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Article *in* Applied Ergonomics · April 2017

DOI: 10.1016/j.apergo.2016.10.012

Nathan J. McNeese
Clemson University

Nancy J Cooke
Arizona State University

Russell J Branaghan
Arizona State University

Applied Ergonomics 60 (2017) 43–51

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

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Nathan J. McNeese [a,*], Nancy J. Cooke [a], Russell Branaghan [a], Ashley Knobloch [a], Amanda Taylor [b]

[a] Arizona State University, United States
[b] Infusionsoft, United States

ARTICLE INFO

Article history:
Received 24 November 2015
Received in revised form
11 October 2016
Accepted 21 October 2016
Available online 6 November 2016

Keywords:
Improvised explosive devices
Expertise
Training

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

* Corresponding author. 150A Santa Catalina, Human Systems Engineering, The Polytechnic School, Ira A. Fulton Schools of Engineering, Arizona State University, Mesa, AZ 85212, United States.

E-mail address: nmcneese@asu.edu (N.J. McNeese).

http://dx.doi.org/10.1016/j.apergo.2016.10.012
0003-6870/

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

Table 1
Location of tour and duration.

Participant	Location	Duration (months)
1- Tour 1	Iraq	11 months
1- Tour 2	Iraq	15 months
2- Tour 1	Mosul	6 months
2- Tour 2	Tikrit	6 months
2- Tour 3	Diwaniya	8 months
2- Tour 4	Kaslu	4 months
3- Tour 1	Baghdad	8 months
3- Tour 2	Kalsu	13 months
4- Tour 1	Kirkuk	15 months
4- Tour 2	Tikrit	12 months
5- Tour 1	Iraq	22 months
6- Tour 1	Iraq	12 months
7- Tour 1	Iraq	15 months
7- Tour 2	Iraq	7 months
8- Tour 1	Iraq	24 months
9- Tour 1	Iraq	36 months
10- Tour 1	Iraq	16 months
10- Tour 2	Iraq	13 months
11- Tour 1	Afghanistan	10 months
12- Tour 1	Iraq	15 months

who participated in interviews and responded to questionnaires. The sample of participants was determined by the availability of individuals at the Military installation who had adequate experience as indicated by the superior officer. Participants had all served at least one tour in Iraq or Afghanistan in which they searched for IED emplacement activities from a UAS platform. The median time conducting IED emplacement detection activity was twenty-four months.

2.3. Procedure

Participants were first interviewed about their experience with IED emplacement detection. This was followed by a questionnaire and a debriefing session. The interview and questionnaires are detailed below.

2.3.1. Interview

Members of the research team interviewed each participant individually for 30–45 min. These were semi-structured interviews that utilized verbal probing techniques. Verbal probing occurs when the interviewer uses a variety of methods to ask the interviewee follow up questions by probing for more information (Willis, 1999). Prior to the interview, participants were asked to fill out a short background survey about their years of experience and amount of training. Personally identifiable information was not collected. Findings from the Cooke et al. (2010) study helped to inform the development of many of the interview questions. Specifically, in the 2010 study, it was identified that cues do play a role in identifying IED emplacement detection, but we wanted to learn more about the specific cues and how they were processed in accordance with each other, time, and space. The interview included the following questions:

- Describe a situation that would be considered extremely suspicious. This situation can be either from experience or a hypothetical situation. Please describe in detail the cues that pertain to this situation.
- Describe an actual situation that may not have been typically considered suspicious, but you were able to detect subtle cues that led to an alert. Please describe in detail the cues that pertain to this situation.
- Do searches for IED emplacement behavior occur more frequently during the day or at night? Please elaborate on the reasons and benefits of one over the other.
- When first examining a new location, where is the first place you would look? Second? Third? Fourth? Please explain why these are most important.
- Please describe some common places to hide IEDs.
- Name at least three things that cause you to focus on a particular area.
- What types of vehicles and/or vehicle behavior tend to signal a possible IED or IED emplacement activity?

Each interview was transcribed and the text was then analyzed using textalyser (http://textalyser.net/), a web based program that provides word and phrase frequency data. This program has been used and validated in previous literature as being effective for understanding properties of textual data (Kol and Scholnik, 2008; Miyazoe and Anderson, 2010). This provided raw word and phrase frequency data for the transcriptions, which was important for shedding light on what experienced MPOs view as perceptual cues. Before the analysis began, the meanings of words and phrases were equated, so that words with the same meaning were counted together. This process includes stemming and lemmatization (Jivani, 2011). In stemming, word roots are kept while removing variations in endings and so on (for example the words buried and bury were considered to have the same meaning). In lemmatization, context of the utterance is considered in determining whether two words have the same meaning (for example trigger and detonator were considered to have equivalent meanings in this context). To illuminate the common categories of words and phrases, words that occurred more than once were analyzed further. Specifically, research team members participated in an affinity exercise (Beyer and Holtzblatt, 1999) by placing related terms into the same pile. Finally, piles were placed into piles until a hierarchy arose and team members agreed that the categorization was at a level suitable for additional analysis.

