Improving Soldier Threat Detection Skills in the Operational Environment

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ABSTRACT

The ability to detect threats is particularly critical for Soldiers who serve in the dynamic and irregular battlefields of the U.S. Army's current Operational Environment (OE). Threat detection encompasses a variety of cognitive and perceptual skills, such as attention management, pattern matching, reasoning about threats, and change/anomaly detection. Training the cognitive skills associated with effective threat detection takes an understanding of the threat detection processes engaged in by experienced Soldiers. To identify these cognitive skills, research was conducted to understand threat detection in the OE and to differentiate between the threat detection performance of more and less experienced Soldiers. From these data, a computer-based training exemplar was developed with the goal of enhancing Soldier ability to detect animate (i.e., human) and inanimate (i.e., IEDs) threats. This paper presents research findings that suggested time pressure, threat relevance, and experience played a role in threat detection performance. A threat search task demonstrated that less experienced Soldiers were more susceptible to time pressure with accuracy increasing slightly with the number of deployments. Results also revealed that all Soldiers could infer threat-relevant locations and appropriately focus their attention on those areas as well as identify threat-relevant changes. Interview analysis provided insight into the reasoning of more and less experienced Soldiers. Less experienced Soldiers tended to make context-free procedurally based statements, indicating they did not have mental models to draw from to make specific interpretations of the situations in the photos. These finding indicated that Soldiers, even in threat search tasks using static photos, directed their search to relevant threats rather than randomly over the photo, making this useful stimulus for training. From this research, a computer-based training prototype was created to improve Soldier ability to identify relevant threats, detect relevant changes, and develop causal reasoning skills applicable to the operational environment.

ABOUT THE AUTHORS

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INTRODUCTION

Threat detection is an important skill that U.S. Army Soldiers must utilize when conducting operations in the Operational Environment (OE). Threat detection relies on a number of perceptual skills, such as attention management, pattern matching, and change detection, as well as higher-order cognition. Humans must reason about the threats, incorporating their previous experiences and knowledge about the context, to assess whether a particular cue might indicate a potential threat. This paper describes research conducted to better understand and improve visual threat detection performance in the OE. By relying on current psychological theories of visual attention and expertise, military doctrine, and Soldiers' threat detection experiences during recent deployments, this research aimed to achieve a greater understanding of how Soldiers' detect threats and to create a training exemplar that enhances Soldiers' threat detection performance. The goals of this research were to:

- Identify the cues, skills, and strategies required to detect threats in the OE.
- Differentiate the cognitive skills employed by experienced versus novice Soldiers.
- Create a training exemplar that enhances the cognitive threat detection skills of Soldiers.

The outcome of this research was a training program aimed at improving the cognitive skills used to detect threats by incorporating exercises that promote novice advancement toward expert performance levels. As experience develops, decision makers tend to rely less on procedures and rules and display greater ability to incorporate novel information, perceive situations holistically, and react with flexibility to situations (Dreyfus & Dreyfus, 1986; Ross, Phillips, Klein, & Cohn, 2005). Previous research also shows that more and less experienced decision makers use similar sensemaking strategies, but experts show a deeper understanding of the situation and provide richer explanations (Klein Phillips, Battaglia, Wiggins, & Ross, 2002). This research provides insight into how threat detection proficiency may change as Soldiers acquire experience.

This paper summarizes a preliminary investigation into how Soldiers detect threats and the development of an expert model of threat detection and then presents findings from an experiment designed to test the cognitive and perceptual skills of Soldiers who had varying levels of experience detecting threats in the OE[i]. During this investigation, Soldiers performed computerized tasks that tracked their prioritized threat search, dynamic threat detection, and change detection activities. The results provided a foundation for the development of a computer-based training exemplar aimed at providing training in the cognitive skills underlying visual threat detection.

