STRATAGEMS: AN INNOVATIVE APPROACH FOR INCREASING COGNITIVE AUTHENTICITY IN GAME-BASED ENVIRONMENTS

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ABSTRACT
Combat Search and Rescue aircrew are tasked with challenging missions, usually under conditions of time pressure, dynamic conditions, and a high degree of uncertainty. Many skills required for successful outcomes (e.g., solving problems quickly; accurately evaluating risks; adapting to rapidly changing environmental conditions) are acquired and maintained through first-hand experiences. This paper describes a research project to develop a pedagogically effective game-based trainer for cognitive skills required for Combat Rescue Helicopter aircrew. Training scenarios are developed using cognitive interviewing techniques in order to promote cognitive authenticity. The trainer will pose critical decisions and provide expert feedback utilizing ShadowBox®, a proven coaching technique that enables trainees to obtain insight into the decision-making processes and reasoning of experts.

Keywords: training, simulation, cognitive skills, game-based training.

1. INTRODUCTION

Personnel Recovery plays a critical role in the success of military missions for both humanitarian and strategic reasons. A chief duty of the United States Air Force is to maintain training of Combat Search and Rescue (CSAR) teams that undertake these important missions. The dynamic nature of these missions requires the ability to be adaptable, solve problems quickly, and maintain a high level of situational awareness in addition to executing tactics and procedures needed for flight in challenging environments.

To prepare aircrew to operate in such complex environments, the Air Force designed a rigorous training program that incorporates a blend of schoolhouse instruction and hands-on training with simulations and live equipment. In the interest of economy and efficiency, simulations are used for most non-tactical training. The Air Force has developed high-fidelity full mission simulators, including custom hardware and software. These simulators typically have a large footprint, and have the benefit of offering a high degree of realism. However, they are often comparable in cost to the equipment being simulated and require a team of dedicated evaluators and technicians to run the simulations. Furthermore, they are not portable; it is costly to move them around, and this limits them to use cases where training is carried out in a fixed location. There are also substantial costs associated with updating them to maintain consistency with real equipment; this is particularly daunting when new equipment such as a new aircraft is introduced. There is a need for training solutions that provide a high level of training effectiveness at a lower cost, with increased portability, and the flexibility required to update training based on evolving platform capabilities and missions.

With regard to training content, flight simulators provide extensive training in tactics, standard operating procedures, and flying skills. Cognitive skills associated with managing the larger mission (e.g., making critical decisions, assessing risk, making sense of the environment, and anticipating next steps) are typically acquired and maintained through mission experience. To complement and extend traditional training for CSAR aircrew, a need was identified for a training platform to build aircrew's cognitive skills. This type of training would be especially useful for overseas deployments, mission rehearsal, and training new missions.

Desktop flight simulations offer a potential strategy for addressing issues of portability and cost-effectiveness while still maintaining the pedagogical benefits of "hands-on" training. Although the degree of realism for manoeuvrability inputs and environmental cues is lessened on desktop simulators, Stewart, Johnson, and Howe (2008) found that a high degree of physical fidelity alone does not necessarily lead to better training outcomes. Instead, criterion-based training strategies are linked with better training outcomes, even when simulators have lower fidelity. A trainer for cognitive skills must have a degree of cognitive fidelity, defined as the extent that the trainer mirrors the actual cognitive activities of the real-world task (Hochmitz and Yuviler-Gavish 2011).

Games, like simulations, are an increasingly attractive and often low-cost alternative to full-mission simulators and have the added benefit of being highly engaging and motivational. In a recent meta-analysis, games were found to lead to 11% higher factual knowledge, 14% higher skill-based knowledge, and 9% higher retention rates in employees who played serious games as part of their training as compared to those who had not played such games (Stizmann 2011). Due to the highly goaloriented nature of CSAR missions, a game-based trainer is a natural way to train and evaluate cognitive skills of aircrews.

