APPLICATION OF COGNITIVE PRINCIPLES IN DISTRIBUTED COMPUTER-BASED TRAINING

Richard C. Deatz and Charlotte H. Campbell
Human Resources Research Organization
Fort Knox, Kentucky

Abstract

As the U.S. Army continues to develop more powerful and more complex digital systems, both training needs and training opportunities are being considered. These highly technical weapons and information systems are upgraded frequently, causing an almost continuous need for training, both for operators and for leaders and staff members who use the information to conduct battlefield command and control. The challenges for trainers and training developers are to keep up with the software drops, deliver incremental training that highlights critical modifications, and provide support so that units can practice using the systems without incurring high training costs or extra wear and tear on systems. By increasing the opportunities for distributed computer-based training that incorporates cognitive learning principles, skill acquisition and retention can be improved.

This paper describes research and development on ways to incorporate instructional techniques and cognitive principles in various distributed training presentations, including standalone (CD-ROM delivered), internet-based, and embedded training. Analysis of a variety of principles and techniques resulted in selection of a limited set to be used in prototype training module development. The prototype training module addresses operator training for the Force XXI Battle Command Brigade and Below (FBCB2), the Army's vehicle-mounted digital system for distributing information to provide situational awareness. The prototype module is PC-based, and demonstrates how the techniques and principles can be incorporated in distributed training.

In this presentation, we will describe how the selected instructional techniques and cognitive principles can be used in distributed computer-based training. We will provide screen captures that illustrate how each technique and principle can be instantiated in individual operator training for FBCB2. Finally, we will discuss lessons learned and issues for future research and development.

Biographical Sketches

Richard Deatz is a Research Scientist in HumRRO's Advanced Distributed Training Program. He completed his M.Ed. in Occupational Training and Development prior to joining HumRRO in 1996, and has over 15 years experience in training development, needs assessment, and facilitation.. Mr. Deatz has been an instructional designer on several projects to design and develop training and measurement prototypes for battalion staffs in a digital environment. He participated in the overall program design and focused on the design and development of the prototype training support materials, in addition to being the primary author of the project's training research report. Prior to his work with digital training, Mr. Deatz participated in training development for units using the Close Combat Tactical Trainer (CCTT), where he designed and implemented the formative evaluation of the training products. In addition to being the primary author of the final research report, he also coordinated the design, development, and production of interactive multimedia demonstrations of training exercises in the CCTT.

Charlotte Campbell is HumRRO's Program Manager for Advanced Distributed Training. She has spent more than 25 years in military training and research. For the past eight years, she has both managed and participated in a variety of projects, including development of structured training for brigade and battalion staffs; training development for the Close Combat Tactical Trainer (CCTT); study of digital back-up training; design of the prototype Commander's Integrated Training Tool (CITT); training and automated measurement projects for battle command reengineering experiments; study of requirements for training support packages and tools to assist user units in developing the packages; and preparation of tools for training development for deploying units. She is the author of ARI's special report on structured training, and is currently preparing a White Paper with ARI on training issues and challenges associated with the U.S. Army transformation to the Objective Force. She leads a team of instructional designers and military experts who are creating a comprehensive overview of structured training for military trainers, including design and development methods, examples of training support package components, summaries of strategies for fielding, implementation, and maintenance, and research issues.

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INTRODUCTION

As the U.S. Army continues to develop more powerful and complex digital information systems, it is essential that both training needs and training opportunities are addressed to meet mission objectives. Initial training for operators, leaders, and staff members who use the information systems to conduct battlefield command and control is one training need. Equally important is the need for retraining those same individuals as highly technical information systems are periodically upgraded. These training needs present trainers and training developers with challenges such as keeping up with the software changes, delivering incremental training that highlights critical modifications, and providing support so that units can maintain and improve operational proficiency without incurring high training costs or extra wear and tear on those systems.

One way to address the challenges of emerging digital systems is through distributed training. Distributed training, as described in Brown (1991), is providing appropriate training and training support at the best location for effective training. Recent work in this area has focused on the use of computer-based instruction (CBI) particularly because of the flexibility it offers in the way training can be delivered (e.g., embedded, distance learning, Internet). Additionally, the training potential of emerging systems includes not only technological capabilities, but also the ability to vary instructional methods and media to meet the cognitive demands of the learning tasks. To improve learning, the application of principles of cognitive psychology to training design also can address the training challenges associated with new digital systems. By increasing the opportunities for distributed computer-based training that incorporates cognitive learning principles and techniques, it is expected that skill acquisition and retention can be improved.

