Defence Research and Development Canada
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Summary of findings on visual scanning and assessment of IED threats by soldiers in operational environments

Jerzy Jarmasz

Defence R&D Canada
Technical Memorandum
DRDC Toronto TM 2010-197
December 2010

Canada

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In conducting the research described in this report, the investigators adhered to the policies and procedures set out in the Tri-Council Policy Statement: Ethical conduct for research involving humans, National Council on Ethics in Human Research, Ottawa, 1998 as issued jointly by the Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council of Canada and the Social Sciences and Humanities Research Council of Canada.

Abstract

Defence Research and Development Canada (DRDC) Toronto has been conducting a research project investigating various training tools designed to support visual Improvised Explosive Device (IED) threat assessment and awareness skills (IED Awareness Training project, sub-project 12rr03 of the Omnibus Counter-IED Technology Demonstration Project), in order to support the Canadian Forces (CF) Counter-IED efforts to protect Canadian soldiers involved in the conflict in Afghanistan. During this project, which focuses on individual perceptual judgment and situation awareness, as well as team situation awareness and decision making skills, we developed an understanding of how soldiers with operational experience in IED threat environments visually scan and assess their environment for IED threats. This report presents a conceptual model of the "IED Awareness" process, gives an overview of the research DRDC Toronto has conducted in developing this model, and provides a number of recommendations for enhancing the CF's Counter-IED training efforts, both for the current Afghanistan conflict and for future conflicts, as it is widely assumed that IEDs will play a role far beyond the current Afghanistan theatre of operations.

Résumé

Afin de soutenir les efforts de lutte aux dispositifs explosifs de circonstance (IED) des Forces canadiennes visant à protéger les soldats canadiens participant au conflit en Afghanistan, Recherche et développement pour la défense Canada (RDDC) Toronto mène un projet étudiant divers outils de formation conçus pour soutenir l'évaluation visuelle des menaces posées par les IED et les aptitudes à en percevoir les indices (projet de sensibilisation aux IED, sous-projet 12rr03 du grand projet de démonstration de technologies sur les moyens de lutte contre les IED). Ce projet, qui met principalement l'accent sur le jugement perceptuel individuel et la connaissance de la situation, ainsi que sur la connaissance de la situation de l'équipe et les aptitudes à prendre des décisions, nous a permis de mieux comprendre comment les soldats ayant une expérience opérationnelle dans des milieux où les IED posent des menaces parcourent du regard ce qui les entoure et évaluent ces menaces potentielles. Le présent rapport présente un modèle conceptuel du processus de « perception des IED », donne un aperçu de la recherche menée par RDDC Toronto afin d'élaborer ce modèle et fournit un certain nombre de recommandations visant à accroître les efforts de formation en matière de lutte aux IED des FC, tant dans le cadre du conflit actuel en Afghanistan que pour tout conflit futur, car il est généralement admis que les IED continueront de jouer un rôle bien après la fin de conflit actuel en Afghanistan.

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Executive summary

Summary of findings on visual scanning and assessment of IED threats by soldiers in operational environments

Jerzy Jarmasz; DRDC Toronto TM 2010-197; Defence R&D Canada – Toronto; December 20100.

Introduction or background: Defence Research & Development Canada (DRDC) Toronto has been developing training tools for improving "Improvised Explosive Device (IED) Awareness" under the Omnibus Counter-IED Technology Demonstration Program (TDP) project. In order to understand the specific skills the tools need to support, the IED threat assessment process in experienced convoy crews and the characteristics of IED incidents were investigated. The methods used included laboratory studies, a task analysis, an analysis of IED attack patterns in theatre (performed by DRDC CORA), and literature reviews.

Results: Taken together, our various studies suggest that (1) IED Awareness is a judgement & decision (J/DM) making task, likely reliant on substantial tacit knowledge and pattern matching mechanisms using complex and ambiguous cues; (2) the J/DM process seems to make use of two distinct types of information, cues that suggest good locations for an IED emplacement, and cues related to the real-time likelihood of an attack at a given location; (3) the cues involved in the "IED Awareness" J/DM process are complex, ambiguous, multimodal, and dispersed in time and space, such that effective IED Awareness requires good team situation awareness; and (4) more experienced troops judge IED emplacements and threats more conservatively than troops with no operational experience in IED environments, while displaying some signs of increased mental effort during these judgements, suggesting that they are not simply less concerned about IED threats due to their deployment experiences.

Significance: The findings have implications for Counter-IED training, some of which we have implemented in our training tools. They also lead us to make a number of recommendations for counter-IED training in the Canadian Forces, namely: improve support for perceptual learning skills; improve support for group situation awareness skills; generalize the video-based perceptual learning approach we have demonstrated to other theatres and other "irregular" threats; collect high-quality video from operational theatres for training (and other) purposes; and conduct more research on how soldiers scan for IED threats

Future plans: The results described in this report will continue to inform the development and refinement of the training tools developed by the project. Some of the further research recommended in the report will be conducted to the extent allowed by project resources.

Sommaire

Sommaire des conclusions concernant le balayage visuel et l'évaluation que font les soldats en milieux opérationnels quant aux menaces posées par les IED

Jerzy Jarmasz; DRDC Toronto TM 2010-197; R & D pour la défense Canada – Toronto; décembre 2010.

Introduction : Dans le cadre du grand projet du Programme de démostration de la technologie (PDT) sur les moyens de lutte contre les dispositifs explosifs de circonstance (IED), Recherche et développement pour la défense Canada (RDDC) Toronto a conçu des outils de formation pour améliorer la « perception des IED ». Afin de comprendre les aptitudes précises que les outils doivent soutenir, la façon dont les équipages de convoi chevronnés évaluent les menaces que posent les IED et les caractéristiques des incidents liés aux IED ont été examinés, notamment grâce à des études en laboratoire, à une analyse des tâches, à une analyse des caractéristiques des attaques par IED dans le théâtre (effectuée par RDDC CARO) ainsi qu'à des études documentaires.

