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Identification of the Emplacement of Improvised Explosive Devices by Experienced Mission Payload Operators

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ABSTRACT

Improvised Explosive Devices (IEDs) have become one of the deadliest threats to military personnel, resulting in over 50% of American combat casualties in Iraq and Afghanistan. Identification of IED emplacement is conducted by mission payload operators (MPOs). Yet, experienced MPOs are limited in number, making MPO training a critical intervention. In this article, we implement a Cognitive Engineering Based on Expert Skill methodology to better understand how experienced MPOs identify the emplacement of IEDs for the purposes of improving training. First, expert knowledge was elicited through interviews and questionnaires to identify the types of perceptual cues used and how these cues are cognitively processed. Results indicate that there are many different static and dynamic cues that interact with each other over time and space. Using data from the interviews and questionnaires, an empirically grounded framework is presented that explains the cognitive process of IED emplacement detection. Using the overall findings and the framework, IED emplacement training scenarios were developed and built into a simulation.

1. Introduction

Improvised Explosive Devices (IEDs) have become one of the deadliest threats to military personnel, resulting in over 50% of American combat casualties in Iraq and Afghanistan (Wilson, 2007). An IED is "*an explosive device that is placed or fabricated in an improvised manner; incorporates destructive, lethal, noxious, pyrotechnic, or incendiary chemicals; and is designed to destroy, incapacitate, harass, or distract*." (The National Academies, 2007; pg. 1). IEDs are generally hidden from plain sight (e.g., buried under sand) and come in many sizes, shapes, and forms, making emplaced IEDs difficult to detect (Nixon et al., 2015). Identifying IEDs after they have been emplaced is not only challenging, but has the potential for lethal consequences if the IED is detonated. The IED needs to be detected before detonation.

One approach to detection before detonation is to ideally detect IEDs prior to, or during emplacement. Typically, Mission Payload Operators (MPOs) in the United States Army operate a camera on unmanned aerial systems (UASs) to detect, among other things, the threat of IEDs. By employing the UAS's camera, the MPOs are provided with real-time data imagery. The vast area monitored, the varied terrain, the variety of IEDs (e.g., vehicle-borne, roadside), the dynamic environment, an intelligent adversary, and the multitude of ways explosives can be hidden pose extraordinary cognitive challenges. Expertise is required to accurately analyze and synthesize full motion video data to detect behavioral and environmental signatures associated with IED emplacement. The literature on expertise, and specifically perceptual expertise, provides a useful foundation to understand the knowledge, skills, and abilities of experienced MPOs, with the ultimate objective of using this information to train other MPOs.

An expert can be defined as someone who has distinguished skill in a specific domain. Experts have acquired a skill along with knowledge about how and when to use it. Perceptual-cognitive skill is defined as "*the ability to identify and acquire environmental information for integration with existing knowledge such that appropriate responses can be selected and executed*" (Mann et al., 2007; pg. 457; Marteniuk, 1976). Experts are also able to scan more of the visual field with each fixation, creating a more efficient search

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within a specific domain (Hershler and Hochstein, 2009). The ability to categorize stimuli (e.g., threat vs. nonthreat) and to recognize objects visually or haptically can be modified through experience (Tanaka and Taylor, 1991; Behrmann and Ewell, 2003).

Johnson and Mervis (1997) found that experts perceived different and more subtle features and cues than did novices. This is demonstrated by differences in object-naming by subject matter experts in contrast to novices. Furthermore, Johnson and Mervis (1997) also identified that object category verification is facilitated in experts at more detailed, subordinate levels, but not the basic level of abstraction. That is, an expert would confirm that a red breast is a feature of a robin faster than a novice; however, both respondents would require the same amount of time to confirm that a robin is a bird. These results show how differences in domain specific knowledge can affect how people classify and hence, perceive objects differently (Tanaka and Taylor, 1991).

A specific method in which experts classify and perceive features and cues is through their reliance on robust schemas. Schemas allow an expert to have a mental framework centering on a specific domain. This is particularly true in chess, for which reading the board and remembering past instances of it are an integral part of the game. Expert chess players were able to produce a given chess position or the moves leading to it (Chase and Simon, 1973). Additionally, players of all levels were more accurate in identifying the strategies unfolding between players close in rating to themselves. This research supports the existence of cognitive schemas and demonstrates that experts using schemas at the same level of abstraction provide most insight into each other's assessment of the situation (Reynolds, 1992).