Background

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) has initiated various research projects to address the training challenges associated with digitization. One such project, documented by Sanders (in preparation), proposes using specific cognitive learning principles and techniques as viable ways to improve training. The emphasis is on organizing and presenting information in ways that track with how learners learn – mirroring the way more complex information is received, stored, and retrieved by the brain (Sanders). This approach could allow learners to acquire and retain digital system skills more readily and adapt as digital tasks evolve with system enhancements.

Purpose of the Research

As an outgrowth of Sanders' work, ARI initiated the present research focused on designing prototype training modules that incorporates cognitive learning principles and techniques in computer-delivered training. The primary goal was not to develop complete training modules, but to demonstrate the training design through the use of storyboards. The cognitive learning principles and techniques used in the design of the training modules are described in Table 1.

Table 1
Cognitive Principles and Techniques

Cognitive Principle or Technique	Description	Source
Learner control and learning styles	Active involvement by learners in the learning process and providing them a learning environment which best suits the way they acquire information	Ertmer & Newby (1993)
Hierarchical sequencing of information	The order in which information is presented, deliberately designed in terms of enabling and terminal skills	Ertmer & Newby (1993)

(table continues)

Table 1 (continued)

Cognitive Principle or Technique	Description	Source
Realistic context	Training content delivered in a job-related context (how the learner will use the information), such as realistic examples, constructive or virtual simulations, or mission-based exercises	Means, Salas, Crandall, and Jacobs (1993); Cannon-Bowers, Salas, & Converse (1992)
Performance feedback and assessment	Learner performance-related information and evaluation provided for, and linked to, completed training tasks to help improve performance	Morrison & Meliza (1999)
Chunking	Organizing information for better comprehension and learning by ordering, classifying, or arranging	West, Farmer, & Wolff (1991)
Concept/Process Map	Graphical depiction of how concepts or processes are linked to aid comprehension	West, Farmer, & Wolff (1991)
Advance Organizer	New instructional content presented with explicit description of relationship to prior knowledge as an aid to comprehension	West, Farmer, & Wolff (1991); Ertmer & Newby (1993)
Metaphor	Analogies between the new instructional content and general background knowledge to improve comprehension	West, Farmer, & Wolff (1991)
Frames, Type 1	Matrix to contrast and compare information to aid recall	West, Farmer, & Wolff (1991)
Rehearsal	Active, repetitive use of instructional content to improve longer term recall	West, Farmer, & Wolff (1991)

Training Focus

The training focus was on individual digital operator skills using the Force XXI Battle Command Brigade and Below (FBCB2) as the exemplar digital system. FBCB2 is a key component of the Army Battle Command System (ABCS) and interfaces with the Army Tactical Command and Control System (ATCCS) at the battalion level. It comprises information technology equipment and software to visually display situational awareness (SA) information provided by weapon systems, sensors, and support platforms; prepare and distribute orders and graphics; and receive, develop, and distribute data based on a common battlefield picture. The FBCB2 supports SA down to the soldier/platform level across all battlefield functional areas and echelons. An FBCB2 screen is depicted in Figure 1.

The FBCB2 system is normally found in fighting vehicles, command vehicles, and command posts. For this effort, the audience was limited to a battalion battle staff.

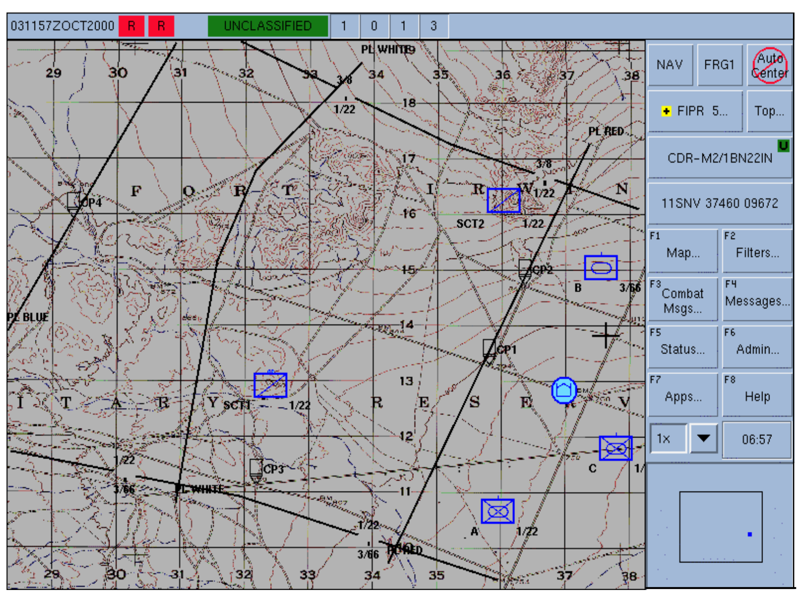


Figure 1. Force XXI Battle Command Brigade and Below system display picture.

