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— METHODS & DESIGNS —

Games teams play: A method for investigating team coordination and performance

CLINT BOWERS
University of Central Florida, Orlando, Florida

EDUARDO SALAS and CAROLYN PRINCE
Naval Training Systems Center, Orlando, Florida

and

MICHAEL BRANNICK
University of South Florida, Tampa, Florida

Teams are playing an increasingly important role in the workplace. However, reviews of the team performance literature have suggested that there are serious deficiencies in our understanding of team processes and performance (e.g., Dyer, 1984). These difficulties may be attributable, in part, to the lack of laboratory methodologies to investigate team performance. This paper describes the use of low-fidelity simulations as a potentially useful paradigm for researching team coordination and performance. This paradigm is advantageous in that it offers relatively high levels of experimental control and task representation at a low cost.

The ability of groups of individuals to work as teams is quickly becoming a prerequisite in the modern workplace. Teams are playing an increasingly important role in a number of critical work environments, including aircraft cockpits, emergency medicine, air traffic control centers, firefighting, military combat information centers, and so forth. Surprisingly, however, this increased demand for effective teams has not been accompanied by improved technology regarding the study of teamwork. It appears that teamwork has been considered an automatic consequence of requiring individuals to work together, with little or no external intervention required. Yet history indicates that teams do not always work together efficiently, and that the consequences of errors in these environments are often disastrous (Foushee & Helmreich, 1988). For example, it has been suggested that the majority of modern aircraft accidents are attributable to inefficient crew processes rather than equipment failure (Cooper, White, & Lauber, 1979). Therefore, there is a clear need for a greater understanding of the nature of efficient teamwork behaviors in complex environments and for the development interventions that may serve to improve team performance in such situations (Salas, Dickinson, Converse, & Tannenbaum, in press).

One factor that complicates the study of team performance is the level of task fidelity in the laboratory that will allow a reasonable application of laboratory results to the study of field settings. It has historically been accepted that high levels of realism are required in the laboratory for research to be "useful" (see, e.g., Forsyth, 1990). Thus, many tasks in past studies of team performance (i.e., building towers from blocks) have been criticized for their artificiality. Therefore, researchers in team performance have been required to use complex, typically expensive, simulations to conduct useful laboratory research. However, some scientists have recently challenged this position. For example, several reviews in Locke's (1986) volume on this topic indicate no advantage of field research in terms of generalizabilty (see De Vader, Bateson, & Lord, 1986; Goldstein & Musciante, 1986). Others have pointed out that the use of complex full-mission simulations might force researchers to trade experimental control for higher fidelity (e.g., Morgan, Lassiter, & Salas, 1989).

Recently, Driskell and Salas (1992) have suggested that although one might not be able to generalize from traditional laboratory research paradigms to the real world, they may actually be *advantageous* in the evaluation of theories about team performance. This is because the laboratory allows researchers to exercise more strict control over extraneous variables than is possible in the field. Thus, ac-

The views expressed in this paper are those of the authors and do not reflect the official position of the Department of the Navy, the Department of Defense, or the U.S. Government. Please address correspondence to Eduardo Salas, Naval Training Systems Center, Code 262, 12350 Research Parkway, Orlando, FL 32826-3224.

cording to Driskell and Salas, "The more artificial the setting, in the sense that it contains only the variables that are relevant to the theory being tested, the more rigorous is the test of the researcher's hypothesis" (pp. 201-202). However, they point out that any laboratory task used in this fashion must possess the sufficient task characteristics to provide an adequate test of the theory. Thus, tasks that have been used in previous research may, indeed, be useful for testing theories relevant to some types of work groups. However, it might be argued that these tasks are not useful for testing theories for teams that must operate in complex, rapidly changing environments that impose higher levels of workload and coordination demands on the operators. Therefore, the purpose of this paper is to describe a paradigm that can be used to conduct research on team performance in a laboratory simulation that imposes more realistic levels of coordination demand and workload.

