Human Factors: The Journal of the Human Factors and Ergonomics Society

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Human Factors: The Journal of the Human Factors and Ergonomics Society 2008; 50; 540

DOI: 10.1518/001872008X288457

On Teams, Teamwork, and Team Performance: Discoveries and Developments

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Objective: We highlight some of the key discoveries and developments in the area of team performance over the past 50 years, especially as reflected in the pages of *Human Factors.* **Background:** Teams increasingly have become a way of life in many organizations, and research has kept up with the pace. **Method:** We have characterized progress in the field in terms of eight discoveries and five challenges. **Results:** Discoveries pertain to the importance of shared cognition, the measurement of shared cognition, advances in team training, the use of synthetic task environments for research, factors influencing team effectiveness, models of team effectiveness, a multidisciplinary perspective, and training and technological interventions designed to improve team effectiveness. Challenges that are faced in the coming decades include an increased emphasis on team cognition; reconfigurable, adaptive teams; multicultural influences; and the need for naturalistic study and better measurement. **Conclusion:** Work in human factors has contributed significantly to the science and practice of teams, teamwork, and team performance. Future work must keep pace with the increasing use of teams in organizations. **Application:** The science of teams contributes to team effectiveness in the same way that the science of individual performance contributes to individual effectiveness.

Teams have become the strategy of choice when organizations are confronted with complex and difficult tasks. Teams are used when errors lead to severe consequences; when the task complexity exceeds the capacity of an individual; when the task environment is ill-defined, ambiguous, and stressful; when multiple and quick decisions are needed; and when the lives of others depend on the collective insight of individual members. Teams are used in aviation, the military, health care, financial sectors, nuclear power plants, engineering problem-solving projects, manufacturing, and countless other domains. They take a variety of forms, from teams of teams to human-robot teams. As the complexity of the workplace continues to grow, organizations increasingly depend on teams.

The good news is that research has kept up with the demand from organizations for scientifically rooted guidance. The science of team performance has produced a wealth of knowledge on how to compose, manage, structure, measure, and promote team performance. Our purpose here is threefold: (a) to briefly discuss what we know about teams, teamwork, and team performance; (b) to highlight recent discoveries and developments, especially as documented in *Human Factors;* and (c) to motivate research for the future. We should note that our review is necessarily selective. We focus only on those areas in which we think significant research has been conducted and in which we think interesting, compelling, and robust discoveries have been made. We first discuss key distinctions needed to

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understand the discoveries. Subsequently, we discuss eight discoveries and end with several key issues that need attention as team research continues to develop over the coming decades.

TEAMS, TEAMWORK, AND TEAM PERFORMANCE: FUNDAMENTAL CONCEPTS

Over recent decades, a "golden age" of interest in team research has emerged. A recent review of the literature revealed more than 130 models and frameworks of team performance or some component thereof (Salas, Stagl, Burke, & Goodwin, 2007). This breadth represents an ongoing balance between models at different levels of granularity. Some are parsimonious and generalizable models of teamwork (Salas, Sims, & Burke, 2005), and others are more contextualized team or task-specific frameworks (Xiao, Hunter, Mackenzie, Jefferies, & Horst, 1996) or models that focus on a specific team process or function (Entin & Serfaty, 1999). Among these varying theoretical models are some core concepts that might be considered common ground. These concepts include the input-process-output (I-P-O) framework, which is the dominant approach underlying these various models, as well as a consideration of the multilevel and dynamic nature of teams (i.e., for a more extensive discussion, see Ilgen, Hollenbeck, Johnson, & Jundt, 2005; Salas et al., 2007).

Teams are social entities composed of members with high task interdependency and shared and valued common goals (Dyer, 1984). They are usually organized hierarchically and sometimes dispersed geographically; they must integrate, synthesize, and share information; and they need to coordinate and cooperate as task demands shift throughout a performance episode to accomplish their mission. During a performance episode, team members engage in taskwork processes and teamwork processes. Individual *taskwork* is defined as the components of a team member's performance that do not require interdependent interaction with other team members. In contrast, *teamwork* is defined as the interdependent components of performance required to effectively coordinate the performance of multiple individuals. *Team performance* is conceptualized as a multilevel process (and not a product) arising as team members engage in managing their individual- and team-level taskwork and teamwork processes (Kozlowski & Klein, 2000). Conceptually, teamwork is nested within team performance and is a set of interrelated cognitions, attitudes, and behaviors contributing to the dynamic processes of performance. *Team cognition* or team-level *macrocognition* is an example of this type of interrelationship between processes and has been the focus of much recent research (Letsky, Warner, Fiore, & Smith, in press; Salas & Fiore, 2004). In general, team cognition research characterizes teams as information-processing units (Hinsz, Tindale, & Vollrath, 1997). Processes such as the encoding, storage, and retrieval of information are thought to apply on the team as well as the individual level (Salas & Fiore, 2004). These processes occur internally in individuals; however, on the team level, communication is viewed as a central mechanism of information processing. In addition, team cognition can be viewed as an emergent phenomenon (Cooke, Gorman, & Rowe, in press; Cooke, Gorman, & Winner, 2007). Finally, *team effectiveness* is an evaluation of the outcomes of team performance processes relative to some set of criteria (Hackman, 1987). The definitions of performance and effectiveness on the team level closely parallel the definitions of these terms on the individual level. That is, performance is the activities engaged in while completing a task, and effectiveness involves an appraisal of the outcomes of that activity (Fitts & Posner, 1967; Motowildo, 2003). With this groundwork in place, we turn to a survey of the crowning achievements of the past decades of team research.