EXPERT MODEL OF VISUAL THREAT DETECTION

Model Development

One objective of this research was to identify the cognitive mechanisms of threat detection in order to create an expert model. Two existing models of decision-making were used as a foundation to create the model of threat detection. One model is Boyd's Observe, Orient, Decide, and Act (OODA) Loop (Boyd, 1987). The intention of the OODA loop is to define the nature of combat in terms of time, with both sides cycling through the OODA loop continuously in an effort to cycle faster and disrupt the other side's cycle. The second model is the Recognition-Primed Decision (RPD) model. The RPD model describes the decision process by distinguishing three levels of processing (Klein, 1998; Klein, Calderwood, & Clinton-Cirocco, 1986).

Level 1 of the RPD model represents the decision process when individuals make a simple match between the situation and the action choice. Embedded in this assessment is the decision maker's recognition of important, as well as usual cues, which generate expectancies about what should happen next. Level 2 represents decision making when the situation is not so easily recognized or matched to internal representations. If the situation is unfamiliar or ambiguous, decision makers cannot rely on recognition; instead, they must assess and comprehend the novel aspects of the situation (Phillips, Klein & Sieck, 2004). Level 3 represents the processes engaged in by decision makers who are able to assess the situation but the best course of action is not immediately clear, therefore they must further evaluate their action choice.

The review of the literature and these models led to the development of a conceptual model to illustrate how expertise in threat detection may emerge (see Figure 1). The intention of this model is not to supplant similar models, but rather to highlight the particular functions germane to threat detection in the OE. However, just as the OODA loop describes a continuous monitoring task, the threat detection loop describes a cyclic set of processes that capture the primary activities involved in threat detection. The threat detection loop is a model of cognitive and perceptual processing which assists in classifying and understanding the component skills of visual threat detection.

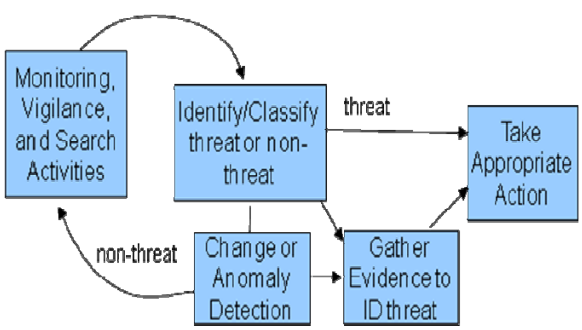

Figure 1. Diagram of Threat Detection Loop

Measurable Behaviors and Metrics of Expertise

To begin to test the current model, we first identified the ways in which experience would influence threat detection performance at each step in the threat detection loop and then defined the corresponding measurable behaviors or abilities (see Table 1). For instance, to effectively engage in monitor and search activities, experienced threat detectors would likely have existing prototypes of threat cues and situations that allow them to sort threat features from non-threat features. Using these prototypes, threat detectors can mentally simulate how a threat situation might unfold and thus demonstrate ability to construct causal stories about situations and predict how the threats might materialize. This ability to incorporate information and construct stories should allow them to identify and classify threats in a selective manner, which would influence their decision threshold for taking action.

Table 1. Threat Detection Loop, Influence of Experience, and Measurable Behaviors

Threat Detection Process	Influence of Experience & Knowledge	Measurable Behaviors
Monitoring, Vigilance, and Search Activities	Provides threat prototypes	Classify threat versus non-threat
	Helps determine *when* to be most vigilant	Encode details for immediate or delayed test
	Guides where to look	Focus on high-priority threat locations
Identify/Classify threat or non-threat	Enables mental simulation of causal sequence leading to threat	Create causal stories about threats
Change or Anomaly Detection	Provides good model of what is typical	Detect change or anomaly
Gather Evidence to ID threat	Considers background probabilities of threat	Incorporate priors into decision
	Enables taking actions to qualify threat	Identify appropriate actions
Take Appropriate Action	Allows calibrated threshold for action	Adapt decisions based on information
	Helps determine appropriate reaction to qualified threat	Balance decision with information gathering