Defining a Team

To evaluate any paradigm for team performance research, one must first define the concept of a team. For the purposes of this discussion, a *team* will be defined as "a distinguishable set of two or more individuals who interact dynamically, interdependently and adaptively to achieve specified, shared and valued objectives" (Morgan, Glickman, Woodard, Blaiwes, & Salas, 1986). Thus, an initial prerequisite for any research paradigm designed to investigate team performance is that there be interdependence of team members. It is the lack of interdependence that renders much of the small group research inappropriate for application to team performance (Dyer, 1984). Furthermore, tasks previously used in the study of small groups typically have involved members performing similar tasks in pursuit of a group goal (see McGrath, 1984, for a review). However, for one to fully understand naturalistic team performance, there is a need to investigate teamwork behaviors among interdependent operators performing different types of taskwork. Thus, the overall team task comprises several subtasks (each, perhaps, falling into different performance dimensions), which increases the importance of interdependence for successful team performance. This increased requirement for coordination is likely to improve generalizability to the operational environment.

For the purposes of team performance research, a useful distinction may be offered by the differences between taskwork and teamwork (Glickman et al., 1987). *Taskwork* involves behaviors associated with the specific task being performed, such as interacting with equipment, collecting task-relevant data, and so forth. *Teamwork* refers to behaviors associated with cooperation, communication, and coordination among team members. Teamwork is likely to comprise a number of skill areas, such as communication, situational awareness, leadership, and others (see Prince, Chidester, Bowers, & Cannon-Bowers, 1992, for a more thorough discussion of coordination skills). It has been suggested that taskwork behaviors are specific to the task being performed and may differ greatly among teams. Teamwork behaviors, on the other hand, are more general (i.e., the behavioral requirements of teamwork are independent of the task being performed), and similar teamwork behaviors can be observed across a variety of team tasks (Morgan et al., 1986). Thus, high levels of fidelity may not be necessary for testing theories regarding teamwork if the lower fidelity simulation is adequately demanding (i.e., if the task is interdependent and imposes a sufficiently high workload).

The preceding discussion suggests that a method that offers realistic task representation and interdependence while allowing empirical investigation of specific principles and theories might be a useful addition to the study of team performance. The purpose of the present paper is to describe a laboratory task that might be useful in this regard. For this task, a commercially available computer game has been modified to impose interdependence upon a team of two subjects. Because the task possesses characteristics and requirements found in operational settings (i.e., time pressure, interaction with equipment, decision making), it is believed that it will be possible to apply the results thus obtained to performance in field settings.

A Laboratory Paradigm for Team Performance Research

This paper will focus on a team coordination paradigm that has been used successfully to study team performance. The paradigm utilizes a low-fidelity simulation of a helicopter flight task. However, it should be noted that similar low-fidelity procedures have been utilized for research in a number of areas of team performance, such as naval team decision making (Kleinman & Serfaty, 1989; Morgan et al., 1989) and emergency reaction crews (Wellens, Grant, & Brown, 1990). Furthermore, the present method might be advantageous because it allows scenarios to be specifically constructed for investigation of the coordination behaviors of interest under various conditions. This flexibility is believed to facilitate the investigation of the effect of various conditions upon team performance.

To date, four studies have used a low-fidelity paradigm in aviation psychology research (Brannick, Roach, & Salas, 1991; Lassiter, Vaughn, Smaltz, Morgan, & Salas, 1990; Smith & Salas, 1991; Stout, Cannon-Bowers, Salas, & Morgan, 1990). For the most part, identical methods have been employed in these experiments. The flight task is a commercially available computer game, such as "Gunship" (Microprose, 1988) or "Falcon" (Spectrum Holobyte, 1988), which is presented by a personal computer and two color monitors (using a video signal splitter). The paradigm is illustrated in Figure 1. In order to create interdependence in the two-person crews, the task is divided so that each team member has specific responsibilities as well as overlapping functions. The member serving as pilot makes input to the computer via a joystick. This member controls the heading and attitude of the aircraft and is also responsible for maneuvering the aircraft into an attack position on enemy targets. The second team member makes input to the simulation via the keyboard. This member is responsible for weapon selec-

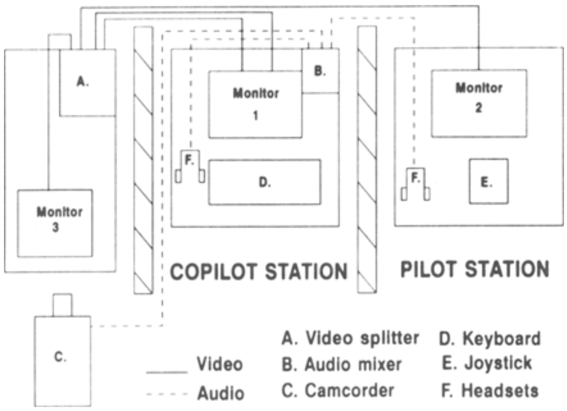

Figure 1. Schematic illustration of the low-fidelity simulation research paradigm.

tion, controlling the team's view options (the simulations allow viewing to each side as well as front and back views), and operating the *right* key, which restores the aircraft to a stable, horizontal position if it is out of control. Interdependence is imposed when subtasks under the control of each member must be performed during a complex operation (i.e., in engaging a target, the pilot must position the aircraft while the copilot selects the weapon; either member may fire on the target).