Résultats : Nos diverses études laissent entrevoir que (1) la « perception des IED » est une tâche liée au jugement et à la prise de décision (J/PD), qui nécessite probablement une grande connaissance tacite et des mécanismes de filtrage basés sur des indices complexes et ambigus; (2) le processus de J/PD semble être fondé sur deux types de renseignement distincts, les indices qui permettent de déterminer ce qui constituerait de bons endroits où placer des IED et les indices quant à la probabilité en temps réel d'une attaque à un lieu donné; (3) les indices liés au processus de J/PD de la « perception des IED » sont complexes, ambigus, multimodaux et répartis dans le temps et l'espace, ce qui fait qu'une perception efficace des IED exige une bonne conscience de la situation d'équipe; et (4) les troupes ayant plus d'expérience jugent l'emplacement des IED et les menaces que ces derniers posent avec plus de circonspection que les troupes sans expérience opérationnelle dans des milieux où il y a des IED, tout en montrant certains signes d'effort mental accru pendant le processus de jugement, ce qui laisse entendre qu'elles ne sont pas moins préoccupées au sujet des menaces posées par les IED en raison de leur expérience de déploiement.

Signification : Les conclusions ont des incidences sur la formation à la lutte aux IED, dont certaines ont été prises en considération pour nos outils de formation. Elles nous ont également amenés à formuler un certain nombre de recommandations pour la formation à la lutte aux IED dans les Forces canadiennes, soit ce qui suit : amélioration de l'appui quant aux aptitudes d'apprentissage perceptuel; amélioration de l'appui lié aux compétences relatives à la connaissance de la situation de groupe; généralisation de l'approche d'apprentissage perceptuel à l'aide de vidéos dont nous avons fait la démonstration dans d'autres théâtres et pour d'autres menaces « irrégulières »; tournage de vidéos de grande qualité dans les théâtres opérationnels notamment aux fins de formation; et recherches supplémentaires sur la façon dont les soldats évaluent les menaces que posent les IED.

Plans futurs : Les résultats décrits dans le rapport continueront de guider le développement et le perfectionnement d'outils de formation conçus dans le cadre du projet. Certaines recherches

recommandées dans le rapport seront effectuées dans la mesure où les ressources du projet le permettent.

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Acknowledgements

The author wishes to acknowledge the team of the Improvised Explosive Device (IED) Awareness Training project, specifically those who have been involved in designing and developing the Environment Familiarization and Indicator Trainer (EFIT), the video-based research tool that drove much of the research reported on in this document, and analyzing data from the studies: Dr. Jocelyn Keillor (who conducted the original study on visual scanning patterns in soldiers searching for IEDs), Mr. Matthew Lamb (who designed the first EFIT prototype), Dr. Vladimir Zotov, Ms Andrea Hawton, Ms Rachel Spiece, Ms Brenda Fraser, Sgt Dorothy Wojtarowicz, MCpl Elena Scourtoudis, MCpl Nick Field, Cpl Nivin Joseph, Cpl Phil Mach, Cpl Ryan McHugh. This work also benefited from the IED attack analysis support provided Dr. Philip Eles and Sgt Darcy at DRDC Centre for Operational Research and Analysis (CORA). This work is also deeply indebted to all the Canadian Forces (CF) soldiers (from The Governor General's Horse Guards, The Ontario Regiment RCAC, 7th Toronto Regiment RCA, 32 Combat Engineer Regiment, The Queen's Own Rifles of Canada, The Grey and Simcoe Foresters, The Lorne Scots Regiment, The Toronto Scottish Regiment, and 25 Toronto Service Battalion) who kindly gave their time and shared their experiences and lessons learned from Afghanistan by watching and annotated hours upon hours of video from theatre, from which we then selected appropriate videos and developed the teaching points included in the EFIT prototypes.

Finally, we thank the CF units who supported the studies and the work described in this report with their time, expertise and personnel: 1 and 2 Combat Engineer Regiments, 1st and 2nd Battalion, Princess Patricia's Canadian Light Infantry, 1st and 3rd Battalion, Royal Canadian Regiment, the Tactics School at Combat Training Centre (CTC) Gagetown, and the Counter-IED Task Force.

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1 Rationale and Background

As part of Defence Research and Development (DRDC)'s Counter-Improvised Explosive Device Technology Demonstration Program (C-IED TDP) project, DRDC Toronto has been investigating training tools to improve soldiers' skills for IED Awareness (IED Awareness Training, sub-project 12rr03 of the C-IED TDP). For the purposes of this document, the concept of "IED Awareness," patterned after the mine awareness that is currently taught in the Canadian Forces (CF), involves more than simply the ability to visually identify IEDs. It also entails the ability to respond appropriately to IEDs themselves, as well as identifying the environmental conditions (terrain, human behaviour) that favour or enable the emplacement of IEDs. It also involves recognizing environmental cues suggesting that an IED is likely to have been emplaced, or is in the process of being emplaced, in a given location. In more military terms, this involves the ability to assess the operational environment for locations insurgents are likely to use for IED emplacements as well as the threat of an IED attack at a given time and place. The focus of this project has been on mounted operations as to date the majority of IED strikes on CF troops in Kandahar (Afghanistan) have taken place during convoys. As the various technologies that have been introduced to help soldiers detect and avoid IED attacks are unable to protect soldiers in all circumstances (Zorpette, 2008), soldiers are still required to assess IED threats using their own senses and abilities, and thus, it is important for CF soldiers deploying to Afghanistan to have solid IED Awareness skills.

At the time the project was being stood up (2006 - 2007) the true nature of the IED threat was emerging, and little was known about the IED Awareness skills of experienced soldiers, or whether or not there was even a skill to train in the first place. The CF's Land Force Doctrine and Training System (LFDTS) was also starting to grapple with adapting predeployment training to address the IED threat, and thus there was little formal or official guidance from military subject matter experts (SMEs) on this issue. Thus, we set out to investigate how soldiers with experience operating in an IED threat environment actually visually inspect or scan their environment for signs of possible IED attacks.

