Relationship between Mission Preparation and Performance During Combat Mission Training

V. Alan Spiker
Anacapa Sciences

Robert T. Nullmeyer
Air Force Research Laboratory
Warfighter Training Research division

and

Steven J. Tourville
Lockheed Martin

ABSTRACT

Although military doctrine assumes that thorough mission preparation is a prerequisite for mission success, empirical data are lacking. The present study investigated the relationship between mission preparation and mission performance during combat mission training of 11 MC-130P (Combat Shadow) aircrews from USAF Special Operations Forces squadrons. Two observers independently rated crew processes and mission performance based on extensive observations taken (a) during a planning period and (b) while the crews executed a simulated mission. A statistically reliable, strong relationship was noted between preparation and performance on a number of indices, with correlations ranging from .60 to .78. Notable preparation behaviors include utilizing personnel effectively, establishing a firm timeline, aggressively questioning a plan's assumptions, and testing a plan's logic against possible contingencies. The paper concludes with a discussion of the characteristics of effective mission preparation and implications for combat mission training.

ABOUT THE AUTHORS

V. Alan Spiker is a principal scientist at Anacapa Sciences, Inc., Santa Barbara, CA. He is responsible for human factors research associated with advanced technology and has conducted field studies on mission planning and command and control systems for all branches of service. He has a Ph.D. in Experimental Psychology from the University of New Mexico and has been with Anacapa Sciences since 1982.

Robert T. Nullmeyer is a research psychologist with the Warfighter Training Research Division of the Air Force Research Laboratory at Mesa, AZ (AFRL/HEA), where he has been since 1981. He has conducted research on training system evaluation and simulator training effectiveness. He earned a Ph.D. in Experimental Psychology from the University of New Mexico.

Steven J. Tourville is a senior instructional designer and training systems analyst with Lockheed Martin Information Systems in Albuquerque, NM. He is an experienced MC-130P instructor navigator. This research was completed while he was a senior training analyst for Raytheon under contract with the Air Force Research Laboratory. He received his Ph.D. in Adult Education from Nova Southeastern University.

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INTRODUCTION

While it stands to reason that more effective mission preparation (planning and briefing) should result in better mission performance, there is surprisingly little empirical evidence to support this assumption. On the one hand, studies of team mission performance have typically not included the mission preparation period as part of the measurement process, forcing investigators to infer the type of process that must have occurred (e.g., Thornton, Kaempf, Zeller, & McAnulty, 1992). On the other hand, mission preparation involves a host of cognitive processes that are inherently more difficult to measure than mission performance (Taylor, 1993). In this regard, it has been noted that the complexities of combat mission preparation require the use of a subject matter expert (SME) with an "eye trained for spotting relevant events in what could be an unintelligible thicket to the uninitiated" (Nullmeyer, Bruce, & Spiker, 1994).

Considerable anecdotal support exists for the role of mission preparation in subsequent mission success. For example, the detailed planning, rehearsal, and briefing of the RAF air assault portion of the D-Day invasion "enhanced the confidence of the men in themselves, their leaders and the plan." Similarly, military analysts reported that "trust and confidence in the mission plan is essential" to mission success (Ross, 1993). Self reports by Army helicopter pilots suggested that more intensive flight chart study before the mission was associated with better subsequent performance (Thornton, et al., 1992).

Consistent with these observations, civilian research has repeatedly underscored the importance of deep, extensive, and effortful planning—loosely defined as "developing a detailed scheme for obtaining an objective" (Taylor, 1993)—in promoting cognitive performance. One area where planning has been studied involves investigations of performance differences between experts and novices. In a representative study, Charness (1989) examined the think-aloud strategies of bridge players planning to play a given bridge hand, and showed that experts perceived problems and constraints better, and planned more extensively, than less skilled players. Indeed, most types of expert performance are mediated by reportable thoughts involving planning, reasoning, and anticipation. Even for perceptual-motor activities, studies reveal the positive influence of planning and generation of expectations for snooker, tennis, ship control, and other types of process control tasks (Ericcson & Lehman, 1996).

Given the importance of good mission preparation, the case for mission preparation effectiveness under controlled conditions with representative military personnel is surprisingly limited, with much of the relevant data coming from field studies of decision-making and command and control. Army planning teams who were given either structured job aids or computer support did a better job of selecting courses of action than did teams without such aids (Fallensen, Carter, Perkins, Michel, Flanagan, & McKeown, 1992). A study of six Army divisions (Keene, Michel, & Spiegel, 1990) showed that certain elements of planning—plan lead time adequacy, monitoring impact of plan, and plan consistency—had higher computer-predicted performance scores than did other planning elements (accuracy of monitoring enemy movements, accuracy of monitoring own movements, completeness of predictions). However, this relationship was not confirmed by independent assessments of unit performance by experts.