Based on this threat detection loop and the hypothesized behavioral measures of expert performance, we conducted preliminary research to learn how Soldiers engage in threat detection during dismounted and mounted patrols and to identify the cognitive processes they engage in to detect, classify, and react to threat cues. In this preliminary research, Soldiers engaged in threat prioritization and causal reasoning tasks. The data revealed informational cues and experiences that are most important for gaining knowledge and developing the ability necessary for visual threat detection. These findings allowed us to make predictions about Soldiers' performance as they gain competency and develop expertise. According to the model, proficient Soldiers should be better able to monitor and search their environment to find and classify threats and non-threats, detect changes or anomalies, and create causal stories about situations. From this preliminary investigation, we conducted an experiment with Soldiers who had varying levels of experience detecting threats in the OE. They engaged in computer exercises that required them to search for threats, prioritize threats, and detect changes in threat environments. The data from this research provided information for a training exemplar created to enhance the cognitive skills associated with threat detection. The remainder of the paper describes the experimental methods and findings and describes the training exemplar created from this research.

EXPERIMENT

Preliminary Research

The preliminary research involved interviews with Soldiers, who also completed questionnaires. This initial research provided information about threat detection situations and activities in the OE. These preliminary findings illustrated possible differences in threat detection processes of more and less experienced threat detectors. Soldiers also viewed images of common threat situations and annotated areas in the images with reasons why these areas were a concern. This analysis provided information about the regions of interest, threat cues, and explanations about the threats. From this, we created materials to track attention management, threat search activities, and causal reasoning about threat environments. During interviews, Soldiers discussed how they gather information, spot cues and trends, scan environments, observe changes, aggregate information, and form mental pictures of situations. Their descriptions of the types of threats and cues present in threat situations provided insight for research stimuli development and informed the exercises Soldiers would complete in the experiments.

The purpose of the subsequent experiment was to test the cognitive and perceptual skills of Soldiers who had varying levels of experience detecting threats in the OE. Soldiers in this experiment had experience levels ranging from zero to four deployments. To test their skills, Soldiers completed a series of computer exercises that examined their performance while doing (a) prioritized threat search, (b) dynamic threat detection, and (c) change detection. This research also sought to identify any differences in reasoning about potential threats in the context of various situations. Soldiers participated in interviews and discussed the threat cues and situational elements depicted in photographs of U.S. Troop activities and terrain in Iraq and Afghanistan.

Methods

Participants

Forty-seven U.S. Army Soldiers participated in computer exercises and interviews. Twenty Soldiers were Non-Commissioned Officers (NCOs; SGT to MSG), one was an Officer (1LT), and twenty-six were junior enlisted (PVT to CPL/SPC). All Soldiers were male. Table 1 lists the average age, mean time in service, and the mean number of times deployed for each group. Soldiers reported zero to four deployments. Thirty-four Soldiers reported deploying at least once. Of those who deployed, 83% were combat arms. Deployed Soldiers rated how often they traveled off their Forward Operating Base (FOB) or similar location (outside the wire), on a scale from 1 (rarely or never) to 4 (almost every day). Twenty-seven Soldiers reported going outside the FOB almost every day (M = 3.65, SD = 0.77).

Table 2. Junior enlisted and NCO mean age, time in service, and number of deployments

Rank	Mean Age	Mean Time in Service	% Deployed
Junior Enlisted	23 (range 18-37)	27 mo. (range 4-72)	54%
NCO/ Officer	29 (range 23-44)	103 mo. (range 31-192)	95%

Computer-Controlled Questionnaire

Participants completed a computer-controlled demographic and experience questionnaire that contained questions such as time in service, current rank, current Military Operational Specialty (MOS), age, number of times deployed, and number of times travelled outside the wire on their most recent deployment. The Participants section (above) presents the relevant data from this questionnaire.