From a theoretical point of view, the act of assessing IED threats in an operational environment corresponds to the judgment and decision making tasks from the cognitive psychology research literature (though distinct, judgment and decision making share many features and thus are often referred to together as J/DM). J/DM (Judgement and Decision Making) is generally understood in terms of the following process (Wickens & Hollands, 2000):

1. Collection of data from the environment (called cues) via perceptual and attentional mechanisms,

2. integrating these cues into a "picture" of the situation (often referred to as Situation Awareness, or SA, in many operational fields) using reasoning processes and knowledge developed through experience, and

3. selecting or determining the meaning of a particular aspect of the environment (judgment) or an appropriate course of action to take in response to the environment (decision making), again using reasoning processes and knowledge developed through experience.

Researchers have determined that there are many variations that naturally occur at each of the stages of the J/DM process. For instance, it is known that the cues entering the J/DM process can

be of different forms (they can come from different sensory modalities, they can be abstract and conceptual, or concrete and perceptual, etc.). The mechanisms for integrating the cues into a coherent "picture" of the situation can also take many forms, from analytical, rational processes that can be easily explained (so-called explicit knowledge), to intuitive processes that a person may not even be aware he/she is using (so-called tacit knowledge). Finally, note that most psychological research on J/DM has occurred in laboratory studies where cues, and the relationship between them and the resulting decisions or judgments, tend to be consistent, constrained and easily expressible. Real world J/DM tasks, however, often include inconsistent, poorly-defined or vague cues, and cue integration and cue-to-decision relationships that can be subjective, variable and difficult to explain. It has also been established that, for real-world tasks, operators often progress from the "novice" stage of trying to apply explicit rules for identifying and integrating critical cues from the environment, and responding to those cues, to the "expert" stage of automatically "picking out" and identifying ambiguous and complex patterns of cues, which then seem to intuitively trigger appropriate patterns of responses, but nevertheless can be applied flexibly as needed in experienced operators (Klein, 1997; Wickens and Hollands, 2000).

Viewing IED Awareness as a J/DM process, the cues would be the combat indicators, as well as cultural and terrain features that favour IED attacks (Department of National Defence, 2006) and intelligence from mission briefs or reports coming over the radio net. Thus, IED Awareness becomes a matter of soldiers integrating these diverse "cues" into a "picture" or "situation awareness" of IED threats; this "picture" is used to assess the situation and to decide on appropriate actions. The issues for developing training for IED Awareness become: identifying the cues required to make the judgment; determining how they are (or should be) integrated and used to determine appropriate situation assessments (judgments) and courses of action; finally, determining how to teach troops these cues and the rules or procedures for integrating them and translating them into action.

We have observed over the course of the project that the CF already includes a significant amount of training with respect to the J/DM processes of IED Awareness, with portions of doctrine and classroom instruction already devoted to imparting knowledge of IED indicators, terrain and cultural characteristics associated with attacks, and TTPs regarding actions to take on IED attacks. Yet our knowledge of threat and target assessment and detection in other areas (e.g., search and rescue, combat identification) and our discussions with SMEs led us to believe that there was a significant aspect of IED Awareness that was much more in line with the poorly-defined J/DM contexts mentioned above and that likely relied on intuitive, tacit perceptual knowledge and experiences that are difficult to verbalize, and thus to capture in a classroom context. Hence, this was our motivation to supplement classroom instruction with more experiential-type training aids that would be more conducive to imparting the more perceptual, intuitive and tacit knowledge that the current classroom training tools may not be able to provide.

The following sections briefly summarize our observations and findings in working with SMEs to understand how soldiers with operational experience actually assess threat. They also present our attempts to characterize their knowledge in a manner that could be imparted to trainees and a number of recommendations regarding C-IED training in the CF following from our observations.

2 Overview of DRDC Toronto Research on IED Awareness

2.1 Building a conceptual model/understanding of IED Awareness

As discussed in the introduction, assessing IED threats in an operational environment can be understood as a J/DM task. Our discussions with SMEs suggest that the processes at work in IED threat assessment judgments are to a large extent of the automated, intuitive and pattern-recognition-based kind typically associated with expert performance, as well as being of the "ill-defined" type associated with many real-world tasks. For instance, many soldiers we spoke to felt they had developed an intuitive sense (which was often called "spidey sense") of when things were amiss or abnormal in the environment leading up to an IED incident. In these situations, soldiers would experience a strong subjective sense of something being out of place, or of imminent danger, often accompanied by physiological effects (e.g., a feeling that their "hair was standing on end"), but without being able to put into words what triggered this impression. In fact, in speaking to us about possible indicators of IEDs, soldiers would sometimes disagree about the relevance of some indicators, or would state that while some indicators were sometimes associated with IED emplacements, they were not consistently so. This makes it difficult to identify what cues (especially visual IED indicators) are being picked out by soldiers experienced at making IED threat judgments, and by extension, to determine what information needs to be included in training regarding IED Awareness skills.

Nevertheless, IED threat assessment is not entirely automated and unconscious. We have been able to identify at least some of the cues (indicators, terrain features), and understand some of the ways these cues are integrated to produce IED Awareness. To better understand the information available to soldiers for making judgments about IED threats, we started by observing videos of Afghanistan terrain collected informally from CF convoys. All materials were unclassified and no operationally sensitive situations were represented. We also made use of an analysis of IED attack patterns based on IED incident reports from the Canadian area of operations (AO) in Afghanistan between 2007 and 2009 (Eles, 2009). This analysis identified environmental patterns (terrain features, road types, etc.) commonly associated with major IED attack types that could serve as cues to the IED Awareness process.

