FCS Intelligent Structured Training - Experimental Results and Future Applications

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ABSTRACT

In support of the Army's objective of developing embedded training for the Future Combat System (FCS), Army Research, Development & Engineering Command (RDECOM) sponsored the development of a technology demonstration and experiment with an integrated architecture linking intelligent evaluation mechanisms with their Command and Control Vehicle (C2V) testbed. Automated evaluation methods based on Intelligent Tutoring Systems (ITS) techniques are applied to monitor simulation and testbed events, and deliver feedback during scenario execution via messages published to the simulation environment. The logic for these intelligent evaluations is captured in hierarchical agent behaviors, and indexed to training principles identified by subject matter experts. This paper summarizes the findings from this effort, including technical methods as well as the results of experiments with human test subjects to measure the effectiveness of the system for training. Specifically, the improvement in performance over time among test subjects receiving automated feedback was contrasted with subjects receiving other forms of instruction such as an instructor-led after action review. These results provide a basis for the discussion of the way forward with FCS embedded training. Ultimately, with the application of automated training methods such as embedded ITS and structured training, a major potential benefit is the ability to train in settings where human instructors are not present or available. The work building the demonstration system sheds light on several areas of potential future work in support of developing full scale Intelligent Structured Training systems to realize these benefits. In addition to further validation of the approach, significant developmental areas include integration and compatibility with simulation common components like OneSAF that are likely to be used by the FCS program, scenario authoring tools to streamline the process for subject matter experts, and rapid behavior definition methods for simulated opposing forces to heighten realism and enhance training benefits.

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INTRODUCTION

In support of the Army's objective of developing embedded training for the Future Combat System (FCS), the Army Research, Development & Engineering Command (RDECOM) Simulation & Training Technology Center (STTC) Embedded Combined Arms Team Training and Mission Rehearsal (ECATT-MR) Army Technology Objective (ATO) sponsored the development of a technology demonstration and experiment with an integrated architecture linking intelligent evaluation mechanisms with their Command and Control Vehicle (C2V) testbed. This testbed is based on likely embedded virtual simulation common components like OneSAF and Terrain Databases built for virtual simulations with the focus being to examine the feasibility of developing an Intelligent Structured Training System that would operate in these classical virtual simulation environments as opposed to environments created solely for the purpose of intelligent tutoring applications. Automated evaluation methods based on Intelligent Tutoring Systems (ITS) techniques are applied to monitor simulation and testbed events, and deliver feedback during scenario execution via messages published to the simulation environment. The logic for these intelligent evaluations is captured in hierarchical agent behaviors, and indexed to training principles identified by subject matter experts. This paper summarizes the findings from this effort, including technical methods as well as the results of experiments with human test subjects to measure the effectiveness of the system for training.

Specifically, the improvement in performance over time among test subjects receiving automated feedback was contrasted with subjects receiving other forms of instruction such as an instructor-led after action review. These results provide a basis for the discussion of the way forward with FCS embedded training. Ultimately with the application of automated training methods such as embedded ITS and structured training, a major potential benefit is the ability to train in settings where human instructors are not present or available. The work building the demonstration system sheds light on several areas of potential future work in support of developing full scale Intelligent Structured Training systems to realize these benefits. In addition to further validation of the approach, significant developmental areas include integration and compatibility with simulation engines that are likely to be used by the FCS program, scenario authoring tools to streamline the process for subject matter experts, and rapid behavior definition methods for simulated opposing forces to heighten realism and enhance training benefits.

OVERVIEW OF DOMAIN AND APPLICATION

FCS has identified training to be a Key Performance Parameter (KPP). The approach to providing training has been identified to be a fully embedded approach, allowing Soldiers to train and maintain tactical knowledge proficiency on the same devices they take to war. Ideally this could be performed with no appended or training unique equipment, thus making the training and operational modes interchangeable based on unit functions. Since the training facilities of the present will be replaced by troops training in motor pools and doing mission rehearsal in assembly areas, the need to provide robust training packages becomes much more important.