Computer-Controlled Imagery Analysis

Three computer-controlled threat detection exercises presented photos selected from a set of 48 images approved for public release. These images were retrieved from three main sources, www.DefenseImagery.mil, www.Flickr.com, and www.defense.gov. Findings from the preliminary research guided the photo selection process for the final set of 40 images. These images were divided into four groups of ten, and each group of ten images was assigned to one of four conditions: time-unlimited prioritized threat search, time-limited prioritized threat search, single-task threat detection, and dual-task threat detection. Four counterbalanced conditions were devised using a Latin square design, and participants were assigned to each counterbalanced condition based on the order in which they participated in the data collection.

Twelve additional images were selected as stimuli for the change detection exercise. Image-editing software enabled the creation of two versions of each image by seamlessly adding or removing specific features from the images. Changes included both threat-relevant features (brickwork, trash, people, vehicles, etc.), and threat-irrelevant features (the length of poles, ornamental architecture detail, etc.). Soldiers viewed one version of each of the change-detection images during the initial prioritized threat search exercise, and tried to detect changes on the second version of each image at the end of the sessions.

Interview protocol

The interviews focused on gathering information about the causal reasoning used to make threat detection choices during the computer exercise. The set of photos used in the computer exercises and previous research were used to gather information about Soldier thought processes and reasoning while detecting threats.

Procedure

After signing informed consents and completing the demographic questionnaire, Soldiers completed five consecutive computerized exercises developed to measure attention, search, reasoning, and prioritization strategies for threat detection, and then participated in a semi-structured interview. The first two exercises involved a resource-limited threat search process, referred to as the prioritized threat search. During this task, Soldiers searched images for potential threat targets. Each image contained approximately ten possible target locations. The annotations provided by Soldiers in the preliminary research formed the basis for these target locations.

The next two exercises involved dynamic threat detection, in which Soldiers engaged in a stimulus detection exercise with distracters. On each trial, the screen displayed an image overlaid with 75 semi-transparent grey dots (noise) distributed randomly, but consistently, over the image. These dots vibrated and obscured the image. This required Soldiers to maintain constant vigilance to detect the target among the field of dots. The dots were cognitively and perceptually distracting in a way that is similar to noise naturally found in the environment. The target dot was identical to the noise, except that it had a light, orange rim around the circle. The Soldiers clicked the mouse button as soon as they detected a target. They could then indicate the location of the target. The threat-consistent locations were determined by examining responses from previous research with the same or similar imagery.

A second round of the dynamic threat detection exercise required simultaneous monitoring of changes occurring on a secondary light monitor. The light monitor was located in the lower right section of the image, and had four virtual LED lights that flashed either blue or red. Soldiers needed to monitor both the photo for the target (grey dot with orange outline) and the light display for three red lights (see Figure 2). In Figure 2, three of the secondary monitor lights are illuminated, indicating that a response was required. The purpose of this manipulation was to assess the degree that threat detection experience affected performance when simultaneously performing multiple tasks.

Figure 2. Screenshot of Dynamic Threat Detection Exercise

Finally, in the change detection exercise, Soldiers viewed changed imagery, which they first saw during the prioritized threat search exercise, and they annotated any changes observed. The changed images were intermixed randomly with the normal threat search imagery, thus Soldiers had no indication that these images would later appear as a test of their change detection skill.

After the computer exercise, the Soldiers discussed their threat detection experiences during interviews that lasted approximately 30 minutes. Soldiers were instructed to look through a set of images (that had been used in the computer exercises) and select one or more that reminded them of a situation they had experienced (in training and/or operational environments). They identified and described the threats in each photo and provided explanations about the threats they deemed important. They discussed the threat-related events that might occur in each photo and described possible threat scenarios. Finally, Soldiers provided feedback about the computerized exercises and made suggestions for computer-based training exemplar development.