Training Tasks

Since the focus of this project was on training design, the project team selected FBCB2 tasks that would best demonstrate the design characteristics (see Table 2). An in-depth task analysis was conducted for each of the four FBCB2 tasks to identify the steps in the process. These task steps provided the training content to which the cognitive principles were applied.

Table 2
Force XXI Battle Command Brigade and Below Task List

Task Title	Abbreviated Task Title[a]
Perform Information Management	Information Management
Prepare/Send Overlays using FBCB2	Overlays
Prepare/Send Reports using FBCB2	Reports
Prepare/Send Order/Request Messages using FBCB2	Orders

Note. FBCB2 = Force XXI Battle Command Brigade and Below.
[a]Abbreviated titles are used in the text for convenience.

PROTOTYPE TRAINING MODULES

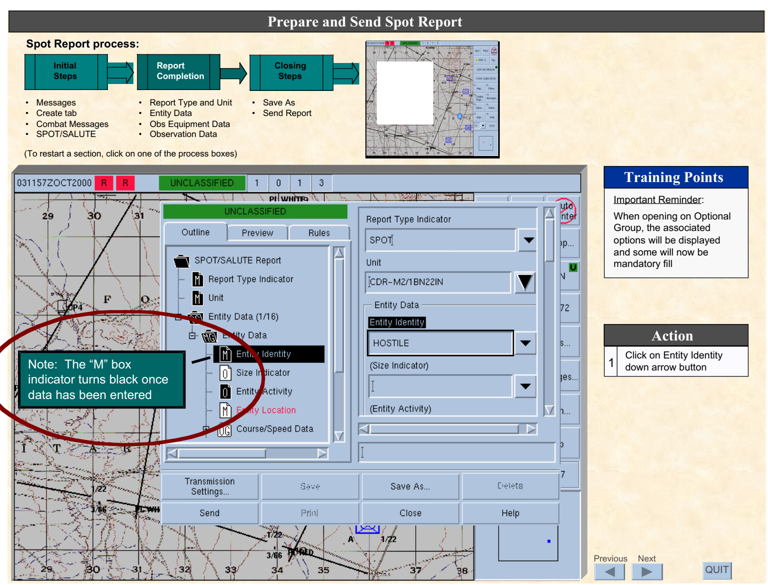
Each training module was designed to focus on one FBCB2 task. Upon selecting a training module, the learner is presented with an introduction to the instructional content followed by a video and audio demonstration of the task. The main part of the module is interactive, and is presented in sections corresponding to the subtasks within the task. At the end of each section of the interactive training, a review of the material is provided in addition to a multiple-choice quiz. When all sections of the module have been completed, the learner is directed to a scenario-based practice exercise.

The training module screen displays combine digitally-captured FBCB2 screen pictures with a text-based description of how each task step is performed and supporting information that explains why or how system information is used to complete the FBCB2 task. The training module screen layouts were constructed in a Microsoft® PowerPoint® presentation graphics program as a way to storyboard the design characteristics. An example of a screen layout for a training module is shown in Figure 2.

The supporting text is displayed in Training Points boxes and in callout boxes that are timed to "fly in" and stop beside a particular screen attribute (refer again to Figure 2). By following the prompts in the Action box for the next step in the training and reading the supporting information as it appears on the screen, the learner is effectively participating in CBI for the FBCB2 system.

Demonstration of Cognitive Learning Principles and Techniques

The remainder of this section provides descriptions and examples of how the cognitive learning principles and techniques were used in the prototype training module design. Although each principle or technique is discussed separately, the reader should not infer that they can or should be used separately. Often the power



Note. Circled area highlights a callout box.
Figure 2. Prototype training module screen layout for the task *Reports* (Spot Report).

