Evaluating the Impact of Improvisation on the Incident Command System: A Modified Single Case Study using the DDD Simulator

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ABSTRACT

This study attempted to evaluate the utility of the Incident Command System (ICS) in varying disaster contexts. ICS is mandated in the United States and practitioners assert that it is an effective organizing system for emergency management. However, researchers contend that the utility of ICS is conflated with inter-team familiarity gained during ICS exercises. A military team-in-the-loop simulator was customized to represent the problems, resources, and command structures found in civilian led disaster management teams. A modified single case design drawn from behavioral psychology was used to explore possible casual relationships between changes team heterogeneity and performance. The design also allowed for the evaluation of improvisation on performance. Further, psychological factors that may underpin improvisation were explored. In addition to some preliminary empirical findings, the successes and difficulties in adapting the DDD simulator are briefly discussed as part of an effort to achieved greater interdisciplinary integration.

Keywords

Incident Command System, simulation, improvisation, psychology, performance assessment.

INTRODUCTION

Several major disasters in recent memory demonstrated significant problems in the United States' ability to respond effectively to these events (NCTA, 2004; Geytanchi, et al., 2007). Much of the national effort to correct these problems has focused on engineering and communications solutions, despite a clear need to further address the human factors aspect central to the success or failure of response efforts (Lalonde, 2007; Franco, Zumel, & Beutler, 2007).

The Incident Command System (ICS) is an organizing approach that emergency managers in the U.S. are mandated to use (DHS, 2004; HSPD # 5, Office of the President, 2003). While ICS is widely embraced, recent research called its effectiveness into question – especially in situations where response teams have never trained together, the event is geographically unbounded, or the scale of the event is extreme (Buck, Trainor, & Aguirre, 2006). These conditions precisely coincide with situations in which improvisational actions are most likely to occur (Weick, 1993; 1998).

Recognizing the need to better understand the strengths and limitations of ICS; how improvisation may impact ICS performance in a variety of disaster management contexts (Mendonça & Wallace, 2004); and to extend the linkages between improvisational action and cognition (Mendonça & Wallace, 2007), it is clear that high quality behavioral research in this arena is overdue. The present study is guided by three main goals: First, it seeks to examine the impact of violating one of the central boundary conditions of ICS by systematically varying the level of team homogeneity and heterogeneity using an experimental design drawn from behavioral psychology. Second, command improvisation is conceptualized and its impact on performance is measured within this examination of ICS; and third, the effects of several psychological traits postulated to modulate the cognitive processes in improvisation are assessed on an exploratory basis.

CRITICISMS OF ICS

Most US emergency managers accept ICS as an improvement over prior art; however, it is unclear whether ICS is an appropriate organizing system for use across all types of response teams and all hazards (Wenger et al., 1990). Extant research on ICS is limited to the few field trials conducted by the FIRESCOPE taskforce – which created ICS – in the mid-seventies (FIRESCOPE, n.d.), informal assessments of the system written by practitioners and response agencies (See e.g. Cole, 2000), and a very limited number of formal qualitative studies conducted by academic disaster researchers (Buck et al., 2006; Wenger et al., 1990).

The most recent – and perhaps most comprehensive – qualitative analysis of ICS was under taken by Buck and his colleagues (2006). The authors conclude that ICS can be successful only when the following preconditions are met:

- There has been extensive multi-agency pre-training which allows social relationships between responders to develop over time so that even geographically separated teams develop trust and shared mental models. The authors argue that the role of ICS training on performance outcomes is conflated with social interaction that occurs in multi-agency ICS training;
- The disaster creates demands that are well matched to the technical abilities of the disaster management team facing it, which can be met using existing operational concepts and procedures;
- Leaders recognize each others' strengths and limitations and are willing to switch between the roles of leader and follower as the situation demands; and
- There is a willingness to accept outside assistance (perhaps because of explicit training in ICS).

IMPROVISATION IN DISASTER MANAGEMENT

Situations that exceed the boundary conditions for ICS also converge with areas where emergency managers have the least experience and training, thus increasing the likelihood that improvisation will supplant prior planning (Weick, 1993; 1998). Improvisation is increasingly recognized as a fundamental and necessary component of disaster management, and responding flexibly to some emergencies can mean the difference between a minor incident and a catastrophe. However, it is also associated significant costs – including decreased situational awareness, group conflict about priorities, and diminished performance in some circumstances (Bigley & Roberts, 2001). This dialectic makes further objective inquiry into the phenomenon a critical priority in emergency management research.