2.3.2. Questionnaire

Following the interview, participants completed a questionnaire that focused on three different, yet related topics. Pilot interviews suggested that some important cues were static in nature (e.g., a vacant house), whereas other cues were dynamic (recent occupancy of that same house). These were addressed separately in the questionnaire. The questionnaire covered: (1) the types and frequencies of various IEDs (e.g., victim operated, radio controlled, etc.); (2) the importance and frequency of various static cues (e.g., out of place objects, wires crossing a road); and (3) the frequency and importance of various dynamic cues (e.g., the unexplained clearing of pedestrians from an area). Participants were asked to provide ratings of frequency and importance on a scale of 1–5, where 5 equals highest levels of frequency and importance. The ratings were collected from each participant and means calculated for cue frequency and importance.

2.4. Development of framework

By applying a grounded theory approach (Charmaz, 2003) to the interview and questionnaire data, a framework explaining the process of IED emplacement detection was developed. A comparative analysis (Glaser and Strauss, 1965) was iteratively conducted on both data sets (interview and questionnaire) comparing the data within and between the two sets. Specifically, the data from the interview transcripts were segmented and then categorically organized. These data were then compared to the questionnaire data to understand the associations between the two data sets. This analytical methodology allowed us to understand how MPOs used specific cues to process IED emplacement detection, resulting in an empirical framework.

3. Results: perceptual cues and the process of IED emplacement detection

3.1. Perceptual cues during IED emplacement detection

Below, the categorized word frequencies derived from the interviews are presented (Fig. 1).

Fig. 1 illustrates the variety of cues identified during the contextual interview. For example, MPOs were concerned about buried items, which could often be detected from heat signatures. They also focused on vehicles, especially if they were abandoned along the side of a road. Indeed, all kinds of items along the roadside prompted further investigation, simply because roads are common targets for IEDs, and many things, such as trash, mounds, and dead animals, could be used to conceal IEDs. Certain structures were also monitored, especially if they could easily accommodate an IED. These included overpasses, abandoned buildings, and bridges. MPOs placed a special focus on people and behavior that were suspicious in some way. For example, a person using a shovel along a roadside in the middle of the day may simply represent a construction project, whereas using a shovel to dig very quickly in the middle of the night, with the person's "head on a swivel" causes concern. Similarly, loitering people or crowds at unusual times of day or times of year might attract a MPO's attention. Interestingly, a lack of traffic or crowds, when these would usually exist, might be just as telling. Finally, MPOs attended to opportunistic targets, including convoys, chokepoints in traffic, intersections and particularly busy areas. It is of interest that the words shape, size or shadow – the cues MPOs are trained to attend to - do not appear in this list. It seems likely that the information they find most useful is not the information they are provided in training.

3.2. Importance and frequency ratings for static and dynamic cues

Fig. 2 shows the mean frequency and importance ratings for static cues provided by participants in the questionnaire. It shows that the most frequent items include cars broken down on the side of the road, objects beside the road, trash, and tires. The most important items included wire going across a road, something new on a road, and out of place objects. Debriefing interviews suggested that MPOs paid particular attention to important items that were exceedingly rare. They saw this combination as possessing a high level of diagnosticity. One example of this was wire going across the road. As one participant stated, "there is only one reason for a wire to be crossing the road".

Fig. 3 shows the mean frequency and importance ratings of each participant for dynamic cues. The most frequent cues included people carrying items, groups of people and groups of people getting into the same car. The most important were person running a wire, people signaling others to stay away, and a seemingly random clearing of pedestrians. Again, according to the participants, the most diagnostic would be those rare events, which were also deemed important. Examples included a person running a wire, people signaling others to stay away, and random clearing of pedestrians.

3.3. An IED emplacement detection framework

The cues are meaningful on their own, but the framework helps to describe and explain how complicated: 1) the process of assigning meaning to each cue is, 2) the importance of the interactions of certain cues, 3) the importance of space and time in relation to each cue, and 4) the role that recognition primed decision making (RPDM; Klein, 1997) plays in the process of IED emplacement detection. RPDM is a theory of decision-making that postulates that people make decisions based on recognizing the situation and then comparing the perceptual cues of that situation