1.1. Stratagems

Our proposed solution is the Stratagems training platform. At its core, Stratagems is a game-based training and mission rehearsal system centred upon cognitively immersive scenarios. Learners are tasked with making high-level decisions about mission planning and execution within the context of rapidly evolving scenarios based on real-world CSAR and MEDEVAC missions. The game-based training setting incentivizes trainees to focus on their own processes and decision-making, and provides opportunities to explore different paths—including those that lead to failure—in a safe environment. Stratagems leverages the pedagogical capabilities of ShadowBox®, a scenario-based training technique that gives learners insight into an expert's thinking during challenging missions (Hintze 2008). Embedded throughout ShadowBox scenarios are cognitive probes, during which learners are required to respond to a question about their current priorities, risk assessment, or assessment of the situation. ShadowBox provides learners with the opportunity to directly compare their answers with the way a subject matter expert (SME) would think about the same situation. Prior to the learner play-through, experts have recorded their feedback about the most and least critical information at specific points in the scenario, how they make sense of complex settings, how they prioritize and establish feasible goals, and the rationale behind their actions. Users also receive a score based on how closely their answers match answers given by SMEs. The ShadowBox approach has shown promise for training cognitive skills in a variety of domains, including with Army and Marine personnel, law enforcement, nurses, social workers, and petrochemical panel operators (Klein and Borders 2016; Flanders, Gunn, Wheeler, Newsome, and Klein 2017; Newsome and Klein 2017; Borders, Polander, Klein, and Wright 2015).

We integrated the ShadowBox functionality of cognitive probing and providing expert feedback to the Stratagems platform. This added capability provided an innovative enhancement, which became the basis for a platform focused on providing training for higher-level cognitive skills in CSAR aircrew, such as planning, decision making, and evaluating risk.

1.2. Overview

This paper will describe the methodological approach for creating an initial prototype of a Stratagems scenario. The technical aspects of the Stratagems game (i.e., game engine, asset selection, non-person characters) are fairly standard for game development and will not be presented. This paper will also discuss our next steps following the completion of the prototype, including gathering user acceptance feedback, pursuing a performance evaluation of the approach, and developing an authoring tool to streamline the scenario generation process.

2. METHOD

Development of Stratagems training included 3 steps: (1) literature review to gain an understanding of the cognitive requirements for CSAR missions; (2) cognitive task analysis (CTA) interviews to elicit critical incidents; and (3) Scenario development, including validation from Subject Matter Experts (SMEs).

First, we began with a literature review, examining publicly available accounts of rescue incidents such as *Leave No Man Behind: The Saga of Combat Search and Rescue* (Galdorisi and Phillips 2009) to understand features that increase complexity in CSAR missions. We also reviewed the Combat Rescue Helicopter Weapons System Training System Requirements Analysis Version 1.0 (TSRA) (Air Combat Command 2015) to identify documented cognitive skill requirements.

Second, we conducted a streamlined cognitive task analysis consisting of interviews with two experienced CSAR pilots and one experienced CSAR gunner/flight engineer. We used the Critical Decision Method (Klein, Calderwood, and MacGregor 1989; Crandall, Klein, and Hoffman 2006) to obtain first-person accounts of challenging, real-world scenarios. The Critical Decision Method is a semi-structured interview technique, during which interviewer and interviewee explore a challenging incident from the interviewee's experience in depth in order to gain a deep understanding of the interviewee's cognitive processes, as well as the context in which the challenging incident took place. Interviews were directed toward cognitive activities such as making sense of a rapidly changing situation, communicating with team members, assessing risk throughout the incident, and identifying the key factors of safety decisions. Although 6-8 interviews is generally recommended when conducting a CTA (Militello and Hutton 1998), because our objective was narrow (i.e., identify challenging incidents) and access to experienced CSAR personnel was limited, we used a streamlined approach in which we explored 1-2 incidents with each of the three interviewees.

Third, we examined findings from the literature review and the streamlined cognitive task analysis to develop a scenario for an initial prototype. Interview notes were transcribed within one week of conducting interviews. We reviewed each incident to determine which provided the best foundation for a first training scenario. We considered the factors that added complexity to determine which could be effectively developed in our initial prototype. We considered whether to focus on the pilot or the flight engineer perspective, and whether the scenario presented challenges that would provide a learning experience linked to cognitive learning objectives. These considerations led us to focus on one incident relayed by one of the pilot interviewees.

After selecting an incident to use as a foundation for the training scenario, we created a decision flow chart providing an overview of the incident, key decisions, and potential variations. Table 1 below provides a section of the decision flow chart for the first decision in the scenario.