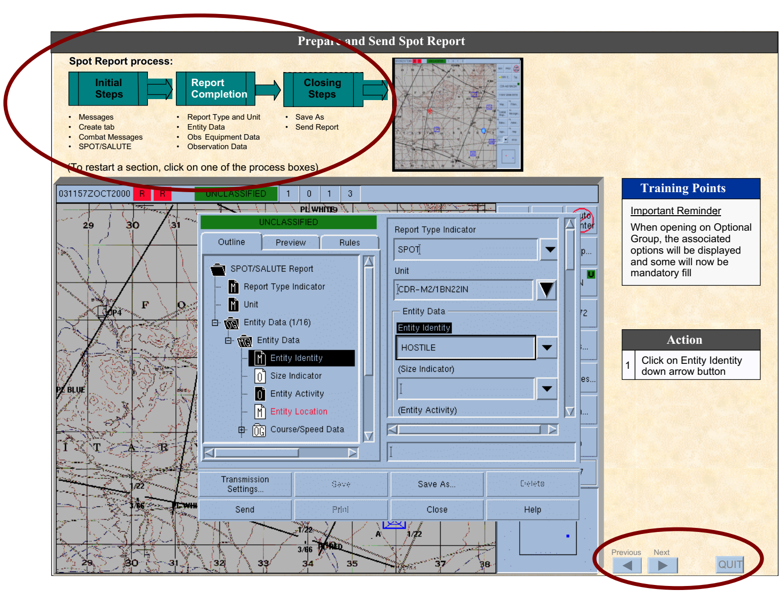
of the principles or techniques is amplified when they are combined (West, Farmer, & Wolff, 1991).

Where appropriate, the principles and techniques are illustrated in a figure by using a training screen picture. To highlight a training technique being discussed, a circle may be drawn around the particular feature.

Learner Control and Learning Styles

The learner control principle is incorporated into the training design by providing learners the ability to move freely throughout the training program and modules. From the main menu screen, the learners may select the desired training module or practice exercise. They are able to either move to a specific section of a module (using process boxes at the top left portion of the screen) or page forward or back (using the "previous" or "next" button at the bottom of the screen) as shown in Figure 3. They can escape from the training module at any point by clicking the "quit" button.

To address a variety of potential learning styles, information is presented in three ways. First, the learner watches the task performed (albeit at a rapid pace) through the use of a video and audio demonstration prior to the start of each training module. Second, the learner begins to interact with the system by following the step-by-step procedures for completing the task. Third, the learner can train, with minimal guidance, using the practice exercise developed for each task.



Note. Circled areas highlight learner control.

Figure 3. Example of use of learner control in the prototype demonstration.

Hierarchical Sequencing of Information

The in-depth analysis of the FBCB2 tasks surfaced information and processes that suggested an order to the instructional content. Although some learning could occur by reading the description of each button's functionality, the buttons do not necessarily work independently. Those relationships between button functions would be found only through trial and error if not described or shown to the learners.

A sequence prescribed by the training design is imposed throughout the training modules. For example, the procedures for establishing the desired SA screen display attributes (e.g., unit icons, terrain features, area of operation) are presented prior to the training on the Overlays, Reports, or Orders task. The users must first customize the SA screen display to provide the information applicable to their role in order to perform the other tasks (Overlays, Reports, or Orders).

Realistic Context

To ensure an accurate understanding of how a digital system will impact mission execution, it is important to provide instruction using real-life examples and situations. Gaining an acceptable understanding of the instructional content may not occur if learners are allowed to practice with a system without guidance or job context (Cannon-Bowers, Salas, & Converse, 1992).

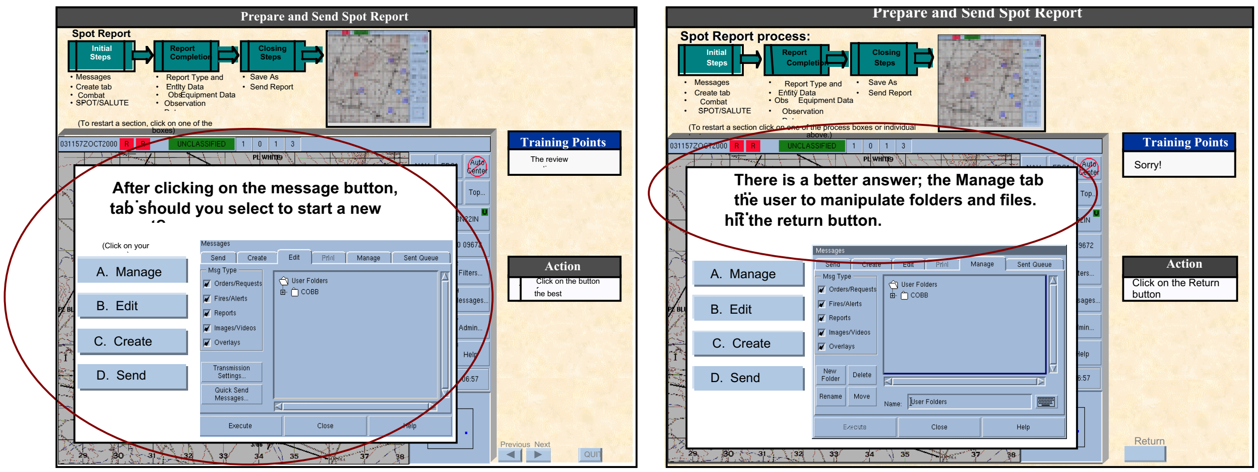
The use of this principle varied in several ways within the training design. First, the design incorporates actual FBCB2 screen pictures so the learner becomes familiar and comfortable with the location of information in preparation for using the FBCB2 system. Additionally, the scenario used in the practice exercises provides the learner an opportunity to analyze information while using the system, as they would when conducting a mission exercise.

