Team Performance and Assessment in GIFT – Research recommendations based on Lessons Learned from the Squad Overmatch Research Program

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INTRODUCTION

In 2015 a set of research objectives were developed for the Army Research Laboratory's (ARL) adaptive tutoring program focusing on designing and developing effective team tutoring environments in GIFT (Goodwin, Johnston, Sottilare, Brawner, Sinatra, & Graesser (2015). An initial objectives is determining the important variables that drive small unit team performance and developing ways to measure and model those factors in an adaptive training system. At the time the objectives were formulated the ARL research team had already begun a joint, collaborative research program called Squad Overmatch (SOvM) that conducted a series of team-based research studies that in part focused on addressing this question (Milham, Phillips, Ross, Townsend, Riddle, Smith, et al., 2017). The purpose of this paper is to describe how the SOvM program approached the problem of team performance measurement and describes lessons learned for measuring and modeling those factors in an adaptive training system.

SQUAD OVERMATCH

The SOvM research objective is to improve dismounted squad decision making under stress, with a focus on the following five skill domains: Tactical Combat Casualty Care (TC3); Advanced Situation Awareness (ASA); Resilience and Performance Enhancement (RPE); Team Development (TD); and conducting an Integrated After Action Review (IAAR). In 2016 an experiment with eight squads was conducted to determine the effect of training these skills using classroom, simulation, and live training compared to traditional live training exercises (Townsend, Johnston, Ross, Milham, Riddle, Phillips, & Woodhouse, 2017). The four-day SOvM curriculum involved Subject Matter Experts (SMEs) conducting classroom instruction on days 1 and 2 that was immediately followed by skills development in a virtual team training simulation, and then conducting practical skills application in an outdoor training facility on days 3 and 4. Following each 45 minute scenario, the Platoon leader and learning domain SMEs led the squads in guided team self-correction IAARs. The IAAR was aligned with the U.S. Army AAR doctrine for discussing the movement and engagement actions the squad performed during significant tactical events during the scenario. The IAAR focused on developing squad member skills in how to take personal responsibility for identifying behaviors that need correction, develop team cohesion, and set goals for improvement in the next scenario. For the first 20 minutes, the Platoon leader led the squad members in a critique of their tactical performance using video snippets of the critical events collected during the exercise. Then each domain SME spent about 5 to 7 minutes leading squad members in identifying tactical triggers, behaviors, solutions, and outcomes as they reflected on each of the areas, sometimes reviewing video snippets. Finally, the Platoon leader led the squad members in setting goals for improvement in the next scenario. In this manner, the teaching points were reinforced based on practical application, and provided a way to "adapt" how they used the next scenario to focus on performance objectives they had set themselves.

Team Performance Measurement Approach

A major goal of the study was to test the hypothesis that squads receiving the SOvM training would demonstrate better performance on TC3, ASA, and TD over the control condition squads during and after the live training exercises. To construct measures of these skill domains, researchers leveraged two types of team competency models and measurement methods that had been previously validated in earlier research. The Team Tactical Decision Making competency model and the Teamwork competency model were used to develop performance objectives and measures for ASA and TD.

Team Tactical Decision Making Competency Model

The Team Tactical Decision Making model was developed by Paris, Johnston, and Reeves (2000) and is comprised of the four related dimensions of Identification, Elaboration, Planning, and Execution. Johnston, Fiore, Paris, and Smith (2013) validated the model by mapping Navy combat team behaviors to the four categories based on their performance objectives (i.e., the detect-to-engage sequence) for managing their air warfare tasks and assessing performance with the measure (Air Warfare Team Performance Index or ATPI) in simulation-based training exercises. Spiker, Johnston, Williams, and Lethin (2010) then used the identification and elaboration categories of the TDM model to characterize dismounted rifle infantry squad member behaviors during training exercises designed to improve their collective decision making skills. The SOvM study used these identification and elaboration behaviors to guide development of ASA performance objectives in the simulation and live scenarios.