Table 1. Excerpt of Decision Flow Chart

	1900: Come on to shift
Information Learned	• Special Operators are doing a mission that requires Rescue crews to stay close. They've started earlier than usual today. • Mission is already underway – you are already 20 minutes behind • Weather: low visibility due to new moon and recent storm that left overcast condition. • Package composition: o 2 HH-60s, 1 AC130, A10s.
Decisions	• What information do you need before you leave? o Why did SOF team leave early? o What is their mission? o Location of enemy threats? o Weather forecast / reports?
Variations	• Weather o Foggy, sandstorm o Daylight, clear night • How far behind is player? (sense of urgency) • Crew composition o New people? o 1 or 2 SMAs? o PJs? Do you know them? Are they experienced?

Using this as a frame, we drafted a narrative timeline, and cognitive probes intended to encourage the learner to articulate key concerns, priorities, and actions at critical points in the scenario. We asked the two CSAR pilots who had participated in interviews to review the narrative timeline, and to provide a response and rationale statement for each cognitive probe. We refined the scenario based on this input, and drafted an expert model linked to each cognitive probe. An experienced pilot who did not participate in the cognitive interviews reviewed the refined scenario, and provided additional feedback and elaboration on the expert model.

Basing our scenario development on CTA findings allowed us to incorporate a high level of cognitive fidelity into the scenario design process. The literature review added breadth to our small-sample CTA, and also helped us stay grounded in training requirements as defined by the U.S. Air Force. Direct feedback from experts about their decision making is an important component of the pedagogical approach of the Stratagems system. The integrated rankings and rationale from multiple SMEs, provided the expert response model to which learner responses will be compared during training.

3. RESULTS

Results from the literature review, the cognitive task analysis, and the resulting training scenario are described in turn.

3.1. Literature review

3.1.1. Common decisions and cognitive skills

To identify a candidate set of critical cognitive skills that could be addressed with Stratagems, we reviewed the Combat Rescue Helicopter Training Requirements Analysis (TSRA) Version 1.1 Master Task Training List (MTTL) (Air Combat Command 2015). Specifically, we examined the TSRA for tasks that require judgment and problem solving. We organized critical skills into a list of skills of interest during Cognitive Task Analysis interviews. Skills were organized into the following categories based on macrocognitive functions: communication, crew management/delegation, sensemaking, anticipating/planning, and monitoring safety.

Table 2. CSAR Aircrew Cognitive Skills

Cognitive Skills
Communication
Communicate with other crewmembers to obtain/relay/provide mission details using tactical communications systems
Brief crewmembers before, during, and after missions—presenting info in logical sequence
Crew management
Manage resources and duties effectively to minimize task saturation, channelized attention, and distractions among crewmembers
Direct maintenance support to correct discrepancies noted during pre-flight
Sensemaking
Understand changing situations and environments
Determine if any restrictions exist on departure, en-route, and at destination
Perform scanning during all flight operations
Analyse weather briefing
Perform battle damage assessment
Recognize ground and airborne threats to aircraft
Anticipating/planning
Evaluate feasibility of divert
Prepare alternate plan
Perform inflight dynamic planning
Perform Landing Zone (LZ) options
Anticipate and respond to terminal area contingencies

Cognitive Skills
Monitoring safety
Apply sound judgment with regard to mission accomplishment and safety
Perform survivor authentication
Maintain aircraft parameters within limits of EM charts

Interviewers were primed to explore the MTTL critical skills as they arose, but were also open to exploring decisions and tasks not previously identified. In addition to identifying specific skills from the MTTL, we reviewed the rescue incidents described in Galdorisi and Phillips' (2009) *Leave No Man Behind: The Saga of Combat Search and Rescue* to understand the operational context of CSAR pilots. We used the incidents to explore how critical skills in the MTTL might play out in real-world scenarios. Some examples of situated critical cognitive skills from our analysis of incidents in the book include:

- Determine whether an area is "too hot" to attempt a rescue.
- Determine the rescue strategy (e.g., landing the helicopter versus hovering to allow personnel to rappel down).
- Modify the mission to deal with unforeseen developments (e.g., more enemy fire than anticipated, weather changes, low fuel due to not being able to locate person).
- React to observations from back crew (e.g., "I see power lines at 900, climb, climb, climb!").

