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Combat Identification (15au):

Project summary and closeout report

David J. Bryant

Defence R&D Canada
Technical Report
DRDC Toronto TR 2009-128
July 2009

Canada

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Abstract

The purpose of this report is to summarize the work conducted within Project 15au "Combat Identification." The report begins with a review of the project objectives and provides some background concerning the need for this work. The project achievements and cost performance are summarized, followed by descriptions of the major work elements undertaken. Among the major outcomes are a) a computer-based methodology for studying the effects of environmental (e.g., types of visual cues) and system (e.g., blue-force tracking) factors on the speed and accuracy of human combat identification judgments, b) an information accumulation model of human combat identification decision making, and c) preliminary experimentation to validate this model and provide insight into the likely effects of blue-force tracking and rifle-mounted combat identification assist systems on human decision making. A complete list of lessons learned from the project is provided. The report ends with a discussion of potential avenues for exploitation of the project results and suggestions of future research and development directions.

Résumé

Le présent rapport vise à résumer le travail effectué dans le cadre du Projet 15au « Identification au combat ». Il commence par un examen des objectifs du projet, ainsi qu'une mise en perspective sur ce qui rend le travail nécessaire. Il y a un résumé des réussites du projet et de l'évolution des coûts, puis des descriptions des éléments de travail majeurs entrepris. Citons parmi les résultats principaux : a) une méthodologie informatique pour étudier les effets de l'environnement (types d'indices visuels, par exemple) et du système (blue force tracking, le suivi des forces bleues, par exemple) comme facteurs de la vitesse et de l'exactitude des jugements humains d'identification au combat humaine; b) un modèle d'accumulation d'information pour la prise de décision en identification au combat; c) des expériences préliminaires pour valider le modèle et donner une idée des effets probables des systèmes d'aide (blue force tracking et système d'identification au combat monté sur fusil) sur la prise de décision humaine. Est incluse une lise complète des leçons apprises grâce au projet. Le rapport s'achève avec une discussion des façons dont on pourrait exploiter les résultats du projet et avec la suggestion d'orientations de recherche et de développement à l'avenir.

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Executive summary

Combat Identification (15au): Project summary and closeout report

David J. Bryant; DRDC Toronto TR 2009-128; Defence R&D Canada – Toronto; July 2009.

Background: This project focused on the human factors pertaining to Combat Identification (CID) with the goal of deriving a better understanding of whether or not this has the potential to enhance situation awareness (SA) and target identification. Human factors also mediate the impact of physical and operational factors on CID. Building a model of human CID decision making is an essential step toward improving CID performance and reducing incidents of fratricide, through the development of decision support devices, improved training, revised doctrine, and so on.

The objective of this project was to develop and evaluate a cognitive model of human CID decision making in the Land Force context. In specific terms, this required a number of work elements.

First, we defined the CID task environment (functions and decision requirements) and developed and tested algorithms/heuristics for multiple uncertain cue integration. Modeling was accomplished by function flow and decision requirement analyses that documented the formal procedures of CID and described all decision tasks involved.

Second, we developed and evaluated models of human information aggregation and made recommendations for human information aggregation processes.

Third, this project investigated how humans use advice from automated systems and identified factors that affect the calibration of judgments and factors that affect trust in advice. We also determine how people deal with information uncertainty.

Major Deliverables: Major deliverables for this project included a revised version of the Instrumented Military Modelling Engine for Research using Simulation and Virtual Environments (IMMERSIVE) software as a platform for experimentation on human performance, and a computer-based methodology for studying the effects of environmental (e.g., types of visual cues) and system (e.g., blue-force tracking) factors on the speed and accuracy of human combat identification judgments.

Major deliverables also included several reports characterizing the CID process in terms of the functional and decision requirements placed on decision makers. The literature relevant to the CID process was reviewed in relation to human information processing. Analysis of this literature provided a description of the CID process for the individual soldier and identified key issues that impact the process of evaluating a contact of interest. A function flow analysis identified the component tasks and processes involved during CID, along with the hierarchical relationships (workflow) between these tasks. Decision descriptions included information requirements, ratings of cognitive workload, decision complexity, decision criticality, time

requirements, CID stage (Detect, Classify, Recognize, Identify or Act), decision outcome, and specific constraints.

Additional work delivered reports documenting models of information aggregation. By categorizing the methods of information aggregation based on their associated decision making frameworks, we were able to identify several heuristics, cognitive biases, and models as being specifically relevant to the tasks of weighing and integrating information as practiced in CID. Based on a review of the CID literature, we developed the Arousal-Excitation-Activation Threshold (AEAT) model, which is a generalized version of an information aggregation model intended to provide a framework for understanding the CID decision process.

To perform an experimental evaluation of the AEAT model of CID decision making [14], a revised version of the IMMERSIVE software was developed to support measurement of human performaance. With this, a major outcome of the project has been a computer-based methodology for CID assessment. Results of the experimental evaluation generally supported the AEAT model as a potential framework in which to further study human CID decision making.

In another work package, we studied factors that affect human trust and reliance on the CID systems, with the ultimate goal of helping them better utilize the systems and reduce fratricide incidents. The work began with a literature review pertaining to operator trust in automation. Three experiments investigated the role of system reliability on users' trust of, and reliance on, the system. Although users do not necessarily have well-calibrated levels of trust in support systems, their use of a system is guided by their trust in it. The results of a third experiment indicated that when the reliability information was displayed as a degrading graphical element method, sensitivity increased and also that an integrated (rather than separated) display format affords more appropriate reliance on the system. The findings highlight the importance of human-machine interface (HMI) design on engendering appropriate trust and reliance on the automated decision aid.

The project also produced reports documenting experiments that examined how people deal with uncertainty associated with visual and behavioral cues for target identity. Results indicated that the accuracy of CID decisions can be affected by uncertainty and could potentially increase the risk of fratricide.

Lessons Learned: Among the major outcomes of the project are: a) a computer-based methodology for studying the effects of environmental (e.g., types of visual cues) and system (e.g., blue-force tracking) factors on the speed and accuracy of human combat identification judgments; b) an information accumulation model of human combat identification decision making; and c) preliminary experimentation to validate this model and provide insight into the likely effects of blue-force tracking and rifle-mounted CID systems on human decision making. A complete list of lessons learned from the project is provided.

Future R&D and Exploitation Activities: This section outlines future research directions and potential exploitation activities for CID research consistent with Canadian Forces' Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) needs. The report discusses the use of the project results for enhancing doctrine, training, and procedures, refining CID decision models, and development and assessment of CID support tools.

Future research could be directed to developing a common framework for evaluation of CID support technologies as well as development of computer-simulation-based training methods.

Sommaire

Combat Identification (15au): Project summary and closeout report

David J. Bryant; DRDC Toronto TR 2009-128; R & D pour la défense Canada – Toronto; Juillet 2009.

Généralités : Le projet s'est attaché aux facteurs humains ayant trait à l'identification au combat (IDCbt), le but étant de mieux comprendre si cela est susceptible d'améliorer la conscience de la situation (CS) et l'identification de la cible. D'autre part, les facteurs humains sont aussi le medium des répercussions de facteurs physiques et opérationnels sur l'IDCbt. Établir un modèle de la prise de décision en IDCbt humaine est une étape essentielle pour améliorer la performance en IDCbt et réduire les incidents fratricides, grâce à l'élaboration de dispositifs d'appui à la décision, de formation améliorée, de doctrine révisée, etc.

L'objectif du projet était d'élaborer et d'évaluer un modèle cognitif de la prise de décision en IDCbt humaine dans le contexte de la Force terrestre. Plus spécifiquement, cela nécessitait divers éléments de travail.

Premièrement, nous avons défini les conditions d'exécution des tâches d'IDCbt (exigences de fonctions et de décisions), puis nous avons élaboré et testé des algorithmes/heuristiques pour l'intégration d'indices multiples incertains. La modélisation s'est effectuée par des analyses de fonctions et d'exigences de décision qui documentaient les procédures formelles d'IDCbt et décrivaient les tâches de décision impliquées.