Recent Navy-sponsored research has documented the importance of good mission preparation. Bergondy, Fowlkes, Gualtieri, & Salas (1998) found that well over half the debriefing topics in Navy Air Wing Integration Training involved mission planning or briefing behaviors. Stout, Cannon-Bowers, Salas, and Milanovich (1999) established empirical links among planning, shared mental models, and task performance for undergraduates who performed a surveillance/defense task.

Although the empirical literature is still scant for military training, there is considerable information on the processes and behaviors engaged in by planning experts across multiple domains—the contents of good mission planning. For example, Taylor (1993) has presented a detailed cognitive task analysis of the ideal mission planning process, and Kolitz and Beaton (1993) hierarchically decomposed planning into constituent components, such as goalpoint planning, trajectory planning, and safety planning, among others. Cognitive studies of expert ground commanders suggest that they use imagery to create a mental model of a problem and then reject/retain that model based on forecasted results from running a "mental simulation" (Klein, Calderwood, & Clinton-Cirocco, 1986). Geiwitz, M'Closkey, Kornell, and Wong (1991) conducted in-depth interviews with expert Army helicopter mission planners using advanced knowledge engineering techniques. These interviews identified 35 dimensions of good plans that were grouped into three major clusters: cover, concealment, and flight characteristics.

In a similar vein, interviews with experienced fixed-wing and rotary wing USAF Special Operations Forces (SOF) planners revealed a core set of ten principles that underlay the planning process and which seem to characterize the best plans (Spiker & Campbell, 1993):

• Plan from the target area backward
• Plan from general to specific
• Plan from high to low
• Plan from big to small
• Plan from qualitative to quantitative
• Build slack into the calculations
• Always plan for the worst case
• Fly as high as the threat dictates but as low as the terrain allows
• Keep the plan as simple as possible
• Time is the true enemy

In a follow-up effort, the authors interviewed ten individuals with extensive operational experience in planning SOF missions (Spiker & Nullmeyer, 1995a). From these interviews, more than 40 specific measures of effective mission preparation were extracted. These indices addressed key aspects of the planning process, the characteristics one looks for in the resulting products (e.g., annotated maps, charts, and sketches), and the various "transformations" the preparing crew should being undergoing (e.g., developing confidence in the plan).

The present study attempted to demonstrate the existence of a positive relationship between the quality of an aircrew's mission preparation and their resulting mission performance. The detail inherent in the measures noted above tapped many of the cognitive processes involved in mission preparation, and formed the basis for an observational instrument that a SME could use to record mission preparation quality. To balance the desire for operational realism while maintaining some control over events, assessments were made during annual refresher training of MC-130P aircrews.

Our primary hypothesis is that crews who engage in more effective mission preparation should exhibit superior performance during the subsequent mission. To the extent that this primary hypothesis is substantiated, a secondary objective is to identify the specific behaviors associated with good mission preparation, including the materials produced and the team coordination processes that are utilized. Once these processes, behaviors, and products have been identified, the next step is to encourage their development within *all* crews by incorporating interventions into a training program so that a more effective curriculum for combat mission training (CMT) is delivered.

METHOD

Participants

Eleven MC-130P SOF aircrews were observed during Day 5 of their weeklong annual refresher training. Crews represented several operational squadrons and had an average of 3056 flight hours, of which 1286 hours were in the MC-130P. This training is provided for six crew positions: an aircraft commander (AC), co-pilot (CP), flight engineer (FE), a left navigator (LN), a right navigator (RN), and a communications specialist (CS).

As an operational aircraft in the USAF SOF inventory, the primary missions of the MC-130P Combat Shadow are to provide aerial refueling support of MH-53J Pave Low and MH-60G Pave Hawk helicopters, aerial delivery of Special Forces (SF) and/or supplies, and airland operations to austere landing zones. The environment for MC-130P operational missions is typically defined as a "moderate threat theater." SOF aircrews may conduct their missions using night vision goggle low-level procedures and precise timing techniques to avoid or minimize detection by hostile forces.