Leave No Man Behind (2009) presented recollections of CSAR missions from conflict in the jungles of Vietnam in the 1960s and 1970s to more recent conflict in Afghanistan. Through a review of these incidents, we also identified features that make CSAR missions especially challenging. These include:

Table 3: Features that increase complexity in rescue scenarios

Features that increase complexity
• Uneven terrain (complicates finding a suitable place to hover or to land) • Technical difficulties (i.e., winch/rappel line won't work) • Injured personnel that are immobile or severely injured • Rescuing multiple people (i.e., added weight, accountability) • Enemy fire • Not being able to locate the pilot (faulty Global Positioning System (GPS), etc.) • Weather changes (i.e., thunderstorm rolling in, fog) • Environmental challenges (i.e., high altitude, high temperature) • Urban environment (i.e., don't know where enemy is and how many there are) • Low fuel

Taken altogether, these three lists (list of cognitive skills in MTTL, situated cognitive skills, and features that increase complexity) informed the general roadmap for the types of incidents we wanted to explore during CTA interviews. Although interviews were geared toward the concepts identified in the literature review, we remained open to discoveries and interesting problems interviewees had encountered in their careers.

3.2. Cognitive Task Analysis

CTA interviews resulted in three incidents—one from each interviewee. Only one incident was a true CSAR mission, defined by being carried out in or near combat zones during a time of war. The other two incidents included a Medical Evacuation (MEDEVAC) mission, and an attempted but aborted rescue mission. Each incident is described in detail below.

3.2.1. Wreck in the ROZ.

This pilot was commanding CHALK 2. The rescue team was tasked with providing back up support for Special Operations Forces (SOF) as they conducted combat missions in Iraq. On this day when the pilot arrived on shift, he learned that the SOF had scrambled to a combat zone approximately 100 miles away, 20 minutes ahead of schedule. He and the rescue crew quickly took off and headed toward an initial rendezvous point. En route, they learned that a U.S. Army HH-60 had crashed inside a Restricted Operating Zone (ROZ), which had been set up for the SOF mission. Soon after, the helicopter crew learned that personnel injured in the crash had been ex-filled, but survivors and deceased crewmembers remained at the crash site. The rescue helicopters flew a racetrack holding pattern just outside the ROZ as they attempted to get more information about the crash from both the ROZ owner and the Tactical Operations Centre (TOC). The crew had to decide at each stage whether to proceed with limited information, and whether to violate protocol by entering the ROZ without permission.

3.2.2. High, hot, and heavy on the side of a mountain

This pilot was commanding CHALK 2. Two rescue helicopters and crew had flown south to a nearby base to join the Army for a steak dinner. On the way back from dinner, they saw traffic on their Internet relay chat about a helicopter that had crashed further north. The rescue helicopters offered to go to the crash site to investigate. They decided to land at a nearby base to collect more information before heading to the crash site. They learned that a CH47 (Chinook) was ex-filling an Army special operations team that had been operating in the area. The Chinook should have returned, but no one had heard from them. The most likely explanation was a crash. They knew there had been three crewmembers on the Chinook, but they did not know the status of the crash or how many of the people being ex-filled had entered the Chinook before the crash. They knew that the terrain near the crash site would be challenging, because it was located on the side of a mountain. Furthermore, the extremely hot weather, the high altitude, and the weight of the survivors would reduce the power of the aircraft. As they approached, they saw the valley below the rendezvous point aflame. The Chinook had struck the side of the mountain when landing, and tumbled down the mountain. During the descent, the Chinook sprayed the valley with jet fuel. The valley was on fire. It was so bright that Night Vision Goggles (NVGs) would no longer work. It was difficult to see much beyond the fire. The crew had to decide whether they could safely attempt a rescue of the surviving Army personnel, and if not, what an alternate plan of action would be.