Deuxièmement, nous avons élaboré et évalué des modèles d'agrégation d'information humaine et fait des recommandations pour les processus d'agrégation d'information humaine.

Troisièmement, le projet a enquêté sur la façon dont les êtres humains utilisent les conseils de systèmes automatisés, puis identifié les facteurs qui affectent la calibration de jugements et la confiance dans les conseils. Nous déterminons aussi comment les gens abordent l'incertitude de l'information.

Principaux résultats attendus : Citons parmi les principaux résultats attendus du projet plusieurs rapports caractérisant le processus d'IDCbt en terme d'exigences de fonction et de décision imposées aux preneurs de décision. Nous avons effectué un examen de la recherche ayant trait au traitement de l'information humain dans le processus l'IDCbt. Une analyse de cette recherche a permis une description du processus d'IDCbt pour un soldat individuel et a identifié les questions clés ayant des répercussions sur l'identification d'un contact intéressant. Une analyse des fonctions a identifié les processus et tâches constituants impliqués dans l'IDCbt, ainsi que les relations hiérarchiques (déroulement des opérations) entre ces tâches. Les descriptions de décision incluaient les exigences en information, la charge de travail cognitif, la complexité de la décision, son caractère essentiel ou pas, les contraintes de temps, l'étape de l'IDCbt (détecter, classer, reconnaître, identifier ou agir), le résultat de la décision et les contraintes spécifiques.

Un travail supplémentaire a permis la production de rapports documentant des modèles d'agrégation de l'information. En caractérisant les méthodes d'agrégation d'information selon les cadres de prise de décision qui y sont associés, nous avons pu identifier plusieurs heuristiques, biais cognitifs et modèles comme étant particulièrement liés aux tâches d'évaluation et d'intégration de l'information pratiquées dans l'IDCbt. Après examen des recherches en IDCbt, nous avons élaboré un modèle de seuil éveil-excitation-activation (SEEA), version généralisée d'un modèle d'agrégation de l'information visant à fournir un cadre pour la compréhension du processus décisionnaire de l'IDCbt.

Pour effectuer une évaluation expérimentale du modèle SEEA de la prise de décision en IDCbt (Famewo, Zobarich, et Bruyn Martin, 2008), a été élaborée une version révisée du logiciel MMMIRESV (moteur de modélisation militaire instrumentalisé pour la recherche à l'aide d'environnements simulés et virtuels), pour appuyer la mesure du rendement humain. Ceci étant, l'un des résultats principaux du projet a été une méthodologie informatique pour l'évaluation de l'IDCbt. Les résultats de l'évaluation expérimentale ont généralement appuyé le modèle SEEA comme cadre potentiel pour poursuivre l'étude de la prise de décision en IDCbt humaine.

Dans un autre ensemble de travail, nous avons étudié les facteurs qui affectent la confiance humaine dans les systèmes d'IDCbt et leur utilisation, l'objectif ultime étant d'aider les gens à mieux utiliser les systèmes et de réduire les incidents fratricides. Le travail a commencé par un examen de la recherche portant sur la confiance accordée par un opérateur a une automation. Trois expériences ont exploré l'influence de la fiabilité du système sur la confiance que lui accorde l'utilisateur et sur son utilisation. Bien que les utilisateurs n'aient pas nécessairement des niveaux de confiance bien calibrés dans les systèmes de soutien, leur utilisation d'un système dépend de la confiance qu'ils lui accordent. Une troisième expérience a montré que quand on affiche la fiabilité de l'information par une méthode d'élément graphique allant se dégradant, la sensibilité augmente, tandis qu'un format d'affichage intégré (plutôt que séparé) permet une utilisation en confiance plus appropriée du système. Les constatations soulignent l'importance de la conception de l'interface homme-machine pour amener une utilisation en confiance plus appropriée de l'aide automatisée à la décision.

D'autre part, le projet a produit des rapports documentant des expériences visant à déterminer comment les gens affrontent une incertitude associée à des indices visuels et comportementaux quant à l'identité de la cible. Les résultats montrent que l'exactitude des décisions d'IDCbt est susceptible d'être affectée par l'incertitude, ce qui pourrait augmenter le risque d'incidents fratricides.

Leçons apprises : Citons parmi les résultats principaux : a) une méthodologie informatique pour étudier les effets de l'environnement (types d'indices visuels, par exemple) et du système (blue force tracking, par exemple) comme facteurs de la vitesse et de l'exactitude des jugements humains d'identification au combat; b) un modèle d'accumulation d'information pour la prise de décision humaine en identification au combat; c) des expériences préliminaires pour valider le modèle et donner une idée des effets probables des systèmes d'aide (Blue Force Tracking et système d'identification au combat monté sur fusil) sur la prise de décision humaine. Est incluse une lise complète des leçons apprises grâce au projet.

Activités à venir de R&D et d'exploitation : La section esquisse les directions de recherche future et les activités d'exploitation potentielles pour une recherche en IDCbt correspondant aux besoins C4ISR des Forces canadiennes. Le rapport discute l'utilisation des résultats du projet pour améliorer la doctrine, la formation et les procédures, pour affiner les modèles de prise de décision en IDCbt et pour élaborer et évaluer des outils de soutien à l'IDCbt. La recherche à venir devrait viser l'établissement d'un cadre commun pour l'évaluation des technologies de soutien à l'IDCbt et pour l'élaboration de méthodes de formation reposant sur la simulation informatique.

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Acknowledgements

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Introduction

Project 15au, Combat Identification, previously investigated ways to reduce fratricide through situation awareness in synthetic environments, under the management of Francois Bernier at DRDC Valcartier. Beginning in fiscal year (FY) 06/07, the project was refocused on developing an understanding of human combat identification (CID) decision making, especially as it affects the viability of decision support concepts. This report is a summary of studies performed under Project 15au, Combat Identification, in the fiscal years 06/07 – 08/09. David Bryant served as Project Manager during this period.

Background

CID is the capability to rapidly and accurately identify friendly, enemy and neutral forces, manage and control the battlespace, optimally employ weapons and forces, and minimize the risk of fratricide. As such, CID is a complex cognitive as well as technological process. Although improvements in sensors and development of Blue Force Tracking (BFT) devices can enhance the effectiveness of CID, it is nevertheless necessary to understand the human decision making processes involved in identification. The work performed under this project was aimed at providing a comprehensive and detailed description of the CID domain as a precursor to empirical study of human CID decision making.

CID is sometimes considered to entail three elements: situation awareness (SA), target identification, and tactics, techniques, and procedures (TTPs) (e.g., [1]). SA refers to the perception and understanding of the operational environment needed to act effectively in that environment. CID clearly requires SA as a precursor to the classification of entities as friendly, hostile, or neutral. Target identification is the process of making that classification judgment based on the characteristics of the entity in question in relation to the TTPs that govern how one interprets objects in the operational environment. One can think of SA as providing the data about objects in the environment and TTPs providing the knowledge needed to interpret that data. Target identification is thus the process by which SA and TTPs are employed [1].

CID is a key element of combat effectiveness. It is the process by which enemies are identified and targeted for destruction. Nevertheless, it is generally the failures of CID that cause the most concern both operationally and nationally. An unfortunate aspect of CID is the occurrence of fratricide, the inappropriate engagement and potential wounding or killing of a friendly soldier or unit. Other potential problems include neutricide (incidents in which civilians and civilian infrastructure are accidentally targeted or misidentified and deliberately targeted [2]) and injury or death to oneself caused by failing to identify an enemy contact[1] (see [4]).

There is no single cause for incidents of fratricide and neutricide. The major risk factors that have been identified are a) the loss of SA, and b) misidentification of the target [4] [5] [6]. Each of these factors, however, is itself a confluence of more proximal factors. These break down further into human, physical, and organizational factors [1]. Exploration of each factor holds the promise of generating solutions to the problem of fratricide.