Equipment

The MC-130P weapons system trainer (WST) is a six-degree of freedom, high fidelity full-motion simulator with a CompuScene V image generator system, fully correlated infrared Detection System, a digital radar landmass system, advanced navigation systems, and out-the-window displays. Navigation systems include Doppler, inertial navigation system (INS), control display units, and a central computer system that integrates various flight systems. An EW database contains pre-programmed ground threats that emulates actual emitters, including visual and audio depictions on the crew's threat warning receiver system (Nullmeyer & Spiker, 2000).

Mission Scenario

This last day of annual training is a capstone event devoted to full-crew, combat operations in a tactically relevant objective area. The intent is to let the crew perform a significantly higher intensity mission that is difficult, complex, and relevant to their real-world mission requirements. As such, the mission scenario encompasses multiple mission objectives that are scripted in real time to instructor- or crew-induced problems, and are designed to push students to near overload conditions.

The training mission took approximately seven hours to complete and was composed of five phases. The first three hours were devoted to the *mission preparation* (MP) phase, during which time crews were instructed to "challenge" and refine a previously developed general plan. The details of this mission were summarized in a scripted mission fragmentary order (FRAG). The FRAG stated that their primary mission was to support the recovery of injured Army personnel by providing aerial refueling tanker coverage for two MH-53J Pave Low helicopters that would be transporting the injured to a field hospital. To support this effort, the crew was to airdrop a team at a Drop Zone (DZ), where the team would prepare the evacuees for transport at the landing site for the transload operation. A secondary tasking was to transport a flag officer and his staff by airlanding at the field hospital.

Crews were given weather reports and detailed charts of the tactical areas, operations and communications details, Rules of Engagement (ROEs), and Order of Battle (OB) threat data. Instructors were present to serve as role players, including airborne command & control, weather, and intelligence. The student-crews were to integrate these materials and other available information sources to develop a mission plan containing navigation checkpoints and time control markers, an aerial refueling execution plan, and a Computed Air Release Point (CARP) prediction worksheet. The mission preparation period concluded with formal crew briefings on the details of that plan.

The crew then entered the WST to execute the other four mission phases: *low-level* (LL) navigation at night requiring terrain masking procedures, an *aerial refueling* (AR) constrained by altitude and threats, an *airdrop* (AD) to a "blind" DZ, and a covert *infiltration/exfiltration* (I/E). The instructional premise is that the mission is to be executed as if the students were flying the actual aircraft (e.g., every checklist will be performed) in the "live" mission environment (e.g., all threats encountered are considered as potentially fatal). Responses to any self-induced, instructor-induced, or scripted stimulus condition must be in real-time, and if that response results in an undesirable situation or condition, the crew must live with their decisions.

In LL, the objective was to penetrate threat territory using tactical mission management procedures such as very low altitude flight, high-speed maneuvering, terrain masking, and optimal tactical routing. This phase, as well as the others, included several scripted occurrences of irrelevant communications and unforeseen events (e.g., a downed friendly helicopter) that would occur in actual missions. For AR, the objective was to conduct tactical in-flight AR operations for multiple MH-53J Pave Low helicopters within prescribed time, course, and altitude constraints.

The objective of the AD phase was to execute the CARP airland of SF personnel in the threat environment within prescribed time, course, and altitude constraints. This demands that the aircraft is correctly positioned for the AD operation, outside visual references identified to locate the DZ, and correct CARP offset aim points entered to support the run-in. Finally, the I/E phase was required to transload the flag officer at the forward-deployed field hospital landing zone (LZ) and to evacuate their aircraft from the unsecured airfield.

Procedure

For each mission phase, a SME-researcher (a former MC-130P navigator) collected crew process data while a second researcher (PhD psychologist) recorded mission performance data. During MP, the SME-researcher sat in one corner of the briefing room where he recorded notable crew behaviors as the crewmembers reviewed the FRAG, planned their mission, and conducted their pre-mission briefings. During mission execution, this researcher observed crews from a station outside the MC-130P WST that was situated in front of four instructor-operator screens which repeated instructor inputs from the WST.

A "record by exception" philosophy was used to capture instances of unusually strong or weak crew behaviors (Tourville, Spiker, Silverman, & Nullmeyer, 1996). This technique has also been successfully used in previous studies of MP and rehearsal (Spiker & Nullmeyer, 1995a, 1995b).