Performance Assessment and Feedback

Performance assessment and feedback are critical aspects of training. In a summary of the performance feedback literature, Throne et al. (1999) stated "…research on the learning styles and knowledge structures of experts suggests that feedback, which helps the learner to analyze and categorize an experience, will result in more long-lasting performance improvement" (p. 17).

The use of performance assessment and feedback is demonstrated in the training design in several ways. First, feedback is provided for each menu navigation action made by the learner. Correct actions cause the screen to change so that the learner can progress to the next task step. Incorrect actions fail to bring a response from the system. In this way the training provides immediate feedback in response to learner actions.

Second, at the end of each section of instruction within a module, the learners are presented with a review and test question. Learners click on the button for the selected answer, as shown in Figure 4, picture A. If the answer is correct (in this example it is Edit), they are advised of the correct answer and are directed to advance to the next section of training. If an incorrect answer is selected (in this example Manage, as in picture B), learners are advised that a better choice is available and additional information regarding the answer they selected is provided. They are instructed to make another selection by clicking on the return button. This sequence is repeated until the correct answer has been selected.



A. Training module quiz page

B. Training module incorrect answer example

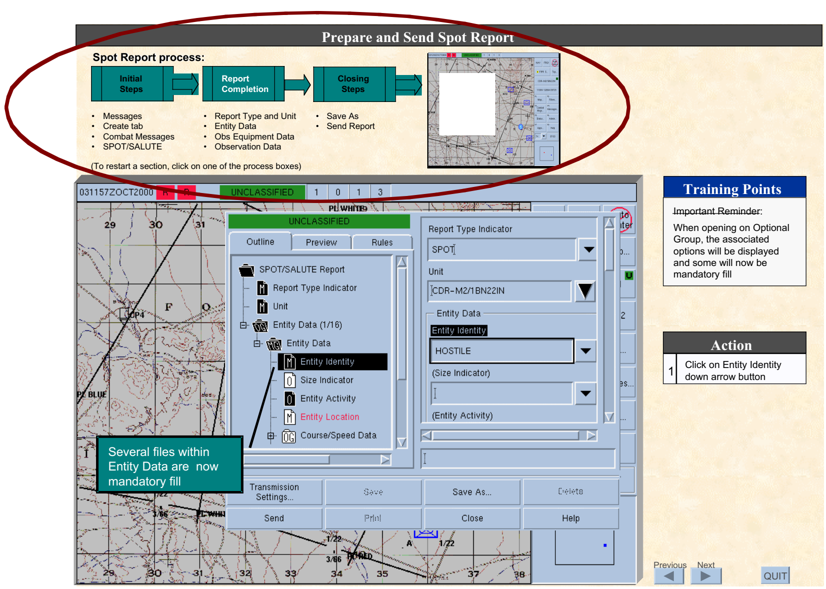
Note. Circled area highlights performance assessment screen attributes.

Figure 4. Examples of performance assessment and feedback in the prototype demonstration.

Chunking

Information chunking is the structuring of information using spatial or linear segments such as time and procedure, or classification segments such as taxonomies and sorting. One way chunking was used in the training modules, as shown in Figure 5, was to organize the FBCB2 task steps into three stages: the initial steps (how to get to the desired system screen), task completion (how to use the system to complete the task), and closing steps (what to do when the task is completed). This information is displayed at the top of the screen so learners can easily track their progress throughout training.

Another use of chunking is found in the training reviews at the end of



Note. Circled area highlights chunking and concept/process map

Figure 5. Example of use of chunking and concept/process map in the prototype demonstration.

each section of instruction. The numerous steps required for completing an FBCB2 task were grouped based on common output characteristics (e.g., observer location information, enemy data). These groupings provide learners with an organizing strategy that can aid retention. Additionally, the groupings are designed to closely resemble the way staff members would execute the task in their current non-digital operational environment.

Concept/Process Map

The concept or process map technique places information in a visual array, such as a chain map, spider map, or hierarchy map. Chunking is a prerequisite to developing a concept map (West et al., 1991).