Improvisation is generally cued by sudden exogenous shocks in the problem space, resulting in significant foreshortening of the time horizon, making successful goal completion contingent on solving the new problem as rapidly as possible (Ciborra, 1998; Pearson, Clair, Misra, & Mitroff, 1997). The activity of improvisation is understood to begin with a search for resources that may be recombined to fit the requirements of the problem; the utility of this novel solution is typically uncertain and must be modified as it is applied; and planning and task execution begin to occur almost simultaneously (Barrett 1998 as cited in Cunha, Cunha, & Kamoche, 2002; Eisenhardt, 1997 as cited in Cuhha, et al., 2002; Moorman & Miner, 1998).

Conceptualizing Command Improvisation

Improvisation has been described along a *degree* dimension, ranging from simple reinterpretations to completely novel solutions (Weick, 1998). We speculate that a second dimension, the *context* of improvisation, should also be considered. This dimension would describe the balance of procedural versus management tasks; anchored, for example, by first responders adjusting procedures to fit a given situation at one end, and the organizational flexibility of an Emergency Operations Center at the other. We argue that flexible command practices – or *command improvisation* – involve distinct management tasks and ultimately exert more influence on overall performance as the scale of the disaster increases (Franco, et al., 2007).

Qualitative studies of complex, *ad hoc*, civilian controlled organizations and large military organizations with similar characteristics suggest that command improvisation is typified by a flattening of hierarchy, sudden shifts in roles and authority, concentrating resources and expert knowledge to support authority shifts, and altering communication flow (Kildare, 2004; Rochlin, La Porte, & Roberts, 1998; Suparamaniam & Dekker, 2003). Although many paths to command improvisation are possible we focus here on resource transfers and communication channel generation in particular.

Resources

As availability of resources is critical to first responders, resolving resource shortages and conflicts is one of the central operational tasks for a command team. Challenges include ensuring that interdependent resources are

scheduled to arrive synchronously to minimize down-time, preventing asset idling, and avoiding the duplication of effort because of lack of situational awareness (Johnston, Serfaty, & Freeman, n.d.; Meissner, Luckenback, Risse, Kirste, & Kirchner, 2002). Resource scheduling and logistics considerations require considerable temporal reasoning skills (Tormos, Barber, & Lova, 2002).

Communication Channels

Studies examining communication in this environment have found substantial differences in performance based on the organization of communication channels in the disaster management hierarchy. For example, Artman (1999) found that when disaster commanders were forced to adopt a "serial communication" approach in which information was filtered before it was passed to the next person in the hierarchy, performance was substantially better. Performance was diminished in a second "parallel communication" condition, in which all members of the organization were able to communicate with one another directly. A third condition allowed the commander to switch the communication style back and forth on the fly (in a somewhat improvisational way) with mixed results (Artman, 1999).

Psychological Factors in Improvisation

As one of the central areas of interest for this project was to extend proposed relationship between cognition and improvisation into other areas of psychology, several theoretical linkages were considered. These included speculation that: 1) Authority shifts that support improvisational action would be associated with greater *tolerance for ambiguity*; 2) the ability to search problem space for resources that might be substituted or recombined would be associated with higher levels of *integrative complexity*; and 3), awareness of future needs along with a bias to act in the moment would be associated with *temporal dualism* – i.e. the ability to simultaneously focus on the present moment and future goals.

Hypotheses

The primary goal of this study was to assess the role of social factors affecting team performance within ICS. This assessment was accomplished by systematically varying the level of team heterogeneity in order to simulate conditions that fall *within the boundary conditions* understood to facilitate the effective application of ICS (i.e. the combination of teams that have had at least some experience training together) and *conditions that violate* these assumptions (i.e. the formation of heterogeneous teams that have not trained together). Secondarily, the impact of improvisation (defined here as resource transfers and changes in communication channels) on performance was explored. Further, the relationships between improvisation and the three proposed psychological constructs were examined. The following hypotheses guided this inquiry:

H1: Team heterogeneity diminishes overall disaster management performance;

H2: Increased improvisational activity improves overall performance;

H3: Teams higher in both present centeredness and future orientation (temporal dualism) improvise more frequently;

H4: Teams with higher ambiguity tolerance scores improvise more frequently; and

H5: Teams with higher integrative complexity scores improvise more frequently.