Identification processes involve strategies for employing and manipulating one's own cognitive resources and available assets to orient, observe, recognize, and identify potentially important hostile, friendly, and neutral players based on a particular configuration of features. Such configurations tap an individual's knowledge of cues in the environment, thereby enabling identification of hostile intent, projecting future actions of the players, and ultimately assigning threat potential (e.g., friendly, hostile, neutral, unknown) to them. Identification is an inherently team task as it requires the exchange of timely and accurate reporting of the ongoing state of those features to team members within the team and up the chain of command to feed the common operational picture. Table 1 lists the identification skill definitions and performance objectives developed by Spiker et al. (2010).

Table 1. Identification Skills and Example Performance Objectives. (Adapted from Spiker et al., 2010)

#	Identification Skills	Example Performance Objective
1	Establish a geometry of fires to create an interlocking network of optics, intelligence, and communications	Team members triangulate their communication, optics, and intelligence data to ensure comprehensive coverage of an event, individual, vehicle, anchor point, or habitual area.
2	Utilize organic assets and natural light to make positive identification	Team members use optics (e.g., binoculars and thermals) as effective substitutes in determining, for example, what part of a body was shot and how bad the wound is based on the color of the blood on the ground.
3	Make innovative use of optics (and other organic assets) to help construct a baseline or profile	Team members use range estimation capability in optics to determine opposing forces social status indicators (e.g., to determine if a person of interest is a leader).
4	Shift field of view – from wide to narrow and back – and thereby avoiding focus lock	Team members watch a distant target for awhile with binoculars and then switch to naked eye in order to better interpret the context surrounding the specific action they are watching.
5	Efficiently refocus observation scan to include both near and far objects in the scene	Team members keep all parts of their viewing sector, both near and far, within their visual field scan and in their focal attention so that no important cues are missed.

6	Orient observation or tracking toward potentially hostile players or good guys and ignore neutrals	Team members economize their profiling by concentrating observations on potential hostiles (insurgents, informants) and potential friendlies (police, security), while reducing attention to the neutrals (regular population).
7	Make effective and efficient identification of anchor points and indications of anti-tracking	Team members economize their observations by localizing their viewing on areas–anchor points–where hostiles tend to concentrate their illicit activities, such as specific parts of town or a building.
8	Make effective and efficient identification of habitual areas and action indicators	Team members economize their observations by localizing their viewing on areas–habitual areas–where townspeople congregate and which might represent a "soft target" for hostile activity, such as a market or mosque.
9	Make effective and efficient identification of opposing force leaders	Team members determine who the leader is in a village by using the four key indicators (entourage, direction, mimicry, adoration) of leadership.
10	Adopt appropriate criteria based on objective cues observed to make timely, accurate decisions	Team members use clue clusters to collect three pieces of evidence, such as three indicators of a leader or a terrorist planning cycle, before taking action.
11	Induce or generalizes a pattern from a few individual cues	Team members infer the presence of a larger event–such as a Vehicle Born Improvised Explosive Device (VBIED) or a complex ambush–by generalizing from the presence of a few cues (e.g., how a car is parked, or how a sniper team has been deployed).
12	Look for prototypes (vs. template matching)	Team members look for signature behaviors (e.g., insurgent, HVT, vehicle, or a track) and signature locations (e.g., habitual area, anchor point, or aerial spoor) through a cluster of cues.
13	Establish an observation baseline to extract normalcy	Team members make a systematic, sustained observation on a person, event, location, or vehicle to determine what behavioral profile constitutes "normal," where this normal is used as the baseline against which deviations are noted. A baseline, for example, might be established for market behavior when insurgents are not present.
14	Look for anomalies – above and below baseline (including the absence of something)	Team members look at the elements to note anything out of place or anomalous, either something there that should not be or something missing. As an example, team members should observe a group of people to see if someone seems out of place based on biometrics (e.g., they are sweating from running) or if a vehicle is parked in an unusual location (possible VBIED).