Higher level cognitive training requires that the trainee's performance be evaluated and that he receives appropriate feedback on that performance. However, in the Embedded Training context, where most FCS training is planned to occur, instructors will not be available to provide these functions like they would at a fixed training site. Intelligent software is required to monitor a trainee's actions in a simulated scenario, evaluate those actions against Army Tactics, Techniques, and Procedures, and provide real-time, dynamic, one-on-one feedback using the Soldier machine interface, audio, and other mechanisms, as appropriate. The field of Intelligent Tutoring Systems provides techniques to accomplish these tasks in automated fashion. A key design objective in the application of ITS technology ultimately in FCS embedded training is the ability to interface with and utilize likely virtual simulation common components such as OneSAF, and operate with the virtual databases supported by current simulations.

To explore the use of ITS technologies in this context, a task area under the Army's FCS concept was selected for the implementation of an Intelligent Structured Trainer to be applied in a set of experiments with students to measure training results. Within this task area, the FCS Soldier manning a Command and Control Vehicle (C2V) crewstation must remotely control robotic platforms to perform reconnaissance and engage the enemy. The operator must maintain situational awareness and apply tactical decision-making principles in a heightened information-rich setting with distributed vehicles and sensors under his command. The increased flexibility allows him multiple ways to detect, track, and identify targets. The following figures show some of the primary screens in the Soldier interface in the C2V crewstation.

Figure 1. Unmanned Ground Vehicle (UGV) Gunner Sensor View

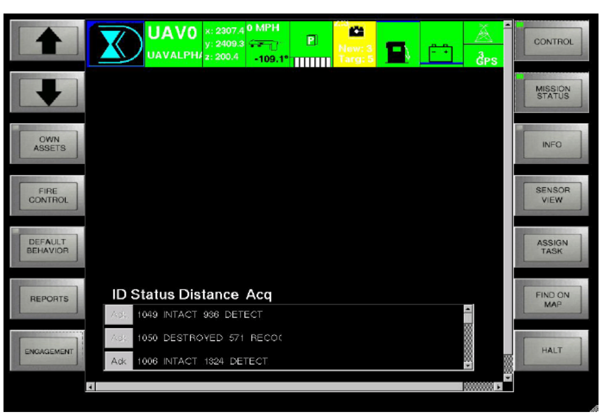

Figure 2. C2V Robotic Asset Mission Status Tool

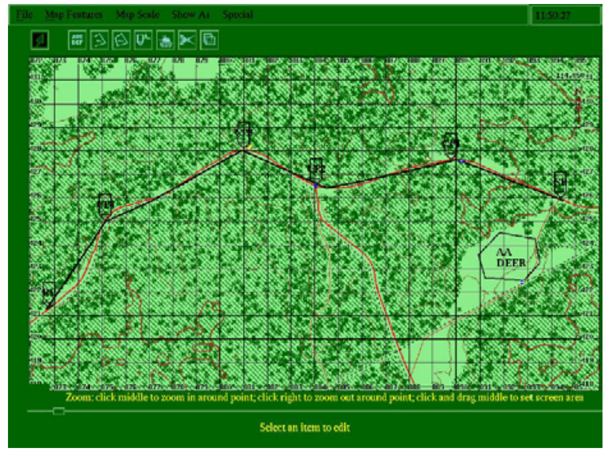

Figure 3. Operational Control Unit

The ITS technology applied for this project centers around automated evaluation and feedback on operator performance, resulting in a training methodology referred to as Intelligent Structured Training. Example feedback is shown in the following screen from the crewstation.

Figure 4. Immediate Directive Feedback Presented in the Visualization Screen

An Intelligent Structured Trainer automates the process of monitoring student actions and providing feedback, either as Immediate Directive Feedback (IDF) in real-time or as delayed feedback to be incorporated with After Action Review (AAR). With practice in a simulated crewstation environment, students can open a scenario, go through an exercise, and receive customized feedback on their application of the FCS concept of operations. The training application developed for this experiment is not a full Intelligent Tutoring System in the traditional sense, as it does not incorporate other technologies from the realm of ITSs such as instructional planning and persistent student models, but the term "ITS" is used as a referential term in this paper for the Intelligent Structured Trainer developed incorporating ITS technology.

The process of constructing the scenario for this experiment started with a task analysis highlighting the functional objectives for each system (Command and Control Vehicle [C2V], Unmanned Aerial Vehicle [UAV], Unmanned Ground Vehicle [UGV], and Armed Reconnaissance Vehicle –Assault [ARV-A], etc), which guided the process of task development. The desired outcome was the training of the robotics operator of the FCS Company Level C2V within a Combined Arms Unit of Action (UA). This was a subordinate task embedded within the larger task of training of the FCS C2V crew, with a focus on the robotics operator. Therefore, the primary training audience was the Robotics NCO and his interaction with the company Executive Officer (XO), as well as the Driver and Vehicle Commander, whose secondary duties include the operation of robotic vehicles within the company.