Mission Preparation Process Data. Five behavioral categories or "processes" were identified during an extensive front-end study (Spiker, et al., 1996). These categories, defined below, were chosen because of their relevance to the SOF mission environment and MC-130P operations, applicability to CMT, and amenability to outside measurement (Spiker et al., 1998). They are by no means exhaustive of all the ones that might be studied, and indeed it is recognized that other areas could have been measured, such as leadership, assertiveness, and decision-making (Brannick & Prince, 1997). The data collection form included a customized set of questions, YES/NO checklist items, space for recording notable behaviors, and a five-point rating (1=poor, 5=good) for the crew for each process in each phase. Figure 1a shows an example from the time management portion of the MP phase.

The five processes were defined as follows. Function allocation (FA) is the division of crew responsibilities so that workload is distributed evenly. Tactics employment (TE) comprises the analytic activities necessary to avoid or minimize threat detection or exposure, and to coordinate complex mission events. Situation awareness (SA) involves maintaining an accurate mental picture of mission events as they unfold over time and space. Command-Control-Communications (C3) are activities required to involve external parties in the mission, maintain communications with these parties, and control the sequence of mission of events according to the mission execution plan. Time management (TM) entails the ability to employ and manage limited time resources so that critical tasks are not omitted and all tasks receive sufficient time to be performed correctly.

Mission Performance Data. A psychologist-researcher recorded mission performance data using a five-page instrument that was organized around the five mission phases. During MP, the researcher was located at the back of the briefing room. The quality of products created during MP was rated using a five-point behaviorally anchored rating scale (BARS). Each crew's performance during the LL, AR, AD, and I/E phases was similarly assessed. With this instrument, the researcher was able to capture such MP items as the number of briefings each crew gave, the contents of those briefings, who performed the briefings, and the number of charts created. Figure 1b depicts the scale that was used to rate the mission flight charts developed by the navigators and pilots during MP.

During mission execution, the psychologist-researcher monitored crew communications, flight path, and threat laydowns from a part-task trainer that contained intercom communications and repeater displays allowing all aspects of the mission to be monitored. This room also permitted the printing of select pages from an instructor operator station (IOS) to record such performance items as the aircraft's ground track, times that each control point were reached, and airdrop accuracy scores.

Design and Statistical Testing Considerations. Since data were collected during actual training, a non-experimental design was used in which correlations between the two researchers' ratings served as the primary statistic. Because the study used the aircrew as the unit of analysis, the total N of 11 and resulting 9-degrees of freedom (for t-tests, df = N - 2) seem rather small to achieve the statistical power one needs to establish a reliable relationship between MP processes and mission performance. However, the 11 aircrews in our sample actually constitute a substantial percentage, 26%, of the population of approximately 42 MC-130P aircrews who go through annual refresher training each year. Sampling such a sizable proportion of the population allows us to reduce our estimated variance of the sample mean by using a finite-population correction coefficient (Winkler & Hays, 1975). Specifically, the correction coefficient decreases the observed sample variance by the square root of (N-1)/(N-n), where N is the population size and n is the sample size. In our case, the reported t-values have been increased by 20% to reflect a 1.2 finite-population coefficient multiplier.

Figure 1: Example data items addressing (a) crew process and (b) mission performance

(a)**Time Management** (TM): Involves the ability of the combat mission team to employ and manage limited time resources, so that all tasks receive sufficient time to be performed correctly, and critical tasks are not omitted.

1.0 An end-mission planning time should be indicated up front - most likely by an emergent "leader."

a. Did any crewmember indicate the need for an end-mission planning time? .... YES / NO
(Explain) ____

b. Was that time noted by all other crew members? .... YES / NO
(Explain) ____

c. Did any crewmember designate activities to establish a proper balance between their own authority, time available, and crewmember participation? .... YES / NO
(Explain) ____

d. Was adequate mission preparation time allocated for a comprehensive pre-mission briefing? .... YES / NO
(Explain) ____

(b) FLIGHT CHARTS

1	2	3	4	5
- Poor. - Incomplete data. - General lack of documentation. - General quality of preparation is poor.	- Marginal. - Insufficient or inaccurate documentation. - Unaccounted for discrepancies between LN, RN, and CP charts. - Deviation plan minimally prepared. - Marginal quality.	- Adequate. - Threats plotted. - Most threat rings plotted. - Deviation plan clearly drawn. - Appropriate altitude considerations made. - Required checklist annotations made.	- Outstanding. - Threat rings plotted. - Deviation plan clearly drawn and visible for NVG conditions. - Appropriate altitude and terrain considerations made and explicitly represented in the deviation plan.	- Exceptional. - Threat contour shading provided. - Deviation plan and threat information highlighted for NVG conditions. - Documentation in excess of minimum requirements. - Threat labels.