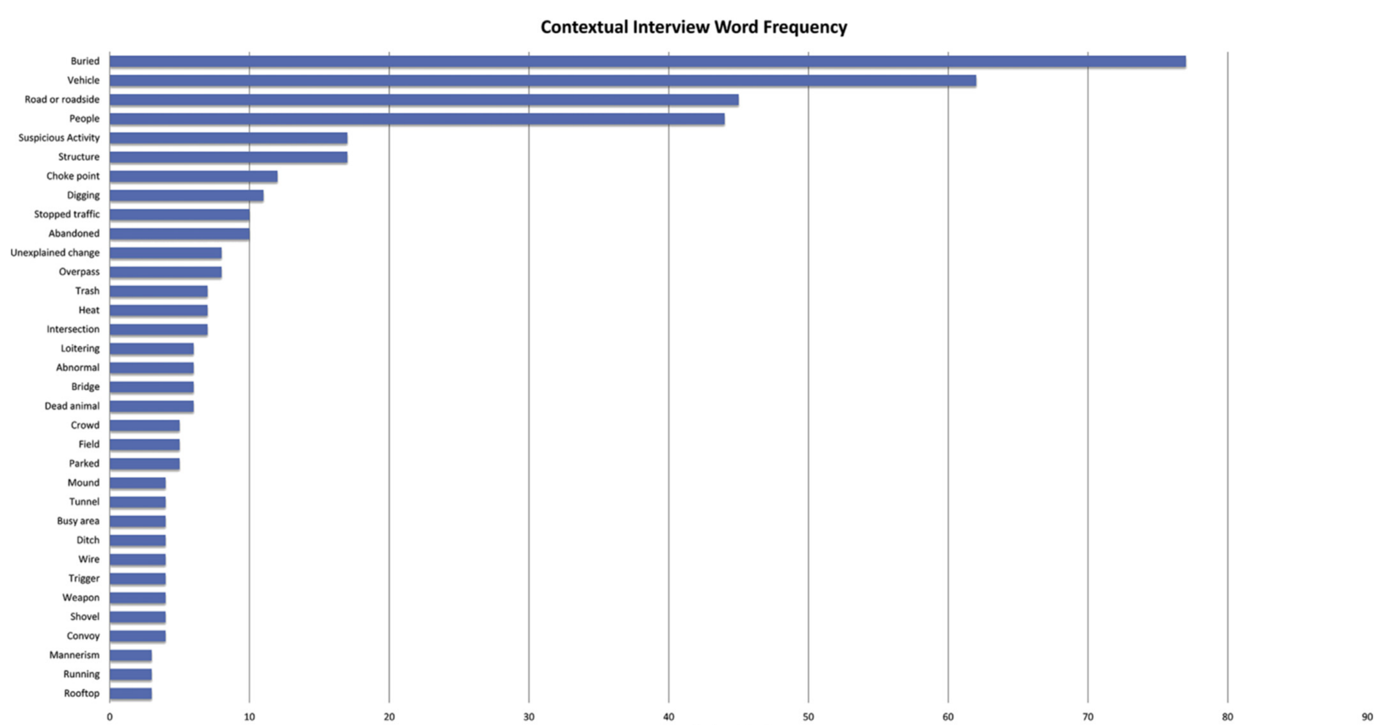

Fig. 1. Word frequency analysis.

