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

Zeno E. Franco, M.S.
Pacific Graduate School of Psychology
zfranco@pgsp.edu

Nina Zumel, Ph.D.
Quimba Software
nzumel@quimba.com

John Holman, M.S., SGT US Army
Pacific Graduate School of Psychology
jholman@pgsp.edu

Kathy Blau, B.A.
Pacific Graduate School of Psychology
kblau@pgsp.edu

Larry E. Beulter, Ph.D., ABPP
Pacific Graduate School of Psychology
lbeutler@pgsp.edu

ABSTRACT

This study attempts to systematically evaluate the utility of the Incident Command System (ICS) in varying disaster contexts. While ICS is mandated in the United States, recent studies suggest it may be ineffective in emergency events that violate its assumptions. A military team-in-the-loop simulator was customized to represent the problems, assets, and command structures found in civilian led disaster management teams. Drawing extensively from behavioral research paradigms in psychology, a modified single case design was used to explore possible casual relationships between improvisation and performance in conditions that both supported and violated ICS assumptions. Further, psychological factors that may play a role in improvisational action were explored. In addition to some preliminary empirical findings, the successes and difficulties encountered in adapting the DDD command and control 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; Homeland Security Presidential Directive #5). While ICS is widely embraced within this community, recent research has called its efficacy 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 gaps in emergency managers' training and represent situations were improvisational actions are most likely to occur (Weick, 1998).

Recognizing the need to better understand improvisation and support the appropriate use of this technique, some preliminary examinations of the phenomenon in the disaster management context have been performed (Mendonça & Wallace, 2004) and attempts to address improvisation from the perspective of cognitive psychology have been undertaken (Mendonça & Wallace, 2007). However, we argue that this research needs to be extended in at least two ways. First, most efforts in this area have focused on the improvisational actions of first responders (Mendonça & Wallace, 2004), while comparatively little attention has been paid to how improvisation is expressed at the command level. Second, because improvisation is a cognitive process undertaken in situations of duress and extreme time pressure, further attention to dispositional traits impacting the cognitive task environment is needed to better inform training and decision support systems.

The present study is guided by four main goals. First, it seeks to examine the impact of violating the implicit assumption in ICS that response teams will have at least some training interaction with one another prior to a major incident. Second, command improvisation is conceptualized and its impact on performance is measured; third, the effects of several psychological traits that may modulate cognitive processes in improvisation are assessed.

A fourth and somewhat more global goal for this effort is to demonstrate avenues toward greater transdisciplinary integration within the overall ISCRAM research effort. To this end, we sought to adapt the DDD® (Aptima, n.d.), an existing military team-in-the-loop simulator, for use in the civilian disaster management context – thus directly exploring some strengths and limitations of command and control (C^2) simulation architectures in civilian controlled events. Further, we were interested more deeply involving the epistemological and methodological frameworks offered by the behavioral sciences in this research, a task that has been asserted as central to extending the applicability of findings from the ISCRAM community into actual practice (Franco, et al., 2007, 2008).

IMPROVISATION IN DISASTER MANAGEMENT

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, improvisation 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 the resulting 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).

Existing empirical research, though scant, has demonstrated a curvilinear relationship between improvisation and organizational performance across several dimensions (Cunha, Cunha, & Kamoche, 2002; Kamoche, Cunha, & Cunha, 2003), suggesting that optimal disaster management may not rely entirely on rigidity or improvisation, but the systematic and timely application of principles from both command stances depending on changing situational factors.

Conceptualizing Command Improvisation

Flexibility has been described along a *degree* of improvisation dimension, ranging from simple reinterpretations to high level improvisation involving 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 control responses of an Emergency Operations Center at the other. We argue that flexible command practices – or *command improvisation* – ultimately exert more influence on overall performance as the scale of the disaster increases, involve distinct management tasks, and warrant further investigation (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 (Rochlin, La Porte, & Roberts, 1998; Suparamaniam & Dekker, 2003). Although many paths to command improvisation are possible, the shifting of authority, resources, and communication channels served as a first step in operationalizing this phenomenon in the present research.

Authority

While the military command model may apply in small- to mid-sized disasters, large *ad hoc* civilian teams are often not governed by a single individual or organization with vested authority from the outset (Suparamaniam & Dekker, 2003). Even in the context of ICS, which specifies an Incident Commander as the overarching authority, "emergent" or negotiated leadership often occurs, in which individuals or organizations begin to take on authority roles based on past experience, domain knowledge, or personal leadership characteristics (Kildare, 2004).