Elaboration involves tapping into one's background store of information that summarizes what has been learned previously about similar situations; it enables the team members to create a shared mental model of the situation. Effective elaboration involves applying and discussing with other team members previous knowledge (e.g., of hostile profiles) about the current situation, such that the most reliable and acceptable hypothesis may be found with regard to the intent of a potentially hostile actor. Team members map their current experiences onto a cognitive template they had developed from previous experiences, and then attempt to match each part of this template with some aspect of the current situation. Table 2 is a list of the elaboration skills that Spiker et al. (2010) produced from their study.

Table 2. Elaboration PCR Skills and Example Performance Objectives. (Adapted from Spiker et al., 2010)

#	Elaboration Skills	Example Performance Objective
15	Take evidence-based approach to identifying hostiles using hard data to confirm or disconfirm a hypothesis	Team members take the time to list three reasons why an individual is a body bomber or an HVT, rather than going with a hunch to save time.
16	Generate explanatory storylines that tie individual items of information together	Team members construct alternative explanations for how individual events or pieces of evidence might be related and part of a larger whole.

17	Imagine alternative courses of action or alternative event outcomes by what-if mental simulations	Team members attempt to “think through” what might be happening in an unfolding event (e.g., a possible complex ambush) by rapidly reviewing different, but plausible, alternative outcomes.
18	Detect an unfolding event or activity by identifying a piece of it and inferring the rest	Team members view a sequence of events as being tied together by some underlying process-unfolding like a movie- such as the steps to create and plant a bomb or the cycle of planning a terrorist attack.

Teamwork Competency Model

The Teamwork competency model is comprised of the four dimensions of information exchange, communication delivery, supporting behavior, and initiative/leadership. Information exchange involves team members passing relevant information to the right team member at the right time, seeking information from all relevant sources, and providing periodic situation updates that summarize the big picture. Communication delivery involves using proper terminology, avoiding excess chatter, speaking clearly and audibly, and delivering complete standard reports containing data in the appropriate order. Supporting behaviors consists of offering, requesting, and accepting backup when needed, and noting and correcting errors, as well as accepting correction. Initiative and leadership consists of explicitly stating priorities and providing guidance, suggestions, or direction to other team members. Smith-Jentsch, Johnston, & Payne (1998) developed and validated the teamwork competency model in a series of studies with Navy combat teams. Then Smith-Jentsch, Cannon-Bowers, Tannenbaum, and Salas (2008) demonstrated in an empirical, field experiment that Navy combat teams that participated in facilitator-led guided team self-correction structured around the expert model of teamwork developed more accurate mental models of teamwork, demonstrated more teamwork processes, and achieved more effective performance outcomes after two training cycles than did those briefed and debriefed using the traditional Navy AAR method. The SOvM program adapted the Teamwork competency model and guided team self-correction method to establish the Team Development and IAAR performance objectives.

Translating Competency Models into Event-Based Training Scenarios

The event-based approach to training method was applied to the SOvM training scenario design to ensure the skills identified in the TDM and Teamwork competency models would be learned (Rosen, Salas, Tannenbaum, Pronovost, & King, 2011). Critical tasks, task stressors, learning objectives, exercise design and execution, performance measurement, and feedback were clearly linked and documented prior to completing the scenarios. An important feature in designing scenarios was including as much of the knowledge-rich environment in the virtual and live scenario events as possible so that pre-specified cue-strategy relationships could be observable and would result in producing team responses that were observable and measureable.

Five event-based scenarios of approximately 45 minutes in length were developed with a single overarching narrative that had the scenarios taking place over a fictional four week period of time. Two scenarios were designed for the team training simulation (B1 and B2) and three scenarios (M1, M2, and M3) were developed for the live training environment. Following the graduated exposure to stress guidelines each scenario was designed to provide an increasing number of task stressors (Driskell, Salas, & Johnston, 2006). Key events and associated ASA, TD, and TC3 performance objectives were developed for each scenario. For example, Scenario M2 had the squad mission objective of conducting a zone reconnaissance in order to conduct a key leader engagement; exploit intelligence; confirm location of a suspected arms cache; and, exploit the site, if able.