RESULTS

A strong, positive relationship between MP and mission performance was present throughout the data structure. First, the SME's rating of overall crew process during MP was significantly correlated with the second researcher's rating of overall crew mission performance, with r=.78 (t=3.74, df=9, p<.001). This relationship is depicted in Figure 2, where crews who exhibited superior MP ratings performed better during mission execution than crews who did not. Having established the significance of the overall process-performance relationship, the data were probed further to determine *which* MP processes were most strongly associated with performance. The crew ratings for each process were correlated with the overall mission performance rating. Two processes, situation awareness (r=.48) and time management (r=.41), approached or exceeded the critical r-value (r=.42) required for significance at the .05 level. The other three processes, tactics employment (r=.27), function allocation (r=.22), and command-control-communications (r=.14), did not. On the other side of the equation, we asked if there were particular mission *phases* for which a superior MP process was most strongly associated. We correlated each crew's overall process rating during MP with their process ratings from each of the four mission execution phases. MP process ratings were most highly correlated with LL (r=.73), moderately correlated with I/E (r=.51) and AR (r=.48), and weakly correlated with AD (r=.22).

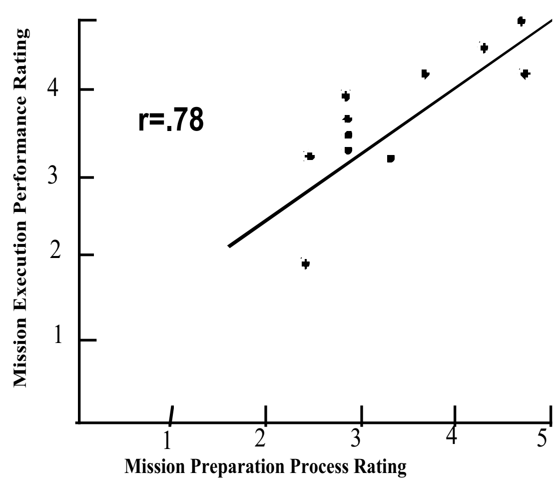

Figure 2. Relationship between mission preparation and overall mission performance

Measures of Effective Mission Preparation

Having established the overall relationship between MP and mission performance, we next determined the *specific* aspects of MP that underlay this relationship. We began by comparing the 42 measures of MP effectiveness identified in a previous study (Spiker & Nullmeyer, 1995b) with the content items from the MP segment of our crew process data collection forms. Of these 42, 12 were judged as relevant to the particulars of our study, i.e., a scenario hand column of Table 1. The 11 crews were then scored on the extent to which each of the 12 measures were present in the observations of notable MPbehaviors recorded in their protocols. As a basic index of MP quality, we simply counted the number of different measures, out of 12, that were represented by one or more behaviors noted in the current study. Examples of behaviors that would be assigned to each measure are shown in the right hand column of Table 1. Since negative behaviors were also recorded, a measure was scored as a -1 if the crew's protocols contained only instances of unacceptable behaviors. While scores could range from -12 to +12, the range in our sample of 11 crews was -1 to 12. We then correlated these derived scores with the crew's rank order on overall mission performance. A fairly sizable and significant correlation, .71, was observed ($t=3.02$, $df=9$, $p<.01$), as crews who exhibited positive behaviors on one or more of these measures of effectiveness performed significantly better during the mission.

Notable Mission Preparation Behaviors

Given a significant link between MP quality and subsequent mission performance, a final question concerns identifying the particular behaviors that characterize effective MP. The present study is but a first step at delineating these behaviors, where our focus was on capturing the processes exhibited by our three strongest aircrews.

Below, we list only a sampling of the MP behaviors of our most successful crews, where different behaviors were evident across crew positions. For the AC, some notable behaviors included establishing an initial task macro-plan and monitoring the team's progress against that plan, orchestrating comprehensive briefings using execution checklists, demonstrating various leadership styles to manage the mission planning process, and maintaining a professional attitude and perspective throughout the entire MP period. Not surprisingly, the list of notable behaviors for the CP resembled the AC's list. However, unique CP behaviors included performing as a "hidden" leader by facilitating the MP process and taking indirect responsibility for many of the AC's traditional duties, providing input and modifications to the navigator's master low-level chart, making decisions regarding the coordination of procedures (ground, drop, emergency) with the necessary agencies, and researching threat capabilities to support the navigators' planning.