METHOD

The study employed an A_1-B_1-A_2 modified single-case design (Kazdin, 1998). Two teams, composed of four decision makers were used in each condition. In condition A_1 (team homogeneity) each team went through an initial training scenario and two full scenarios to establish a performance baseline. In condition B_1 (team heterogeneity) two members from each team were exchanged as a proxy for the level of team heterogeneity found in rapidly formed *ad hoc* command groups. Finally, in the A_2 condition, team members from the heterogeneous groups returned to their original teams. This is similar to the real world experience of emergency managers in that they often train within a group of local jurisdictions (condition A_1), are occasionally called up to assist with disasters in unfamiliar jurisdictions and temporarily integrate into these teams (B_1), and then return to their normal, local activities (A_2).

Simulator

The present inquiry uses the Dynamic Distributed Decision-making simulator (DDD® 4.0; Aptima, n.d.) to recreate many of the problems and tasks encountered in an actual disaster. The DDD has been used by the U.S. military, NASA, and other high reliability organizations for over 20 years to investigate the performance of

teams in cognitively intense task environments (see e.g. Shebilske, Gildea, Freeman & Levchuk, 2007). For the purposes of this study, the simulator was modified to display a series of six disasters in various cities in the U.S. Decision makers interacted with a shared map, communication tools, and icons representing threats and resources.

Operationalizing Improvisation Variables

The DDD 4.0 simulation software is designed to allow explicit transfers of individual resources and entire bases via a transfer button and each transfer is logged. Further, chat rooms or "channels" can be created by any of the decision makers, allowing for communication with all participants using one channel (the default setting) or fine grained distinctions in channels allowing smaller working groups to be formed dynamically. These capabilities within the DDD provide easily observed, measurable, and fully operationalized indicators of resource transfer and communication channel generation – two command improvisation variables as set forth here.

Scenarios

Six XML based disaster scenarios were generated using Aptima's Visual Scenario Generator (VSG™ 4.0, Aptima, n.d.). Publicly available threat analyses and historical accounts of prior disasters were used in the development of each scenario script (e.g. Homeland Security Council, 2005). Consultation about the fidelity of the scenarios to actual disaster events was sought from subject matter experts in the local emergency management community in Northern California. We obtained advice from technicians with Aptima and a DDD lab at Wright State University about how best to make the DDD's controls – which are steeped in military terminology and assumptions – best fit the emergency management context.

Each scenario was scripted prior to being inputted into the VSG so that events were distributed fairly evenly across a 24 minute period. Scenario complexity was varied in a constrained fashion across several dimensions, including: geographic extent; number of primary events, number of contingent events, primacy of functional areas (e.g. some scenarios weighted to use fire resources heavily, etc.); number of jurisdictions involved; number of distinct incident types; map complexity; and role complexity (e.g. if decision maker had to accept automatic asset transfers to respond effectively). Our goal was to make the scenarios as similar as possible to allow for comparison, while also maintaining a level of uncertainty encountered by actual emergency managers responding to new situations. As the single case design requires multiple presentations of similar stimuli, this approach fit the method and strengthened external validity, while trading off some experimental control.

Participants

Eight participants were recruited from graduate programs at a private graduate school and a major private university in Northern California, USA. Participants included seven women and one man all in their mid- to late-twenties. While using professional disaster managers for this study would have been desirable, students have been successfully used as proxies for military aviation specialists and other cognitively intensive roles simulated in the DDD with appropriate training (Dr. Shebilske, Wright State University, personal communication, 2008). Participants were each paid USD $150.

Psychometrics

Three instruments designed to measure the psychological factors of interest were administered to the participants. These included the Multiple Stimulus Types Ambiguity Tolerance (MSTAT-I; McLain, 1993); a modified Integrative Complexity scale (ICSR; Tetlock, 2005); and the Zimbardo Time Perspective Inventory (ZTPI; Zimbardo & Boyd, 1999). The MSTAT-I and the ZTPI are validated measures, the ICSR was included on an exploratory basis.