The chronological list of nine key events for M2 were:

1. Establish listening post (LP)/observation post (OP).
2. Depart LP/OP.
3. Observe civilian interactions in village.
4. Conduct key leader engagement and tactical questioning with high value target.
5. Observe proxemic push as village civilians move away from the central square.
6. Squad moves north to tea shop to interview civilian woman.
7. Sniper fire results in soldier receiving gun shot wound (GSW) to arm and a civilian woman receiving GSW to chest.
8. Squad conducts movement toward sniper locations.
9. Soldier receives GSW to chest at sniper location.

Performance objectives were then mapped to scenario events. Table 3 presents 51 objectives developed for M2 and shows many objectives are repeated across events. The ASA behaviors represent the identification and elaboration behaviors described in Table 1 and the TD behaviors representing the four dimensions of teamwork. Multiple performance domains are represented in specific events to ensure the scenarios had sufficient levels of stressors. For example, the last row in Table 3 shows events 1, 7, and 9 had many more performance objectives (15, 22, and 19, respectively) compared to the other six events.

Many of the ASA identification and elaboration performance objectives were planned in Events 1 through 6. For example, in Table 3, the ASA performance objective #1 expected squad members to “use tools or otherwise visually identify objects that are hidden in windows or shadows through the town.” From Table 1, this behavior represents Identification skill #2 – “utilize organic assets and natural light to make positive identification.” The TD performance objectives were inserted throughout all the events. For example, the TD performance objective #17 expected squad members to “pass information among teams about their observations of the town.” This behavior is representative of the TD behavioral dimension of “information exchange.” During Event 7 a sniper fire results in a Soldier receiving a GSW to his arm and a civilian woman receiving a GSW to her chest. This was expected to elicit multiple TD behaviors, such as objective #26 – “provide complete and accurate medical reports” (Communication Delivery), and objective #31 – “squad leader and team leaders provide guidance and state priorities regarding roles for continuing mission” (Initiative/Leadership). Event 7 also involved the TC3 behaviors, such as objective #38 - waits for suppressive fire or other cover before retrieving casualty (Care Under Fire), and Objective #49 - provides medical updates to Squad Leader; completes MIST report, and 9-Line (Casualty Evacuation Activities).

Table 3. Event-Based Performance Objectives for ASA, TD, and TC3 in Scenario M2.

	PERFORMANCE OBJECTIVES	M2 EVENTS								
		1	2	3	4	5	6	7	8	9
	Advanced Situation Awareness									
1	Squad divides into two separate forces for two LP/OPs to establish geometry of observation	X								
2	Use tools OR OTHERWISE visually identifies objects that are hidden in windows or shadows through the town	X								
3	Establishes geographic points of interest (avoidance or common use of an area)	X								
4	Establishes atmospheric details (information that is or is not in line with baseline from intelligence)	X								
5	Establishes that groups of civilians are engaging in mimicry, adoration, directing attention, or are part of an entourage	X								
6	Positively identifies Key Leader	X								