Task development included the identification of a proposed mission (Route Reconnaissance) and a decomposition of tasks needed to support this goal. This task decomposition process included the identification of conditions under which the tasks would be accomplished and the development of measures of performance and effectiveness. Using a cognitive task analysis approach, a modified Goals, Operators, Methods, and Selection (GOMS) Rules Model was developed, including fuzzy production and selection rules. This GOMS model enabled the identification of goals and sub-goals supporting the overall tactical mission of Conduct a Route Reconnaissance. This critical step allowed for the development of subordinate tasks, conditions and standards for small unit collective tasks, as well as identifying the skills, knowledge and attributes required by the robotics operator. Figure 5 below shows a partial task decomposition.

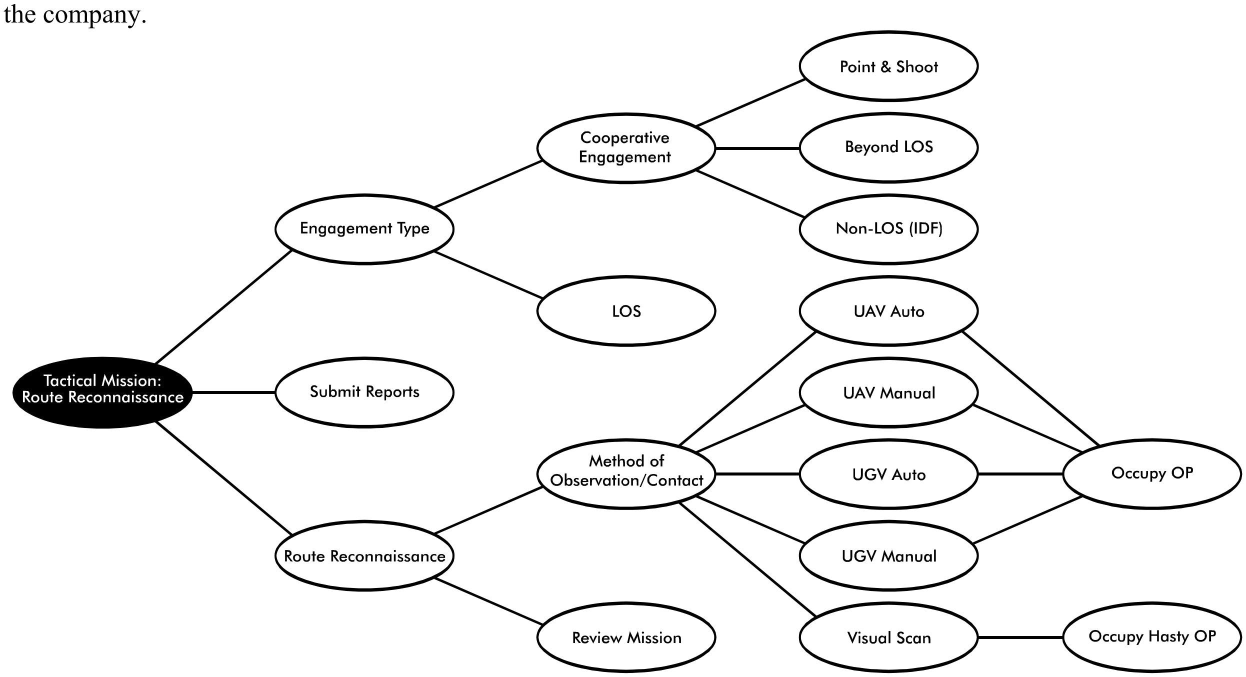

Figure 5. Partial Task Decomposition

The diagram above shows how the tactical mission, Conduct a Route Reconnaissance, can be decomposed into its major supporting tasks. The first major subgoal was the Route Recon task itself. This task immediately triggered a concurrent task, Submit Reports. The Submit Report Sub Task is a recurrent task which is triggered anytime there is a change state (beginning movement, launching an Unmanned Vehicle, engaging the enemy, etc). The Route Recon task required two major sub tasks; Review the Mission and selection of a Method of Observation. Method of Observation included five principal techniques (variables) and each of these techniques were defined and refined, one technique at a time. This task refinement yielded conditions and standards for each technique. After all five techniques were defined separately they were again refined to work in conjunction with one another. This entire process yielded Tasks, Conditions, and Standards for each task and subtask. It also identified tasks and actions that other crew members were required to perform to support the Robotics Operator, and additional conditions for the execution of the training scenario. For example, once a target was detected, the Robotics NCO was required to select an engagement type, generally consisting of a subset of tasks within the Cooperative Engagement technique. Permission to engage targets would generally flow from the Commanding Officer to the XO. Requests for engagement authority and permission to engage were simplified into a single action, Call for Fire, and automatically handled within the simulation. This identified a needed precondition for the training scenario, authority to engage, and an area for future experimentation, the automated handling of calls for fire.

In order to appropriately evaluate for operator performance during an exercise, the training system requires two primary sets of data. First, real-time information about the state of the simulated exercise is necessary in order to assess the conditions under which the student performs different actions. Data in this category includes information about vehicle locations, headings, control status and sensor input, as well as the outcomes of contact with enemy forces. Outcomes can provide useful feedback to the student as to the appropriateness of decisions during an exercise. However, simulation