DISCOVERIES AND DEVELOPMENTS

What we offer next is a sample of the literature presented as high-level themes that constitute important discoveries, especially as reflected in the pages of *Human Factors.* See Kozlowski and Ilgen (2006), Salas et al. (2007), and Kozlowski and Bell (2003) for recent and comprehensive reviews.

1. Shared cognition matters in team performance. Shared cognition is a critical driver of team performance (Salas & Fiore, 2004), especially in shared mental models, team situation awareness, and understanding communication as a fundamental component of how information is processed at the team level. Shared cognition has been the theoretical basis for understanding how teams adapt their performance processes under varying task conditions (Entin & Serfaty, 1999), interpret environmental cues in a similar or complementary manner (Naylor & Amazeen, 2004; Salas, Prince, Baker, & Shrestha, 1995), and make compatible decisions and carry out coordinated action (Mohammed & Dumville, 2001). The implications and applications of this line of research have been far-reaching. For example, Entin and Serfaty (1999) have shown that team training that builds shared mental models of the situation, task environment, and interactions of team members increases a team's ability to function effectively under high levels of stress. In addition, Wilson, Salas, Priest, and Andrews (2007) have provided groundwork for understanding how breakdowns in shared cognition can lead to errors on the battlefield and other high-stress operational contexts. Specific failures in communication and coordination behaviors as well as deficient cooperation (i.e., motivation or desire to work as a team) derail the process of building a shared understanding of the situation between team members, which leads to poor performance and errors (Stout, Cannon-Bowers, Salas, & Milanovich, 1999).

2. Shared cognition can be measured. The developments discussed earlier have been made possible by advances in the ability to measure shared cognition (Cooke, Salas, Cannon-Bowers, & Stout, 2000). In general, the available measurement approaches and tools frequently limit the ability to test any given theory; therefore, additions to the measurement approaches for capturing shared cognition constitute a significant development in team research in their own right. These efforts have resulted in techniques to measure team knowledge in terms of an aggregate of individual knowledge or the "collection of task- and team-related knowledge held by teammates and their collective understanding of the current situation" (Cooke et al., 2000, p. 154). Langan-Fox, Code, and Langfield-Smith (2000) have provided a comprehensive review of the methods of elicitation, analysis, and representation of team mental models along with practical guidance for choosing a specific approach based on trade-offs between methods. More holistic measures focus on the dynamic processes used by teams to filter and distribute information (Bowers, Jentsch, Salas, & Braun, 1998; Cooke, Gorman, & Kiekel, in press; Gorman, Cooke, & Winner, 2006). These holistic measures focus on the analysis of communications with recent efforts moving toward task-embedded, real-time measures of shared cognition (Cooke, Gorman, & Kiekel, in press).

3. Team training promotes teamwork and enhances team performance. A series of studies in the military and aviation (and more recently in health care) has clearly shown that team training works (Cannon-Bowers & Salas, 1998; Morgan, Coates, Kirby, & Alluisi, 1984). It works because sets of teamwork competencies have been identified and articulated in a manner that affords the development of systematic programs of instruction (Cannon-Bowers, Tannenbaum, Salas, & Volpe, 1995). In addition, these competencies have been coupled with methods of training delivery and design suited to the nature of team performance. For example, simulation-based training (SBT) has proven to be a powerful training methodology for team performance because it allows teams to engage in the dynamic social, cognitive, and behavioral processes of teamwork and receive feedback and remediation based on team performance (Gorman et al., 2007). In sum, well-designed team training is systematic, rooted in explicitly defined team competencies, and theoretically based; it also employs measurement and feedback (Salas, Prince, et al., 1999).