In addition to these specific responsibilities, overlapping functions include monitoring airspeed, altitude, heading, vertical speed, radar, and threat indicators. Given the nature of the task, communication among team members is typically required for successful performance. For example, the crew must agree on the target to be engaged before selecting and firing an appropriate weapon. Team members are permitted to communicate using an intercom system. These communications are taped for later coding and analysis.

Teams are typically required to complete an assigned mission, which is chosen to allow the investigation of the independent variables (i.e., workload might be manipulated by the number of enemy targets encountered). This mission usually requires subjects to take off (using specified procedures), navigate to a particular location, engage an enemy, return to base, and land. The assignment also establishes specific performance goals for the teams, such as assigned altitudes, routes, or time limits. Although team members receive instructions and practice, the mission usually requires a great deal of situational awareness, planning, and decision making by the crews for performance to be successful.

Performance Measures

Each crew's performance is recorded on videotape for later rating. Performance measures (team accomplishment) in this case might include time to complete the mission, radar locks by the team, radar locks by the enemy, number of missiles fired, number of misses, number of intercept radar activations, number of crashes, the number of times that teams use the *right* key, and the number of times that the simulation ceiling (the maximum altitude allowed in the scenario) is reached. In addition, the tapes can be used to derive measures of team processes such as aircrew coordination and communication patterns. One scale that appears effective in this regard is the Air Crew Observation and Evaluation Scale (ACO/E; Franz, Prince, Cannon-Bowers, & Salas, 1990), which is used to assess the frequency and quality of coordination behaviors along seven behavioral dimensions (see Table 1 for examples of these behaviors).

Results of previous studies have supported the utility of the paradigm in team research. For example, Stout, Cannon-Bowers, Salas, and Morgan (1990) have demonstrated that the "Gunship" simulation is effective in eliciting coordination behaviors from a sample of novice crews. Furthermore, it appears that the frequency of these behaviors is an effective predictor of crew performance (Urban, Bowers, Franz, & Morgan, 1991). In fact, the behaviors that are related to effective performance in low-fidelity studies do not appear to differ significantly from those observed in full-mission simulations (Urban et al., 1991). Other studies have indicated that low-fidelity simulation may provide a low-cost method of examining the effectiveness of teamwork training interventions (e.g.,

Table 1
Examples of Coordination Behaviors Recorded in the Low-Fidelity Simulation Research Paradigm*

Communication
Acknowledged communication
Asked for clarification
Used standard terminology
Situational Awareness
Noted deviations
Identified problems or potential problems
Recognized the need for action
Leadership
Focused attention to task
Provided feedback on performance
Asked for input
Assertiveness
Asked questions when uncertain
Advocated a specific course of action
Made suggestions
Decision Making
Identified alternatives and contingencies
Gathered data before making a decision
Mission Analysis
Devised plans
Critiqued existing plans
Adaptability
Altered behavior to meet situational demands
Stepped in and helped others

*Adapted from Prince, Chidester, Bowers, and Cannon-Bowers (1992).

Lassiter et al., 1990; Smith & Salas, 1991). Finally, low-fidelity simulations also seem to be an effective platform for the investigation of the psychometric properties of various team effectiveness measures (Brannick et al., 1991).

Summary

In this paper, we have attempted to demonstrate the utility of low-fidelity simulation as a research method of studying team performance. This method offers a number of advantages for researchers in that (1) it is available at relatively low cost, (2) it possesses the requisite characteristics for team research (e.g., 2 or more subjects, interdependency, requirement for coordination), and (3) it provides increased experimental control of independent variables. Furthermore, several of the studies cited above converge to suggest its reliability and validity as a research tool. However, there exist relatively few studies in which this method has been used, and important research issues remain unresolved. Future research is required for further investigation of the predictive validity of these simulations, their utility in evaluating training interventions, and the task parameters within which they may be effective.

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