Human factors are characteristics or traits of human beings, related to their physiology, cognitive capabilities, and development (e.g., through training), that can negatively affect CID performance. One such factor is the natural limit to information processing capacity exhibited by

[1] Referred to as a mistake akin to 'suicide' on the battlefield by Karsh, Walrath, Swoboda and Pillalamarri [3].

people, which makes it difficult for soldiers to maintain SA in complex environments [6]. CID is made especially difficult for soldiers in environments such as Afghanistan by the asymmetric nature of that conflict, characterized by a difficulty in knowing who one's enemy is, where they are, and how and when they will attack. Human beings are also subject to stress and other emotions that can impair performance, leading to misidentifications, lack of fire discipline, etc. Training and education can be positive factors but poor training can impair both SA and identification [1].

Physical factors include both environmental conditions and the state of equipment, especially sensors. Environmental conditions that reduce visibility or hinder the functioning of sensors are key factors in many fratricide incidents [7]. Equipment failures can also make CID more difficult and error-prone. Increasingly, operational zones will feature the presence of similar or even identical equipment being used by friendly, neutral, and enemy forces and this can cause tremendous confusion in the identification process [6].

Operational factors pertain to the unique geographical, cultural, and historic features of the operational setting, as well as the organizational structure in which soldiers function. Operating afield in unfamiliar nations often leaves soldiers with limited knowledge of the kinds of information needed to distinguish neutral from potentially hostile factions. It often is the case that such knowledge is difficult and time-consuming to acquire. Constraints imposed from higher command in the form of Standard Operating Procedures (SOPs) and Rules of Engagement (ROE) can further hinder the CID process. Failures of command and control (C2) and communication frequently contribute to fratricide and neutricide incidents [7]. All of these issues are exacerbated in high-tempo operations that decrease margins of error [4].

Current project

This project focused on the human factors pertaining to CID. There are many ways in which human cognition is central to CID and so deriving a better understanding of this has the potential to enhance SA and target identification. Human factors also mediate the impact of physical and operational factors on CID. Building a model of human CID decision making is an essential step toward improving CID performance and reducing incidents of fratricide, through the development of decision support devices, improved training, revised doctrine, and so on.

Objectives

The objective of this project was to develop and evaluate a cognitive model of human CID decision making in the Land Force context. In specific terms, this required a number of work elements.

First, we defined the CID task environment (functions and decision requirements) and developed and tested algorithms/heuristics for multiple uncertain cue integration. This, in addition to a thorough review of the scientific and military literatures, provided a comprehensive description of CID decision making. Modeling was accomplished by function flow and decision requirement analyses that will document the formal procedures of CID and describe all decision tasks involved.

Second, we developed and evaluated models of human information aggregation and made recommendations for human information aggregation processes.

Third, this project investigated how humans use advice from humans and automated systems and identify factors that affect the calibration of judgments and factors that affect trust in advice. We also determine how people deal with information uncertainty. The results of these studies supported the development of procedures, training, and technology to enhance CID decision making.

This work will provide a framework in which to understand how humans make combat ID decisions, which will be useful in identifying what kinds of support are needed, how decision support will be used, and what impact various system parameters have on human performance.

Personnel/Contractors

DRDC Toronto

Dr. David J. Bryant – Project Manager
Dr. David J. Smith – Scientist
Dr. Justin Hollands – Scientist
Elaine Maceda – Research Assistant
Matthew Lamb – Research Assistant
Sabrina Kanani – University of Waterloo co-op student, research assistant

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Achievement of the project objectives

Table 1 lists the major milestones for this project. Milestones 1 through 7 were completed prior to fiscal year 2005/2006, when Francois Bernier was project manager. They are listed here for the sake of completeness but will not be discussed as this report deal solely with work performed at DRDC Toronto.

Table 1. Milestone Completion Report

No.	Milestones	Planned Completion Date	Actual Completion Date	Status
1	Definition of initial vignette (scenarios) set	1-Dec-04	30-Jun-05	Completed
2	Analysis and review of synthetic environment frameworks (JCATS, STRIVE, OneSAF)	1-Dec-05	1-Dec-05	Completed
3	Analysis and review of agent and multiagent systems	1-Dec-05	1-Dec-05	Completed
4	Identification of knowledge engineering of LAV III command tasks	1-Feb-06	31-Aug-06	Completed
5	Interim report on virtual and constructive simulation objectives and progress	1-Oct-05	31-Mar-07	Completed
6	Report on virtual simulation for fratricide study	31-Dec-06	31-Mar-07	Partial
7	Report on constructive simulation for fratricide study	31-Mar-07	31-Oct-07	Completed
8	Literature review on probabilistic cue integration	31-Mar-07	31-Aug-07	Completed
9	Report documenting functional analysis	31-Mar-07	31-Mar-07	Completed
10	Experiment plan	31-Mar-07	31-Mar-07	Completed
11	Literature review on information aggregation methods	31-Mar-07	31-Mar-07	Completed
12	Human use of advice experiment results	31-Mar-07	31-Mar-07	Completed
13	Experiment plan for evaluation of models of information aggregation	31-Mar-08	31-Mar-08	Completed
14	Experimental methods, materials, and scenarios for all experiments	31-Mar-08	31-Mar-08	Completed
15	Report on experiments (results of evaluation of models of information aggregation)	31-Mar-08	31-Mar-08	Completed
16	Human CID task performance	31-Mar-08	31-Mar-08	Completed
17	Field evaluation of cognitive models of CID decision making	31-Mar-09	31-Mar-09	Terminated

All major milestones performed at DRDC Toronto (8-17) were completed, with the exception of milestone 17. This milestone corresponds to a field evaluation that was to have been performed to evaluate models of CID decision making under actual operational conditions. This work element, however, was terminated due to the inability of the research team to locate a field exercise that would afford sufficient experimental control to perform a scientifically valid evaluation. Most field exercises are conducted to meet certain specific training objectives and so organizers are very reluctant to alter their exercise plan in ways that are necessary for an experimental comparison of conditions, as such alterations would have significant impact on the types of activities in which participants would be engaged, as well as the pacing of the exercise as a whole. The project manager explored the potential for data collection at Exercise Bold Quest Plus (Ex BQ+), conducted at Eglin Air Force Base (AFB) in Florida, July 11-25, 2008. Unfortunately, Ex BQ+ did not allow for the direct measurement of relevant human performance. In addition, key decision makers in the CID process, the Forward Air Controllers, participated as part of the team running the exercise rather than players in that exercise and so contributed no data whatsoever.

All deliverables from these milestones are listed in Annex A.

Schedule and cost performance summary

Table 2 presents a summary of funding and spending for Project 15au in the FY 06/07 through 08/09.

Table 2. Budgeted and Actual Spending by Fiscal Year

	Fiscal Year (FY)		
	06/07	**07/08**	**08/09**
Budgeted Allocation	$160K	$200K	$100K
Actual Amount Spent	$124K	$196K	$65K

Funding was under-spent in FY 06/07 because $30 was transferred to WBE 15au02, delivered by DRDC Valcartier.

Funding was under-spent in FY 08/09 because no suitable opportunity was available to conduct an experimental evaluation in a field exercise setting. The project manager explored the potential for data collection at Ex BQ+. As the bulk of the funding that year was intended for such a field exercise, it was decided to not attempt to spend the funding on an exercise that did not provide adequate opportunities to collect human decision making data. Some funds from this FY were used to support research on deployable day/night goggle simulation for another DRDC project.

Summary of achievements

Analysis of CID issues

Bruyn Martin, L., Famewo, J., Zobarich, R., & Lamoureux, T. (2007). Function Flow Analysis for the Combat Identification Process. DRDC Toronto Contractor Report (CR 2007-130).

Vilhena, P.G.S., Zobarich, R.M. & Lamoureux, T.M. (2007). CID Literature Review. DRDC Toronto Contractor Report (CR 2007-131).

Famewo, J. J., Bruyn Martin, L. E., Zobarich, R. M., & Lamoureux, T. (2007). Decision Requirements Analysis for the Combat Identification Process. DRDC Toronto Contractor Report (CR 2007-132).

Famewo, J. J., Bruyn Martin, L. E., Zobarich, R. M., Vilhena, P.G.S., & Lamoureux. T. M. (2007). Combat Identification: A Summary of the Literature, Function Flow Analysis and Decision Requirements Analysis. DRDC Toronto Contractor Report (CR 2007-123).