To better understand what information experienced soldiers use during IED threat assessment, and how it is integrated it into a "picture" of IED threat, we used various methods to elicit information from soldiers with deployment experience in Afghanistan. We asked soldiers to view videos of Afghanistan terrain taken from CF convoys (unclassified, not depicting any operationally sensitive incidents) and recorded their assessment of the videos for potential IED indicators or threat cues. We also used a formal interview process, called a cognitive task analysis (CTA), to determine the information requirements for convoy crews assessing IED threats during mounted operations (Bruyn Martin & Karthaus, 2009). These various approaches confirmed that, while assessing IED threats in operational environments is difficult, and seems to rely on the intuitive detection of anomalies mentioned above, soldiers do make use of the terrain characteristics identified in the analysis of IED incident reports (Eles, 2009). They also make use of indicators related to patterns of human activity specific to the AO, often referred to as the "pattern of life" in the area, as well as many other indicators mentioned in CF C-IED doctrine, combined together to form a holistic assessment of threat. This work also supported the importance of teamwork and crew SA in maintaining good IED Awareness in a convoy.

Based on these different sources of information, we have developed a model of IED Awareness and threat assessment, suggesting how different types of information get combined (see *Figure 1*). The model separates fairly stable and enduring information about how the local environment may favour IED emplacements from more fluid and variable threat information (indicators, intelligence) that can help assess the likelihood that a potential emplacement site may be used in an attack at a given moment.

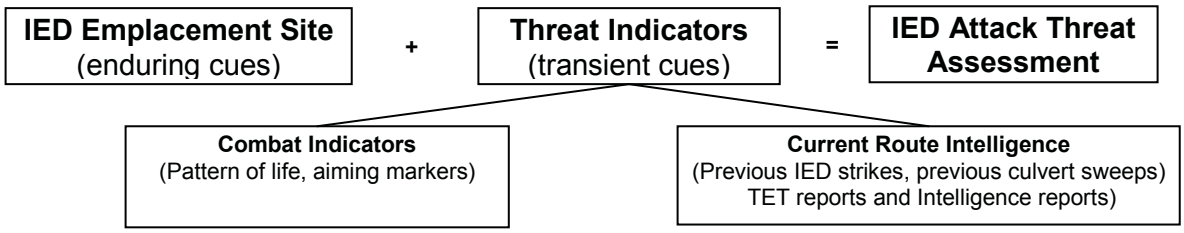

Figure 1: Model of IED Awareness and threat assessment

Based on our analysis, IED emplacement information is mainly a function of the physical aspects of an environment, and the opportunity it provides for staging an IED attack with respect to basic military tactics. Thus, it can be considered more objective, or at least, more readily agreed upon by SMEs, than the threat indicator information. This type of information is not only likely to be more contextually-dependent and influenced by cultural factors than cues relating to IED emplacement; it is also more likely to be ambiguous and variable. It will likely require more in-theatre experience to learn, and more reflection and mental effort to assess, than the physical features related to IED emplacement locations. Thus, this model may permit the separation of IED Awareness-related information into modules requiring potentially different levels of effort to learn, and to construct training materials tailored to supporting different aspects of this knowledge. We have used this model to construct the instructional content we have built into some of the training tools developed in our project (see overview in Jarmasz et al., 2010). Further below we discuss a study we conducted to validate one of these training tools, focusing on its implications for understanding how troops actually assess IED threats in operational settings.

2.2 Understanding how SMEs visually scan the environment for IED threats

Before we developed the conceptual model of IED Awareness discussed above, we sought to gain a preliminary understanding of how experienced soldiers actually scan their environment for IED threats by studying their eye movement patterns. In 2006 – 2007, we conducted a study that compared the eye movements of soldiers who had recently returned from a deployment to Afghanistan (infantry and combat engineers) and civilians who were given basic instruction on searching for IED indicators (Keillor et al., 2007). Both groups of participants were asked to view videos of Afghanistan terrain recorded from a civilian convoy and to identify scenes in the video that denoted to them a higher likelihood of IED threat. The study showed that soldiers paused their eyes more frequently to take in information (a mechanism known as a "fixation"), and made smaller eye movements (known as "saccades") than did the civilians. An inspection of the participants' eye movements superimposed over the videos suggested that the soldiers with experience in IED environments inspected objects (vehicles, roadside objects, etc.) that could

conceivably contain IEDs than the civilians, who seemed to visually inspect the horizon more than nearby objects (a phenomenon consistent with the research literature on eye movements while driving; see Underwood, Chapman, Brocklehurst, Underwood & Crundall, 2003). It is also known that people make more fixations when they are engaged in a cognitively difficult or stressful visual task, in particular with static images (though this effect has not been clearly replicated with moving stimuli such as those found in videos; see Ikehara & Crosby, 2005, for a discussion). Together, these effects suggest that soldiers with operational experience in IED threat environments scan their environments for IED threats more systematically and more carefully than people without such experience.

We conducted a follow-up study in 2008 - 2009 in which soldiers with recent experience in Afghanistan were compared to reservists who had not been deployed to Afghanistan, in order to ensure that the findings of the first study reflected operational experience rather than merely a military - civilian difference (Zotov et al., 2009). Participants were again asked to view videos of terrain from Afghanistan, this time recorded from CF convoys. The second study also recorded heart rate variability data, as a physiological measure of stress. This study replicated the main finding of the first study, namely that personnel with operational experience in an IED threat environment seem to make more fixations and shorter saccades than personnel without such experience. The analysis of the heart rate variability suggested that the personnel with IED experience also experienced more stress while viewing the videos than did the inexperienced ones.