In this training module, Figure 5 shows the technique (a chain map) being used to provide the learner with an overview of the entire process. It is displayed across the top of the screen through each step of training. As learners advance through the stages of the training module, the appropriate process box is highlighted with a solid color. The learner is provided a small picture of the expected outcome of the training next to the process map.

Advance Organizer

Advance organizers provide an initial structure for new information that allows learners to organize and retain the instructional content. The advance organizer has a specific use by being presented just prior to the beginning of new instructional content. It is usually based on relevant concepts that are already established in the learner's mind and these concepts are used as part of the organizing framework.

In the example shown in Figure 6, the advance organizer is displayed at the start of the training module and points out that what the learner already knows about sending Spot Reports will also apply when using the FBCB2 system. What does change is the way the information is gathered and how it is used to create a Spot Report. The information within the text box (Figure 6) appears as bullets that are displayed sequentially, allowing time to read each bullet before the next one appears.

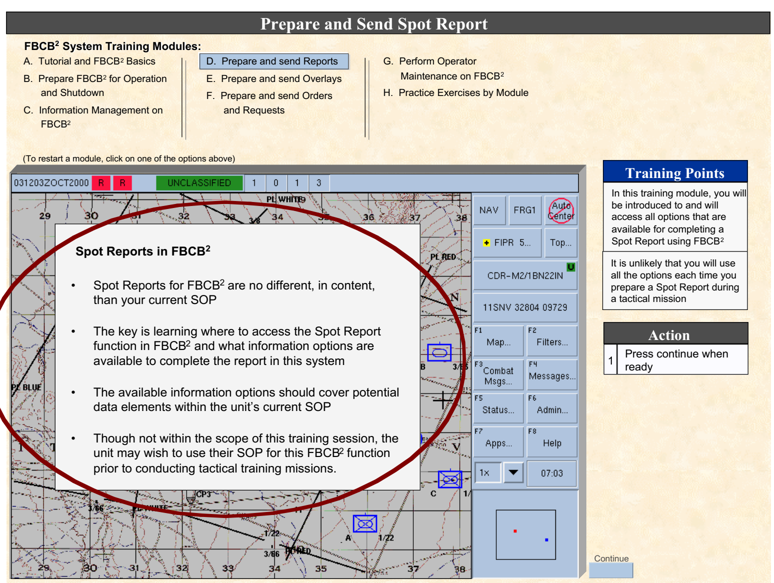
Metaphor

This cognitive technique is like the advance organizer, bridging prior knowledge and new knowledge by emphasizing the similarities between them. Metaphor, however, is often based upon general knowledge and lacks the specific detail relevant to technical content found in the advance organizer.

Metaphor was used as the basis for the training screen layout. The FBCB2 system uses a map or SA display in the lower left corner of the monitor. Information is provided above the display with the available system function buttons to the right. The training module has employed a similar screen layout, as seen in the FBCB2 screen layout comparison in Figure 7. The FBCB2 screen picture is positioned in the lower left corner with supporting information above. The "Action" box to the right provides the cues for the next step to be taken during training while the "Training Points" box provides reasons why the action is required, how the system will respond, or other options available to the learner. With this screen layout, the learner becomes accustomed to viewing the system display to the left and looking to the right for the available actions.