The objective of work done in this area was to characterize the CID process in terms of the functional and decision requirements placed on decision makers. The first step was to conduct a review of the scientific and military literatures. The CID literature review [8] investigated CID from the perspective of the dismounted infantry and the Light Armoured Vehicle perspective. The literature relevant to the CID process was reviewed in relation to human information processing. Analysis of this literature provided a description of the CID process for the individual soldier and identified key issues that impact the process of evaluating a contact of interest.

The review indicated the importance of several concepts to effective CID and the reduction of fratricide incidents: Situation Awareness (SA), Target Identification (TI), Tactics, Techniques and Procedures (TTPs), and operational effectiveness. Good SA will necessarily improve CID performance, because the observer will have less unknown information in the environment. The implications for the soldier performing the CID task are that s/he must take more time and search for more information in order to complete TI. TTPs affect the likelihood of a soldier coming into contact with a potential threat, how the soldier searches for that threat, how the soldier aggregates information to arrive at a decision, and what further action the soldier will take (e.g. the ROE for an operation).

The review indicated that CID is not a simple stimulus-response task, but involves the aggregation of information. The authors put forward an information aggregation model of human CID decision making in which an individual's activation threshold can be considered to be the comfort the soldier has with the situation, and excitation can be considered the data points the soldier has about the situation. Both the consideration (value) of the stimulus and the level of the activation threshold are subjective to the individual soldier. The report discusses the factors influencing the level of the threshold and the stimuli that contribute to activation, ranging from those that change the level of the activation threshold, to those that increase or decrease the level of excitation.

A function flow analysis was conducted to identify the component tasks and processes involved during CID, along with the hierarchical relationships (workflow) between these tasks. By decomposing CID into its component parts in a function flow diagram, we were able to evaluate the complexity of the CID task and acquire insight into the activities and requirements of the mounted and dismounted soldier. A report [9] describes the method used to develop the function flow diagrams in which the CID process was identified and collected from a review of the literature, results from nine multi-player experiments, and interviews with Subject Matter Experts (SMEs).

Based on this analysis, we identified four high-level functions performed by individual mounted or dismounted soldiers during the CID process:

- Function 1: Prepare for the mission;
- Function 2: Perform mounted/dismounted functions;
- Function 3: Take action; and
- Function 4: Evaluate action taken.

Each main function was further decomposed to progressing levels of detail concerning the decisions and actions of the soldier. The function flow diagrams detail the component tasks performed by the mounted or dismounted soldier to at least three levels of decomposition.

With reference to the typical definition of CID (described in [8]), Function 1 reflects the building of baseline situation awareness, Function 2 mirrors target identification and Function 3 reflects the TTPs. Function 4 adds an important element to the CID task that allows the soldier to calibrate his/her SA thereby continually improving his/her CID skills.

We conducted a decision requirements analysis to identify and describe the decisions associated with CID as performed by individual mounted and dismounted soldiers in a Land Force context [10]. Decision descriptions included information requirements, ratings of cognitive workload, decision complexity, decision criticality, time requirements, CID stage (Detect, Classify, Recognize, Identify or Act), decision outcome, and specific constraints. The analysis was based on the CID functions previously diagrammed through a function flow analysis and a review of the CID literature.

The analysis resulted in the identification of 67 decisions, which were grouped and summarized to represent seven core CID decisions distributed across the four functions. The analysis also resulted in an in-depth description of the decisions involved in each of the four functions, such that recommendations were possible regarding the needs of the CID decision maker, such as experience, training, good visual resolution, availability and accessibility of information (e.g., regarding enemy, friendly, neutral forces and specific individuals of interest), meta-cognitive skills, and intuition.

Models of information aggregation

Famewo, J., Matthews, M., & Lamoureux, T. (2007). Models of information aggregation pertaining to combat identification: A review of the literature. DRDC Toronto Contractor Report (CR 2007-062).

Bryant, D. J. (2007). Classifying Simulated Air Threats with Fast and Frugal Heuristics. ***Journal of Behavioral Decision Making, 20,*** **37-64.**

We conducted a literature review to examine methods of aggregating information in order to develop models that could be applied to human CID decision making. The review focused on identifying ways to improve the quality of decisions through optimization of formal and informal models of information aggregation. A report documenting the results of the review [11] highlighted major principles and theories of human information aggregation and developed a categorization scheme in which to evaluate the applicability of models of information aggregation to human decision making, especially in the context of CID.

By categorizing the methods of information aggregation based on their associated decision making frameworks, we were able to identify several heuristics, cognitive biases, and models as being specifically relevant to the tasks of weighing and integrating information as practiced in CID. Early analytic approaches to explaining decision making were based on normative theories of probability and logic, whereas intuitive methods encompass a range of informal heuristics. The review found that the characteristics of combat identification fit it to the intuitive decision making framework. By determining the methods of aggregation associated with this framework we were able to form a list of principles, heuristics and biases that may affect CID decision makers.

Based on a review of the CID literature, we developed the Arousal-Excitation-Activation Threshold (AEAT) model [12], which is a generalized version of an information aggregation model intended to provide a framework for understanding the CID decision process. The AEAT model proposes that an individual uses discrete pieces of information, or cues, to assess a potential target [8]. In this model, the decision of whether to engage a target as hostile is a function of the level of arousal of the decision maker, where “arousal” represents a hypothetical state of psychological readiness [13]. The decision maker’s arousal is in turn a function of the available data that provides confirmatory evidence that the target is hostile. The relationship among cues, arousal, and the CID decision is illustrated in Figure 1, which presents a hypothetical plot of arousal level over time. The baseline level of arousal indicates the existing tendency to classify a target as hostile, whereas the activation threshold is the level of arousal necessary for the decision maker to assign the hostile designation to the target. The arousal level fluctuates over time as data are perceived and evaluated. Data consistent with the target being hostile raise the arousal level, whereas data inconsistent with it being hostile decrease the arousal level.

The soldier’s activation threshold is the level of excitation that must be exceeded for the soldier to exercise his/her ROEs (therefore deciding that a contact poses a threat). Individual factors, such as the experience and training received by the soldier (e.g., previous experience with a particular location; beliefs about one’s degree of accuracy on past decisions) and psychophysiological factors (e.g., fatigue, fear) affect the level of the activation threshold, making it either easier or more difficult to reach the point where one views the situation as requiring an action.

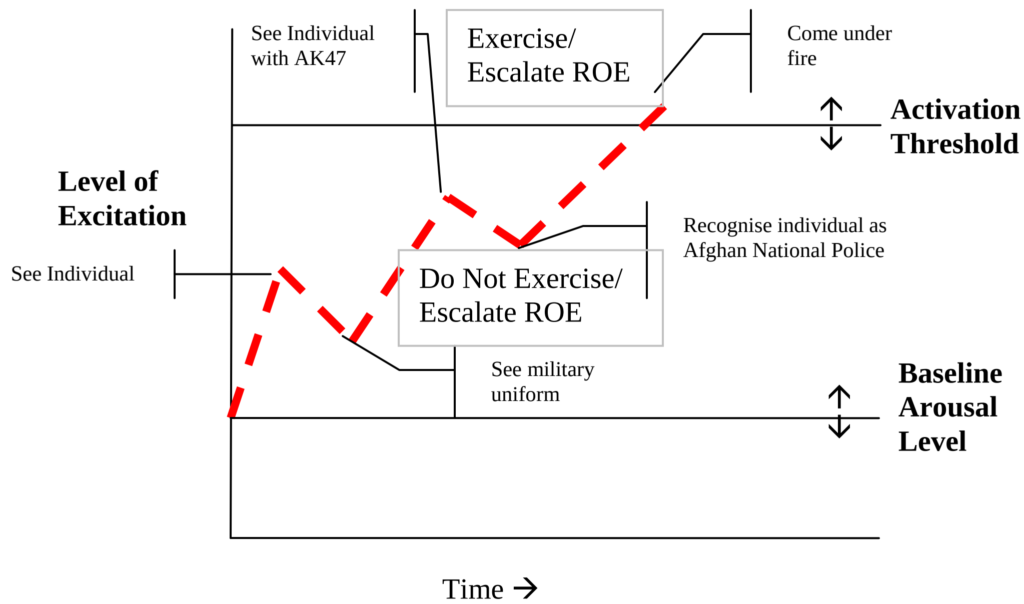

Figure 1. Information Aggregation Over Time According to the Excitation-Activation Threshold Model

The baseline arousal level is predicted to be affected by psycho-physiological factors and concepts such as trust and confidence, whereas the activation threshold is set with respect to the individuals' subjective interpretation of tactics, techniques and procedures, and ROEs. Such interpretations could be influenced by factors like stress and fatigue leading to variability across individuals.