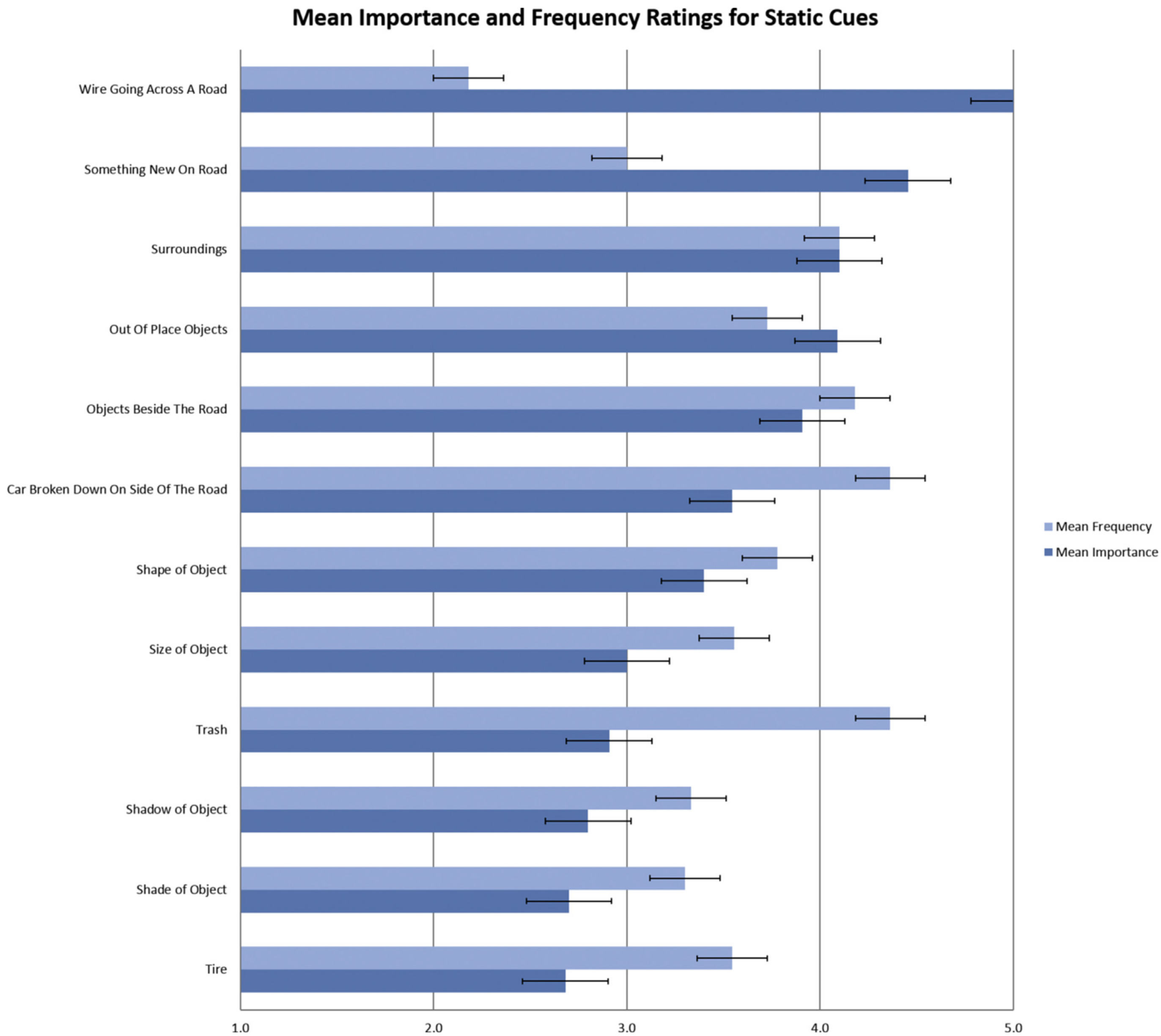

Fig. 2. Importance and Frequency of Static Cues (error bars represent standard error of mean).

with previous experiences.

The grounded theory oriented comparative analysis suggests that three categories of stimuli capture the MPO's attention (Fig. 4). The first, anomalies, refers to unexpected or unexplained changes in context or situations. These situations may involve people (e.g., crowds gathering for no obvious reason), items (e.g., wires or misplaced shovels), vehicles (e.g., abandoned cars), or terrain (e.g., a ditch where there should not be one). The second category, concealments, refers to common places and methods for hiding IEDs. The interview and questionnaire results suggest that IEDs are often concealed in abandoned structures or vehicles as well as in dead animals. The third category, vulnerabilities, refers to those places and situations in which an IED could deliver the most damage. These include military convoys as well as any place traffic is likely to be slowed or stopped.

These cues are critical to the IED emplacement detection framework (Fig. 5). Within each category, the MPO analyzes the importance and meaning of the cues (*Phase 1 of framework)*. The importance and meaning of each cue depends largely on context (space and time). The time of day, day of the week, time of year, and where a cue is spatially located are all characteristics that bring forth either decreased or increased meaning and importance of the cue. In addition to simply taking note of the cues orientation of current time and space, MPOs also look for change in contextual patterns. For example, a stopped vehicle may not raise eyebrows, but the same vehicle stopping at the same place (importance of space) several days in a row (importance of time) may be alarming. A stopped vehicle that has not moved for multiple days may be equally worrisome. Thus, it is not only the cue that is meaningful, but how the cue changes or does not change over time and space that might provide the most value.

Once the MPO has identified the cues and developed associated meaning to each, they then move to a decision-making phase involving situational assessment and pattern matching (*Phase 2 of*