outcomes are not always relevant to student feedback, as a free-play simulation allows for a degree of flexibility where negative outcomes may occur even if the student has performed well on all or most all the relevant principles. The second category of data involves the student's activities within the software and user interfaces. This second category is particularly helpful in diagnosing mistakes that the student has made, since it reveals useful information about the student's intentions.

AUTOMATED EVALUATION METHODOLOGY

The automated evaluations at the core of the ITS were implemented as Behavior Transition Networks (BTNs), an extension of a Finite State Machine (FSM) approach suited to the complexity of the operational domain, involving free action in complex, dynamic scenarios. With this approach, evaluation BTNs are indexed to relevant principles through a scenario definition interface. This is a generalizable task, which can easily be delegated to an instructor or subject matter expert for training systems with a plurality of exercise scenarios. Thus, when the exercise is executed in the simulation, each evaluation BTN for each principle relevant to the scenario is activated.

The use of BTNs represents a number of enhancements to the traditional FSM model. In particular, the evaluation machines are composed using an authoring and execution tool called SimBionic (Fu et al, 2003). SimBionic provides a visual toolset for defining simulation behaviors, with support for multiple chained conditions between states, local and global variables, and the organization of different BTNs in a hierarchically nested structure. This tool can be used to control the behavior of simulation entities, or in instructional applications, to specify the behavior of instructional agents running as virtual entities within a simulation. The run-time engine for these BTNs interprets all active behaviors in parallel and invokes actions and predicates implemented within the application as specified by each behavior. A behavior may be composed of actions, conditions, connectors, and other behaviors. Actions are functions that are invoked to carry out activities, such as sending a message; these often correspond to functionality provided in the API of a given simulation or other environment with which the behaviors are integrated. Conditions perform checks, typically whether an entity is in a specified state, invoking predicates to determine state information from the simulation or testbed. Predicates are functions that return values representing the state information of an entity, such as IsTheTargetLazed(target). This is a predicate that returns true in the C2V testbed if the user has performed the laze function on a target or location. Connectors connect actions, conditions and behaviors to specify their relative order of execution.

These BTNs form the structure for defining and executing automated evaluations that monitor states and performance in the integrated testbed. For each entity created in the testbed, the ITS creates a corresponding monitoring entity which invokes specified evaluation behaviors, and places it under the control of the behavior execution run-time engine. As a general rule, behaviors are invoked for each principle in the principle hierarchy which applies for the training domain and testbed.