3.2.3. Popeye in a Sandstorm

This incident was told from the perspective of an SMA. The rescue team was sitting alert when they received the call to scramble. The SMA was doing engine checks, putting on armour, and listening to the radio for the 9-line all at the same time. He learned that there had been an improvised explosive device (IED) explosion, and the injured person had lost both legs and an arm. The injured person was a member of NATO ally forces. This was all happening during an on-going sandstorm. The weather did not look impossible, but the SMA knew the conditions were challenging. As the helicopters took off, within seconds they called blind. The crew had to decide how to reorient and find straight and level flight, then had to formulate a plan to continue with the mission or return. Note: although he didn't know it at the time, the interviewee told us that he later learned a NATO ally MEDEVAC team declined the mission because the weather was too severe.

After careful analysis, we selected the "Wreck in the ROZ" scenario for further development into a prototype scenario based on three criteria. One, the focus on the pilot/co-pilot role was most appropriate for our initial effort, because of the executive decision-making role of pilots/co-pilots. While the SMAs handle the logistics of the mission, the pilot and co-pilot manage executive decision-making, such as making go/no go decisions, selecting routes, navigating the aircraft, receiving and interpreting intelligence briefings, and responding to changes in the environment (e.g., weather, terrain, enemy fire, etc.). Thus, a scenario from the pilot/co-pilot scenario would more directly address the cognitive training objectives articulated in the literature review. Two, the "Wreck in the ROZ" scenario would require limited terrain mapping and therefore would be suitable for a limited prototyping effort. Three, this scenario also required the pilot to make a series of difficult judgments in the face of uncertainty and introduced a range of complex elements, including some from the list of features that increase the complexity of CSAR missions presented above.

3.3. Training scenario

After selecting the *Wreck in the ROZ* incident, we deepened the scenario and added detail, which included integrating ShadowBox probes, articulating learning objectives, and soliciting feedback from Subject Matter Experts. We describe the resulting prototype below.

3.3.1. Gameplay

Because the objective of the Stratagems game is to develop learners' cognitive skills rather than their flying or procedural skills, we deliberately simplified the look and feel of the game environment in order not to detract from the cognitive focus of the game. Thus, helicopter gauges and terrain features were relatively low-fidelity representations. We further emphasized decision making and cognitive skills by removing the need for the learner to pilot the aircraft during the training scenario. This style of gameplay results in an experience that is similar to a flight lead's role in the mission; the duty of flying the aircraft is typically assigned to the co-pilot, while the pilot concentrates on higher-level decision making and communication tasks. Instead of having an active flying role, the learner is tasked with monitoring the flight of the aircraft and to make sense of incoming information. Learners must also respond to ShadowBox probes, when prompted. The choices and rankings learners submit at each decision influence the course of the scenario, as well as the probability of events happening throughout the scenario. For example, selecting "Option A" may result in higher risk of enemy fire because it makes the aircraft more visible to the enemy than "Option B." Figures 1a and 1b provide screenshots of the Stratagems gameplay.