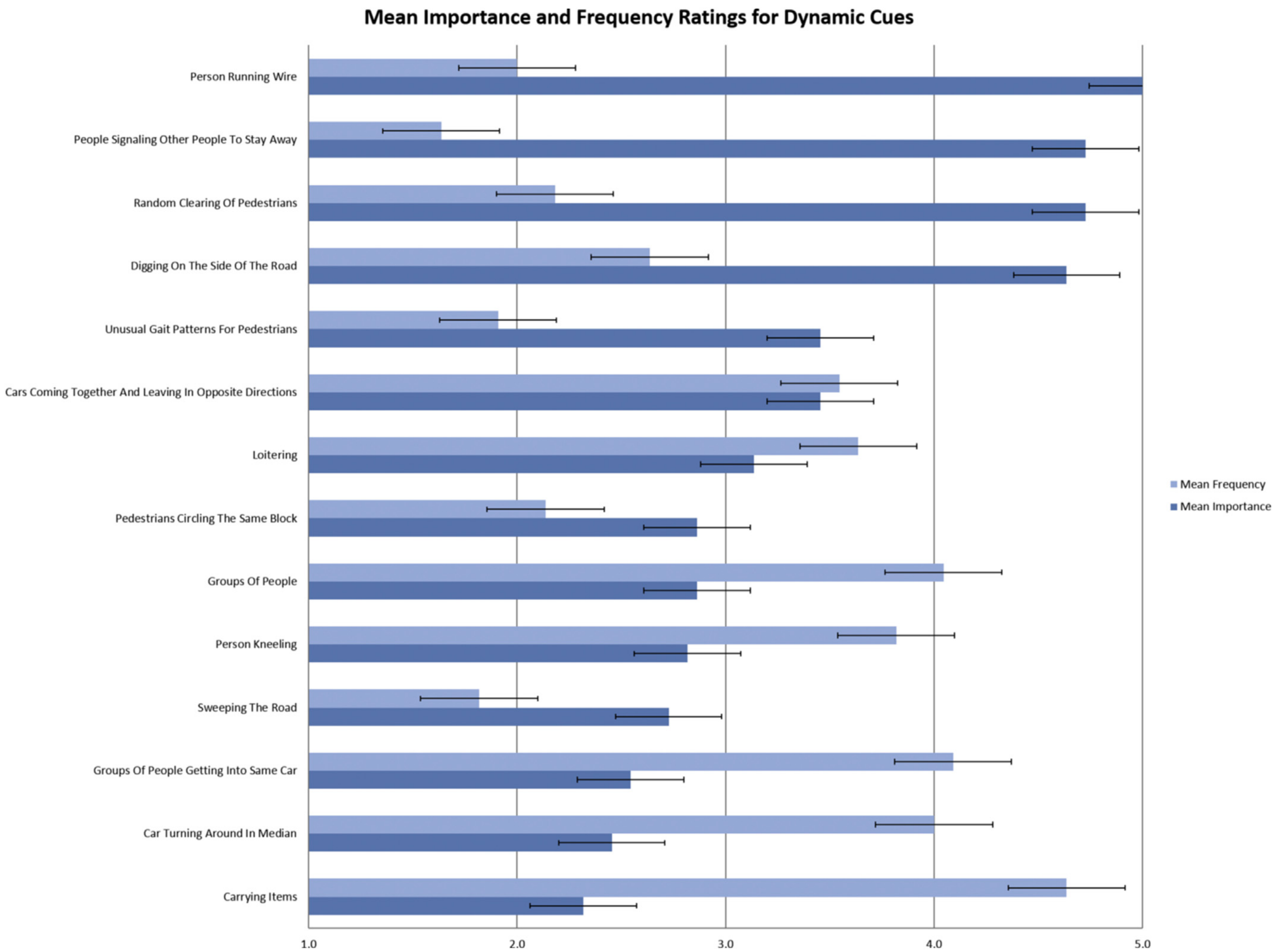

Fig. 3. Importance and Frequency of Dynamic Cues (error bars represent standard error of mean).

framework). During this phase, the MPO integrates the cues to develop a more complete understanding of the situation. This involves comparing and contrasting all of the cues to identify interactions among them. An example of this is the relationship of a bongo, dead animal, and loitering. Each cue on their own might be valuable, but when they are assessed together the MPO knows that the bongo was sitting on the side of the road for a few days with multiple people loitering around it, and then when the bongo left, a dead animal was found underneath it (with an IED in it).

During this phase, the MPOs also rely on experiential pattern matching. This activity is very closely linked to RPDM. MPOs indicated during interviews that they will attempt to recall previous situations that are related to the current situation. Based on which previous situation is most closely aligned to the current situation, the MPO will then adopt the actions they took in the previous situation and apply those to the current situation. This decision-making process routinely happens during IED emplacement detection. Using their previous experiences as a foundation for what is critical or important to the current situation allows them to decide on the actions that need to be taken. Phases 1 and 2 of the framework highly depend on storytelling (Swap et al., 2001) and sensemaking (Weick et al., 2005) activities, taking multiple variables and making sense of them within the context of the situation to help tell a story of what is happening.

Finally, it is important to note that though the MPO moves forward to situational assessment and pattern matching utilizing identified cues as the basis for decision making that this process is highly dynamic. The MPO is constantly updating his or her knowledge corpus specific to cues, meaning that if a new cue is identified this is instantly integrated into situational assessment and pattern matching. Information is constantly changing in this context, so all aspects of the framework are dynamic in regard to the identification and integration of new information being processed.

Depending on the current situation and how it compares to previous situations, the MPO will either: 1) initiate *immediate action*, 2) *further investigate* the situation, or 3) decide that the situation is not critical or important, resulting in *no action*. These final actions are the culmination of the information synthesis that occurs in all of the framework's phases. If the cues are important based on context (space & time), interacting with each other in an alarming way, and the MPOs previous experience indicates that this situation is critical, then the MPO will respond to the threat immediately.