Notable behaviors exhibited by one or both navigators during MP included assuming responsibility as an alternate "leader" to ensure all MP activities are completed, employing automated mission planning systems to assist in developing the tactical mission plan, pre-coordinating tactical options for AR and AD if conditions precluded using standard procedures, and negotiating fuel requirements with mission planners as necessary. The two enlisted personnel onboard the MC-130P, the FE and CS, also exhibited notable behaviors. Examples include providing an extra "set of eyes" for the navigator's map contour analysis by advising him of potential obstructions, coordinating with the navigators' to establish opportune locations for objective area 'warnings' and advanced checklists, querying the parajumper team members regarding their evasive plan of attack needs, and acknowledging the mission's complexity.

Table 1. Measures of Mission Preparation Effectiveness

Measure of Mission Preparation Effectiveness	Representative Behaviors
All planning personnel are effectively utilized	AC asked all crewmembers for "what you need to do your job" and then got it for them
Establish timeline for managing the planning process	AC told crewmembers when they had to be completed with their planning tasks in time for the crew briefing
Precise times are determined for accomplishing the key mission events	Planned AR control time and route backwards from the AR control point. Determined optimal T/O time from these.
High-quality crew briefings are given during various stages of planning	After each crewmember briefs, the AC adds final comments for the crew's consideration
Planning crew achieves an in-depth awareness of threat capabilities along the route	To avoid threats, crew planned to fly very low altitude, terrain mask, and high speed (as necessary) maneuvering
The plan is developed to an appropriate level of detail	FE and CS prepared the evasion plan of action (note: a level of detail not provided by many of the crews)
All information sources are checked for recency	AC asked when intel had last been updated
Information is cross-checked for accuracy and the plan's assumptions are aggressively questioned	AC questions assumptions in each crewmember's plan
Ground team and support asset requirements are incorporated into the overall plan	AC modifies plan to incorporate considerations of helicopters for the transload
Mission essential equipment is well thought out and incorporated into the plan	Crew listed the minimum equipment needed to accomplish the mission, such as INS, chaff, flares, etc.
Planning assumptions are subject to extensive "what iffing"	Crew planned to "bump up" their airspeed if they encountered threats during the AR
Planners incorporate their real world experience into the planning process	Crewmembers related their own experiences in the area of operations as they developed the execution plan

DISCUSSION

This study provides empirical evidence that more effective MP is associated with better mission performance by experienced military aviators. Using independent ratings from two observers, we showed that MC-130P crews who engage in higher quality MP reap the benefits of superior performance during a challenging training mission. This relationship was strongest during the tactically demanding low-level phase of the mission, and was primarily mediated by two processes—situation awareness and time management. Concrete behaviors indicative of a superior MP process included using one's personnel effectively, establishing and following a timeline for completing a mission plan, aggressively questioning a plan's assumptions, giving informative briefings at the conclusion of planning, and comparing the plan against possible contingencies ("what-iffing") to eliminate potential problems. While these characteristics should be part of *any* mission plan, they are particularly important to instill during combat mission training. Since concluding this study, we have been working with the 58th Special Operations Wing to modify their training curriculum so that instructors are able to reinforce and shape the desirable mission preparation behaviors in subsequent generations of SOF student-crews (Tourville, Spiker, Thompson, & Nullmeyer, 1999).

The robustness of the mission preparation-mission performance link was established through two additional studies, representing different weapon systems (Thompson, Tourville, Spiker, & Nullmeyer, 1999; Spiker, Tourville, Bragger, Dowdy, & Nullmeyer, 1999). In particular, we have found that indices of mission preparation effectiveness were significantly correlated with mission performance for MH-53J crews ($r=.69$) as well as C-5 crews ($r=.86$). In the case of the former, time spent planning served as an even better predictor of performance ($r=.76$). The latter case is particularly notable as it involved a non-tactical training environment, in which crew stress and workload was induced through insertions of system failures. Taken collectively, these findings suggest that the relationship between preparation and performance is quite strong, widespread, and potentially trainable.

In the longer term, this research has important implications for military training. Planning and briefing skills have historically been honed "on the job" with junior aviators acquiring many critical skills by observing the activities of more senior crewmembers and adopting what they see as effective behavior patterns. The decreasing experience levels in today's military crew force present several challenges for this traditional master-apprentice approach.

First, lower times to upgrade (e.g., wingman to flight lead) reduce the time available for apprenticeship. Second, many "masters" are relatively inexperienced themselves. To the extent that planning and briefing skills are important, accelerating the learning curve will be beneficial, if not necessary. As researchers define effective planning and briefing behaviors, these insights need to be integrated into course content.