The literature clearly notes that experts afford certain advantages over novices, many of which are directly relevant to an MPOs mission relevant tasks. Unfortunately, experienced MPOs are limited in number (Cooke et al., 2006), making MPO training a critical intervention. Currently, MPO training can be greatly enriched. Training is in many cases limited to rules for using the camera and attending to basic cues such as shape, size, and shadow, with little use of actual video footage and with the remainder relegated to on the job training (Cooke et al., 2010). In other areas, training based on the harnessing of expert skills and knowledge has been very successful. Staszewski (2007) was able to improve detection of the most difficult to find landmines, improving detection rates from approximately 15%–97% percent by tapping into an expert's skills and knowledge and translating that to novices through training.

A method that can be used to develop insights regarding IED emplacement detection is Cognitive Engineering Based on Expert Skill (CEBES). CEBES is an approach that harnesses human expertise for the purposes of training or design. CEBES takes the expert's knowledge and skills in a rich, complex, high risk domain such as landmine detection and suggests that this information can be used to design a 'blueprint' for instruction. The general approach is to: 1), recruit experienced operators and validate expertise empirically; 2), develop an information-processing model of expert skill; 3), use the model to develop instruction for novices; and 4), test the instructional program (Staszewski, 2004).

As previously noted, this approach has been used to examine expertise in landmine detection. IED detection has similarities with landmine detection, such as, location and categorization of non-apparent, spatially-dispersed threats, visuospatial and auditory pattern recognition, and use of indirect or "non-literal" technology-generated signals (Staszewski, 2004). For years, many people thought a fully automated system would help to save the lives and limbs of soldiers and civilians. Despite significant technological advances, human operators have more success detecting landmines than automated systems (Staszewski, 1999). The CEBES approach has resulted in models of expertise that involve human-technology interaction that can be harnessed for training novices (Staszewski, 2004).

Cooke et al. (2010) have effectively used the CEBES approach within the context of IED emplacement (focusing on Stage 1 of CEBES- recruit experienced operators and validate expertise empirically). In their study, researchers examined the cognitive strategies and training methodologies used in detecting IED emplacement threats. Training programs were reviewed and interviews were conducted with experienced MPOs. Through this research, the findings highlight an overall lack of MPO training on threat detection with the primary focus of training being on operation of equipment. Furthermore, there was a heavy reliance on *the job* training with very little feedback thus making it difficult for novices to assess and improve their performance. Also, in this early work some general cognitive strategies were outlined, indicating that MPOs value the knowledge of cultural norms in identifying IED emplacement and used both top-down and bottom-up cognitive information processing to aid in identification strategies. The current work presented in this article uses Cooke et al.'s (2010) work as a foundation to better understand IED emplacement detection strategies, and more specifically to identify perceptual cues used for identification and how those cues are processed.

The aim and objective of this article is to implement the CEBES methodology to elicit knowledge from experienced MPOs on how they identify the emplacement of IEDs. A concurrent goal is to develop training scenarios based on how experts process and identify knowledge in regard to IED emplacement. The first three stages of CEBES direct the study presented in this article. First, in accordance with Stage 1, we conducted a study aimed at better understanding how experienced MPOs process dynamic video imagery to monitor their environments and identify IED emplacement. Through knowledge elicitation sessions, we identify behavioral and environmental cues. Second, in accordance with Stage 2, and using the knowledge gained from Stage 1, we develop an empirically founded framework of IED emplacement detection based on the concept of recognition primed decision making (RPDM) (Klein, 1997). Finally, we utilize Stage 3 of CEBES, and the findings from Stages 1 and 2, to develop scenarios for training simulation of novice MPOs. For a problem in which there is no shortage of technological solutions, but few successes, this leveraging of human skill is a promising approach.

2. Methods: eliciting knowledge from mission payload operators

2.1. Research overview

Our research team traveled to a Military installation to conduct Stages 1 and 2 of the CEBES approach. During this time, members of the research team both *interviewed* and collected *questionnaire* data with the goals of 1) identifying the types of perceptual cues MPOs use during IED emplacement detection, and 2) understanding how cues are used to make decisions during IED emplacement detection. The data were then analyzed in multiple ways to identify the cues and also develop a framework explaining the cognitive processes of IED emplacement detection. Once cues were identified and a framework was in place, the research team then used the findings from each to inform the development of scenarios for training simulation of novice MPOs. Details on the data collection and analysis process follow.

2.2. Participants

Table 1 summarizes the experience of twelve US Army MPOs