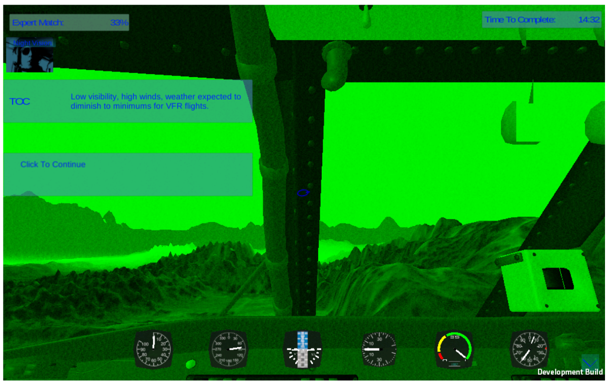

Figure 1a: Stratagems Player View

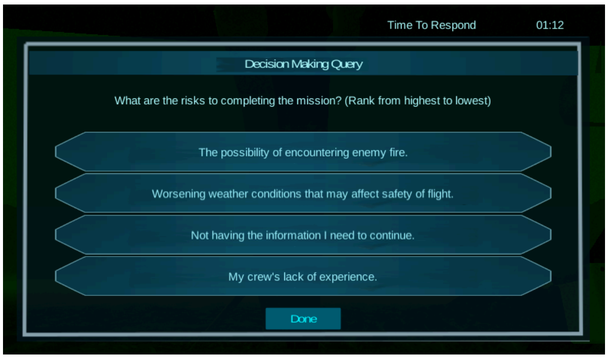

Figure 1b: ShadowBox Probe

3.3.2. ShadowBox Probes

The purpose of the ShadowBox probes is twofold: First, to encourage learners to articulate their understanding and priorities at key points in the scenario, and second, to show the learners how experts think about the same situations. The ShadowBox probes are provided in real-time as the learner plays through a game. Questions asked generally fall into one of three categories: Information needs probes ("What information do you need before leaving?"), risk assessment probes ("What are the risks to completing the mission at this time?"), prioritization probes ("What are your most pressing priorities?"), or strategy probes ("What strategy would you use to land safely?"). Generally, decisions immediately followed an information inject (e.g., updated weather briefing, additional information from the command centre) that changed the learner's understanding of the situation.

As the scenario was instantiated in the game format, we found that we needed a visual representation of the incident to facilitate discussion and common ground across subject matter experts, software developers, and cognitive task analysts. The resulting scenario map (see Figure 2 below) allowed us to quickly orient to specific points in the scenario, consider placement of branches and probes, and quickly identify information gaps and inconsistencies.

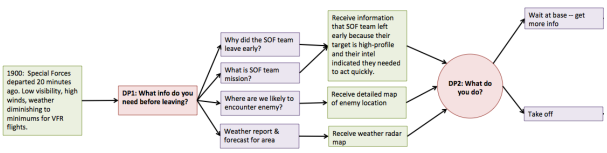

Figure 2: Scenario Branching Diagram

A second critical aspect of the ShadowBox approach is the ability to review an expert's perspective on the scenario and specific decision points. To encourage reflection without disrupting the flow of the game, expert feedback is provided at the end of the scenario. This also gives learners the opportunity to make decisions based on their own assessments and choose actions without being influenced by expert rankings. After completing a scenario, the after-action review (AAR) provides the opportunity for students to compare their rankings with those of experts and reflect on the similarities and differences.

3.4. Scoring

To score performance on Stratagems scenarios, learners will be evaluated using two separate criteria. One measure of performance will be the degree to which their chosen tactics, strategies, risk perception and decision making capabilities align with the expert model at decision moments. Learners will receive an overall percentage match score, and will be encouraged to review decisions in which their answers did not align with SME answers. Due to the heavy emphasis on outcomes in this domain, we wanted to increase the realism of our scoring paradigm by rewarding learners for not only making the right choices, but also for achieving the most desirable outcomes. Therefore, a second performance measure will be based on the scenario outcome attained based on the learner's chosen strategy (e.g. if injured personnel were rescued; if the helicopter was damaged or crashed; if rules of engagement or protocol were violated).

4. SUMMARY AND NEXT STEPS

The focus of Stratagems is to create a game-based trainer with a high degree of cognitive authenticity in order to facilitate the development of cognitive skills. Strategic design choices including the integration of ShadowBox and using Cognitive Task Analysis to inform scenario development, allowed us to address specific learning objectives such as sensemaking, anticipating, and crew management. Decision feedback from experts was incorporated into the scoring function, to encourage learners to compare their choices to those of a panel of experts.

A next step for enhancing the Stratagems tool is to create an authoring tool to allow trainers to create scenarios on their own. Although we believe Cognitive Task Analysis is the best way to create a detailed and challenging scenario, it can often be a time- and resource-consuming process. Therefore, we are designing an authoring tool interface to support instructor pilots in building cognitively challenging scenarios based on their own lived experiences. The system would prompt the trainer to select from certain pre-sets such as terrain, crew, or mission type (e.g., CSAR or MEDEVAC) before helping them build a timeline of the incident and populate decision points. Finally, the system would prompt the trainer to review alternate paths or branches through the scenario and the consequences for choosing alternate decision options.

Another logical next step would be to build a training scenario from the perspective of the SMA. This would require additional literature reviews and cognitive task analysis for examples of cognitive skills and challenging incidents from the SMA perspective. We are also in the process of gathering user acceptance data from current CSAR pilots and trainers. We hope to collect reactions in order to more formally assess the validity of our scenario and decisions, the level of cognitive realism, and the perceived value of the Stratagems training platform.

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