Taken together, these findings suggest that operational experience in an IED threat environment alters the way that personnel inspect and experience their visual environment. As we lacked an objective measure of how effective the participants in these studies would have been at finding real IEDs emplaced in a real operational environment, it is difficult to determine from these results alone with certainty whether these differences reflect real difference in soldiers' ability to find IEDs, or merely the effects of being re-exposed to a stressful environment. Nevertheless, other findings (including a large-scale study conducted for the US Army, see Murphy 2010) suggest that experience in theatre does correlate with improved skills at finding IEDs. Thus we tentatively take these results as one indication that experience in theatre imparts better skills for finding IEDs, and therefore we suggest that there are trainable skills for IED threat awareness, even at a basic, perceptual level.

2.3 Understanding how soldier population interpret IED threat situations

Having evidence that experienced soldiers visually scan the environment differently from inexperienced troops, we have also attempted to assess what these differences are in terms of the J/DM process we have postulated as being at the core of IED Awareness. This was done in the context of a study conducted to test the effectiveness of a prototype of a training tool designed by DRDC Toronto to train IED threat assessment skills, the Environment Familiarization and Indicator Trainer (EFIT; study described in Jarmasz et al., 2010). The study also allowed us to obtain some data bearing on the validity of the conceptual understanding of IED Awareness described above.

In order to asses the effect of EFIT on soldiers' IED assessment skills, two video-based tests were devised and administered to trainees before and after the training. The two tests corresponded to the two categories of IED Awareness-related information in our conceptual model (*Figure 1*). One test asked participants to identify "good" IED emplacement locations (i.e., locations that seemed to provide favourable conditions for staging an attack) as they watched videos of roadside

terrain from Afghanistan, by pressing a button when they felt the video showed a "good" IED emplacement location. The second test presented participants short video vignettes, also of roadside terrain from Afghanistan, and asked participants first to determine whether or not the vignette displayed a "good" IED emplacement location (yes-no answer), then to rate the vignette for their subjective impression of IED threat (1 to 5 scale, with 1 = low threat and 5 = high threat), and finally to identify the indicators that led them to that assessment (freeform text). The same tests were administered to SMEs (soldiers from the same unit with previous experience in Afghanistan) in order to collect baseline responses against which to evaluate trainees' responses. This study was approved by the DRDC Human Research Ethics Committee.

The data collected from SMEs, and the comparison of their data to the trainees' responses, sheds some more light on how experienced soldiers perform the IED threat assessment task, and how these skills change during the course of deployment to IED threat environments. In general terms, the SMEs selected fewer scenes as depicting "good" settings for an IED attack, and judged the threat level of the selected scenes to be lower, than did the trainees. However, responses were not uniform across the SME pool. We determined that within the group of approximately 30 SMEs who contributed to our study, there were 3 distinct subgroups, according to the vehicle roles they reported that they occupied during their tours: "front of vehicle" roles (i.e., drivers and crew commanders, who are the crewmembers who spend the most time inspecting the environment in front of the vehicle for IED threats), gunners (who also inspect the environment for threats, but typically look for human or vehicular threats rather than IEDs and often scan arcs that are not directly in front of the vehicle), and "rear of vehicle" roles (i.e., infantry soldiers who tended to be in vehicles as passengers rather than crew, and who typically did not have a good view of the terrain from within the vehicle). The "Front" subgroup tended to report fewer scenes as good settings for an IED attack than did the other two groups, whose rate of responses were more in line with the trainees. With regards to the judgments of IED threat levels upon selecting a scene as depicting a good IED emplacement site, both the "Front" and gunner subgroups gave consistently lower ratings than the "Rear" group, who again gave ratings closer to those of the trainees.

The results from the EFIT effectiveness study reveal some interesting patterns. First, soldiers with experience in IED environments tend to rate IED threats and possible IED emplacements more conservatively than do trainees. Note that at the time the study was conducted, the trainees were near the end of their training for an impending deployment to Afghanistan; they had received months of counter-IED training, including classroom briefings on typical IED threats, tactics and indicators, and field exercises. Thus, the differences between trainees and SMEs are not due to the trainees not having received C-IED training, and likely reflects SMEs operational experiences. Second, the three subgroups of SMEs we identified based on their roles in theatre performed the IED threat judgment task differently, again with soldiers who spent more time actively scanning the environment for IEDs rating threats more conservatively than their colleagues. As with the studies described above, we lacked the opportunity to objectively assess proficiency at identifying real IED sites, as we did not have video footage of actual IED emplacements, thus it is difficult to conclusively relate the SMEs' threat assessment responses to IED detection performance[1]. Nevertheless, it is reasonable to assume that the "Front" subgroup of

[1] Data on how many IEDs the SMEs detected during their deployments to Afghanistan, and perhaps more importantly, how many they may have failed to detect, were not available to us. Such data would be exceedingly difficult to collect from theatre for operational reasons, and would likely be difficult to obtain even if it were available, for security reasons. The difficulty in assessing the effectiveness of soldiers' ability to detect IEDs in an operational environment is a major challenge in evaluating the effectiveness of C-IED training in general. Other researchers (e.g., Murphy, 2009), have constructed artificial IED detection tasks (physical training ranges or synthetic environments with simulated IEDs emplaced in them) to assess

SMEs, who had the most experience with scanning the environment for IED threats, would also be better at the task than the other groups as well as the trainees. Thus we considered this group to be the "reference" group, whose performance provided the norm against which the trainees' results were compared during our study of the effectiveness of EFIT.

The question arises whether or not the more conservative judgment displayed by the "Front" SME group in the study just described reflects a higher degree of complacency with regard to IED threats (i.e., an excessive tendency to discount IED threats even when they are likely or actually present) relative to the other groups. Again, in the absence of being able to objectively assess soldiers' ability to detect real IEDs in operational environments (or what their performance would be in such conditions), it is difficult to correctly assess the significance of the "Front" SMEs' more conservative judgment. However, the fact that comparable populations of soldiers showed higher numbers of fixations (associated with higher vigilance and workload, as discussed in Ikehara & Crosby, 2005) when viewing videos from an IED environment suggests that even the "Front" SMEs were likely carefully inspecting the videos for IED threats and that their more conservative judgment represents more extensive understanding of IED threats, rather than simply a cavalier attitude towards threats. That is, "Front" SMEs have learned that "not everything is an IED" (an impression that is common among less experienced troops), and to distinguish between credible and less credible IED threats. Also, since the SMEs in the study had last been deployed between 1 and 3 years prior to the study, it is likely that their understanding of, and skills for assessing, IED threats would have faded over time since their deployments. However, the fact that there were still significant differences between the groups of SMEs so long after their last deployments suggests that, even if "skill fade" did occur, some important portion of the skills that they developed survived since the end of their tours, and that their conservative judgment is not merely "tour fatigue" as might be expected right at the end of a deployment.