FINDINGS

This research examined how more and less experienced Soldiers performed during exercises involving threat detection and responded to situations that contained potential threats. Soldiers were divided into more and less experienced groups by their designation of NCO/Officer or junior enlisted. While these groups are not entirely dichotomous, they provide for analysis based on general experiences associated with rank. Future analysis with groups that are distinct in their experience levels will provide further insight beyond those presented here. Some of the key findings suggest that time, threat relevance, and expertise played a role in Soldiers' performance.

Prioritized Threat Search

Soldier performance in the prioritized threat search exercise demonstrated that novices were more susceptible to time pressure, with the number of deployments slightly increasing accuracy under time pressure. The prioritized threat search exercise measured performance with and without time pressure. The number of threats discovered by Soldiers provided a metric of performance in both conditions. Soldiers found targets in an average of 2.14 clicks while under time pressure, and 2.32 clicks when not under time pressure. A Welch 2-sample t-test determined these to be significantly different, $t(1374) = 2.05$, $p < .05$, Cohen's $d = 0.11$, showing that time pressure reliably reduced the number of targets found.

Dynamic Threat Detection

Results in the dynamic threat detection task revealed that Soldiers were able to infer threat-relevant locations and appropriately focus their attention to those areas during single and dual task conditions regardless of experience level. The threat search exercise involved searching for targets that appeared in a dynamic field of semi-transparent dots that jittered throughout the search. Soldiers correctly responded if they clicked the mouse while the target appeared on the screen and then indicated the location of the target within 100 pixels of its actual location. Out of 5,734 total trials in which a target appeared on the image, Soldiers clicked the mouse to indicate the target was present 3,107 times, and 2,598 of these times, Soldiers indicated the target location within 100 pixels. To assess whether the differences between conditions were statistically reliable, a model predicting log (accuracy) based on condition (single-dual), relevance, a condition x relevance interaction, and participant, enabled within-subject comparisons. Results of an Analysis of Variance (ANOVA) on this model indicated a statistically significant effect of threat relevance, $F(1,45) = 92$, $p < .001$, $\eta^2 = .67$, and no reliable effect of either single versus dual task condition, $F(1,45) = 2.1$, $p = .15$, $\eta^2 = .044$, nor was there a reliable interaction, $F(1,45) = .65$, $p = .42$, $\eta^2 = .014$. A second performance measure analyzed was Soldier time-to-respond when they detected a target. Similar to accuracy, Soldiers responded faster to targets in relevant locations than to targets in irrelevant locations. An ANOVA performed on log (reaction time) again revealed a reliable effect of relevance on response time, $F(1,44) = 6.3$, $p =.016$, $\eta^2 = .12$, a reliable effect of the single and dual task conditions, $F(1,44) = 23.7$, $p <.001$, $\eta^2 =.345$, and no reliable interaction, $F(1,43) = .04$, $p = .82$, $\eta^2 = .001$.

Change Detection

Finally, the change detection exercise indicated that Soldiers were able to identify changes related to threats. To assess change detection ability, each base image was coded according to its critical change locations. Coding changes in each image indicated the presence, absence, or the change of a feature. In addition, coding differentiated each change as threat relevant or threat irrelevant. Results showed that Soldiers annotated 355 cues but 281, or 79% of these cues did not involve an actual change between the two images. These 281 false alarms were not coded as threat relevant or irrelevant. Of the remaining 74 identified targets, 71 were in threat-relevant locations, providing evidence that when Soldiers noticed changes they were related to threats. Furthermore, Soldiers were more likely to identify a target when a feature was absent in the first viewing but present in the second viewing (56 trials) versus when the target was present in the first viewing, but absent in the second (15 trials).

The overall high proportion of false alarms indicates that change detection skill was poor. However, the proportion of targets actually found indicates an existing ability to detect change. Although only about 20% of the responses were for actual changes, Soldiers were about 6.7 times more likely to indicate actual changes than if they had been responding by chance. To assess whether performance differed reliably from chance, mean accuracy rates (the number of change cues identified relative to the total number of attempts) were compared to the proportion expected by chance. The mean proportion of attempts that identified a change target was .233, with a 99% confidence interval between .14 and .32. The chance proportion of .03 to identify change targets lies far outside the region, $t(42) = 5.9$, $p < .0001$, Cohen's $d = 0.90$.