3.4. Developing IED emplacement detection training scenarios using perceptual cues & the framework

The study elicited knowledge from MPO's on IED emplacement behaviors and detection strategies through interviews and questionnaires. The information and results obtained from this study

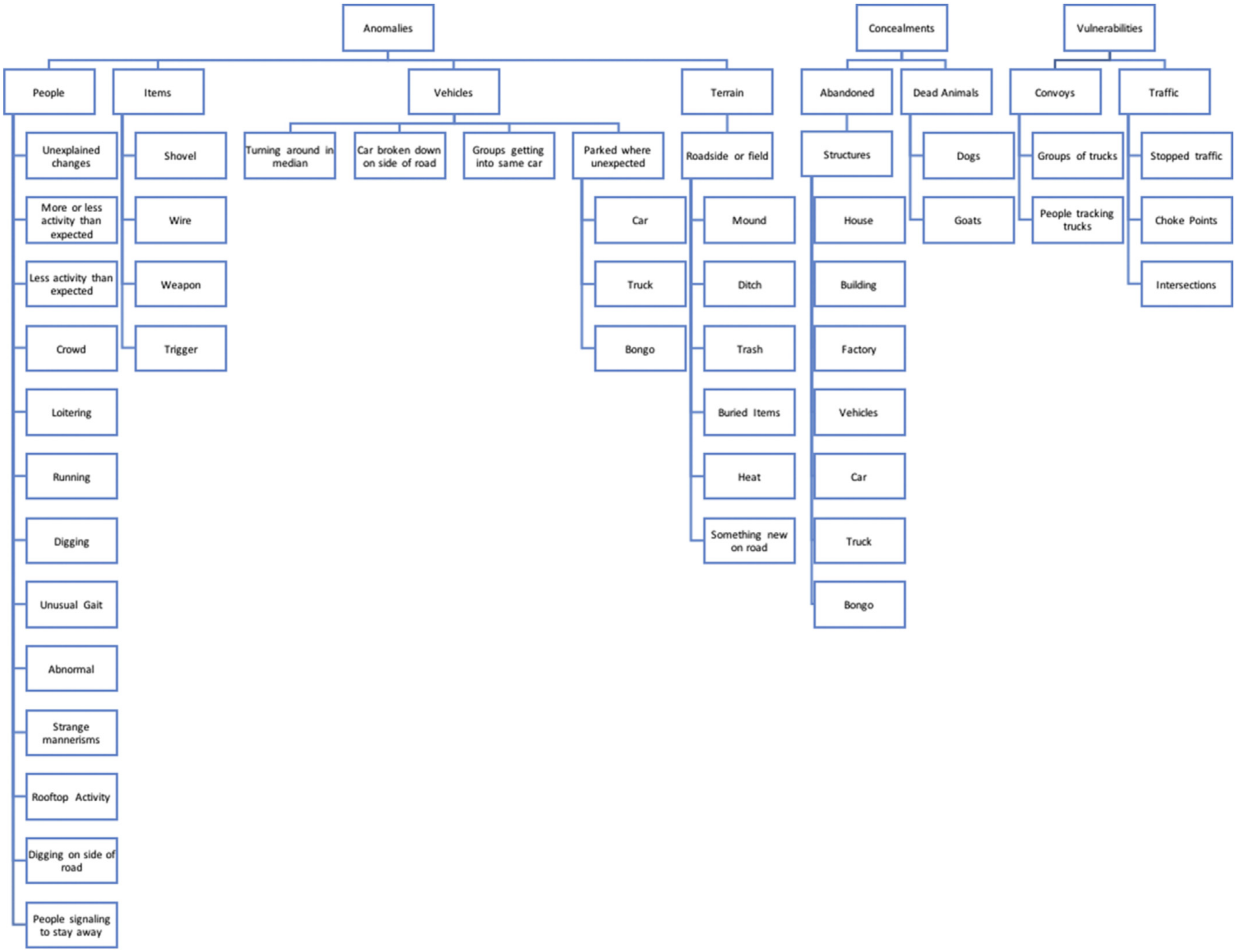

Fig. 4. Categorization of perceptual IED emplacement detection cues.