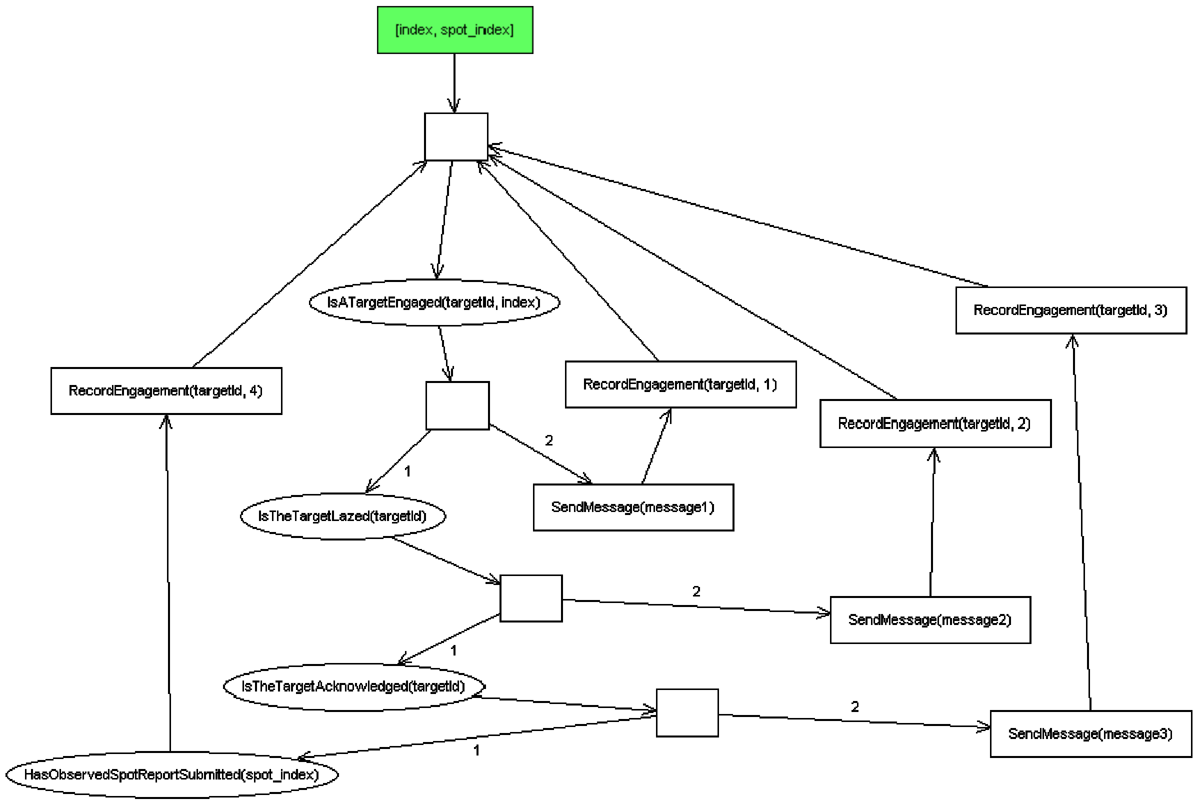

Figure 6. Example Evaluation BTN, "Follow Correct Engagement Procedure"

An example ITS behavior is shown in Figure 6 above, taken directly from the SimBionic authoring environment. This behavior monitors how the operator performs the procedure for engaging a target. Actions and sub-behaviors are represented in rectangles, and conditions are represented in ovals. For each step of the proper engagement procedure, this BTN checks if the step has been performed according to the proper sequence. Due to the sequential nature of the correctly executed engagement procedure, this behavior serves as an example where it is appropriate to capture several specific feedback points corresponding to different training sub-principles. For example, if the user performs a call for fire on a target without having lazed the target, this violates one of the procedural execution principles. As a result, the behavior executes an action, SendMessage(message2), where message2 is indexed to specific feedback text authored in a central feedback collection. The SendMessage function adds the message to the message queue to be delivered and presented to the operator in the testbed interface, as Immediate Directive Feedback. This interaction is then recorded via the RecordEngagement action.

With the BTN-based approach for implementing automated evaluation measures, these evaluations function like instructional agents, identifying conditions that are instructionally significant. Since the goal is to mimic tasks performed by a human instructor, these evaluation measures also logically serve as a tool for automated instructional decision making about triggering OPFOR responses to certain conditions or simulation states. As a result, a mechanism was developed for controlling simulation entities in the OneSAF Testbed Baseline (OTB) remotely from the instructional evaluation measures. This form of responsive OPFOR behavior was implemented with specific operational retreat behaviors. Still more complex OPFOR behavior remains an area for potential further development, in conjunction with possible future investigation with the more flexible design of the OneSAF Objective System (OOS) simulation.

