

Figure 1. Culture's proposed influence on multioperator teams in sociotechnical systems.

The potential influence of cultural factors on sociotechnical system operations is illustrated in Figure 1, a model of how culture can affect team performance in the systems.

The literature indicates that cultural factors must meet two criteria to influence team performance: (a) Team cultural differences must be sufficiently great in the dimensions that influence critical performance (Thomas, 1999), and (b) the dimensions must be sufficiently influential (i.e., tight rather than loose; see Gelfand et al., 2006). Cultural factors within sociotechnical system teams that meet these criteria can affect team performance.

Team errors in sociotechnical systems can take several forms (Strauch, 2002). Team members can fail to catch or mitigate the errors of others, they can adversely influence the performance of others, or they can fail to properly coordinate or communicate critical information. These errors, primarily social-interpersonal in nature, are in addition to those that individual operators could commit, irrespective of whether they are working within teams. These errors include misinterpreting system cues, incorrectly assessing system state, and taking incorrect action in response to the system state—errors that are largely cognitive-perceptual in nature.

The research on sociotechnical system operations and on cultural differences indicate that situation assessment errors, that is, errors involving cognition and perception, and coordination and communication errors, which involve social and interpersonal skills, are those most likely to be committed in sociotechnical systems. Furthermore, these errors are not expected to be equally likely in all system operational phases. High-workload, high-stress operational phases are more unforgiving of operator performance and are thus more likely to have team errors committed in them than would likely occur during routine operations. This is because of the increased demands these operational phases place on team cognitive processes and coordination and communication.

Two types of cultural factors appear to influence team performance. These are social and interpersonal (e.g., Early, 1989; Hofstede, 1980, 1991; Kang, 2004; Oetzel et al., 2001; Schwartz, 1999) and cognitive and perceptual factors (e.g., Blais et al., 2008; Hong et al., 2000; Ji et al., 2000; Nisbett et al., 2001; Nisbett & Norenzayan, 2002). Differences in social-personal factors could affect team coordination and communication, and differences in cognitive-perceptual factors can affect team situation assessment.

It is possible that system factors, such as operator and team training, duration of team membership, operating procedures, and company or regulator oversight, may moderate the influence of culture on team performance. Team training, especially for performance during high-stress operating phases (Burke, Hess, & Salas, 2006; Klein & Steel-Johnson, 2007), and extended team stability can moderate the potential adverse influences of culture on team performance (e.g., Thomas, 1999) by allowing team members to practice team performance and to familiarize team members with their perceptual and social styles during these system phases.

The proposed model is consistent with Moray's (1994, 2000) theory of error in sociotechnical systems. Moray argues that culture interacts with other system elements, through the general expectations and "philosophy of life" that are imparted to members of the culture, to influence operator decision making and risk tolerance. Thus, it is expected that in sociotechnical systems, culturally heterogeneous teams would be more likely to perform differently than would culturally homogeneous ones.

Reason's (1990, 1997) model of latent errors, and organizational defenses against those errors, does not directly account for the effects of culture, but he gives prominence to the actions that companies can take to moderate or reduce the effects of "latent" or hidden errors that adversely affect operator performance. Training in performance in high-stress operational phases and strict procedures with systematic and thorough company oversight are examples of defenses that may moderate the effects of cultural differences on team performance.

Sutton, Pierce, Burke, and Salas (2006) argue that teams can "culturally adapt," that is, change in response to changing circumstances (Burke, Stagl, Salas, Pierce, & Kendall, 2006) by recognizing, acknowledging, and addressing cultural differences within the teams (see also Stone-Romero, Stone, & Salas, 2003). H. A. Klein (2005) and Klein and Steele-Johnson (2007) suggest that training can lessen potential adverse effects of cultural differences on multinational team performance; both studies propose ways in which systems can moderate or "defend" against the potential role of cultural differences on team performance.

Researching Culture in Sociotechnical System Operations

The relatively little research directly examining the influence of culture on sociotechnical system operations may be attributable to difficulties in measuring performance in these systems. To illustrate, four types of cultural studies have generally been conducted in or have had findings applied to sociotechnical systems: (a) attitude surveys used to identify cultural factors (e.g., Hofstede, 1980, 1991; House et al., 2004; Schwartz, 1999), (b) the results of attitude surveys applied to sociotechnical systems (e.g., Soeters & Boer, 2000), (c) close familiarity with a culture used to apply cultural factors to a sociotechnical system (e.g., Fang, 2003; Jing et al., 2001), and (d) retroactive survey of cultural factors directly in a sociotechnical system (e.g., Transportation Safety Board of Canada, 1995).

Although the first and second types can reveal differences in attitudes and suggest social-behavioral differences in general, studies involving those methods did not examine such differences in sociotechnical operations and, as noted, may have limited applicability. Cultural research in system operations has generally involved the third type, inference based on close familiarity with a particular culture, but neither this nor the previous two methods directly focused on the effects of operator performance in sociotechnical systems. Only the fourth type provides an examination of culture in sociotechnical systems, but few such studies have been conducted.