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). Further, resource scheduling and logistics considerations in this setting 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 organizational 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 a “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).

MODIFYING THE DDD 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 disaster related events in various cities in the U.S. Teams of four decision makers interacted with a shared map, communication tools, and icons representing threats and resources. The simulation server automatically scored each scenario run and stored the actions of the decision makers in an XML log file, allowing for replay and further analyses.

Scenario Development Process

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. 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. One minute of real time was set to equal one hour of simulator time, allowing participants to encounter the types of problems that might develop over a 24 hour response cycle. 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. Thus each scenario had a new map, no primary disaster events were shared, and the timing and exact number of sub-events varied across scenarios.

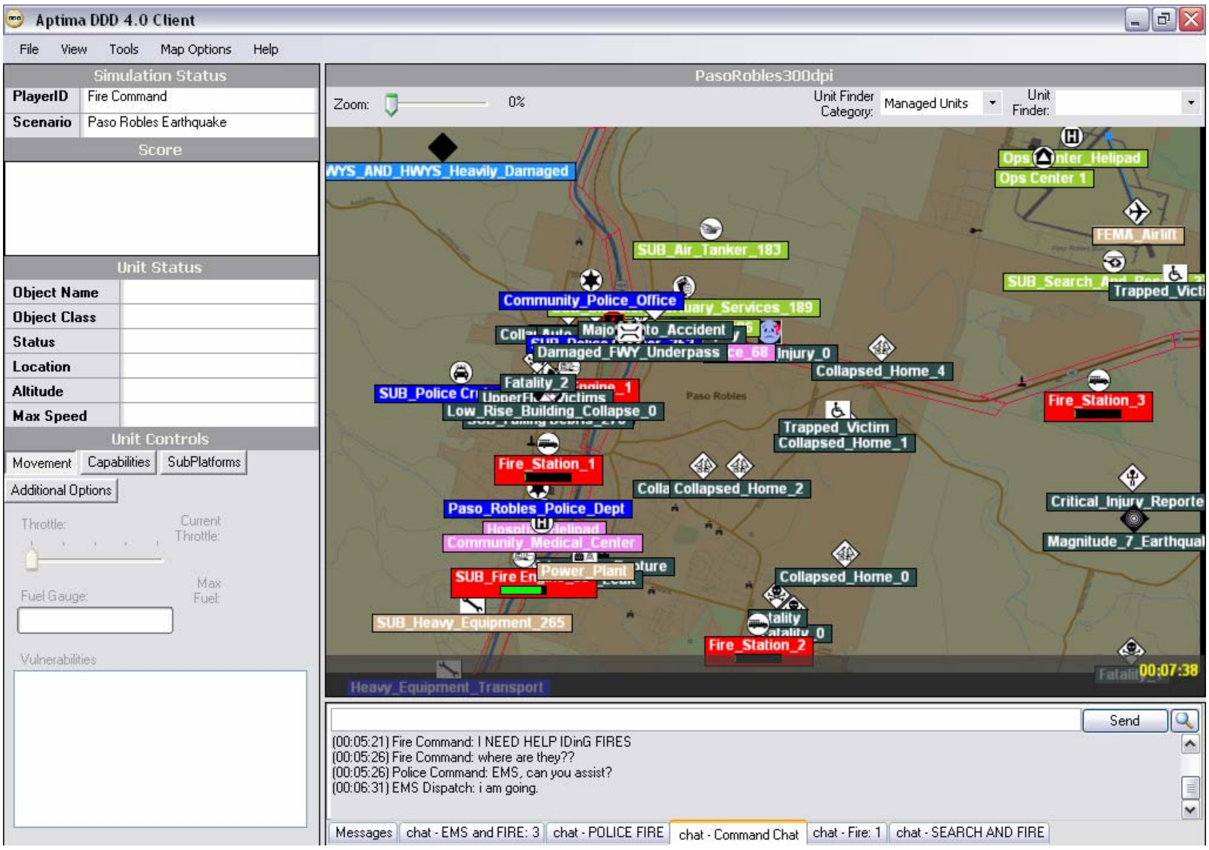

Figure 1. DDD Disaster Management Simulation Interface

Maps & Incidents

Six maps were generated using ArcGIS, representing several major metropolitan areas, smaller cities, and semi-rural locations in the U.S. The incidents included: 1) a major building collapse in Toledo, Ohio; 2) a major earthquake and aftershock in Paso Robles, California; 3) tornadoes in Newton, Kansas; 4) a major train derailment and hazardous materials spill in Augusta, South Carolina; 5) wildland fires in Escondido, California; and 6) civil unrest in San Antonio, Texas.