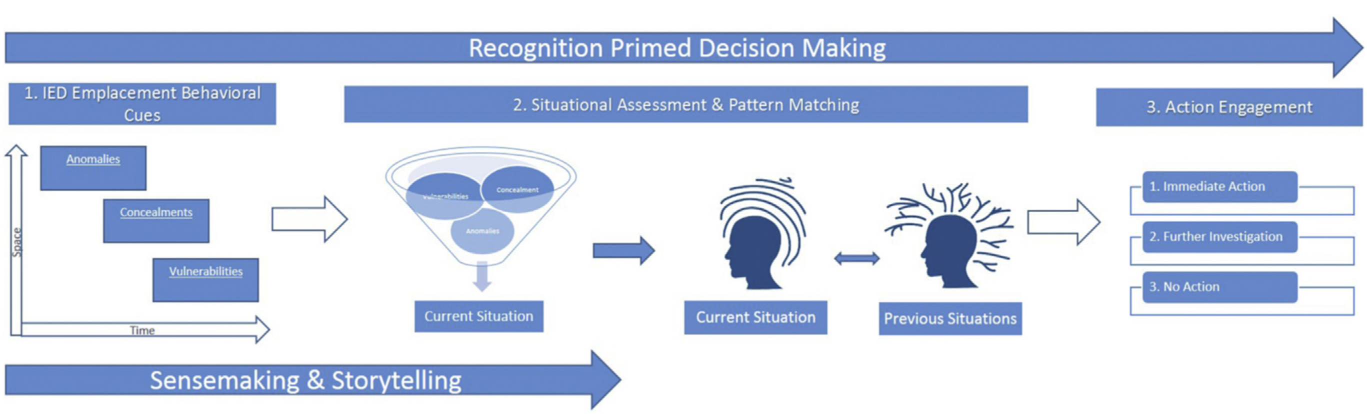

Fig. 5. A framework of IED emplacement detection.

guided the development of scenarios for an IED emplacement training simulation. Specifically, perceptual cues of IED emplacement detection and the framework presented in this article are critical to developing accurate and meaningful scenarios for training simulation. We view the framework as a hypothesis regarding the process of IED emplacement detection. Critical to this process is the processing of multiple complex cues, the understanding of their interrelatedness, and the development of the background sociocultural knowledge to provide context for these cues. Simulation scenarios of carefully composed cue combinations could provide the deliberate practice that is informed by expertise (Ericsson et al., 1993). That is, rather than developing expertise by hours of on the job training that may turn up very few distinct cues in a small number of contexts, deliberate training could provide a very rich array of cues and contexts and hypothetically allow trainees to reach higher levels of expertise in a shorter amount of time.

Using the static/dynamic perceptual information cues and the framework, three scenarios were developed and incorporated by an interdisciplinary team into a simulation that generates full motion video. The process began with storyline creation, which directly integrated the aforementioned cues into the scenarios. In addition to utilizing the appropriate cues, cultural accuracy was addressed through research on the area in which the scenario took place. This process was important in establishing validity, reliability, and accuracy of each scenario. For example, a small Iraqi town has culturally specific characteristics such as patterns of daily activity (traffic, market, prayer, etc.), dress, animals, landscape, etc. The goal of the scenarios, and ultimately the simulation, was to display normal patterns of life embedded with the perceptual cues indicating anomalies.

A three-part storyline was created that spanned several months in the fictional Middle Eastern town of Nramas. Each scenario was 48 min in length and comprised of four twelve-minute segments. Each part represents a different time of day (morning, mid-day, late afternoon, and night). The scenarios occurred in chronological order spanning several months. As noted before, one of the goals of developing these scenarios was to embed the perceptual cues in the most realistic setting possible to allow for learning. The aforementioned study with MPOs provided the basis for choosing cues. As a result, a cue database was developed (Tables 2 and 3). The cue database consists of all cues, both static and dynamic, as previously identified through the interviews and questionnaires (see Figs. 1–4). Cues are organized by type (static or dynamic), and by category (automobile, house, transit system, human/animal, human behavior, change in topography). Each cue has a numerical code assigned to it, which was used to track and identify which cues were written into the different parts of the scenarios. Cues that have an asterisk next to them in the cue databases indicate that these were additional cues suggested during our discussions with SMEs.

Table 2
Static cue database.

Static Cues		Code
Automobile	Parked car (wonky park job)	1
	Multiple cars at one house	2
	Abandoned cars	3
	Lack of work trucks	4
	Car parked in the same spot for a long time	5
	Bongo trucks	6
Houses	Vacant houses	7
Transit System	Tunnels	8
	Bridges	9
	Overpass	10
	Abandoned Street	11
Human/Animal	Dead animal	12
	Vacant Market	13
Change in Topography	Mound	14
	Marked spots	15
	Obvious IED	16
	Disturbed Earth*	17

Cues that have an asterisk next to them in the cue database indicate that these were additional cues suggested during our discussions with SMEs.

Table 3
Dynamic cue database.