A fifth type, incident and accident investigations, has provided insights on the role of culture in sociotechnical system operations. However, the infrequency of these events, the small sample sizes involved, and the influence of other, potentially more important elements in accident causation, among other potential factors, limit the generalizability of the cultural insights derived. Consequently, to examine relationships between culture and sociotechnical systems, researchers have had to draw inferences from studies of cultural factors and from studies of team performance and apply them to team performance in sociotechnical system operations. This has limited the hypotheses and theories proposed to explain how culture affects sociotechnical system operations.

Because no single method of studying the effects of culture is without flaws, researchers need to select appropriate methodologies to obtain meaningful data on cultural factors. As Tayeb (2001) notes, "the debate surrounding the best paradigm and method to use to collect data cross culturally is as old as the life of cross cultural investigation itself" (p. 101). Researchers may also consider applying multiple methods to obtain meaningful results regarding the effects of culture on sociotechnical system operations.

An ethnographic or anthropological method, as Hutchins, Holder, and Perez (2002) advocate, is resource intensive, requires considerable expertise, and may be subject to observer variability. However, such methods can produce subtle insights into culture that more rigorous experimental methods could miss. Cultural research conducted during system operations is especially challenging because of the need to avoid interference with system operations. Yet Mumaw, Roth, Vicente, and Burns (2000) demonstrated that insightful observations of operator performance can be obtained during ongoing system operations by a combination of systematic observations with structured interviews of operators.

In-depth interviews can elicit cultural insights not available through other methods, but the results, which may not be quantifiable, depend on the expertise of the interviewers and the context of the interviews. Tayeb (2001) recommends that participants maintain diaries that record their perceptions of given events and can provide subtle insights into how culture affects operator perceptions and cognitions. Kitayama (2002) advocates a method he calls "situation sampling," in which participants from different cultures assess a variety of situations, imagine themselves in those situations, and indicate how they would act in them. Each of these methods, although offering the possibility of subtle cultural insights, lacks experimental rigor and the ability to effectively test hypotheses.

The use of system simulators to observe operator performance avoids interfering with system observations and allows experimental control of system- and operator-related variables. However, the lack of situation verisimilitude, because team errors have no consequences, alters a critical element on which our understanding of sociotechnical system operations is based, that is, the high risk for operators following team error or system component failure. However, simulators can allow researchers to control independent variables to study cultural effects in system operations in a way that is superior to other methods.

Other "unconventional" methods, based on data routinely collected in system operations, may provide researchers with valuable insights. For example, analysis of recordings of air traffic control communication may allow insights into multicultural exchanges, within a limited range of communications. Some sociotechnical systems routinely use video and/or audio recorders in their operating environments, and these, too, may provide insights into operations with culturally heterogeneous groups. Methods such as these that allow for analysis and categorization of the nature of the communications may provide insights into cultural effects as well.

Recommendations for Future Research

Many questions regarding the influence of culture on sociotechnical systems remain unanswered, and research should be undertaken to determine how culture affects sociotechnical systems. For example, it is unknown whether cultural differences derived from attitude surveys, from populations other than system operators, are observable within sociotechnical systems. It has also not been determined whether social-interpersonal factors influence team performance in these systems as much as cognitive-perceptual differences do, whether one is more critical to effective system performance than the other, or whether there are no differences in the influence of the two. We do not know whether the potential effects of culture are constant across systems or whether they are likely to occur more in some systems than in others. It has also not been demonstrated whether differences in system operating phases can influence the likelihood of errors among culturally heterogeneous teams as compared with homogeneous ones.

Moreover, although research has demonstrated that training can improve team performance (Salas, DiazGranados, Klein, Burke, Stagl, Goodwin, and Halpin, 2008), and researchers have suggested that training can moderate the effects of culture (e.g., Klein & Steele-Johnson; 2007; Sutton et al., 2006), the actual effects of proposed moderators on cultural differences are unknown. In short, because of the relative scarcity of research on the effects of team cultural differences on performance in sociotechnical system operations, numerous questions remain unanswered regarding the likelihood of multi-operator team errors according to the types of cultural differences, the nature of the sociotechnical systems, and the operating phases of those systems.

Final Thoughts

Intercultural interactions in sociotechnical systems occur regularly. The Cosco Busan accident illustrates a potentially pernicious type of interaction, in which team members from cultures different in critical technical and social dimensions, with no shared training or experience, briefly work together in high-stress, high-workload operations. The subsequent breakdown in team performance that resulted in that accident illustrates the need to better understand how culture can affect sociotechnical system operations. Was the captain's perception of the pilot consistent with Asian perceptions? The answer is yes, as supported by literature on the role of face in Asian cultures. Can his perceptions explain the breakdown in team performance? Here, too, the answer is yes, according to literature on culture and social loafing, although other explanations cannot be ruled out.

In the title of this article, I ask whether cultural differences can lead to accidents in sociotechnical systems. The research suggests that under certain conditions, during some operational phases, and in the absence of system moderators, they can. At least one aviation accident and likely a marine accident suggest that, at the least, cultural factors played a role in the breakdown in team performance that led to the accidents. As intercultural interactions increase in sociotechnical systems, the need for research to better answer how culture can influence sociotechnical system operations increases as well.

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