Cues come from perceptual input from the environment and outputs of artificial sensors and other technologies. The interpretation of cues depends on the individual's knowledge, derived from all sources including training, intelligence briefings, etc. Different cues carry varying weights or strengths and effects (i.e., size of increase or decrease in excitation) based on the certainty the decision maker perceives about the information, and the meaningfulness of the cue [10].

Evaluation of models of human information aggregation

Famewo, J. J., Zobarich, R. M., & Bruyn Martin, L. E. (2008). Experimental Evaluation of the Combat Identification Process. DRDC Toronto Contractor Report (CR 2008-116).

We performed an experimental evaluation of the AEAT model [14]. The experiment made use of the Instrumented Military Modelling Engine for Research using Simulation and Virtual Environments (IMMERSIVE) software developed at DRDC Valcartier in an earlier phase of the project. IMMERSIVE is based on a modified gaming environment called "Unreal Tournament" and is a first-person perspective environment in which the participant assumes the role of a dismounted infantry soldier. In the experiment, participants (28 CF Reservists) assumed the role of a dismounted infantry soldier in a simulated environment and patrolled an area in which soldiers appeared and moved. Participants' decided whether each soldier was a friend, neutral, or enemy based on criteria provided and whether to engage a soldier believed to be hostile.

The main variables manipulated in the experiment were the strength (i.e., combination of salience, number, meaning) of the confirmatory cues associated with a contact and the arousal level of the participant. Hostile contacts were indicated by the presence of specific characteristics (i.e., cues) that had been identified in the previous function flow analysis [9]. High and low strength targets were created by varying the number and salience of the cues associated with a given target. The subject's baseline arousal level was manipulated through instructions regarding the presence or absence of a generalized threat in a block of trials.

Each experiment session consisted of four blocks of 12 trials (i.e., encounters with a target). The first and last block served to establish baseline performance levels. Each block of trials began with the participant reading a short description (a "read-in") on the computer screen regarding the set of trials he or she is about to complete. In each trial, the participant maneuvered through a village scene in the simulated environment. The participant was provided with ROE that distinguished friendly/neutral from potentially hostile targets and governed when the participant was to engage hostile contacts.

Participants' performance was assessed in terms of engagement accuracy (correctly engaging foes but not friends or neutrals), confidence in engagement decision, level of engagement force employed, and the cues used to form the CID decision as determined through an open question at the end of each trial.

Results indicated that participants were more likely to report the presence of hostile contacts when their baseline arousal was heightened and when cues were stronger. This trend was only partially valid when considering the accuracy of participants' reports. That is, participants were more accurate about the presence of a hostile contact (i.e., hit) when cues were strong, but were not influenced significantly by heightened arousal level. However, arousal level did marginally affect the proportion of false alarms (i.e., identifying a friend/neutral as hostile) such that more of these errors were made when the arousal level was heightened. This finding suggests that expectations may affect fratricide/neutricide. Participants' confidence was directly related to cue strength with stronger cue strengths eliciting higher confidence. Confidence was also somewhat affected by the arousal level, such that confidence was lower for hits when participants did not expect the presence of a hostile contact (i.e., lower baseline arousal).

Human use of CID decision support concepts

Jamieson, G. A., Neyedi, H. F., & Wang, L. (2008). Developing Human-Machine Interfaces to Support Appropriate Trust and Reliance on Automated Combat Identification Systems. DRDC Toronto Contractor Report (CR 2008-114).

Wang, L., Jamieson, G. A., & Hollands, J. G. (in press). Trust and reliance on an automated combat identification system: The role of aid reliability and reliability disclosure. *Human Factors*.

Neyedli, H., Hollands, J. G., & Jamieson, G. A. (2009, accepted). *Human reliance on an automated combat identification system: Effects of display format*. Submitted to the Annual Meeting of the Human Factors and Ergonomics Society.

Wang, L., Jamieson, G. A., & Hollands, J. G. (2008). Selecting methods for the analysis of reliance on automation. In *Proceedings of the Human Factors and Ergonomics Society – 52nd Annual Meeting* (pp. 287-291). Santa Monica, CA: Human Factors and Ergonomics Society.

Wang, L., Jamieson, G. A., & Hollands, J. G. (2008). Improving reliability awareness to support appropriate trust and reliance on individual combat identification systems. In *Proceedings of the Human Factors and Ergonomics Society – 52nd Annual Meeting* (pp. 292-296). Santa Monica, CA: Human Factors and Ergonomics Society.

Neyedli, H. F., Wang, L., Jamieson, G. A., & Hollands, J. G. (in press). Evaluating reliance on combat identification systems: The role of reliability feedback. In D. H. Andrews & T. Hull (Eds.), *Human factors issues in combat identification*. Aldershot, England: Ashgate.

A variety of technical solutions have been developed with the aim of improving soldiers' CID ability. The fact that the contemporary warfare often involves dismounted urban operations draws attention to one of these technologies – the individual combat ID system [15]. The device consists of a gun-mounted interrogator and a helmet mounted transponder. The interrogator sends out a laser inquiry, which the transponder decodes and sends back a reply. The key drawback of such a system is that it cannot positively identify a target without a working transponder device [16] [17] [18]. Therefore, when no transponder signal is received, the target can be hostile, neutral or friendly. It appears soldiers have difficulty relying on this imperfect automation appropriately, which may limit the benefit of this technology [19].

Humans are prone to misuse or disuse imperfect automation [20]. Misuse occurs when individuals rely on automation inappropriately, usually by over relying on an imperfect aid. Disuse occurs when participants under use or reject the capabilities of automation [21]. Previous studies have consistently demonstrated that humans' trust in automation is a major factor that determines their reliance on the automation [21]. The goal of the work conducted under this portion of the project was to study factors that affect the humans' trust and reliance on the CID systems, with the ultimate goal of helping them better utilize the systems and reduce fratricide incidents.

The work [22] began with a literature review pertaining to operator trust in automation. Based on this review, two experiments were performed to address gaps in this literature. Experiment 1 was designed to determine whether providing system reliability information would lead to appropriate trust and reliance on CID systems. Experiment 2 was designed to test whether the differences between simulated CID systems and real system prototypes would influence operator trust in, and reliance on, the system feedback. Because previous empirical studies had not clearly defined reliance on automation we developed a new experimental method for this measurement.

The literature review revealed weaknesses in previous measures of system reliance. Thus, we developed a new measurement approach based on signal detection theory [23] [24], in which two indicators, *sensitivity* and *response bias*, characterize an observer's responses. Both measures are derived from the probability with which a subject correctly engages an enemy (hit rate) and the probability with which a subject incorrectly engages a friend (false alarm). Importantly, an observer's optimal response bias can be defined in any given condition (i.e., presence of a given type of decision support system) with a predetermined signal rate and decision payoff structure. By comparing subjects' observed response bias to the computed optimal response bias, we can determine whether an observer over- or under-relies on the system. This measurement approach is described in detail by Wang, Jamieson, and Hollands [25].