Training & Manipulation Check

Participants completed the FEMA ICS-100 course and accompanying final test one week prior to the study. ICS-100 is an entry-level prerequisite for professional emergency managers, and provided a way of familiarizing participants with the vocabulary and the basic conceptual framework used in emergency management. In order to verify an acceptable level of understanding, participants were required to present a FEMA issued training certificate indicating 75% of test questions for the course were answered correctly.

An overview of the DDD interface was presented. At the end of this presentation, participants moved to computer workstations and were given a set of written instructions guiding them through each of the DDD's functions. Participants practiced each function with a simplified training scenario. When all skills were executed without assistance from the trainer, training ceased and the experiment began.

Scoring & Score Normalization

Toward the end of this effort, it became clear that despite concerted attempts to control for scenario complexity *a priori,* the "logic" of each disaster scenario differed enough to introduce score variations. In order to compare performance across scenarios, it was necessary to renormalize the raw performance scores. A group familiar with the scenarios from pilot testing process was assembled, and a modified Delphi method (Linstone & Turoff, 1975; Norcross, Hedges & Prochaska, 2002) was used to generate near optimal scenario scores.

The highest optimal score for any of the scenarios was 51, this was rounded to 50 for convenience, and all scores were raised by 50 points to move extremely low scores above zero. The shifted scores were then expressed as a percentage of the (shifted) optimal score so that normalized performance scores all range from zero to one hundred, independent of the scenario. The adjustment was made as follows: $n' = K(n+50)$, where n = raw optimal score, n' = normalized optimal score, and $K = 100/(n+50)$; hence $s' = K(s+50)$, where s = raw experimental score and s' = normalized experimental score.

RESULTS

Single case designs are understood to provide causal explanations (Kazdin, 1998), however this method relies on visual interpretation of the data rather than statistical inference. Several charts follow that explore the data obtained as it relates to each of the hypotheses in turn.