It is also difficult to determine whether the differences between the SME groups reflect better (rather than merely different) skills at assessing IED threats for some groups. In fact, given the variability and complexity of IED threats, the safest assumption to make might be that, even if the "Front" SMEs are more experienced at assessing IED threats from moving vehicles, all crew members have something to contribute to an accurate assessment of threats in mounted operations. That is, as suggested above, constructing an accurate picture of IED threats during mounted operations is a collective task, different crew members contribute different elements to this common picture, and the collective SA on IED threats in a vehicle or a convoy will only be successful if the group is effective at combining the different elements into a coherent whole. Our discussions with SMEs suggest that crew or vehicle and convoy commanders play a key role in integrating all the IED threat information in mounted operations, although this has not been confirmed empirically. More to the point, even if a crew or convoy commander is ultimately responsible for integrating IED threat information, passing IED information down to crewmembers and making decisions about avoiding or investigating potential IEDs, the nature of IEDs probably requires that all crewmembers play an active role in constructing collective SA on threats, rather than just acting as a "sensor" for the commander. In effect, we are suggesting that effective SA on IED threats (and probably other "ill-defined" threats in the environment) often needs to be "crowdsourced" from all crew members due to the fact that cues to IED attacks are complex, ambiguous, and dispersed in time and space.

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soldiers' ability to detect IEDs more objectively. However, the validity of these surrogate tasks are also difficult to assess with respect to true IED detection effectiveness, for the reasons given above. For the purposes of this report, we assume that troops with operational experience in IED threat environments are better at detecting IEDs than those without such experience, while acknowledging that we can only state with confidence that they inspect their environment differently.

In summary, our research indicates that IED Awareness involves an intuitive judgment of IED threats in the environment by individuals in a convoy crew and the integration of individuals' judgments into a collective "situation awareness" of IED threats. The differences in IED emplacement and threat level judgment across SME groups and trainees in our EFIT effectiveness study suggest that IED threat judgments rely on an experience-based, perceptual judgment skill set, involving tacit (i.e., hard to access consciously) knowledge of the meaning and relationship of various perceptual cues (indicators, terrain features) and background information (previous events, intelligence). This is consistent with an extensive body of research that shows that experts in various domains rely heavily on rich perceptual pattern-matching skills that are often difficult to explicitly verbalize (see Kellman & Garrigan, 2009, and Klein, 1997, for reviews). Our studies on the physiological aspects of visual search for IED threats in videos suggests that the task is likely associated with high cognitive load and elicits a strong stress response from experienced soldiers. This also lends support to the hypothesis that the more conservative IED threat judgments that they produced in the EFIT evaluation task were not the product of complacency but rather of a careful evaluation of the videos. The differences between SME groups, as well as our CTA of IED threat assessment, also underline the collective aspect of IED Awareness and the need for convoy crews to integrate their individual assessments into a "collective" or group SA of IED threats. Finally, the fact that trainees who underwent training with EFIT produced responses to IED threat assessment tasks that became more in line with those of SMEs suggests that the "mental model" that SMEs have of IED situations, and which likely (tacitly) guides their visual search behaviour, is similar to the model of IED threat situations (stable, enduring emplacement conditions plus transitory, contextual threat indicators) that formed the basis of the instructional material in EFIT.

To conclude this section, it is necessary to note some caveats on the inferences drawn from our studies. First, as mentioned above we were not able to apply objective measures of actual IED detection performance against which to measure the validity or relevance of the measures we did apply. Second, the various measures we reported were drawn from different groups of soldiers, who, while sharing similar roles and experiences in Afghanistan, had been back at home base for different lengths of time since their last deployment, which raises the possibility that different amounts of "skill fade" and decompression from tour may have affected the IED threat awareness skills of different groups of soldiers in different ways. Thus, more research is required to determine, among other things, that the physiological patterns suggesting high stress and workload really co-occur with the more conservative and discriminating judgments by SMEs. Note also that the IED Awareness skill retention that seems to occur, as suggested by the different SMEs subgroup responses, also raises the possibility that soldiers with previous operational experience with IEDs may be deployed for new rotations with an existing skill set that may bias their judgment of IED threats towards the types of threats that were current during their previous rotation rather than the new threats that would have developed since that time. Further research is required to ascertain the extent to which previous experience inappropriately biases IED Awareness in a new deployment or a new theatre of operations, and the extent to which this bias, if it exists, can be corrected.

3 Recommendations

3.1 Better support for perceptual learning skills

C-IED training should include materials that focus on the perceptual learning aspects of IED Awareness. Kellman and Garrigan (2009) have argued that most institutional training neglects the perceptual learning aspects (i.e., perceptual pattern recognition) of training, especially with respect to the complex and "fuzzy" patterns that can occur in real-world settings, whereas this type of learning constitutes one of the key aspects of expertise. As discussed above, our research has shown that perceptually-based skills are a key aspect of IED Awareness in experienced troops.