In addition, existing training experiences need to be reviewed for their potential to facilitate development of mission preparation skills. For example, future tactical training will involve distributed simulations with multiple crews operating from remote sites. Despite the current emphasis on simulation capabilities and fidelity, it is also essential to maximize training when student-crews meet together, face-to-face, "outside the box." Emphasizing mission preparation skills during this training would be low cost (relative to simulation itself) yet can have a large impact on mission performance. In this vein, we have evidence showing that even though students view such distributed simulator training very favorably, they still value the "face time" that comes from meeting with crews from other weapon systems (Spiker, Tourville, & Nullmeyer, 1998).

Although the preparation-performance relationship seems fairly robust, future work needs to explore *why* effective MP is related to better mission performance. In this regard, there are a number of plausible mechanisms underlying the effectiveness of MP that should be studied. One possibility directly follows from social learning theory (Bandura, 1977), whereby we learn to deduce the intentions of leaders and colleagues through observation. Effective MP may result in improved mission performance to the extent that participants share intentions or "mental models" (Stout, et al., 1999). Such a view is consistent with recent developments in instructional design, where learning is assumed to occur most efficiently in a collaborative environment. MP may be viewed as establishing the conditions for effective mission specific-learning in which face-to-face communication, context sensitivity, and mutual intelligibility are maximized (Law, 1995). Such a view is consistent with the results of the C-5 study, in which the more successful crews were ones where the pilot and flight engineer shared a similar vision of the best ways to resolve the in-flight emergencies (Spiker et al., 1999).

Another cognitive explanation for the facilitative effects of MP is that such periods allow participants to practice cognitive skills that prepare them for contingencies so that less time is needed once those events arise. Effective MP thus reduces the need for real-time decision-making, allowing more automated responses to take over. Along these lines, MP may create the opportunity for mental practice, where there is evidence that imaginative rehearsal may improve subsequent performance in a variety of domains, although the underlying mechanisms (e.g., motivation, imagery) are still unknown (Nullmeyer & Spiker, 2000).

A less interesting possibility is that the planning-performance relationship may simply reflect the fact that crews exhibiting superior MP are superior on all mission phases because they simply are better crews. Thus, the effects of MP will be more apparent for superior crews in general, suggesting that the utilization of the findings lies in the area of personnel selection rather than training. Allied against this view, though, is the observation that crews with more experience in our study did not necessarily plan better. In fact, the crew exhibiting the poorest planning (and performing) had the most experience at several key crew positions (i.e., AC and LN).

A more intriguing prospect is whether effective MP increases the chances that crews will have worked out the "sticky" problems in advance so that uncertainty and workload during the mission are reduced. Increased crew confidence in the plan should result as well. Determination of the cognitive, social, and personality mechanisms underlying MP effectiveness will require that these behaviors be subjected to experimental analysis, in which the amount and type of planning is subject to experimental control rather than self-selection. Further work in this area has important implications for future developments in military training, doctrine, and in the implementation of automated mission planning and simulation technologies.

REFERENCES

Bandura, A. (1977). Social learning theory. Engelwood Cliffs, NJ: Prentice-Hall.

Bergondy, M., Fowlkes, J., Gualtieri, J. & Salas, E. (1998). Key team competencies for Navy air wings: A case study. Proceedings of the 19th Interservice/ Industry Training Systems and Education Conference. Orlando, FL.

Brannick, M.T., & Prince, C. (1997). An overview of team performance measurement. In M.T. Brannick, E. Salas, and C. Prince (Eds), Team performance assessment and measurement: Theory, methods, and applications (pp 3-18). Hillsdale, NJ: Erlbaum.

Charness, N. (1989). Expertise in chess and bridge. In D. Klahr and K. Kotovsky (Eds), Complex information processing: The impact of Herbert A. Simon (pp 183-208). Hillsdale, NJ: Erlbaum.

Ericsson, K.A., & Lehmann, A.C. (1996). Expert and exceptional performance: Evidence of maximal adaptation to task constraints. Annual Review of Psychology, 47, 273-305.

Fallesen, J.J., Carter, C.F. Jr., Perkins, M.S., Michel, R.R., Flanagan, J.P., & McKeown, P.E. (1992, August). The effects of procedural support and computer support upon selecting a tactical course of action. (ARI Technical Report 960). Alexandria, VA: US Army Research Institute for the Behavioral and Social Sciences.