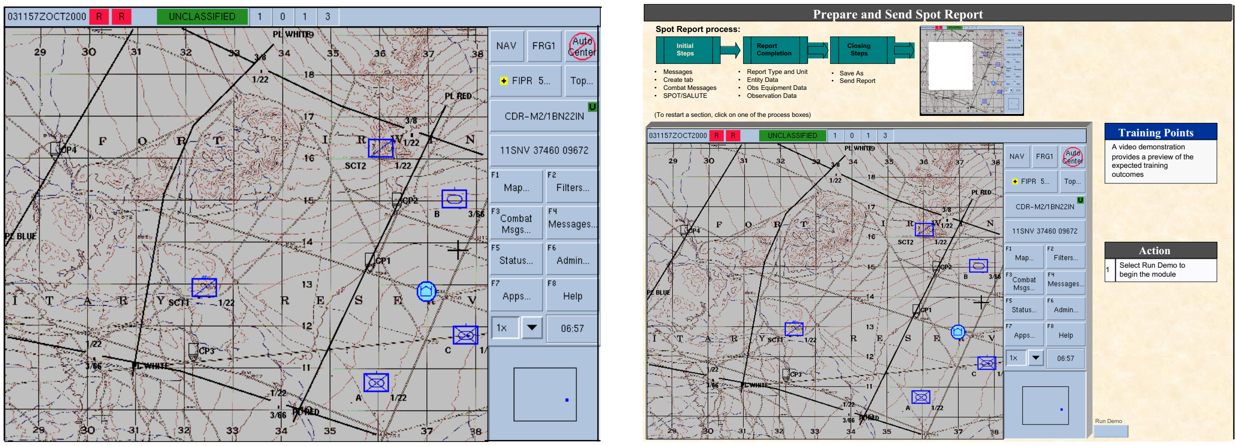
Frames, Type 1

The frames, type 1 matrix provides a visual array of the relationships between main ideas. The technique was used in the prototype to indicate relationships between the various steps in the execution of an FBCB2 task.



Note. Circled area highlights advance organizer.

Figure 6. Example of advance organizer presentation in the prototype demonstration.



FBCB2 system   Prototype training module

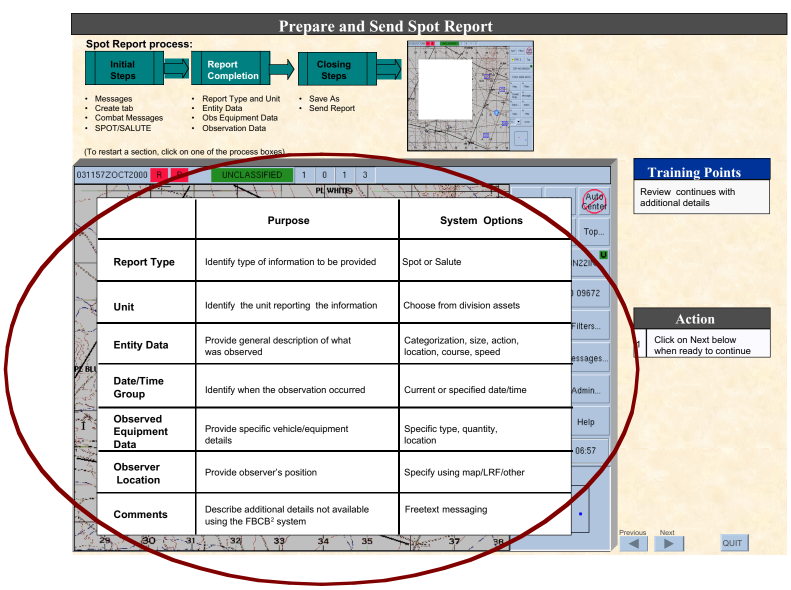
Figure 7. Depiction of use of metaphor, showing comparison between Force XXI Battle Command Brigade and Below (FBCB2) system screen and prototype training module screen.

For the example in Figure 8, the task is Prepare/Send Reports using FBCB2 (in this case, a Spot Report). Although the Spot Report process is not difficult using FBCB2, it does involve numerous steps, making it awkward to remember. Those steps were reduced into seven general groups using chunking and were entered into the first column of the matrix. The purpose column describes the general groupings followed by a third column providing more detailed system options for each group. The key is to understand and recall what can be accomplished using the particular system function, not necessarily to recall each detailed step, since the system prompts the user with that information.

In this example, the frames technique was used as a review tool, summarizing the instructional content at the end of each stage of the training. It is also used as a preview tool at the start of a practice exercise.

Rehearsal

Rehearsal is the repetitive use of instructional content and can take many different forms, such as note-taking, questioning, or paraphrasing in addition to the more common practice exercise. West et al. (1991) stated that rehearsal can also include repeated presentation or exposure to new material for it to be more deeply ingrained for long-term recall.