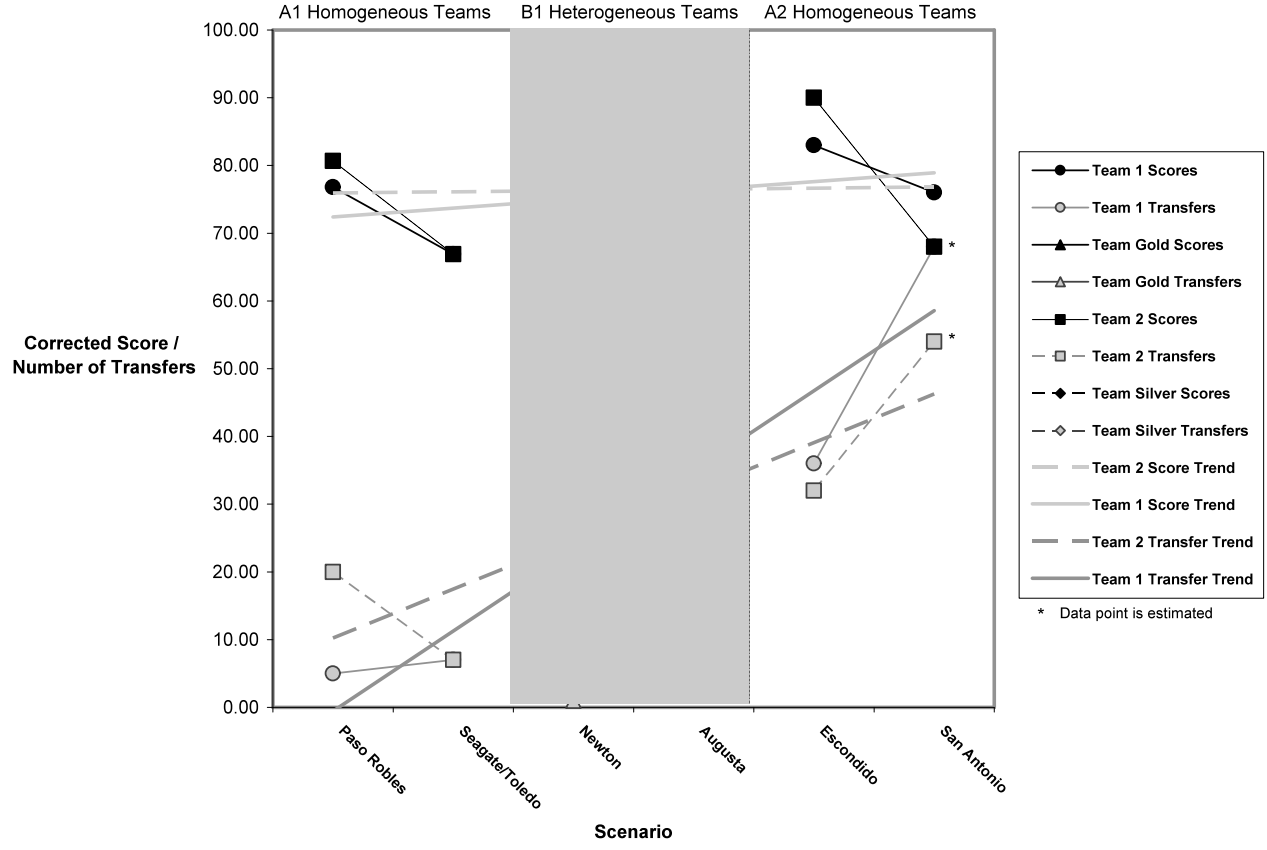

Figure 1. Performance & Resource Transfers

It should be noted that during the experiment, the simulation server began generating errors during the last scenario for one of the teams and the run was terminated early. Observation suggested that the low score (well into the negative numbers) was indicative of the team's failure to observe status changes for machine controlled assets. It is unlikely that the team could have significantly recovered from this position; however, in order to account for the possibility of modest score recovery, the performance and transfer scores were adjusted upward by 10%.

Hypothesis 1

Hypothesis 1 was designed to test one of the boundary conditions that has been posited as central to the effectiveness of ICS – i.e. that ICS presupposes teams will have had at least some experience working together

prior to a major disaster event. Thus, Hypothesis 1 predicted that team heterogeneity would diminish overall performance. This was tested by comparing the average scores for teams in each of the conditions (see trend lines in Figure 1). For condition A_1 the average team scores were 72.8% of the optimal Delphi, 87.7% for condition B_1 and 79.3% for condition A_2. These data demonstrated that the team heterogeneity condition (B_1) did not adversely impact overall performance. On the contrary, groups in the team heterogeneity condition most closely approximated the optimal scores, and the average score for this condition was 8.4 percentage points higher than the average of teams in the final condition (A_2) – the condition in which participants had the most experience with the simulation interface and with each other. These data suggest that in some situations, team heterogeneity may actually improve the performance of *ad hoc* disaster management teams. Hypothesis 1 was not supported.

Hypothesis 2

Hypothesis 2 stated that increased improvisational activity would improve performance. A visual inspection of Figure 1 shows that substantially increasing the number of transfers appears to be related to modest performance improvement in most simulated scenarios. For instance, the average score of Team 1 improved by 7.7 percentage points across the two homogeneous team conditions, with an average of 6 transfers in condition A_1 and an average of 52 transfers in condition A_2. In contrast, Team 2's performance improved more modestly, by 5.2 percentage points across the two conditions, with a higher initial average number of transfers – 13.5 in condition A_1, but fewer transfers than Team 1 in condition A_2, with an average of 43. Similarly, in condition B_1, team Silver's average score was 92% of the optimal score, with an average of 51.5 resource transfers, while Team Gold had an average score of 83% and a lower average of 36 resource transfers.

In contrast, an examination of the relationship between the number of communication channels formed and team performance suggests the opposite effect (see trend lines in Figure 2). The improvement in the average performance of Team 1 appears to be associated with a *drop* in the average number of communication channels from six in condition A_1 to three in condition A_2. Thus, the results for Hypotheses 2 were mixed; showing some forms of command improvisation may be associated with performance gains, while others appeared to be associated with diminished scores.

Hypothesis 3

Hypothesis 3 stated that teams with higher scores in both present centeredness and future orientation (temporal dualism) would improvise more frequently. This was tested by comparing the average performance scores for each team across all conditions against the total number of improvisational actions (resource transfers and number of communication channels; see Figure 3). The team with the highest average number of resource transfers (Team Silver) had one of the highest present centered orientation scores in combination with the lowest future orientation score. Further, the team with scores that most closely approximated temporal dualism (Team 1, with a high present centered score and an elevated future orientation score in comparison with Team Silver) was the second lowest in average number of resource transfers. In terms of number of communication channels, the team that appeared to best fit the definition of temporal dualism (Team 1) had the highest number of communication channels.