The results of Experiment 1 suggested that participants' beliefs about the system reliability and their trust in the system feedback are positively correlated. The findings further indicated that participants' trust in the feedback is positively correlated with their reliance on the feedback. Thus, individuals tended to trust what they perceived to be reliably accurate systems and to make use of systems that they trusted. However, participants' beliefs about the system reliability and their reliance on the feedback were not highly correlated, suggesting that trust acts as an intermediary between belief and reliance. This indicates that an individual's trust in a system was not well calibrated to the system's true accuracy. Thus, a person might over-rely on an inaccurate system incorrectly perceived to be accurate or under-rely on an accurate system misperceived as inaccurate. Others results confirmed that participants had difficulty estimating the system reliability. However, informing participants of the true reliability of the system led to appropriate trust in, and reliance on, the system.

The results of Experiment 2 suggested that, although the participants' reliance on the system feedback was generally not affected by activation mode and feedback form, their trust in the system feedback was influenced by them. These findings indicate that the dissimilarity between the simulated aids and the real system prototypes can lead to changes in humans' trust in the system feedback. This change in trust may then influence their use of the system.

Displaying feedback reliability information and acknowledgement of aid activation for a manual system were deemed especially important requirements. Three methods of displaying these requirements were suggested: a graphical element which degrades and dims as the reliability decreases and two analogue proportion displays, one that was continuous and one with discrete segments. The first two of these displays were examined in the experimental environment.

A third experiment was performed to evaluate different means of presenting feedback reliability information. In particular, the experiment examined whether integrating or separating the feedback reliability and the feedback identification information affords a performance advantage, and/or more appropriate reliance on and trust in the CID system. The results of this experiment indicated that when the reliability information was displayed as a degrading graphical element method, sensitivity increased while an integrated (rather than separated) display format produced more appropriate reliance on the system. The findings highlight the importance of human-machine interface (HMI) design on engendering appropriate trust and reliance on the automated decision aid.

Taken together, it is clear that the design of feedback plays an important role in engendering appropriate trust in, and reliance on, combat identification aids. These findings will be of value to both designers of combat ID systems and human factors scientists who study human reliance on imperfect automation.

Probabilistic cue integration

Bryant, D. J., & Smith, D. G. (2009). Impact of Uncertain Cues on Combat Identification Judgments. Defence R&D Canada – Toronto Technical Report (Submitted).

Bryant, D. J. (2009). Threat Classification Strategy: Effect of a Secondary Task. Defence R&D Canada – Toronto Technical Report (In Progress).

The research conducted under this element built on the results of the function flow and decision analyses performed earlier. Those studies described the "task ecology" of CID, laying out the decisions to be made by soldiers and the information available to them. In this work, algorithms and heuristics for the decision process were developed and compared to those used in human decision making. By identifying human models, we will be able to support the development of procedures, training, and technology to enhance combat ID decision making. The nature of the decision making process determines how human factors affect CID and can also help us better understand the kinds of physical and operational conditions that will challenge soldiers.

Bryant and Smith [26] report the results of an experiment that examined elements of human CID decision making. In particular, the experiment provided insight into the way people deal with uncertainty associated with various kinds of cues (visual and behavioural) that indicate whether a target is friendly or hostile. This experiment was conducted using the IMMERSIVE platform, in which the participant assumed the role of a dismounted infantry soldier. Participants completed blocks of trials in which each trial comprised a human figure moving into view. The subject's task was to engage (i.e., shoot) only those figures that were enemies. Friendly and enemy forces were distinguishable by differences in uniforms, equipment, and whether they are identified as friendly in the combat ID system.

The initial objective of the experiment was to investigate the impact of cue uncertainty on engagement decision making (accuracy, speed). Two factors were considered: 1) the type of characteristic that is uncertain (visual or behavioural), and 2) the salience of the uncertain feature (salient or non-salient). These factors were systematically varied across blocks of trials. Uncertainty as to which characteristics are important, or diagnostic, to the identity of targets can impair CID [6]. This is especially true in asymmetric environments in which the enemy uses diverse equipment and attempts to blend into civilian populations, as well as in coalition operations in which allies may use different, unfamiliar equipment. Determining the specific impact of uncertainty of different types of cues will help us better predict the impact of uncertainty in operational settings.

The results indicated that both hit rate (i.e., correctly engaging an enemy) and false alarm rate (i.e., incorrectly engaging a friend) can be affected by uncertainty associated with visual and, to a lesser extent, behavioural characteristics of targets in the environment. When uncertainty was associated with the characteristics of friends, the false alarm rate increased, whereas hit rate was primarily affected by uncertainty associated with potential enemies. In both cases, effects depended on the salience of the characteristics that were uncertain. When a salient visual or behavioural characteristic of friends was uncertain (i.e., a friend may possess a characteristic normally associated with enemies), subjects' false alarm rates tended to be greater than that of the baseline or when a non-salient characteristic was uncertain. Thus, subjects were more likely to make a serious error of engaging a friend in these cases. When the characteristics diagnostic of enemies were uncertain, participants' hit rates declined but their false alarm rates were unaffected.

In another experiment [27], we contrasted the potential use of different decision strategies for CID decision making. A major question in decision research concerns the value of heuristics in relation to analytic procedures. Whereas an heuristic is a simple decision procedure that offers the potential to quickly and easily solve a specific problem, an analytic procedure promises an optimal solution at the cost of extensive computation and time. Both approaches have received empirical support and both can be successful approaches to problem solving, and this precludes a simple conclusion that one is an inherently better approach than the other. The results of these experiments have indicated that people can employ both analytic and heuristic decision strategies but an individual's choice of one or the other appears to be a complex interaction of individual and situational factors.

Lessons learned

There are three major outcomes of the Applied Research Project (ARP) 15au ("Combat Identification"). These were: a) a computer-based methodology for studying the effects of environmental (e.g., types of visual cues) and system (e.g., blue-force tracking) factors on the speed and accuracy of human combat identification judgments, b) an information accumulation model of human combat identification decision making, and c) preliminary experimentation to validate this model and provide insight into the likely effects of blue-force tracking and rifle-mounted combat identification assist systems on human decision making. These outcomes are documented in a series of reports published, or in preparation, by DRDC Toronto.

The following are the major lessons learned during the course of this project.

1. It is possible to identify decision procedures used by individuals through controlled experiments. We developed a methodology to examine human CID decision making [26] [28] which can be used to contrast decision models.

2. A relatively simple and inexpensive gaming environment simulator can be used to study CID decision making. The IMMERSIVE environment, which is run on standard personal computers, is low cost, portable, and offers precise control of experimental factors.

3. Combat identification involves three main components, SA, target identification, and TTPs (which comprise knowledge needed to interpret information pertaining to the environment and targets). Failure of any one of these components can significantly impair CID performance. Moreover, failure of one component increases the difficulty of successfully performing or maintaining the others. For example, insufficient knowledge of TTPs makes it difficult for a soldier to build SA and to correctly interpret cues in target identification.

4. CID activities cover four stages/activities of any combat mission [9]: a) Preparation, b) Monitoring, c) Taking action, and d) Evaluating the outcomes of action. Current technological systems proposed to support CID deal only with the second and, to a lesser extent, third of these stages. Blue-force tracking systems are intended to improve SA and make monitoring easier and more accurate. Interrogate-Friend-Foe (IFF)-type systems that warn a soldier when a weapon is directed at a friend are meant to assist in making an identification. These systems provide no support for preparation (i.e., learning about the enemy, terrain, local culture, etc.) even though our function flow analysis [9] indicated that this knowledge was a primary contributor to successful CID. Likewise, there is no support for after-action learning.

5. Asymmetric conflict increases the difficulty of all components of CID. Given the need for an asymmetric opponent to remain hidden and the rapidity with which that opponent can change tactics, it is difficult for our forces to maintain appropriate TTPs. There is more to learn (e.g., wider range of potential cues to identify targets, cultural knowledge) and less time in which to learn compared to traditional state versus state warfare. SA is also harder to maintain. The enemy can conceal itself more effectively and there is often a civilian activity in operational areas. Finally, asymmetric conflict makes TI harder. The enemy will wear clothing similar to that of civilians, carry a range of equipment that may be unfamiliar,

variable from individual to individual, or similar to that carried by coalition partners. This decreases the usefulness of these cues for making unambiguous identifications.