Symbols

Where possible, symbols for disaster incidents and decision maker controlled resources used the U.S. Federal Geographic Data Committee's Homeland Security Working Group symbol set (FGDC HSWG, 2005). This is a black and white symbol set intended for mid-scale maps and designed to meet the needs of a variety of agencies at the local, state, and federal level in the U.S. Critical limitations were addressed through symbol substitution, annotation, and limited generation of new symbols.

Scoring

Team scores were obtained by summing scores for each role. Scores were incremented for successfully extinguishing fires, rescuing trapped victims, and decontaminating hazmat incidents, etc. Scores were decremented if resources were damaged or destroyed, decision makers overreacted to non-threatening events, if time-sensitive responses were not executed rapidly, and so forth.

Research Method

The study employed A_1-B_1-A_2 modified single-case design (Kazdin, 1998). In condition A_1 each team went through two scenarios to establish an initial performance baseline. In condition B_1 (intervention condition) two members from each team were exchanged as a proxy for the level of team heterogeneity found in rapidly formed *ad hoc* command groups typically found in disaster management situations. Finally, in the A_2 condition, team members from the newly formed 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 (B_1), and then return to their normal, local activities (A_2).

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). Participants were each paid USD $150.

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, demonstrating how to deploy and operate assets; how to determine the capabilities of each asset; how to communicate with other players through chat; how to create new chat rooms; and how to transfer asset to other players. 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 functions just described. Participants practiced each function with a simplified training scenario. When all skills were executed without assistance from the trainer, *in vivo* training ceased and the experiment began.

Operationalizing Improvisation Variables

If it is assumed that the three variables of interest: authority, communication channel assignment, and resource allocations can be dynamically configured, a number of possible command stances, with varying levels of conformity to the assumptions of ICS can be generated by the incident command team in response to anticipated and unanticipated events. In this paper we focus on resource allocation and communication channel configuration in particular. The data related to authority vesting has yet to be fully analyzed.

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 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 command improvisation as set forth here.

Psychometric Instruments

As one of the central efforts areas of interest in this demonstration 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 shits 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 combined with a bias to act in the moment would involve *temporal dualism* – with team members simultaneously employing present centered and future orientated time perspectives. Three instruments with acceptable levels of reliability and validity were administered to the participants, including 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). None of these measures are directly correlated with cognitive style, but are postulated to play a modulating role in the cognitive processes underpinning improvisation.

Hypotheses

The following hypotheses guided this research: <u>H1</u>: Team heterogeneity would diminish overall performance; <u>H2</u>: Increased improvisational activity would improve performance; <u>H3</u>: Teams with higher scores in *both* present centeredness and future orientation (temporal dualism) would improvise more frequently; <u>H4</u>: Teams with higher ambiguity tolerance scores would improvise more frequently; and, <u>H5</u>: Teams with higher integrative complexity scores would improvise more frequently.

Score Correction

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 particular, the San Antonio civil unrest scenario proved problematic. This scenario required decision makers to *refrain* from acting where they normally were encouraged to do so; particular attention had to be paid to incident status changes in order to gain situational awareness; and failure to apprehend the intent of the scenario narrative could result in a score below zero.

To resolve this problem, we elected to establish scores for near optimal performance within each scenario and correct the experimental scores based on this information. In an effort to simulate the performance of subject matter experts, a group of individuals familiar with the scenarios from pilot testing process was assembled, and a modified Delphi method (Linstone & Turoff, 1975; Norcross, Hedges & Prochaska, 2002) was used.

Score corrections were made by setting the value of scenario's optimal score to 100 and expressing the experimental score as a percentage of the re-scaled optimal score. 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. Adjustments were made such that $n' = K(n+50)$, where n = raw optimal score, n' = normalized optimal score, and $K = 100/(n+50)$; and such that $s' = K(s+50)$, 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.