Interviews

The purpose of the interview analysis was to identify differences in causal reasoning skills between more and less experienced Soldiers as they identified and discussed possible threats in photographs depicting real-world situations. Findings from the interviews represent typical responses from Soldiers with 0, 1, or 2-4 deployments. Soldiers in all three groups (0, 1, or 2-4 deployments) were able to identify or discuss types of threats, threat cues, and threat detection activities. Soldiers with deployment experience more often discussed strategies for threat detection, threat detection skills, challenges in detecting threats, and solutions. Less experienced Soldiers tended to discuss specific cues and make general comments about behavior, such as "They look kind of suspicious" or "being by himself doesn't look right." These Soldiers tended to describe suspicious behaviors in general terms, for instance, "I guess the biggest thing would be any specific individuals who brought attention to themselves, just through their actions, just wherever I'm observing at the moment." These Soldiers also mentioned environmental cues such as rock piles, garbage piles, buildings with windows, tinted windows, lowered vehicles, and wires. Soldiers with one or more deployments typically listed threat cues but also provided more contextual details and interpretations of the cues and situations. These experienced Soldiers also reasoned about why specific cues may or may not indicate a threat. As represented in the Threat Detection Loop, Soldiers were able to incorporate prior information into their decisions and create causal stories about threat situations by discussing their experiences with situation-specific cues and the likelihood that such cues indicated threats. This suggests they are able to classify cues as threats or non-threats based on the context of the situation. They also took a more active stance in their threat detection tasks by creating stories about the threat situations and incorporating prior knowledge to hypothesize about events that might take place and the actions they might take, again reflecting the Threat Detection Loop.

TRAINING EXEMPLAR

From this research, we identified four learning objectives. These learning objectives map onto the expected behaviors of experienced threat detectors identified as part of the threat detection loop (see Figure 1). For instance, the initial exercises focus on encoding details to identify and classify relevant threats. The purpose of the reasoning exercises is to enhance ability to gather evidence to determine threat importance. The change detection exercises focus on perceiving changes and determining the relevance of the change (see Table 3).

Table 3. Relationship between Learning Objectives and the Threat Detection Loop

Learning Objectives	Step in Threat Detection Loop	Threat Detection Loop Behaviors
Demonstrate improved ability to identify relevant threats in a variety of situations.	Monitoring, vigilance, and search activities	- Encode details for immediate or delayed test
Distinguish between threat-relevant and threat-irrelevant cues in time-limited situations.	Identify and classify threat or non-threat	- Classify threat vs. non-threat features - Look at high-priority threat locations based on knowledge
Recognize the importance and potential impact of each detected	Identify and classify threat or non-threat	- Adapt decision based on information - Balance

threat.	Gather evidence to ID threat	decision with information gathering - Create causal stories about threat situations
Identify threat-relevant changes in the environment	Change or anomaly detection	- Detect change or anomaly

Design and Development

The training exercises developed for this exemplar take a crawl-walk-run approach. The first series of exercises involve threat searches. Soldiers view photos with threat cues already marked and click on these cues to read about the possible threat, why the threat is relevant, and common enemy tactics used to succeed in carrying out the threat. Soldiers then view another set of unmarked photos and click on potential threat cues. If the places they click are threats, annotations pop up, again providing information about those cues. They then engage in timed threat search exercises (see Figure 3).

Figure 3. Screenshot of the Threat Search Exercise

Following the threat search, Soldiers view photos with questions that require them to reason about the situations presented and evaluate the threats in context of a hypothetical situation. They engage in critical thinking about the potential threats and read several possible solutions (Figure 4). They also read comments made by experienced Soldiers who discussed the photos during the interviews.