6. Soldiers depend on a range of visual and behavioral cues to make identification judgments. SA can help by providing expectations that speed the search for diagnostic cues and aid the interpretation of cues. Poor SA, however, can also hinder identification. An inaccurate model of the environment can slow the search for cues and guide incorrect interpretation that can lead to mis-identification.

7. We do not know exactly how soldiers use cues in making identifications. There are numerous models of information aggregation [11], any of which could serve as a valid procedure for CID decision making. The problem of determining the kinds of decision procedures actually employed by soldiers is simplified somewhat by contrasting broad classes of models, such as formal/analytic models versus intuitive/integrative models. Nevertheless, our research has indicated that individuals use different decision strategies for a given task, depending on personal, environmental, and educational factors. Not knowing how a soldier combines cues makes it harder to design decision support systems and to predict how a soldier will use those systems [22].

8. The effectiveness of a decision support system will be mediated by the user's perception of, and trust in, the outputs of the system [22]. Automated systems (e.g., BFT) can be misused if the user's trust is not well calibrated to the actual accuracy of the system. Factors that affect a user's trust include the system's general level of accuracy, its reliability (i.e., propensity to avoid large errors), and the ability of the user to accurately gauge the accuracy and reliability of the system. A support system should include information about the reliability of system outputs to which users can refer to help them calibrate their trust levels [25].

Project manager's observations

The 15au, Combat Identification, project was largely successful. It has advanced our understanding of human CID decision making as well as our understanding of how human decision makers are likely to interact with automated CID support systems.

Progress in this project has been made largely in the laboratory setting, albeit with significant results being obtained through interviews with SMEs. The positive aspect of this situation is that an effective computer-based system was developed to study CID decision making. The IMMERSIVE environment proved flexible and easy to use while offering complete experimental control. This simulation environment allows measurement of a wide range of relevant human performance related to CID decision making. It is also readily configurable to allow study of CID decision making in a wide range of different environments. One downside of the IMMERSIVE environment is its low fidelity or lack of realism. A computer simulation cannot replicate all aspects of the CID task and certainly lacks the contextual factors of an operational setting.

Nevertheless, the IMMERSIVE environment should remain an important tool because human CID decision making is difficult to study in field exercises. The Bold Quest (BQ) exercises, for example, were set up to examine the technical performance of various BFT systems. Unfortunately, examination of human factors have frankly been an afterthought in the design of these exercises. Although researchers were able to administer surveys to participants, this cannot be said to constitute an adequate scientific study. To perform effective studies of CID decision making in a field setting requires (at a minimum):

- The capability to directly measure human decision making and task performance, such as decision accuracy, decision making latency, and information use; and
- Enough control of the design of an exercise to allow experimental comparison of conditions based on important theoretical factors (e.g., with versus without the use of a particular support system, with extensive versus impoverished SA, etc.).

A field study is undoubtedly an expensive and time-consuming endeavor, but we cannot simply "take it on faith" that introducing a decision support system, even one that works exactly as designed, will necessarily produce better human performance. When such systems are based on the intuitions of the engineers who design them, incorrect assumptions about human cognition may yield counterproductive results.

Future R&D and exploitation activities

This section outlines future research directions and potential exploitation activities for CID research. There are many interesting directions for new research associated with human decision making in this area. However, the major criteria for the future directions outlined in this section are that they address CF needs in C4ISR and CID and are also consistent with the vision and goals of the Human Systems Integration Section at DRDC Toronto.

Research priorities for the CF in CID

Achieving good SA and CID are challenging given the increased tempo and spatial dispersion of current operations and the likelihood of working in coalitions with nations employing different C2 systems and procedures. Thus, establishment and maintenance of a CF-wide SA capability is a prime goal of Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR). Likewise, the CF continues to seek improvements in C4ISR and CID that will directly impact SA and decision making in network-enabled operations, performance of distributed teams, intelligence gathering, information operations, and enhance the development of decision support, communications systems, doctrine, and training.

A key priority for the CF is the investigation of CID and SA technologies that have the potential to prevent fratricide. One such technology is the Battlefield Target Identification Device (BTID), which is a millimetric-wave (mmW) CID technology developed under NATO Standardization Agreement 4579 so that interoperability can be achieved in a Coalition environment. It is currently Canada's favoured CID solution.

In reality, BTID encompasses a family of CID solutions, all based on the above-mentioned mmW technology. The BTID Target ID interrogation solution was demonstrated and assessed at the Urgent Quest operational demonstration in 2005. The BTID digital data link, a Situational Awareness / Blue Force Tracking (SA/BFT) solution, was demonstrated and assessed at the BQ Operational Demonstration in 2007. A proof of concept of the BTID Transponder Airborne Platform Surveillance System was also demonstrated at BQ. The CF is expected to continue to pursue these technologies in the future.

New technologies, however, are only part of any solution to the problem of fratricide. The C4ISR challenge is to design doctrine, procedures, and training that will allow the CF to optimize performance and the effectiveness of tools. For this reason, human-oriented research will continue to be an essential component of CID research.

Potential directions for exploitation

This section discusses a number of ways in which the results of the current project could be used to enhance the CF's CID capabilities.

Enhanced TTPs

The lessons learned from this project offer suggestions for enhancing doctrine, tactics, procedures, training methods for individual and team decision making. For example, it seems that the preparation phase of missions is currently being neglected in the primarily technology-based approaches to CID (e.g., BTID). These technologies provide positional information on friendly units but do not help soldiers learn the characteristics that distinguish enemy and neutral entities from friends, nor do they provide contextual information to help interpret visual data.

Refinement of CID decision models

This project has identified a large number of formal decision making models applicable to CID (see [11]). Moreover, results of several experiments [27] [28] indicate that different individuals employ different decision processes within the same task environment. Thus, rather that seeking a single universal model of CID decision making, it is likely necessary to create an integrative framework in which to understand how soldiers will make CID decisions.

The AEAT model [12], which is a generalized version of an information aggregation model, could serve as a preliminary framework in which to explore how soldiers search for and aggregate discrete cues in the CID process. This model combines several key psychological processes, such as psychological arousal or readiness and threshold response. This framework can be augmented in the future by integrating more specific models of how information is aggregated and how information translates into neural arousal in the decision process.

Another model is the Integrative Combat Identification Entity Relationship (INCIDER), which was developed in the United Kingdom to model the decision making process culminating in outcomes of combat ID encounters. It considers SA, the contribution of sensors (technologies), and personal characteristics (e.g., personality, experience, expectations) as an inter-related variable set that enables predictions of the outcome of an identification process undertaken by a single decision maker observing a single unknown entity. The INCIDER model could also be translated as a framework to deal with specific CF issues pertaining to CID.

Development and assessment of decision support systems

One goal in developing a cognitive model of human CID decision making has been to provide the basis for making intelligent choices concerning the design of decision support for CID. We can further advance this goal by modeling key aspects related to SA, decision criteria, and categorization learning, including the interaction of SA and CID. Future decision support development should take into account, at the earliest stages of concept development, the basic elements of human decision making revealed by this project; i.e.:

- Humans aggregate perceived cues, weighted by their perceived diagnosticity;
- Cue perception is affected by a range of individual and situational factors that can result in significant biases in interpretation;
- Different decision makers use different information aggregation procedures based on radically different principles (e.g., analytic versus intuitive/heuristic processes) such that the outputs of a given decision support tool can be interpreted in very different ways;
- The user of a decision support tool will respond to the perceived reliability of that tool and could potentially over- or under-utilize a tool if its reliability has been misperceived; and
- HMI design is critical to engendering appropriate trust and reliance on the automated decision aid; presenting a more integrated display format yields more appropriate reliance on a system.

A cognitive model can serve as the basis for developing a methodology to assess the impact of soldier assist devices on CID performance, as well as performance of other tasks carried out while doing CID. Thus, any assessment should consider the impact of decision support for CID on cognitive workload and a range task performance.