Dynamic Cues		
Automobile	Convoys	18
	Throwing something out of car	19
	Stopped traffic	20
	Avoiding area on road*	21
	Inappropriate speed*	22
Transit System	Stopped traffic	23
	Choke points	24
Human Behaviors	People patrolling/circling	25
	Digging	26
	Children	27
	Carrying objects	28
	Pacing	29
	Running	30
	Man looking around	31
	Wandering	32
	Adding to trash heap	33
	Moving something back and forth	34
	Throwing something out of car	35
	Heat signatures	36
	Hanging around culverts	37
	Moving long objects	38
	Moving near the road	39
	Scouting with binoculars	40
	Patrolling	41
	Carrying shovel	42
	Peaking through walls on the side of the road	43
	Keeping pace with a convoy	44
	Shadowing military personnel	45
	Men working along road and looking around	46
	Men working along road and crouching	47
	Men working alone road and digging	48
	Walking slower than others	49
	Walking with one arm moving and the other not	50
	People working off road	51
	Walking funny (heavy on one side)	52
	Digging without breaks*	53
	People gathering*	54
	Digging in high traffic area*	55
	Digging without clear purpose*	56
	People clearing/avoiding area*	57
	Behaving differently from majority*	58
	Carrying backpack and shovel*	59
	Lookout role*	60
	Suspicious cell phone/radio use*	61

Cues that have an asterisk next to them in the cue database indicate that these were additional cues suggested during our discussions with SMEs.

Transforming the storyline into a full motion simulation was achieved by writing them into a Modern Air Combat Environment (MACE) and Virtual Reality Scene Generator (VRSG). MACE is a program designed for aerial combat, therefore it was not equipped to do all of the things necessary for this scenario, so further development was required. Finally, drafts of the scenarios were analyzed by subject matter experts (SMEs) at The Air Force Research lab over the course of four meetings. Suggestions and comments provided by the SMEs resulted in multiple revisions of the scenarios.

This simulation is the first step toward developing a training systems for future MPOs that focus on how to detect the suspicious behavioral cues associated with IED threats. Future work will involve participant testing and iterative development.

4. Discussion & concluding remarks

The knowledge elicitation activities conducted in this study revealed interesting characteristics of perceptual expertise associated with IED emplacement detection. In particular, the cues that experienced MPOs relied on were more complex than simple features like shape or color typically used in laboratory tasks and presented in their own training. Some of the cues were only meaningful in a particular sociocultural context (e.g., absence of work trucks may only be notable in a place in which they are commonly found) or in a dynamic spatio-temporal context. Many of the cues were played out over time. Some played out over short periods of time (e.g., throwing something out of a car) and others played out over longer periods of time (e.g., throwing something out of a car last week and digging in that spot this week). Storytelling also played a role in the identification of threat. Cues may only be meaningful in a particular sequence that corresponds to a story. Clearly the cues are not simple and would require significant experience to learn.

Based on earlier interviews (Cooke et al., 2010), it was revealed that MPO training did not touch upon the kind of perceptual information identified in this study. This type of information tended to be learned on the job – in theatre. Further, there seemed to be inadequate feedback to the MPOs who would identify threats. In many cases they never found out whether they identified a true threat or a false alarm. This type of feedback would be invaluable for cue learning. The addition of cue-specific training and the introduction of feedback on decisions made is likely to greatly strengthen MPO expertise and requires little in the way of advanced technology. The full motion video simulation is being developed to address limitations of current training and provide both cue-specific training and feedback.

Future work will require verification of the cues embedded in the simulated full motion video and then development of a training program that centers on those cues and the video. Previous perceptual learning research indicates that cues can be directly taught, however, these cues are much more complex and contextually dependent than cues taught in previous research (Staszewski, 1999). The amount and type of guidance required from an instructor while a student observes the video simulation is an open research question. Beyond the cues there is significant sociocultural knowledge that is needed to appropriately interpret them. This is also something that can be trained and even documented by individuals as they are on the job. Documentation of specific features, habits, and people of a geographic region would be helpful as handoffs occur.

In terms of perceptual expertise, this research has identified truly complex cues that unfold over time and that require integration with sociocultural knowledge. These kinds of rich and dynamic cues are probably not rare in real-world contexts. Uncovering them in this study amplifies the need understand work and in this case, expertise in context.

As highlighted in this article, the process of IED emplacement detection is very complicated. MPOs must understand complex cues, the spatio-temporal and cultural context, changes in that context, and then must integrate that information in a meaningful way to take action. Training aimed at this process has the potential to leverage human expertise that together with technological developments can have positive impact on the threat of IEDs.

Acknowledgements

Thanks to Cade Bartlett, Michael Dinan, Bryant Foster, Bruce Hunn, James Staszewski, Kathleen Stefanik, and Mistey Taggart for their assistance in data collection and simulation development. We would also like to acknowledge the support of the AZ Science Foundation: SFAz - Human Factors: Aerospace & Defense Initiative - Partnerships in Innovation grant and a contract from L3 Communications Corporation (WRSTPCERI38_3.6.6).

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