EXPERIMENT DESIGN

Test subjects were given a combination of human tutored and computer aided instructions while occupying the Robotics NCO crew station in a FCS equipped C2V Testbed simulator, located at STTC. This experiment required test subjects to learn both

Procedural and Conceptual Knowledge tasks in order to accomplish a tactical mission. Procedural Knowledge tasks included the control of unmanned robotic assets in a virtual environment and learning the correct procedures for conducting: reconnaissance, surveillance and target acquisition tasks, two target engagement techniques, and submitting situation reports. Conceptual Knowledge tasks included learning a defined set of the tactical principles associated with the planning and execution of a tactical reconnaissance mission and their associated supporting tasks. Test Subjects were given a timed tactical scenario which required them to perform a reconnaissance mission in order to demonstrate proficiency in the application of both Procedural and Conceptual Knowledge (Sanders, 2005).

The available sample for this experiment included undergraduate students consisting of 14 males and 11 females, ranging in age from 18 to 33 with 11 subjects pursuing a Bachelor of Arts degree and 9 subjects pursuing a Bachelor of Science degree. The average test subject was a 20.5 year old male pursuing a Bachelor of Arts degree and was self-assessed as having good computer experience with several types of software programs. Ten test subjects were randomly assigned to one of two feedback condition groups: Immediate Directive Feedback (IDF) only and AAR Only (Delayed Feedback).

In the Intelligent Structured Trainer developed for this experiment, every action performed by test subjects within the scenario is evaluated to determine if it is the correct response to the current situation. If the response is incorrect, immediate feedback is provided in the form of an error message provided to the test subject. No immediate feedback was provided for following correct procedures. The three types of immediate feedback included:

- Battlefield heuristic feedback – “Conduct a sensor scan before beginning movement”
- Error detection and directive feedback – “Submit a report anytime there is a change to the tactical situation”
- Directive feedback – “You have failed to correctly submit a SITREP. The correct procedure is…”

Immediate Directive Feedback prompts were triggered either when a test subject conducted a procedure incorrectly, or failed to take an appropriate action after receiving an error prompt.

Human tutoring on both Procedural Knowledge and Conceptual Knowledge used open-ended prompts during the AAR to elicit elaboration and self-explanation from the trainees. The AAR protocol used followed a typical Army After Action Review format as outlined in TC 25-20, *A Leader’s Guide to After-Action Reviews* (DA, 1993), and focused on answering three top level questions: What happened; Why it happened; and How to fix it. It is during the review of tactical principles and the “How to fix it” portion of the AAR that the tutor focuses on Conceptual Knowledge. Conceptual Knowledge includes general tactical principles and definitions of concepts which provide a framework for Procedural Knowledge. For example, Conceptual Knowledge includes understanding the tactical principles of reconnaissance, the various methods for engaging a target, and the purpose for submitting reports; Procedural Knowledge is the understanding of the correct sequence of steps to actually engage a target.

During the AAR, test subjects were required to review both concepts and procedures and then asked open-ended, content neutral prompts to elicit elaboration and feedback. For example, one measure of Conceptual Knowledge required the test subject to define the term “Cooperative Engagement” and give an example. As part of the AAR, the test subject reviewed the definition of Cooperative Engagement and was asked the following questions:

- “Can you explain this concept in simple terms?”
- “Can you give an example?”
- “When have you done something like this?”

If, in answering these questions, the test subject provided an incorrect answer, the tutor identified the answer as incorrect and asked the test subject to try again.

All test subjects were administered an un-timed paper and pencil pre-test to establish a baseline of subject knowledge. Each subject knowledge test consisted of 10 Procedural Knowledge questions and 10 Conceptual Knowledge questions. Procedural Knowledge questions included skill acquisition tasks and asked the test subjects to write down the steps to accomplish a procedural task, i.e. “What is the correct procedure for Submitting a SITREP?” Conceptual Knowledge questions included general tactical principles and definitions of concepts, i.e. “What are the tactical principles for reconnaissance?” and “Define a Line of Sight Engagement”. Test subjects had to provide the answers to each question, were instructed not to guess, and to write "I do not know" after any question they could not answer.