Most typical institutional training focuses on imparting "factual" knowledge (objective facts, standardized procedures, etc.), which is easier to transmit in a classroom lecture rather than the more complex, experienced-based, perceptual knowledge. One method for training these perceptual skills is the use of "perceptual learning modules," or PLMs (Guerlain et al., 2004; Kellman & Garrigan, 2009). In the case of teaching visual perceptual skills, PLMs are sets of brief videos that show a particular perceptual pattern under many guises and variations. This allows learners to experience the pattern under different presentations and learn to "extract" the common aspects across the different presentations that make up the "essence" of the pattern. It has been shown that appropriately structured PLMs can teach trainees to more effectively distinguish critical patterns in a variety of fields, such as assessing x-ray images, pilot training, and surgery (see reviews in Guerlain et al., 2004, and Kellman & Garrigan, 2009). Our EFIT tool is a prototype of a tool that can support perceptual learning-based training for C-IED, in that it focuses on the perceptual aspects of making judgments about IED threats. It also includes some materials structured in the form of PLMs designed to teach recognition of the common IED attack scenarios identified by Eles (2009). Other tools or variations on the EFIT concept could easily be designed, and we continue to investigate refinements to the EFIT design in our project.

3.2 Better support for group Situation Awareness (SA) skills

In addition to supporting individual perceptual learning for IED Awareness, the CF should consider the "collective" or "group" SA aspect of IED Awareness in training. Group SA is a psychological construct that is a key component of team performance in stressful environments such as military operations (Wellens, 1993). Thus, it is not surprising that our research has shown that it is a key aspect of IED Awareness in convoys as well.

C-IED training could support group SA in at least three ways. First, individual video-based training with a tool such as EFIT could be tailored to specific convoy or vehicle roles, such as a driver, gunner, crew commander, etc. This would require an analysis of the specific information requirements of the individual roles, something that has not been addressed in our project, and tailoring the video presented for training to the role. For instance, driver-specific IED Awareness should make use of video that captures the driver's specific point of view. Training for gunners, who typically scan large arcs in their visual environment, could have training tailored to them by recording video with so-called "360 degree" camera technology that captures video in all directions around the camera that can later, using special software, be panned in all directions, similar to the way an immersive synthetic environment can be traversed. An example of such equipment is the LadyBug2 "spherical camera" system from Point Grey Research, Inc. (Richmond, British Columbia). The Tactics School at Canadian Forces Base (CFB) Gagetown

also recently acquired a similar system from Immersive Media Corp. (Vancouver, Washington, USA) for producing training materials.

A second way in which the group SA aspect of IED Awareness could be supported in training would be to use EFIT-type tools to train small teams or crews together, allowing the group to discuss and assess the threats depicted in the video as a collective. It is known that human beings learn though imitation and observation of the reaction of peers to stimuli and situations (Bandura, 1986), thus, it would also be useful to ensure that every team in this type of training includes, whenever possible, at least one soldier with previous deployment experience to share his or her experiences and reactions to the training material. In addition to providing a forum for conveying lessons learned, this would provide an opportunity for soldiers to learn by observing the behaviours of their more experienced comrades. These can often convey very valuable information about threat situations through non-verbal gestures and facial expression, which often represent information that people have difficulty putting into words in the first place. In fact, EFIT has already been used in this manner by instructors from 2 Combat Engineer Regiment (CFB Petawawa) who were trialing the tool with troops in pre-deployment training for Task Force 3 - 08. During one training session, an early EFIT was shown (with no voice over) by instructors to a group of approximately 50 soldiers; the instructor would pause the video at key points and allow soldiers to "shop talk" their assessments of the situations presented in the video, which allowed those with previous deployment experience in the group to discuss their experiences and explain why their assessments different from that of less experienced troops.

Finally, a third way in which group SA could be supported in training would be to develop collective simulation-based training tools that provide role-specific training. For instance, convoy teams could practice C-IED convoy drills in synthetic environments following mission scenarios specifically designed to stress different team member roles. For instance, a training scenario could require different crew members to gather information appropriate to their roles (e.g., road conditions for drivers, individuals of interest or observation spots in high places for gunners) and share that information in order to make the training audience piece together a holistic picture of the operational environment in order to correctly assess the IED threat. Such a scenario would require complex "models" of IED events that involve multiple indicators spread out in time and space (e.g., civilian pattern of life, a team of insurgents dispersed throughout the terrain, multiple combat indicators, some of them spurious or "hoax" indicators, terrain features suggestive of good IED emplacements) in the simulation. DRDC Toronto has already been working with such scenarios using the Virtual Battle Space 2 (VBS2; Bohemia Interactive Simulations Inc., Orlando, Florida) simulation platform (Jarmasz et al., 2010), as have various Army Simulation Centres (e.g., see Thomson, Karthaus, Brown & Ste-Croix, 2009). While more work is needed to develop a consistent methodology for this approach to C-IED training and to overcome a number of limitations with VBS2, it is an approach that shows much promise.

3.3 Generalize the video-based perceptual learning approach beyond IED threats in Afghanistan

We recommend that our general approach of using training tools that support perceptual learning, for both individuals and teams, be extended beyond the context of preparing soldiers for IED threats in Afghanistan. First of all, it is widely assumed that the IED threat will persist as a global security threat in a variety of current and emerging theatres, and, in principle, the approach presented here could be transferred easily to new theatres of operation. Second, it is likely that other "irregular" threats that troops (or even civilian security or humanitarian workers) are likely to encounter in new security environments, such as ambushes or crowd incident situations, would rely on similar perceptual judgment skills and expertise that seem to underlie IED Awareness.

Thus, a similar perceptual learning and PLM paradigm could be applied to new threats and new environments as the CF encounters them.