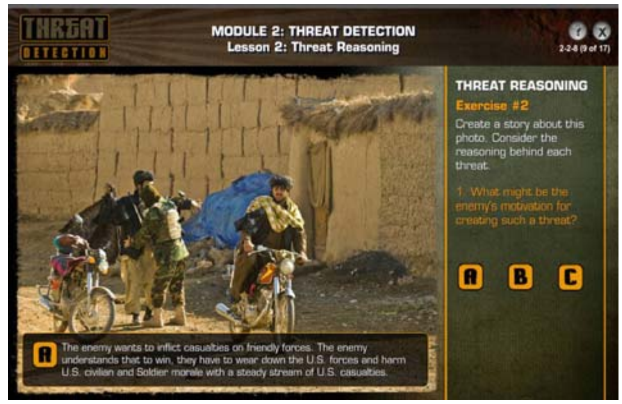

Figure 4. Screenshot of the Reasoning Exercise

Finally, Soldiers complete the threat search and reasoning exercises by reading scenarios that frame the context of the photos and then consider that context to identify threats and determine relevance (Figure 5). Soldiers also complete two change detection exercises during the training, one in the context of a threat search and one in the context of causal reasoning.

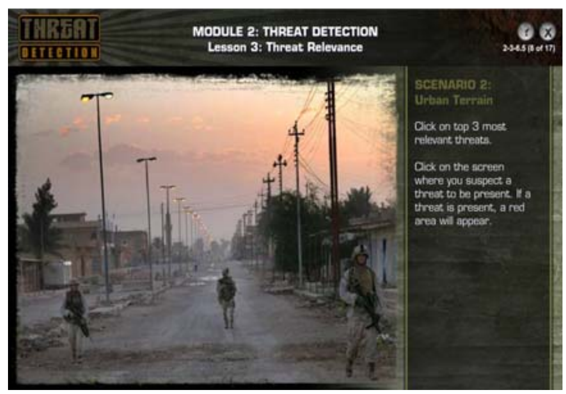

Figure 5. Screenshot of the Threat Relevance Exercise

Development

The Instructional Systems Design (ISD) process informed the development of the Computer-Based Training (CBT) materials. The data and storyboards contributed to the development of the look, content, and functionality of the training product. We created a Graphical User Interface (GUI), edited, validated, and verified and then developed a SCORM compliant version of the CBT course. When developing a SCORM compliant CBT course, the major sections of each module, such as introductions, lessons, and summaries, are wrapped into their own Sharable Content Object (SCO). Formative evaluation took place throughout the ISD process, first with reviews of the storyboards, then through initial reviews of the introduction slides, followed by an evaluation of the entire training exemplar.

Formative Evaluation

Three instructors at Ft. Hood, TX, completed two evaluations of the training while it was under development. Their early assessment included suggestions for improving the narration, providing feedback at the end of the exercise, and collecting demographic information. They also provided feedback about the CBT format and design. Once the initial version was revised, these reviewers conducted a second evaluation of a more advanced version of the training. The reviewers answered questions about their ability to interact with the training exemplar and the realism and relevance of the scenarios and photos. They also provided opinions about who might be the best audience for the exemplar.

Overall, the responses were positive. Some feedback addressed functioning issues within the training exemplar. The reviewers appreciated the sense of urgency that time restrictions within the training exemplar presented, stating that the restriction modeled actual time stress to some extent. They suggested that the training exemplar is most appropriate for new Soldiers so that they can learn important skills before deploying, but also useful for combat veterans who need to refresh and sharpen skills before deploying again. Finally, the reviewers suggested that the exemplar, in combination with an instructor, would provide students with additional insight to enhancing threat detection skills.

CONCLUSION

The preliminary phases of this research provided insight into the key threats Soldiers consider important and clarified the difficulty Soldiers have in distinguishing ambiguous cues from definite cues when searching for threats. Data from the preliminary investigation enabled us to create the Threat Detection Loop and identify the behaviors reflective of proficient threat detection. The outcome of the computerized exercises was stimuli for the final experiment that included key threat locations, cues in photos, and critical situational factors that influence threat relevance.