From very simple cross-training interventions designed to improve team members' understanding of each other's roles and consequently improve coordination (Cannon-Bowers, Salas, Blickensderfer, & Bowers, 1998; Volpe, Cannon-Bowers, Salas, & Spector, 1996) to training approaches such as crew resource management (CRM), which directly train team skills such as assertiveness, maintaining shared situation awareness, and communication (Salas, Fowlkes, Stout, Milanovich, & Prince, 1999), well-designed team training increases the quality of team processes and overall performance outcomes. In addition, Shebilske, Jordan, Goettl, and Paulus (1998) have developed methods for maintaining high levels of training outcomes while minimizing the amount of time in training by mixing observational learning and practice-based learning during team training. So, there are diverse methods of team training available. Applying meta-analytic synthesis, Klein et al. (2007) have shown that across different training methods, team training accounted for approximately 20% (unweighted $r = .456$) of the variance across knowledge, affective, behavioral, and performance outcome variables, with different training methods having stronger relationships with different types of outcome variables.

4. Synthetic task environments (STEs) provide context for research. A significant development in team methodology has been the realization of the importance of synthetic task environments. Teams are complex, dynamic systems; consequently, team research requires a method for observing teams under these conditions and not as static entities divorced from context. STEs are tasks used for research purposes and developed so that they systematically incorporate features of a real task (Martin, Lyon, & Schreiber, 1998). As such, STEs provide a valuable compromise between the complexity of the real world, which is an important influence on team performance and critical for establishing externally valid results, and experimental control, which is necessary to establish internally valid results (Cooke & Shope, 2005). The widespread and fruitful use of STEs in the team arena is documented in Schiflett, Elliott, Salas, and Coovert (2004).

5. Team performance can be modeled. A more recent development has been the application of new linear and nonlinear modeling methods to the scientific understanding of team performance. First, linear techniques such as hierarchical linear modeling (HLM) have aided in understanding how performance compiles across multiple levels to yield team performance (Kozlowski & Klein, 2000). Second, just as network and dynamical systems theories are influencing thinking in a wide range of scientific disciplines, including psychology, nonlinear models of team performance are emerging as powerful quantitative and qualitative tools (e.g., Gorman, 2006; Gorman, Cooke, Pedersen, et al., 2006; Gorman et al., 2007). Gorman, Cooke, Pedersen, et al. (2006) modeled team coordination using a dynamical systems approach and found that newly composed teams exhibited more flexible patterns of interaction and responded more effectively than teams that had been together longer. These modeling results were used successfully to design team training that mimicked the coordination dynamics of newly composed teams (Gorman et al., 2007).

Another relatively recent development is the application of computational architectures such as ACT-R to model synthetic teammates (Gluck et al., 2005). Such models are of tremendous applied value for team training or complex operations but also of significant theoretical value as tests of theories of individual contributions to team performance.

6. Factors that influence team performance have been identified. From issues of team composition (e.g., personality, cognitive ability, motivation, cultural factors) and work structure (e.g., team norms, communication structure, work assignments) to task characteristics (e.g., workload, task type, interdependency), a host of factors influencing team performance have been identified (Baranski et al., 2007; Urban, Weaver, Bowers, & Rhodenizer, 1996; Waag & Halcomb, 1972). For example, Xiao and colleagues (1996) identified four task characteristics (multiple and concurrent tasks, uncertainty, changing plans, and high workload) that pose difficulties for trauma teams and discussed how team coordination training and work design can be used to overcome these obstacles. For example, multiple and concurrent tasks pose challenges to effective teamwork in that the team must reconcile conflicting goals and task interference. Training in explicit communication skills and strategies can help the team members overcome these and other roadblocks to coordination. In addition, Driskell and Salas (1992) highlight the importance of having team members with a collective orientation, an important team composition variable. Team members who are high in collective orientation are more likely to attend to the task inputs and needs of fellow team members during performance. This increased attention to fellow team members facilitates the processes of coordination and communication and ultimately improves team performance outcomes.

7. Well-designed technology can improve team performance. Whereas team performance improvements have been achieved via the application of team training programs, the science of teams has led to the development and implementation of technology to support team performance as well. This includes the development of displays and tools to support shared situation awareness by, for example, providing individuals with representations of fellow team members' actions and intentions as well as by tracking and displaying complex task performance over time (Gutwin & Greenberg, 2004). However, the mere insertion of technology into a system does not guarantee that it will augment team performance or even be used by the team. Just as training must be well designed to be effective, technology also must be guided by a thorough understanding of team needs and capabilities. Naikar, Pearce, Drumm, and Sanderson (2003) provide a method based in cognitive work analysis for concurrently designing teams and technology for complex first-of-a-kind systems.