The results for Hypothesis 3 were mixed; suggesting that present centeredness as opposed to temporal dualism was associated with more frequent resource transfers – the form of improvisation associated here with performance improvement. In contrast, temporal dualism was associated with increasing the number of communication channels, a form of improvisation associated with poorer overall performance.

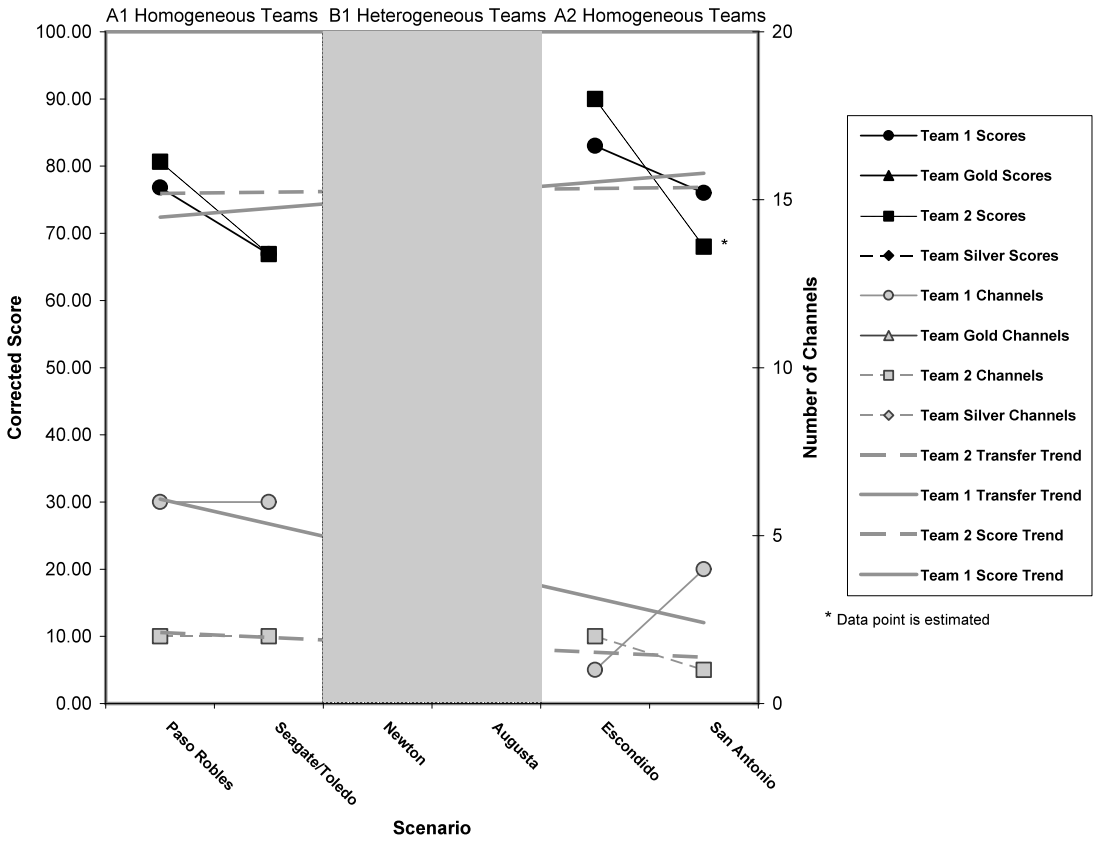

Figure 2. Performance & Communication Channels

Hypothesis 4

Hypothesis 4 asserted that teams with higher ambiguity tolerance scores would improvise more frequently. This hypothesis was also tested by comparing the average frequency of two key improvisational actions against the average tolerance for ambiguity score for each team (Figure 3). However, all teams appeared to be fairly similar in terms of ambiguity tolerance. The results for Hypothesis 4 were inconclusive.

Hypothesis 5

Hypothesis 5 asserted that teams with higher integrative complexity would improvise more frequently. Again, this hypothesis was tested by examining the relationships between the average number of resource transfers and the number of chat channels created as compared to the average integrative complexity score for each team (Figure 3). The team with the highest integrative complexity score (Team 1) created the greatest number of chat channels. Further, the team with the lowest average integrative complexity score (Team 2) utilized the smallest number of chat channels. The remaining two teams had intermediate scores for both integrative complexity and number of chat channels used. In contrast, high scores in integrative complexity were not associated with increased resource transfers. The results for Hypothesis 5 were mixed.