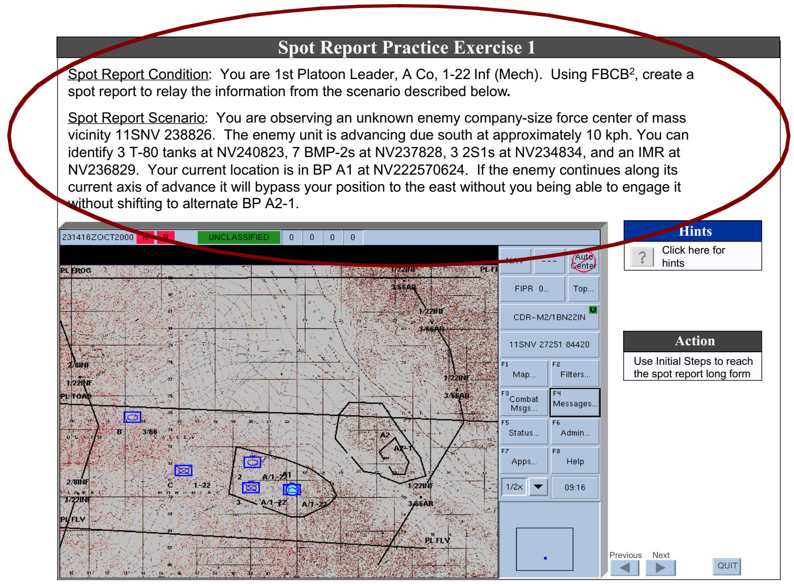
	Purpose	System Options
Report Type	Identify type of information to be provided	Spot or Salute
Unit	Identify the unit reporting the information	Choose from division assets
Entity Data	Provide general description of what was observed	Categorization, size, action, location, course, speed
Date/Time Group	Identify when the observation occurred	Current or specified date/time
Observed Equipment Data	Provide specific vehicle/equipment details	Specific type, quantity, location
Observer Location	Provide observer's position	Specify using map/LRF/other
Comments	Describe additional details not available using the FBCB² system	Freetext messaging

Note. Circled area highlights frames, type 1

Figure 8. Example of frames, type 1 matrix in the prototype demonstration

A practice exercise is used in the training modules and is based on a tactical situation that requires users to analyze a situation and perform an FBCB2 task based on that analysis. In the example in Figure 9 the task is Prepare/Send Reports using FBCB2 (specifically, a Spot Report). The scenario, circled in the figure, is displayed across the top portion of the screen as a reference throughout the exercise. Instead of providing the next step in the process, the "Action" box now references the stage (from the training module's process map) of the process in which the step is found. There is also a "Hints" link, developed for the training module, to refresh their memory.

In addition to practice exercises, the rehearsal technique is used within each module by introducing the information several times and in several ways. When starting a training module, the learner first receives information through the video and audio demonstration of the task. The second time is in the step by step instruction, along with a summary of the information appearing in the process map at the top of the screen. Finally, the material is also summarized in the review at the end of each section of instruction.



Note. Circled area highlights the practice area scenario.
Figure 9. Example of rehearsal, using a practice exercise, in the prototype demonstration.

SUMMARY

The project team members and ARI personnel conducted several informal design trials because a formal evaluation was not required for this project. In addition, a total of about 35 soldiers (vehicle to brigade commanders and staff NCOs and officers) with varying FBCB2 experience informally reviewed the training modules and provided feedback for design revisions. The experiences and comments from the project team members, ARI personnel, and soldiers have provided the basis for the lessons learned.

Lessons Learned

Several important points concerning the development, use, and collective training should be made. The first is that CBI can be developed with commonly used presentation software as a "low cost" alternative or supplement to embedded training on tactical equipment. As the project's storyboard evolved using Microsoft® PowerPoint®, more capabilities were added so that it realistically emulated FBCB2 system functionality being delivered through CBI. The prototype training modules did not look, or respond, like typical slide presentations. The user reads the instructions and clicks over the appropriate FBCB2 button to advance through the module. In support of this point, comments from soldiers indicated that they felt they received good training, and at times, forgot they were not actually using an FBCB2 system. Although PowerPoint® may not be the optimum system for interactive training development, other, more powerful systems require more expertise and time to develop and modify.

Secondly, although the demonstration of the training modules was CD-ROM based, it appears the design would also apply to fully embedded training. On-board or surrogate "White Box" systems, equipped with objective embedded training capabilities, can provide the soldier with full system capability with software already on the system. Additionally, the design would also apply to training delivered through the Internet.

Another lesson learned is the need to evaluate the effectiveness of this training design. Although prior research has indicated that the use of cognitive principles may improve learning, the retention of skills acquired using the prototype training modules was not formally evaluated during this project. It is important that formal trials be conducted to gather data regarding the effectiveness of the training design.

Finally, there is a need to investigate ways to link users together, after completing individual training, in order to conduct collective, scenario-based practice exercises. Although this project focused on individual digital system skills training, it is difficult to escape the need for soldiers to be able to train collectively. This is becoming even more important with the advent of a lighter, faster digital army. Future efforts should determine ways, perhaps the Internet, to allow learners using stand-alone or embedded CBI programs to conduct a scenario-based practice exercise as a team.

CONCLUSION

The U.S. Army continually looks to identify what the future holds, in order to lay the groundwork required for successful operations. To this end, work is being conducted to develop new and more efficient digital systems, in addition to finding ways to improve the training needed to support those systems. Distributed training, based on solid design principles, can provide the soldier with the skills and knowledge to meet the challenges associated with emerging digital systems.

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