8. The field belongs to many disciplines. The formation and growth of organizations such as the Interdisciplinary Network for Group Research (INGRoup) are indicative of the trend toward the convergence of knowledge developed within separate disciplinary traditions that are often stove-piped. It is more apparent than ever that psychologists and human factors researchers do not own team research. Researchers from the fields of computer science (Stahl, 2006), communication (Hirokawa & Poole, 1996), organizational sciences (Carley, 1997), and engineering (McComb, 2007), to name but a few, make important contributions to the scientific understanding of teams. This diversity of perspectives has enabled a robust understanding of team performance to evolve.

A LOOK AHEAD FOR TEAM RESEARCH

We now attempt to provide a glimpse of the road ahead – the future of team research. Although the science behind our understanding of teams and team performance is strong, there is much left to accomplish. The future holds many challenges and opportunities. Again, our coverage is selective rather than comprehensive.

1. We need better measurement. Although there have been great strides in the measurement of team behavior (Brannick, Prince, Prince, & Salas, 1995) and cognition (Cooke et al., 2000; Cooke, Salas, Kiekel, & Bell, 2004), there remains a need for more robust, reliable, valid, and diagnostic measurement approaches. For example, the pursuit of dynamic and adaptive systems that are sensitive to team-level performance requires *unobtrusive* and *real-time* measures of team performance that can be *practically* implemented, especially in the field. Although steps have been taken toward this goal, including work with embedded measurement (Cooke, Gorman, & Kiekel, in press; Zachary, Bilazarian, Burns, & Cannon-Bowers, 1997), much remains to be done.

2. We need to study teams "in the wild." Teams are embedded in organizations and broader sociotechnical systems. The nature of couplings between the team and other components of the system undoubtedly affects team process and outcome; however, there are few rigorous studies of teams "in the wild," in their full situated context. This type of research and concomitant methodology (e.g., Arthur, Edwards, Bell, Villado, & Bennett, 2005) can enable researchers and practitioners to provide higher-quality "context-specific" guidance to organizations that complements the extant theoretical models. In addition, an increased understanding of the factors that influence team performance "in the wild" can be used to guide the development of future STEs, which subsequently will provide increasingly refined tools for testing theory. Pioneering work by researchers such as Ed Hutchins (1990, 1995) and many others has provided a strong groundwork, but much remains to be done.

3. We need a better understanding of dynamic assembly of adaptive teams. Modern military and civilian organizations are adopting rapidly reconfigurable organizational structures to maintain responsiveness to changing environments (e.g., Alberts, 2007). This entails flat organizational configurations with a collaborative technology infrastructure, enabling spatially and temporally distributed personnel to be assembled dynamically to meet the changing needs of the organization. The literature shows that merely connecting people with collaborative technology is not sufficient to guarantee effective team performance (Stagl et al., 2007). Work is needed to understand these modern teaming parameters in a manner capable of guiding technology and training. In addition to a better understanding of distributed or virtual teams, meeting this challenge will require more work in mixed human/agent teams as well.

4. We need an increased emphasis on team cognition. Although much is known about the moderators of behavioral coordination in action or performing teams (i.e., what can generally be considered rule-based performance), relatively speaking, far less is understood about complex cognitive tasks performed by teams (i.e., tasks requiring cognitive coordination, such as problem solving, negotiation, and planning). With increasing automation of tasks requiring monitoring, coordination, and complex decision making in the workplace, teams increasingly will be called on to perform complex cognitive tasks. Today, teams are even responsible for the production of the majority of high-impact scientific knowledge (Wuchty, Jones, & Uzzi, 2007). Consequently, theories of teamwork and methods of measurement must evolve to better represent and capture this type of collaborative cognition.

5. We need a better understanding of teams in a multicultural context. As globalization progresses, the need to understand the role of culture in team performance becomes more salient. To date, the bulk of team performance research involves U.S. or Western populations. However, the increasing prevalence of organizational structures such as globally distributed virtual teams in industry and joint-coalition forces in the military raises the possibility that the extant models are insufficient for teams with a heterogeneous cultural composition. The degree to which the existing models and frameworks apply to these multicultural contexts must be assessed, and the models must evolve to include the role of culture in team performance (Altman-Klein & Pongonis-McHugh, 2005).

CONCLUSION

In sum, there is a science of team performance that has met much of the demand from organizations for guidance on the formation and management of teams. But the work is not done; there are discoveries and developments yet to come. The field must continue to keep pace with new demands from a continuously changing workplace. To achieve advances in our abilities to understand, predict, control, and design for team performance in the coming decades, we must forge functional partnerships between researchers and practitioners across scientific disciplines and domains of application.

ACKNOWLEDGMENT

We thank John Lee and three anonymous reviewers for comments on an earlier version of this article. The work behind this paper and much of the work reported within were partially supported by the Office of Naval Research, Grant Nos. N00014-03-1-0580, N00014-06-1-0118, and N00014-06-1-0446.

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Date received: November 5, 2007
Date accepted: March 30, 2008