Geiwitz, J., M'Closkey, B.P., Kornell, J., & Wong, R. (1991, June). Decision aids for the selection of effective knowledge acquisition techniques. Presented at the 8th annual conference on command and control decision aids, National Defense University, Ft. McNair, Washington DC.

Keene, S.D., Michel, R.R., & Spiegel, D.K. (1990, September). Army command and control evaluation system (ACCES) review. (ARI Research Note 90-140). Washington, DC: Army Research Institute.

Klein, G.A., Calderewood, R., Clinton-Cirocco, A. (1986). Rapid decision making on the fire ground. Proceedings of the Human Factors Society 30th annual meeting, 1, 576-580.

Kolitz, S.E. & Beaton, R.M. (1993, October). Overall system concepts in mission planning. 1-1 through 1-17. Presented at an AGARD Lecture Series on 'New Advances in Mission Planning and Rehearsal Systems.'

Law, L.C. (1995). Constructivist instructional theories and acquisition of expertise. (On-line) (Research report No. 48). Available: http://infix.emp.paid.uni-muenchen.de/lslmandl/.

Nullmeyer, R.T., & Spiker, V.A. (2000). Simulation-based mission rehearsal and human performance. In H. O'Neal and D. Andrews (Eds), Aircrew training research issues. Hillsdale, NJ: Lawrence Erlbaum Associates.

Nullmeyer, R.T., Bruce, P.D., & Spiker, V.A. (1994, April). Simulation-based mission rehearsal: Some behavioral issues. Paper presented at the 14th Applied Behavioral Sciences Conference, Colorado Springs, Colorado.

Ross, I. (1993, October). Human factors of mission planning systems: Applications and implementation. 3-1 through 3-7. Presented at an AGARD Lecture Series on 'New Advances in Mission Planning and Rehearsal Systems.'

Spiker, V.A., & Campbell, J.L. (1993, May). Functional analysis of Combat Talon I mission planning: Opportunities for integration with advanced mission rehearsal technology. (AL/HR-TR-1993-0058). Williams AFB, AZ: Aircrew Training Research Division, Armstrong Laboratory.

Spiker, V.A. & Nullmeyer, R.T. (1995a, April). Benefits and limitations of simulation-based mission planning and rehearsal. Eighth International Symposium on Aviation Psychology, Columbus, Ohio.

Spiker, V.A. & Nullmeyer, R.T. (1995b, September). Measuring the effectiveness of mission preparation in the special operations forces. (AL/HR-TR-1995-007). Mesa, AZ: Aircrew Training Research Division, Armstrong Laboratory.

Spiker, V.A., Silverman, D.R., Tourville, S.J., & Nullmeyer, R.T. (1998, July). Tactical team resource management effects on combat mission training performance. (AL/HR-TR-1997-0137). Mesa, AZ: Air Force Research Laboratory, Warfighter Training Research Division.

Spiker, V.A., Tourville, S.J., & Nullmeyer, R.T. (1998, July). Multi-crew combat training using networked simulation strategies. Modeling & Simulation Technology.

Stout, R.J., Cannon-Bowers, J.A., Salas, E., and Milanovich, D.M. (1999). Planning, shared mental models, and coordinated performance: an empirical link is established. *Human Factors, 41,* 61-67).

Taylor, R.M. (1993, October). Human factors of mission planning systems: Theory and Concepts. 2-1 through 2-28. Presented at an AGARD Lecture Series on 'New Advances in Mission Planning and Rehearsal Systems.'

Thompson, J.S., Tourville, S.J., Spiker, V.A., & Nullmeyer, R.T. (1999, December). Crew resource management and mission performance during MH-53J combat mission training. Proceedings of the 20th Interservice/Industry Training Systems and Education Conference. Orlando, FL

Thornton, R.C., Kaempf, G.L., Zeller, J.L., & McAnulty, D.M. (1992). An evaluation of crew coordination and performance during a simulated UH-60 helicopter mission (ARI-RN-92-63). Fort Rucker, AL: U.S. Army Research Institute for the Behavioral and Social Sciences.

Tourville, S.J., Spiker, V.A., Silverman, D.R., & Nullmeyer, R.T. (1996, November). An assessment methodology for team combat mission training and rehearsal. Proceedings of the 17h Interservice/Industry Training Systems and Education Conference. Orlando, FL.

Winkler, R.L. & Hays, W.L. (1975). Statistics: Probability, inference, and decision. New York: Holt, Rinehart, and Winston.