Test subjects occupied the Robotics NCO crew station in an FCS equipped C2V simulator and received an orientation to the simulator. Each training trial began with a review of the procedures and training tasks to be accomplished during the training exercise. After this review, each test subject executed a 30 minute timed training scenario that measured their ability to correctly apply these concepts and conduct these procedures in a manned simulator. At the end of each training trial, the test subjects assigned to the IDF Only feedback condition group conducted a self-paced review of the concepts and procedures and completed a subject knowledge test. The IDF Only feedback condition group received no delayed feedback in the form of an AAR. Test subjects assigned to the AAR Only feedback condition group received a human facilitated AAR and then completed a subject knowledge test. Four tests were developed, Subject Knowledge Test Alpha, Bravo, Charlie, and Delta with the same 10 procedural and 10 concept knowledge questions from the pre-test presented in a random order for each test. Each test subject was randomly assigned one of four different subject knowledge tests upon completion of each training trial. Tests were not timed. All training trial scenarios were identical, with no change to the tactical scenario occurring between iterations.

During phase two, a randomly assigned, un-timed subject knowledge paper and pencil test was administered to measure retention of knowledge. Test subjects were then given a transfer task which was identical to the previously learned concepts about the task, Conduct a Route Reconnaissance, and included the same goal, constraints and options for completing the tasks, but the terrain was different than the terrain used during the training tasks. Test subjects had to plan a route on a paper map and identify concepts and procedures when answering questions about the task. Test subjects then re-occupied the FCS C2V simulator and executed the transfer task on a proctor provided scenario.

EXPERIMENTAL RESULTS

The overall results of the experiment support the hypothesis that the timing and type of feedback received during training does effect the acquisition, retention and transfer of both Procedural and Conceptual Knowledge. Significant differences did exist in individual measures, suggesting that immediate directive feedback has a significant effect in reducing the number of errors committed while acquiring new procedural skills during training as well as retention of these procedural skills. Also, delayed feedback, in the form of an AAR which includes open-ended prompts to foster elaboration, has a significant effect on the acquisition, retention and transfer of higher order Conceptual and Procedural Knowledge about a task.

The results of this experiment show that the timing of feedback, immediate and delayed, and the type of feedback, directive and explanatory, has an impact on the acquisition, retention and transfer of knowledge. Immediate feedback to correct detected errors promoted skill acquisition, retention and transfer for procedures. Providing feedback on procedures, whether immediate or delayed, resulted in improvement, as shown in Table 1.

Table 1. Retention Scores for Procedural Knowledge Following Feedback

	M	SD
IDF Only	3.72	.92
AAR Only	3.80	1.21

However, providing Immediate Directive Feedback significantly reduced the amount of procedural errors committed during training, versus Delayed Feedback, as shown in Table 2.

Table 2. Procedural Errors Following Feedback

	M	SD
IDF Only	28.22	19.50
AAR Only	42.08	24.59

An analysis of variance (ANOVA) was performed on the data, following the practice of using a combination of between-subjects and within-subjects variables. For this analysis, the between-subjects factor is Feedback Conditions (IDF Only and AAR Only), and the within-subjects factor is Training Trials. The results of the ANOVA found a significant main effect for Feedback Conditions ($F(1,18) = 5.87$), and Training Trials ($F(2,24) = 13.05$), with a $p < .05$. The ANOVA results tell us that there are significant differences in the number of IDF prompts triggered by each test subject and that these differences are explained by both the number of Training Trials (learning occurring over time) and by Feedback Condition, IDF Only and AAR Only. The significantly lower number of error prompts triggered during the execution of the training and transfer scenarios demonstrates that the IDF Only Feedback Condition had a significant effect on the acquisition and transfer of the performance of procedures. This supports earlier studies on the benefits of immediate and directive feedback (Anderson et al., 1995; Buzhardt and Semb, 2002; Dihoff et al., 2004; Guthrie, 1971; Kulik and Kulik, 1998).

Delayed feedback, like that used in the AAR Only Feedback Condition group, promoted retention of new Conceptual Knowledge better than the IDF Only condition, as shown in Table 3.

Table 3. Retention Scores for Conceptual Knowledge Following Feedback

	M	SD
IDF Only	3.10	2.03
AAR Only	5.60	2.12

One of the areas of suggested future investigation would involve experimentation with exercise pre-briefs or post-briefs which offer Conceptual Knowledge explanation to the Soldier to boost retention. Providing feedback on performance, whether immediate or delayed, directive or explanatory, resulted in improvements in the acquisition, retention and transfer of knowledge. These results should prove useful to the Army as it continues its development of its ET strategy for the Future Force.