A decision support system should help the human arrive at better decisions. The usual design approach to developing decision aids, however, can create unanticipated problems [21]. Computer advice invokes unfamiliar deliberation and ambiguity about its interpretation within the context of a particular decision and about system performance, for which neither decision makers nor system developers are prepared. The results of this project provide a first step in defining the mechanisms by which a computer's decision becomes helpful to a human decision maker, identifying common fallacies in the decision-aid concept, setting minimum standards that decision aids must meet if they are to be useful, pointing to the crucial role of trust, and illustrating how system developers can integrate expert systems following rational principles of trust [22].

Areas of future research interest

This section describes research topics that could be pursued in the future. These areas address the ongoing need to enhance the CF's capability to rapidly and accurately identify friendly, enemy and neutral forces, manage and control the battlespace, optimally employ weapons and forces, and minimize the risk of fratricide.

Assessment of technologies

In considering the human dimension of decision support systems, there are two important issues concerning any decision support technology to be implemented:

1. **Functionality/System Performance:** Do the combat identification and situation awareness technologies under investigation individually and collectively enhance the capability of the pilots to identify friends, foes, and neutrals in the battlespace?

2. **Warfighting/Operational Impact:** Do the systems individually and collectively make a positive contribution to fratricide reduction and combat effectiveness?

Currently, in exercises such as Ex BQ+, the emphasis has been on evaluating the functionality of BFT technologies, with less attention paid to the question of how they affect human decision making. This situation creates an opportunity to consider approaches to evaluating the impact of CID decision support systems. Research that investigates the effectiveness of decision support technologies in enhancing the overall CID performance of individuals and teams should accomplish the following:

- Evaluate whether the technologies are being used by soldiers as designed;
- Determine whether the technologies, when used properly, have the intended enhancing effect on human performance;
- Determine whether the technologies, when used properly, do not have unintended negative impact on the performance of other operationally necessary tasks; and
- Provide a high-level assessment of the appropriateness and effectiveness of the technology training (predominantly from users' perspective).

The proposed work could support an effort to develop standardized metrics for the evaluation of decision support systems. This would allow the measurement and comparison of CID and SA technologies on the basis of timeliness, accuracy, and completeness. A standardized evaluation methodology would be valuable for addressing numerous research questions:

- How will the introduction of new technologies impact upon operational tempo (measured by the reduction of decision cycles and increase in engagement ranges)?
- How will the introduction of new technologies impact upon fratricide rates? (Will warfighters trade off safety for improved effectiveness?)
- What impact does Joint, Coalition and CID training have on operational effectiveness?
- How much information can the human take in and comprehend in high pressure combat situations?
- How effective are CID training systems?
- When in the decision cycle should SA systems be used?

Training and development issues

Gaining operational experience takes time, during which soldiers are at heightened risk. The CF needs an effective and economical way to provide CID training prior to deployment to operations. Training should also be able to flexibly adapt to changes in operational setting or requirements.

A worthwhile avenue of research to pursue is the development of a computer-based CID training system that enhances target identification skills and helps soldiers build a knowledge base to improve SA when deployed. Specifically, the potential of the IMMERSIVE environment as a training instrument should be evaluated.

A computer CID training instrument could improve both the rate of learning of soldiers as well as the ultimate level of performance. Specifically, soldiers could acquire high levels of expertise and operationally-relevant knowledge prior to deployment, leading to significantly increased levels of combat effectiveness and decreasing the risk of fratricide and neutricide. Computer-based training has the potential to reduce training costs and manpower requirements.

The genera l effort to improve training options could be broken into several specific areas of research:

1. **Case-based versus rule-based learning:** This area focuses on model development and evaluation. There are two broad approaches to CID learning that could be contrasted. The first is an experiential, case-based view in which a soldier learns to use target and situation cues that are diagnostic by building memory representations of instances in which hostile targets are encountered. The other is a rule-based view in which a soldier extracts underlying rules or regularities of the operational environment and learns to use these to predict potential hostile entities. These views have implications for the types of training that would be most effective and so it is important to distinguish which offers the better description of actual soldier performance.

2. **Effects of CID systems on soldier performance:** CID decision support systems will be deployed in the near future. An unexplored issue has been what, if any, effect do these

systems have on training and ultimate performance of soldiers? Will soldiers who have trained to use support systems come to rely too heavily on them, possibly failing to learn how to distinguish targets based on their own observation?

3. **Requirements for a training system interface:** If a computer-based training system can be developed, research will be needed to examine the design of an optimal interface for the CID training system. One issue to be addressed is the degree of realism needed to promote learning that is transferable to operational contexts. In addition, interface design issues concerning CID systems (blue force tracking, IFF) can be explored.

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Annex A List of outputs (project deliverables)

Famewo, J., Matthews, M., & Lamoureux, T. (2007). Models of information aggregation pertaining to combat identification: A review of the literature. DRDC Toronto Contractor Report (CR 2007-062).

Famewo, J. J., Bruyn Martin, L. E., Zobarich, R. M., Vilhena, P.G.S., & Lamoureux. T. M. (2007). Combat Identification: A Summary of the Literature, Function Flow Analysis and Decision Requirements Analysis. DRDC Toronto Contractor Report (CR 2007-123).

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Bryant, D. J. (2009). Threat Classification Strategy: Effect of a Secondary Task. Defence R&D Canada – Toronto Technical Report (In Progress).

List of symbols/abbreviations/acronyms/initialisms

AEAT	Arousal-Excitation-Activation Threshold
AFB	Air Force Base
BFT	Blue Force Tracking
BQ	Bold Quest
BQ+	Bold Quest Plus
BTID	Battlefield Target Identification Device
C2	Command and Control
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CF	Canadian Forces
CID	Combat Identification
DRDC	Defence Research & Development Canada
FY	Fiscal Year
HMI	Human Machine Interface
ID	Identification
IFF	Interrogate Friend Foe
IMMERSIVE	Instrumented Military Modelling Engine for Research using Simulation and Virtual Environments
INCIDER	Integrative Combat Identification Entity Relationship
mmW	Millimetric-Wave
NATO	North Atlantic Treaty Organization
PC	Personal Computer
ROE	Rules of Engagement
SA	Situation Awareness
SMEs	Subject Matter Experts
SOP	Standard Operating Procedure
TI	Target Identification
TTPs	Tactics, Techniques, and Procedures

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(U) The purpose of this report is to summarize the work conducted within Project 15au “Combat Identification.” The report begins with a review of the project objectives and provides some background concerning the need for this work. The project achievements and cost performance are summarized, followed by descriptions of the major work elements undertaken. Among the major outcomes are a) a computer−based methodology for studying the effects of environmental (e.g., types of visual cues) and system (e.g., blue−force tracking) factors on the speed and accuracy of human combat identification judgments, b) an information accumulation model of human combat identification decision making, and c) preliminary experimentation to validate this model and provide insight into the likely effects of blue−force tracking and rifle−mounted combat identification assist systems on human decision making. A complete list of lessons learned from the project is provided. The report ends with discussion of potential avenues for exploitation of the project results and suggestions of future research and development directions.

(U) Le présent rapport vise à résumer le travail effectué dans le cadre du Projet 15au « Identification au combat ». Il commence par un examen des objectifs du projet, ainsi qu’une mise en perspective sur ce qui rend le travail nécessaire. Il y a un résumé des réussites du projet et de l’évolution des coûts, puis des descriptions des éléments de travail majeurs entrepris. Citons parmi les résultats principaux : a) une méthodologie informatique pour étudier les effets de l’environnement (types d'indices visuels, par exemple) et du système (blue force tracking, le suivi des forces bleues, par exemple) comme facteurs de la vitesse et de l’exactitude des jugements humains d'identification au combat humaine; b) un modèle d’accumulation d’information pour la prise de décision en identification au combat; c) des expériences préliminaires pour valider le modèle et donner une idée des effets probables des systèmes d’aide (blue force tracking et système d’identification au combat monté sur fusil) sur la prise de décision humaine. Est incluse une lise complète des leçons apprises grâce au projet. Le rapport s’achève avec une discussion des façons dont on pourrait exploiter les résultats du projet et avec la suggestion d’orientations de recherche et de développement à l’avenir.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

(U) combat identification;decision making