3.4 Collect high-quality video from operational theatres

Tools designed to support a perceptual learning approach need to provide "rich" learning materials that adequately expose learners to the complexity of the domain that they are learning (Guerlain et al, 2004; Kellman & Garrigan, 2004). In many cases, the richness and the complexity of the domains in question will be supported more effectively with materials based on real, up-to-date video from an operational theatre rather than with synthetic or abstract mathematical models. Thus, we highly recommend that the CF institutionalize the collection of video data (and possibly other data such as audio and geographic data) in theatre, whether in current theatres such as Afghanistan, or new theatres to which the CF will likely be deployed in the future. Such data could easily support various functions in addition to training, such as intelligence analysis, or mission planning and rehearsal in theatre. Thus, while formalizing such a capability in the CF would require an initial investment in terms of equipment, data/knowledge management systems to handle the generated data, and personnel to maintain and collect data on an ongoing basis, the payoff could be quite large and would support various users across the CF. The lessons learned that have been gained by DRDC Toronto during its own data collection efforts in support of EFIT could serve as a starting point for the CF to implement an in-theatre data collection capability.

3.5 More research on how soldiers scan for IED threats

Finally, it should be clear from the above that more research is required to build on our findings and better understand how experienced troops actually scan for IED threats. This includes both refining our understanding of IED Awareness skills in general, and developing our understanding of role-specific IED Awareness skills and requirements. While we will continue to advance our understanding of IED Awareness as much as possible within our project, given the remaining resources and timelines in this project, advancing this work as much as necessary is beyond our current scope.

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List of symbols/abbreviations/acronyms/initialisms

AO	Area of Operations
CF	Canadian Forces
CFB	Canadian Forces Base
C-IED	Counter-IED
CORA	Centre for Operational Research and Analysis
CTA	Cognitive Task Analysis
CTC	Combat Training Centre
DRDC	Defence Research & Development Canada
EFIT	Environment Familiarization and Indicator Trainer
IED	Improvised Explosive Device
J/DM	Judgment and Decision Making
LFDTS	Land Force Doctrine and Training System
SA	Situation Awareness
SME	Subject Matter Expert
PLM	Perceptual Learning Module
TDP	Technology Demonstration Program
VBS2	Virtual Battle Space 2

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(Security classification of the title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (The name and address of the organization preparing the document, Organizations for whom the document was prepared, e.g. Centre sponsoring a contractor's document, or tasking agency, are entered in section 8.)

Publishing: DRDC Toronto
Performing: DRDC Toronto
Monitoring:
Contracting:

2. SECURITY CLASSIFICATION (Overall security classification of the document including special warning terms if applicable.)

UNCLASSIFIED
(NON-CONTROLLED GOODS)
DMC A
REVIEW: GCEC JUNE 2010

3. TITLE (The complete document title as indicated on the title page. Its classification is indicated by the appropriate abbreviation (S, C, R, or U) in parenthesis at the end of the title)

Summary of findings on visual scanning and assessment of IED threats by soldiers in operational environments. (U)
Sommaire des conclusions concernant le balayage visuel et l'évaluation que font les soldats en milieux opérationnels quant aux menaces posées par les IED. (U)

4. AUTHORS (First name, middle initial and last name. If military, show rank, e.g. Maj. John E. Doe.)

Jerzy Jarmasz

5. DATE OF PUBLICATION (Month and year of publication of document.)	6a NO. OF PAGES (Total containing information, including Annexes, Appendices, etc.)	6b. NO. OF REFS (Total cited in document.)
March 2011	38	16

7. DESCRIPTIVE NOTES (The category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of document, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

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8. SPONSORING ACTIVITY (The names of the department project office or laboratory sponsoring the research and development – include address.)

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Tasking:

9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant under which the document was written. Please specify whether project or grant.)	9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.)
12RR	

10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document)	10b. OTHER DOCUMENT NO(s). (Any other numbers under which may be assigned this document either by the originator or by the sponsor.)
DRDC Toronto 2010–197	

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(U) DRDC Toronto has been conducting a research project investigating various training tools designed to support visual IED threat assessment and awareness skills (IED Awareness Training project, sub–project 12rr03 of the Omnibus Counter–IED Technology Demonstration Project), in order to support the Canadian Forces (CF) Counter–Improvised Explosive Device (IED) efforts to protect Canadian soldiers involved in the conflict in Afghanistan. During this project, which focuses on individual perceptual judgment and situation awareness, as well as team situation awareness and decision making skills, we developed an understanding of how soldiers with operational experience in IED threat environments visually scan and assess their environment for IED threats. This report presents a conceptual model of the "IED awareness" process, gives an overview of the research DRDC Toronto has conducted in developing this model, and provides a number of recommendations for enhancing the CF's Counter–IED training efforts, both for the current Afghanistan conflict and for future conflicts, as it is widely assumed that IEDs will play a role far beyond the current Afghanistan theatre of operations.

(U) Afin de soutenir les efforts de lutte aux dispositifs explosifs de circonstance (IED) des Forces canadiennes visant à protéger les soldats canadiens participant au conflit en Afghanistan, RDDC Toronto mène un projet étudiant divers outils de formation conçus pour soutenir l'évaluation visuelle des menaces posées par les IED et les aptitudes à en percevoir les indices (projet de sensibilisation aux IED, sous–projet 12rr03 du grand projet de démonstration de technologies sur les moyens de lutte contre les IED). Ce projet, qui met principalement l'accent sur le jugement perceptuel individuel et la connaissance de la situation, ainsi que sur la connaissance de la situation de l'équipe et les aptitudes à prendre des décisions, nous a permis de mieux comprendre comment les soldats ayant une expérience opérationnelle dans des milieux où les IED posent des menaces parcourent du regard ce qui les entoure et évaluent ces menaces potentielles. Le présent rapport présente un modèle conceptuel du processus de « perception des IED », donne un aperçu de la recherche menée par RDDC Toronto afin d'élaborer ce modèle et fournit un certain nombre de recommandations visant à accroître les efforts de formation en matière de lutte aux IED des FC, tant dans le cadre du conflit actuel en Afghanistan que pour tout conflit futur, car il est généralement admis que les IED continueront de jouer un rôle bien après la fin de conflit actuel en Afghanistan.

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(U) IEDs; visual scanning; cue integration; IED detection; Afghanistan

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