FUTURE APPLICATIONS

The varying effects of feedback condition and trials on the performance measures selected to measure training effectiveness argue for additional research and experimentation. Individual findings of significance between feedback condition measures within trials and the effect of within feedback condition measures between trials suggest that feedback timing and type does have an overall effect. Significant differences did exist in individual measures, suggesting that immediate error detection and directive feedback has a significant effect in reducing the number of errors committed while acquiring new procedural skills during training as well as retention of these procedural skills. Also, delayed feedback, in the form of an AAR which includes open-ended prompts to foster elaboration, has a significant effect on the acquisition, retention and transfer of higher order Conceptual Knowledge about a task. Therefore, the following list offers a variety of potential focuses for future work supporting Intelligent Structured Training for FCS embedded platforms.

- Develop an automated exercise pre-brief or post-brief capability to explain to the Soldier the Conceptual Knowledge points within the exercise, to amplify the benefits of immediate feedback for Conceptual Knowledge.
- Update the capabilities within the FCS C2V simulator to include a freeze option to allow trainees an opportunity to freeze the scenario while attending to error detection and directive feedback. Enhance the procedural fidelity by preventing actions from occurring within the STE if proper procedures are not followed.
- Automate the AAR protocol to remove humans completely from the feedback process. Include support for trainee self-elaboration during the AAR.
- Refine the feedback condition categories and effectiveness measures to reflect updated capabilities with the C2V simulator. The mixed feedback condition should focus immediate feedback on procedural errors and delayed feedback on Conceptual Knowledge. Extend the length of time for retention, and manipulate the variables to determine if the linear association between highest levels of training achieved impact retention.
- Perform further principle hierarchy development for automated evaluation in a broader range of scenarios within FCS tactical domains.
- Refine interfaces to interoperate with FCS common components such as OneSAF.
- Abstraction of principle application conditions, so that evaluations can be applied to different scenarios with minimal adaptation.
- Domain specific methods for implementing automatic adaptation of evaluations to different scenarios, such as automatic line of sight predicates.
- Scenario authoring tools to accelerate the development of scenarios that operate as intended on a chosen testbed.
- Experimentation with enhanced modes of feedback during exercises.
- Enhanced methods for defining and controlling complex OPFOR behavior in scenarios.
- Capabilities to adjust difficulty levels, either before execution or dynamically during execution in response to the actions of the operator.
- Extension to team training use cases.

The Intelligent Structured Training concept can be applied widely throughout FCS. The use of BTN-based evaluation methods combined with real-time, dynamic, tailored feedback represents a key innovation with wide applicability. Many FCS positions require tactical decision-making and the use of complex equipment, under new and developing doctrine. Each such position requires a large number of different tasks to be performed. Thus, the Intelligent Structured Training concept reasonably applies to a large number of tasks associated with different positions. In fact, an instructional software system that monitors the events in a team executed simulation actually has a greater capability to note all instructionally relevant actions and events for all participants than a human instructor or observer can. Thus, although human instructors will always have value in a training regimen, there is the potential for the average commander augmented with intelligent structured training to greatly exceed the performance of even the best instructor without it, in at least this one metric. In fact, one augmented commander should outperform a whole group of instructors. This is a powerful notion for widespread FCS adoption, as the benefits can be expressed in terms of direct manpower savings.

Other Intelligent Tutoring System concepts can also be brought to bear, such as student modeling and instructional planning. By combining the performance evaluations across scenarios with information about what knowledge and skills were required for correct performance, an ITS can estimate the mastery of a trainee in each skill and knowledge component. This information can be used to automatically select scenarios that force the trainees to practice the skills and knowledge in which they are the weakest until a specified level of mastery is reached. Scenarios can also be selected to make sure each skill and knowledge component is tested a specified minimum number of times. Additional remedial exercises can be added for trainees that have continued difficulty in specific areas.

WAY FORWARD

In addition to the experiments discussed in this paper the C2V ITS system has been reviewed by several possible users including TARDEC CAT ATD, FCS, Common Gunnery Architecture (CGA), PM OneSAF and Future Force Warrior (FFW) programs. Due to possible interest in this technology by the Future Force Warrior program the RDECOM is planning to build a prototype based around the man wearable fully immersive virtual simulations that they are developing. They will also be developing streamlined authoring tools to build robust exercises at a fast rate using virtual simulation operational environments and common components. This initial system experiment supports the possibility that an ITS can be developed and effectively utilized to provide effective embedded virtual tactical instruction without an instructor. The future research will refine this system to make embedded training a reality for the Army of the Future.

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