What We Know About Teamwork and Multiteam Coordination in Aviation: Emergent States Supporting Teamwork in Aviation

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This paper describes a variety of factors that can facilitate teamwork. These include team orientation, collective efficacy, mutual trust, psychological safety, shared situational awareness, shared mental models, and transactive memory. Aviation-specific research on each of these states is reviewed.

A number of factors have been identified that facilitate effective teamwork. These include emergent cognitive and affective states can serve as coordinating mechanisms to support effective teamwork and team performance (Salas et al., 2005). These states are developed or refined during team interaction and impact subsequent team processes. The importance of each of these states has been documented in the general team literature. Aviation-specific research has focused on some states, while other states have received little research attention.

Team Orientation

Team orientation is an attitude that team performance can be improved by coordination and cooperation with other team members (Salas et al., 2005). A meta-analysis (Bell, 2007) indicated that preference for teamwork was positively related to team performance. Although team orientation is generally conceptualized as an individual characteristic, one's orientation toward working with teammates can be shaped by interactions within the team. While aviation research has not focused directly on team orientation, Cahill et al.'s (2014) series of interview and observational studies of flight operations suggested that shared task responsibility and the need for coordination across disciplines are essential for safe and efficient airline operations.

Collective Efficacy

Collective efficacy is the shared belief that the team can perform its tasks. Meta-analytic evidence indicates that collective efficacy is related to effective team performance (Stajkovic, Lee et al., 2009). We found few studies of collective efficacy in aviation, and those were limited to ATC teams. Studies of ATC teams indicate that collective efficacy is related to backup behavior (Smith-Jentsch et al., 2009) and effective team performance (Mathieu et al., 2010).

Mutual Trust

Mutual trust involves a shared belief that team members will properly perform their duties and protect the interests of other team members (Salas et al., 2005). Trust promotes cooperation, information sharing, and willingness to rely on information provided by others. Although we are not aware of studies of trust among aviation professionals, a study of occupational stereotypes among aviation students suggests that a lack of professional trust is not a major issue (Lillard et al., 2015).

Psychological Safety

Psychological safety refers to the belief that it is safe to take interpersonal risks such as suggesting changes, raising doubts and objections, or admitting mistakes or a lack of knowledge or expertise. Edmondson & Lei (2014) review extensive evidence indicating that a climate of psychological safety can facilitate the discussion of problems leading to error correction and improved work practices.

Creation of a psychologically safe climate facilitates team error prevention and management, and this is one of the major goals of CRM (Tullo, 2010; Velazquez & Bier, 2015). Surveys of first officers and flight attendants suggested that psychological safety facilitates questioning or challenging of actions and decisions of superiors in both groups. Psychological safety was related to flight attendants speaking up to the lead flight attendant and also mitigated the chilling effects of status on first officers' speaking up to the captain. Feelings of psychological safety within the flight attendant group facilitated boundary spanning and was associated with lead flight attendants speaking up to pilots (Bienefeld & Grote, 2014).

Situation Awareness and Assessment

One of the most critical emergent cognitive states supporting teamwork and multiteam coordination is a shared awareness and assessment of the situation (Endsley, 2015). Aircrews need to have a shared understanding of weather conditions, terrain, altitude, location, flight traffic, airport conditions, flight plan deviations, and the mechanical condition of the aircraft. Situation assessment requires not only an awareness of the situation, but also an accurate interpretation of its meaning and implications. Analysis of a national accident database indicted that about 62% of accidents involved failures of situation awareness (Endsley, 2010). Examples include fatal crashes that have occurred where distracted cockpit crews failed to monitor basic situational factors such as fuel or altitude. Results of flight simulator studies and analysis of incident reports provide additional evidence indicating that situation awareness among pilot teams is related to effective teamwork processes and team performance (e.g., Brannick et al., 1995; Nullmeyer, & Spiker, 2003). Ineffective aircrews displayed situation awareness deficiencies such as lack of vigilance and lack of awareness of the environment and of aircraft systems (Hausler et al., 2004). Examination of ATC incident reports revealed that the lack of situation awareness was related to the frequency and severity of errors (Rodgers et al., 2000).