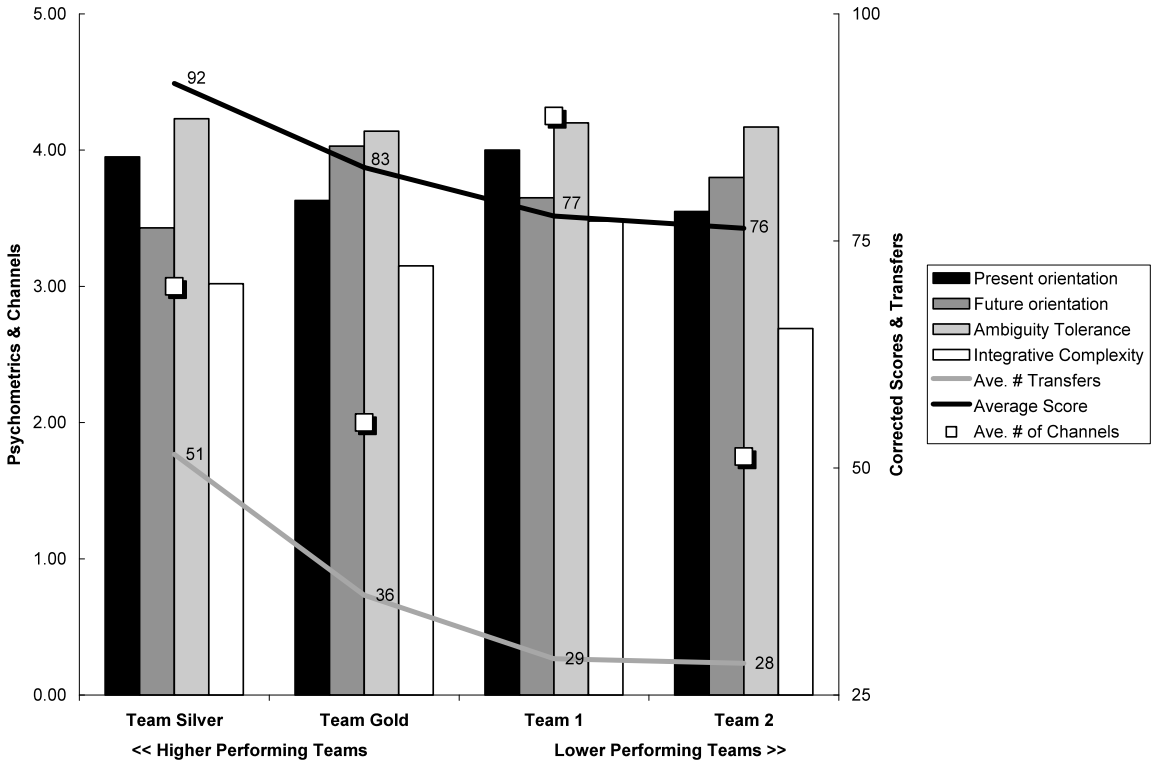

Figure 3. Performance & Improvisation – Exploring Psychological Components

CONCLUSION

This research sought to assess the impact of violating one of the key assumptions of ICS by systematically varying team composition using a modified single case design – an approach that allows causal inferences to be drawn from very small samples. It also demonstrated some possible paths toward more systematic evaluation of the relationship between performance and improvisation at the command level within the ICS framework.

While this design is efficient in its use of participants and comparatively less expensive than running multiple teams through simulation trials, this research suffers from a number of limiting factors, including among other things: an emphasis on ecological validity at the expense of experimental control; use of trained student subjects rather than expert emergency managers; a partial failure of the simulation server in one of the trials resulting in the estimation of some data points; and an emphasis on emergency management principles specific to the U.S. As such, this study should be viewed as an exploratory effort and the findings regarded as extremely tentative. Further, these problems profoundly limit the generalizability of the study (Franco, et al, 2008).

Having offered those caveats, the findings suggest that under some circumstances heterogeneous teams using ICS may experience performance *gains*. Second, command improvisation in the area of resource transfer and allocation may be particularly important in improving performance, while other forms of improvisation may adversely impact performance. Finally, the results underscore the importance of the team psychological make up, showing that present centeredness may impact improvisational actions that improve performance.

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