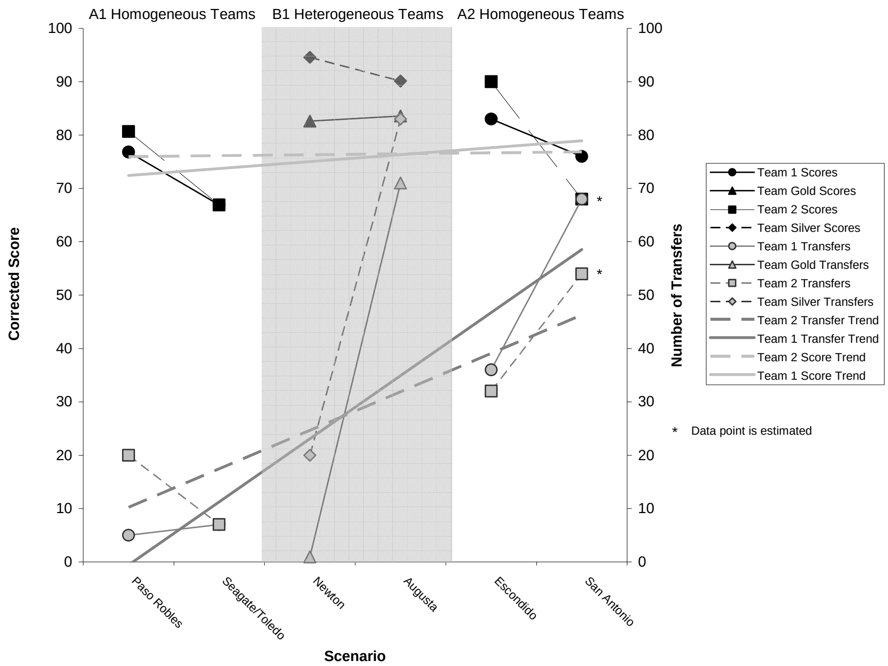

Figure 2. Performance & Asset Transfers

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%.

A visual inspection of the data shows that overall performance was not adversely impacted by team heterogeneity as predicted. In fact, the opposite happened with both heterogeneous teams enjoying substantial increases in performance scores. <u>Hypothesis 1 was not supported</u> (see Figure 2).

The <u>results for Hypothesis 2 were mixed</u>; showing some forms of command improvisation may be associated with performance gains while others appear to be associated with diminished scores. For example, substantially increasing the number of asset transfers seems to be related to modest performance improvement (see Figure 2). However, increasing the number of communication channels seems associated with poorer performance scores and teams quickly began limiting the number of channels they created (see Figure 3).

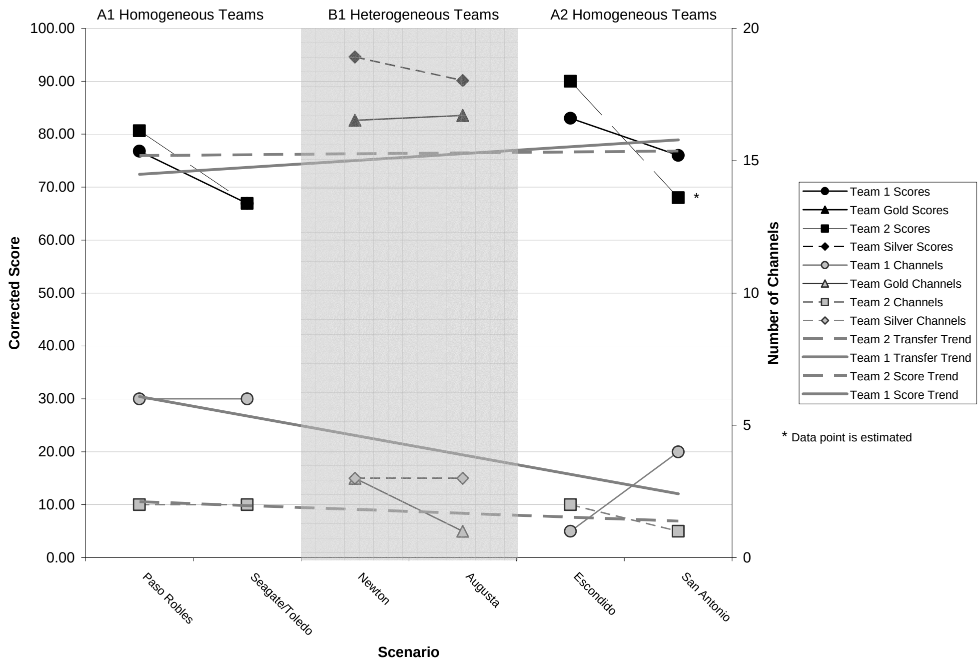

Figure 3. Performance & Communication Channels

The psychological component of this study is somewhat more complex, and it must be stressed that these are only intended as exploratory findings. Examining the relationships between the psychological constructs and performance was accomplished by organizing this information in terms of the high performing team and by examining the performance of the two lowest scoring teams in conjunction (see Figure 4).