	PERFORMANCE OBJECTIVES	M2 EVENTS								
		1	2	3	4	5	6	7	8	9
7	Establishes key leader identification to include how key leader was identified and why it is believed it is the key leader	X								
8	Establishes baseline behaviors of target	X								
9	Employs guardian angel / geometries of observation		X		X		X			
10	Verbalizes nature of target nonverbal behaviors		X		X					
11	Communicates an assessment to include why s/he believes the validity, quantity of the information received		X							
12	Communicates deviations in baseline of behavior of target		X							
13	Offers some medical care to local national (good shepherd)			X						
14	Identifies that townspeople exhibit slight proxemic push away from the squad					X				
15	Identifies nonverbal and paralanguage cues that townspeople are uneasy about squad's presence					X				
	Team Development									
16	Squad leader gives direction to separate into two LP/OPs	X								
17	Squad members pass information among teams about their observations of the town	X								
18	Use available resources to determine identifying characteristics (e.g., OPORD)	X								
19	Communicate to team members when a townsperson fits description of key leader	X								
20	Communicate to team members when groups of people are engaging in mimicry, adoration, directing attention, or are part of an entourage	X								
21	Communicate to chain of command when key leader is identified	X								
22	Correct errors in information repeated on radio	X								
23	Backup is provided to the squad member engaging in the interview		X		X					
24	Communicates a situation update up the chain of command		X		X					
25	Communicates changes in priority from chain of command to other team members		X		X					
26	Provides complete and accurate medical reports							XXX		XXX
27	Support Squad Leader & establish medical SA exchanges casualty information with Squad Leader and Village Leader / casualty.							X		X
28	Squad asks higher for guidance in further care of civilian casualty							X		
29	Directs TMs to provide care							X		X
30	Squad leader and team leaders exchange information about status of the squad								X	
31	Squad leader and team leaders provide guidance and state priorities regarding roles for continuing mission								X	
32	Squad members call out enemy position and status to squad, giving a complete report									X
	Tactical Combat Casualty Care									
33	Delivers some medical care to local national (good shepherd)			X						
34	Returns fire/provide security; weapons up; scans for enemy; fires weapon							X		X
35	Provides MANDoWN Report to Squad Leader							X		X

	PERFORMANCE OBJECTIVES	M2 EVENTS								
		1	2	3	4	5	6	7	8	9
36	Provides casualty status info to medic							X		X
37	Establish security / provide cover after injury occurs, TMs face outward from casualty (360); guns up, looking for enemy. TMs lay suppressive fire to provide cover							X		X
38	Waits for suppressive fire or other cover before retrieving casualty							X		X
39	Retrieves casualty							X		X
40	Treats casualty							X		X
41	Squad Leader directs TLs to suppress enemy to maintain tactical focus							X		X
42	Squad Leader collects medical and tactical info							X		X
43	Squad asks higher for guidance in further care of civilian casualty							X		
44	Squad leader determines capability to continue mission							X		X
45	Assigns medical & tactical resources to establish CCP							X		X
46	Send up first 5 lines of 9-line report; Complete, accurate, brief, and clear reporting							X		X
47	Medic provides advanced care							X		
48	Directs TMs to provide care							X		
49	Provides medical updates to Squad Leader; completes MIST report, and 9-Line							X		
50	Squad leader decides that squad remains combat effective and decides to move forward with the mission								X	
51	Consolidates CCP									X
	Total Objectives Per Event	15	7	1	5	2	1	22	3	19

Measures Development and Application

The performance objectives for ASA, TD, and TC3 in each scenario were transformed into individual behavioral observation checklists in a spreadsheet format and on an android tablet so that SME raters could assess the squads during the scenarios. Observations of behaviors in virtual scenarios B1 and B2 were attempted, but proved difficult as it was challenging to hear and see squad member behaviors within the virtual world (Townsend et al., 2017). In addition, squad members were sitting next to each other using VBS3 and they often communicated face-to-face instead of using their radios, which added to the challenge to effectively observe. It was also difficult to observe multiple team members in the virtual environment from one control station. These challenges made it difficult to determine whether behaviors occurred or not, or were simply missed.

During the live scenarios, assessors observed squad members moving through the urban village buildings and outdoor spaces on multiple video screens in the control room, and listened to squad communications via an audio system that was specifically developed for the experiment to enable isolation of communications among any needed subset of squad members in real time. The ASA and TC3 instructors followed and observed squads in the outdoor training site. The ASA and TC3 raters used spreadsheet based checklists. Following the exercises, they met with the respective SME instructors to establish ground truth for squad performance on ASA and TC3 behaviors. This approach enabled the ASA and TC3 raters to obtain almost 100% certainty about squad performance.