The aim of the final research phase was to compare the threat detection performance of more and less experienced Soldiers. This research illustrated the cognitive skills Soldiers employ when searching for threat-relevant cues and changes in situations with and without time pressure. Interviews provided data that mapped onto the threat detection loop and contextual details that informed our knowledge of the threat detection process.

While this research provided contextual detail about how Soldiers think about threat cues, threat detection activities, attention management, and search priorities, the final experiment contributed empirical evidence of Soldier threat detection abilities. This research showed that time pressure influences Soldier ability to detect threats, with fewer threats being detected when under time pressure. These results provided some indication that experience reduces the effects of time pressure, but this effect was small and thus more research is required. Regardless of experience, Soldiers focused their attention toward detecting relevant threats compared to irrelevant threats. They were more accurate and responded faster to relevant threats, indicating that targeted searching in relevant locations is a necessary component of visual threat search. While experience did not mediate this effect, the interview data indicated that Soldiers with deployment experience had a deeper understanding of why threats were relevant and under what circumstances threat relevance would increase or decrease. They were able to construct stories around the threats, reason about various action choices, and hypothesize about potential outcomes.

The change detection exercise revealed a high false alarm rate when trying to find changes in the photos presented. However, when Soldiers accurately identified changes, the majority were threat-relevant changes. This finding adds to the existing change detection literature by demonstrating that Soldiers were able to notice changes at rates greater than chance. This is contrary to previous research that shows observers fail to notice large changes, because of a phenomenon called change blindness (Simons & Rensink, 2005). Researchers have identified some situations that mitigate change blindness, such as intentional encoding (Hollingsworth, 2004; Brady, Konkle, Oliva, & Alvarez, 2009). In the current research, Soldiers received no explicit instructions to study the photograph for subsequent testing. It also should have been difficult for Soldiers to detect changes because the subsequent testing after the target picture provided significant interference (Makovski, Shim, & Jiang, 2006). While research has shown that experts detect changes more often than novices when the change is related to their domain of expertise (Werner & Thies, 2000), the results of this current research showed no difference in change detection performance based on experience. Further research should attempt to provide an explanation for these findings.

Results of this research provide an increased understanding of threat detection and provide directions for future research and training development. The current training used static images and exercises developed during research that also used static images as stimuli to inform our knowledge of Soldier threat detection. This had some practical advantages, in that Soldiers could study imagery closely without time pressure and make annotations in detail. However, new technologies may improve both data collection and training products in three important ways: 1) use of dynamic video imagery for improved data collection and training, 2) use of eye-tracking hardware and other means to identify directly the locus of attention during threat detection behavior, and 3) use of immersive environments to improve training realism. Soldiers of various skill levels tend to focus on relevant threats; however, experience adds context and reasoning to the threat identification process. Future training should continue to highlight the causal reasoning and critical thinking components of threat detection. This research indicated that Soldiers have an ability to notice changes, but this ability was limited relative to the high false alarm rate. Given that change detection accuracy was not random, it may be possible to improve this existing skill with targeted training.

From this research, we developed a training exemplar that focused on enhancing the cognitive skills associated with threat detection. This training utilized data obtained from Soldiers with recent threat detection experience in the OE. We linked this data to the Threat Detection Loop and created learning objectives aimed at enhancing the behaviors underlying each step in the model. The outcome was training that focused on the key cognitive tasks associated with dynamic threat searching, causal reasoning, and change detection. Future research should evaluate the ability of the training exemplar to improve visual threat detection performance in a variety of contexts. With the Army's current focus on home station training and the use of contemporary technological assets, the combination of novel, research-based products with established simulation technologies provide a valuable asset to Soldiers in the OE.

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[i] Portions of this paper appear in Zimmerman, Mueller, Marcon, Daniels, & Vowels (under review).