- Highest performer: Team Silver (Heterogeneous): Rather than having a team composition that was dominated by temporal dualism, this group had one of the highest present centered orientation scores in combination with the *lowest* future orientation scores, <u>Hypothesis 3 was not supported</u>. This team had the lowest ambiguity tolerance score and an integrative complexity score near the mean; <u>Hypothesis 4 was not supported</u>. The performance improvement obtained by this team was associated with substantially higher levels of asset transfers, high numbers of individual communications, and creation of the average number additional communication channels.

- Two lowest performers: Team 1 & 2 (both homogeneous): While their overall performance scores were nearly identical, Team 1 had the highest integrative complexity score and the highest number of generated communication channels. In contrast, Team 2 had the lowest integrative complexity score and the smallest number of generated communication channels. These findings are consistent with the notion that integratively complex individuals seek to incorporate information from as many different sources as possible, even when this results in diminishing returns. <u>Hypothesis 5 was supported</u>.

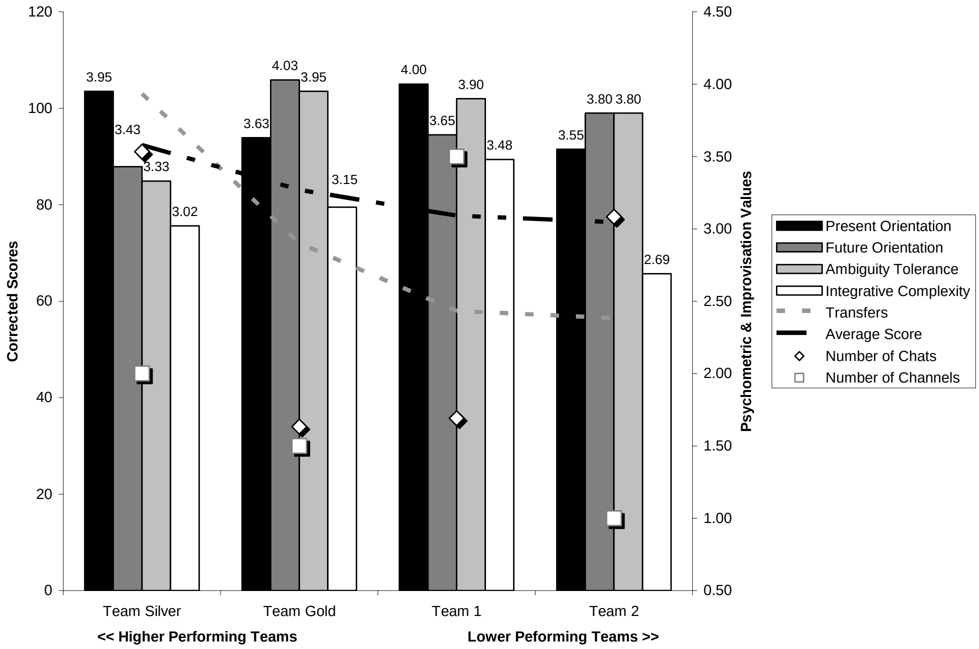

Figure 4. Performance & Improvisation – Exploring Psychological Components

CONCLUSION

This research demonstrated some possible paths toward more systematic evaluation of the relationship between improvisation and performance at the command level within the ICS framework. It also 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 is understood to allow causal inferences to be drawn from very small samples.

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.

Having offered those caveats, the findings suggest that ICS may be quite robust in situations where teams have no prior experience working together, that under some circumstances heterogeneous teams experience performance gains, and that command improvisation in the area of resource transfer and allocation may be particularly important in improving performance. Further, the results indicate that present centeredness, a psychological factor distinct from cognitive style, may play a role in improvisational actions related to resource allocation.

We were also interested in examining the process of converting a military C^2 simulator for use studying civilian led disaster management teams. Although this effort seemed successful overall, it also posed a number of challenges. These included: 1) difficulty creating command level tasks, as by default the simulation tool favored tasks typical to first responders; 2) the lack of a fully developed common symbol set for emergency management; 3) simulation interface inflexibility, forcing military terminology to be used rather than allowing for substitution or using more general terms; 4) scoring systems that implicitly favor action, while the ability to *refrain* from acting may be just as important; and 5) resource consumption in idled assets, which offers a way of evaluating performance based on cost, but is not fully addressed with the simulator we selected.

In addition to offering preliminary findings, we also sought to more deeply integrate the tools, assumptions, methods and evidentiary rules used in the information sciences and psychology that inform disaster studies as part of the evolutionary process toward a transdiscipline spanning all three areas of inquiry (Franco, Zumel, & Beutler, 2008).

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