The two TD observers used the android tablet – based Mobile Performance Assessment Tool to make their event-based ratings during each live scenario run. Townsend et al. (2017) found the average percent agreement score for scenarios M2 and M3 was 80%. The M2 scenario agreement score was higher (89%) than the agreement score for scenario M3 (70%), and the raters suggested that because the M2 scenario had fewer complex events it may have been easier to see squads and hear their communications, whereas, scenario M3 was more complex and the raters may have had more trouble seeing or hearing the squad members. In addition, raters determined that more practice was needed to make the right assessments of squad behaviors. All raters also used the recorded videos and squad member communications following the experiment to correct missing ratings and for the TD raters to develop 100% consensus on the performance assessments.

Team scores for ASA, TD, and TC3 performance were calculated as the percent of tasks accomplished in a scenario. It was calculated by summing the number of behaviors performed by the squad on each of these skill domains and dividing it by the total possible number of behaviors that were expected to be performed in that skill domain.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Implications for the GIFT architecture

The measurement strategy defined in this study has implications for the Sottilare, Brawner, Sinatra, and Johnston (2017) GIFT functional concept for a "learning effect model for teams" that we briefly discuss here. The GIFT learning effect model presents an iterative data collection and learning methods delivery approach that presents specific functional features for team assessment (as noted in italics below). In this conceptual architecture, *team members* produce behavioral data during a training exercise that are detected and tagged by pre-defined *behavioral markers*. The *behavioral markers* populate the *initialization data for teams (e.g., competencies)* that in turn populates the *long-term team model*, and also the *team data* function. The *team data* function informs the *team states*. The TDM and Teamwork models could provide the competency framework for *the initialization data for teams* function and the *long –term team model*. The TDM and Teamwork competency behaviors could serve as the *behavioral markers* that GIFT needs to seek from the behavioral data generated by the *team members* during the exercise. As the *behavioral markers* of TDM and Teamwork are collected GIFT would generate *team states* for each of the four TDM and four Teamwork dimensions. *Team states* for the TDM and Teamwork dimensions would then be able to inform the GIFT *team instructional strategy selection*. For example, if the team is doing well on information exchange, but they are not catching and correcting errors (supporting behaviors), then GIFT would provide feedback in the AAR that the team needed to improve on supporting behaviors such as error correction, and sustain their good information exchange.

Future Research

Below are several research recommendations to continue to address the initially stated objective in this paper to develop ways to measure and model team behaviors in an adaptive training system.

Recommendation 1

The SOvM study demonstrated that team competency models for TDM and Teamwork are generalizable for assessing dismounted squads conducting tactical and TC3 tasks and can be used to assess team performance progress during training. It is recommended that these competency models be used as a tool to diagnose team performance and that further analysis of the SOvM data needs to be conducted to categorize observed behaviors into the TDM dimensions for planning and execution to further validate the model and increase the diagnosticity of the measures.

Recommendation 2

The majority of TDM and TD behaviors assessed were obtained from a team's verbal and non-verbal communications that trained human raters could hear, see, and categorize. A fairly high level of rater agreement can be achieved on TD behaviors using a tablet-based device, but increased rater error likely occurs as scenario events become more complex. It is recommended that adaptive tutoring needs to develop natural language recognition and processing to automatically categorize verbal behaviors into the TDM and TD competency models.

Recommendation 3

It was easier to observe and evaluate squads in the live exercises because the audio and video technologies were available and configured to the raters' needs. Team assessment in the virtual training environment was impossible due to the noisy communications and inability to effectively observe the squad actions in the scenario on the small PC monitors. Research needs to focus on developing technologies that can diagnose squad performance information in a rapid and organized method in both simulations and live training exercises. Tools need to be developed for capturing event-based team simulation interactions representative of the TDM and TD models and organized for the event-based IAAR. For example, the virtual team simulation currently records squad actions in a scenario for human-controlled replay in the AAR, but it is labor intensive and complicated to manipulate, and does not support the event-based approach to conducting the IAAR. With simulation recordings and speech to text recordings a more accurate representation of TDM and TD could be obtained with few to no humans in the loop collecting this information. In the live environment, sensor worn technologies that record audio and visual information, and location would enable more accurate and efficient assessments.

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