Maintenance is often performed by teams and involves initial inspection, diagnosis, repair, and final inspection. Typically, these activities are performed by different individuals and frequently multiple systems are serviced simultaneously by different technicians. It is important

to maintain shared situation awareness about the status of the airplane and the maintenance activities, including assessments and reasons for actions (Endsley & Robertson, 2000).

Awareness of risks (e.g., severe weather, mechanical issues) provides a foundation for threat detection and effective decision making, and is critical to mission success (Helmreich et al., 1999). The National Transportation Safety Board (NTSB) has identified distraction as one factor that can undermine situation awareness. Examples include accidents and issues that occurred when pilots failed to monitor flight conditions while attending to a minor problem, used portable electronic devices, or engaged in social conversations with a flight attendant. (Chute & Wiener, 1996; Endsley, 2010; NTSB, 2017).

Mental Models

Shared mental models provide shared expectations that allow for more efficient coordination and reduce the need for explicit communication. This is especially important under time-sensitive and high workload conditions. Task mental models focus on procedures, strategies, and cue-response associations. Teamwork mental models reflect roles, interdependencies, and interaction requirements. Equipment mental models involve understanding of equipment operation, and technology (Cannon-Bowers et al., 1993). A meta-analysis indicated that both task mental models and teamwork mental models were related to teamwork and to team performance (DeChurch & Mesmer-Magnus, 2010).

Importance of mental models has been demonstrated for pilots, ATC, and for multiteam operations. While there have been some conflicting results, overall patterns have emerged. Performance is highest when both task and teamwork mental model are shared and accurate (e.g., Mathieu et al., 2005; Mathieu et al., 2010; Smith-Jentsch et al., 2005). An accurate and shared task model allows team members to have a common and appropriate understanding of actions that need to be taken. An accurate and shared teamwork model allows team members to allocate tasks and coordinate activities to effectively implement actions deriving from the task mental model.

Not only are shared mental models important within teams, they are important in multiteam contexts as well. Lack of shared mental models can lead to disconnects. Bearman et al., (2010) identify three types of disconnects common to aviation: informational, evaluative, and operational. Informational disconnects are when the two team members do not have the same information. Evaluative disconnects occur when both parties have a different interpretation or give different weights to the information. For example, pilots and air traffic controllers have different framing and cue utilization for risk assessment (Mosier & Fischer, 2015). ATC personnel tend to base risk assessments on distance between aircraft, but pilot's risk assessments are largely based on time to respond and options to control the situation (Fischer et al., 2003). These evaluative disconnects can lead to operational disconnects (mismatches between different team members plans and/ or actions) such as a pilot choosing to avoid challenging weather rather than adhere to ATC directives (Bearman et al., 2010).

Although there is limited research on equipment or technology mental models in the general team literature, there is evidence that shared mental models of technology are important

within aviation. One area where an inadequate technology mental model is evident is mode errors (Sarter, 2008; Sarter et al., 2007; Sarter & Woods, 1994). Mode errors occur when the pilots do not understand the current state of a system, the permitted actions, and the future actions taken by an automated system. Mode errors result in inappropriate or ineffective actions or failure to take action when needed. Other studies indicate that differences in experience and comfort level with aviation technology may create different perceptions of individual workload and confidence and can undermine shared situation awareness (Fernandes & Smith, 2011; Martin et al., 2011).

Transactive Memory

Transactive memory refers to a shared understanding of the areas of expertise held by specific team members. An effective transactive memory system allows for specialization and coordination among team members. Meta-analysis revealed a strong relationship between transactive memory and both team processes and team performance (DeChurch & Mesmer-Magnus, 2010). Aviation requires coordination among various specializations, therefore a shared understanding of the types of knowledge possessed by each specialization is needed. Little research has examined the role of transactive memory in aviation, but a study of senior aviation students indicated that they showed relatively high levels of transactive memory (Littlepage e al., 2016). In a related study, transactive memory was found to predict teamwork and to have an indirect effect on both routine and adaptive performance (Wertheimer & Littlepage, 2017). A study of ATC teams found that transactive memory was related to requesting and accepting backup behavior (Smith-Jentsch et al., 2009).

Conclusions

These studies illustrate the importance of emergent states. They also indicate that while aviation research has addressed some emergent states, others are in need of additional aviation-specific research. The next paper in this series describes research on teamwork processes.

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