Defence Research and Development Canada | Recherche et développement pour la défense Canada

DEFENCE R&D DÉFENSE

Impact of Civilians on the Effectiveness of Blue Force Tracking

David J. Bryant

Defence R&D Canada
Technical Memorandum
DRDC Toronto TM 2012-100
October 2013

Canada

Impact of Civilians on the Effectiveness of Blue Force Tracking

David J. Bryant

Defence R&D Canada – Toronto

Technical Memorandum

DRDC TM 2012-100

October 2013

Principal Author

David J. Bryant

Defence Scientist, Socio-Cognitive Systems Section

Approved by

t

Keith Stewart

Head, Socio-Cognitive Systems Section

Approved for release by

Joseph V. Baranski

Chair, Knowledge and Information Management Committee

Chief Scientist

This research was supported through funding by ARP 14dq.

Abstract

Blue Force Tracking (BFT) systems seem to be promising decision aids for Combat Identification (CID), although their effectiveness is reduced by lag in data updating. Previous studies have evaluated BFT for dismounted soldiers in environments containing only friendly and enemy forces, but the presence of civilians has the potential to reduce the usefulness of BFT. An experiment examined the effectiveness of BFT decision support for dismounted infantry soldiers in a simulated environment containing civilians in addition to friendly soldiers and enemies. Twenty-four subjects performed five conditions: (a) a baseline with no decision support, (b) a condition with BFT providing real-time positional information, (c) a 10-second delay condition with no warning that the BFT data would lag actual movement, (d) a 10-second delay condition in which subjects were told of the delay, and (e) a final end baseline with real-time update of the BFT. Providing real-time BFT greatly improved subjects' CID performance. Adding a 10 second delay to the updating of position information in the BFT resulted in subjects being significantly more likely to mistakenly engage a friend but did not affect the likelihood of mistakenly engaging a civilian. Providing real-time BFT to dismounted soldiers can enhance combat effectiveness, in particular, reduce the risk of fratricide, even in environments containing civilians. However, real-time BFT produced smaller benefits than those previously observed.

Résumé

Les systèmes de suivi de la force bleue (SFB) se présentent comme des aides à la décision prometteuses pour l'identification au combat (IDCbt), même si le retard de la mise à jour des données réduit leur efficacité [17] [21]. Des études précédentes ont évalué le suivi de la force bleue pour les fantassins débarqués dans des environnements ne contenant que des forces amies et ennemies. La présence de civils pourrait cependant réduire l'utilité du SFB. Une expérience a été réalisée pour étudier l'efficacité du SFB pour l'aide à la décision des fantassins débarqués dans un environnement simulé contenant des civils en plus des soldats amis et ennemis. Vingt-quatre sujets ont été mis dans cinq situations, soit : un essai de référence sans aide à la décision; un essai où le SFB fournissait des données de localisation en temps réel; un essai où les données avaient un retard de 10 secondes sans que les sujets soient avisés que le SFB était en retard sur le mouvement réel; un essai avec un retard de 10 secondes dans lequel les sujets étaient avertis du retard; un essai de référence final avec une mise à jour en temps réel du SFB. Le SFB en temps réel améliore considérablement les résultats d'IDCbt des sujets. L'ajout d'un retard de 10 secondes avant la mise à jour des données de localisation du SFB augmente sensiblement la probabilité que les sujets engagent un soldat ami par erreur, mais n'a pas d'effet sur la probabilité d'engager un civil par erreur. Le SFB en temps réel peut augmenter l'efficacité au combat des fantassins débarqués, particulièrement en réduisant le risque de fratricide, même dans les environnements qui contiennent des civils. Toutefois, les avantages du SFB en temps réel sont dans ce cas moindres que ceux observés dans des études précédentes.

This page intentionally left blank.

Executive summary

Impact of Civilians on the Effectiveness of Blue Force Tracking

David J. Bryant; DRDC TM 2012-100; Defence R&D Canada – Toronto.

Introduction or background: The Canadian Forces (CF) will, in the near future, acquire technologies to support Blue Force Tracking (BFT) and position awareness, target designation capability, and Situation Awareness (SA) for the dismounted infantry soldier. BFT systems seem to be promising decision aids for Combat Identification (CID), but research examining their impact on human judgment has been equivocal. In an earlier experiment on BFT, Bryant and Smith (2013) found that BFT systems could improve CID judgments for the dismounted soldier but that adding a 10-second delay to the updating of position information in the BFT significantly impaired subjects' ability to identify enemies relative to real-time BFT. Subjects were as likely to commit fratricide when using a lagged BFT as when they had no decision support, whether they were warned of the lag or not. The presence of civilians in the environment also has the potential to interfere with participants' ability to spatially match observed targets with friends shown on the BFT display. In that event, participants' CID performance, particularly in terms of fratricide, would show little or no improvement with BFT than with no decision support.

Results: The experiment examined the effectiveness of BFT decision support for dismounted infantry soldiers in a simulated environment containing civilians in addition to friendly soldiers and enemies.

Twenty-four subjects performed five conditions: (a) a baseline with no decision support, (b) a condition with BFT providing real-time positional information, (c) a 10-second delay condition with no warning that the BFT data would lag actual movement, (d) a 10-second delay condition in which subjects were told of the delay, and (e) a final end baseline with real-time update of the BFT. Providing a real-time BFT device led subjects to exhibit a greater hit (H) rate and lower false alarm (FA) rate than observed when subjects had no decision support. Adding a 10-second delay to the updating of position information in the BFT resulted in subjects being significantly more likely to mistakenly engage a friend but did not affect the likelihood of mistakenly engaging a civilian. Subjects exhibited friend FA rates comparable to the No Decision Support System (DSS) condition in both the 10s No Warning and 10s Warning conditions. Subjects' civilian FA rates were not affected by BFT condition, and mean civilian FA rates were roughly equivalent when subjects had real-time or lagged BFT, or no decision support at all. Overall, a delay in BFT updating made subjects significantly more likely to mistakenly engage a friend but did not affect the likelihood of mistakenly engaging a civilian.

Significance: Providing real-time BFT to dismounted soldiers can enhance combat effectiveness, in particular, reduce the risk of fratricide, even in environments containing civilians. However, real-time BFT produced smaller benefits than those previously observed. Thus, the presence of civilians has the potential to reduce the usefulness of BFT to dismounted soldiers.

Future plans: Future experiments will examine the impact of temporal and spatial error on the effectiveness of BFT decision support as well as the performance implications of different display

types. Displays that convey information pertaining to system reliability and data uncertainty may mitigate the negative effects of update lag and civilian presence in the environment.

Sommaire

David J. Bryant ; DRDC TM [enter number only: 9999-999] ; R & D pour la défense Canada – Toronto ; .

Introduction : Dans un futur rapproché, les Forces canadiennes (FC) se doteront de technologies servant au suivi de la force bleue (SFB) et à la connaissance de la position, à la désignation d'objectifs et à la connaissance de la situation pour les fantassins débarqués. L'utilisation de systèmes de SFB pour aider aux décisions d'identification au combat (IDCbt) semble prometteuse, mais des recherches sur leurs effets sur le jugement humain ont un bilan équivoque. Bryant et Smith [17] [21] ont observé qu'un système de SFB peut améliorer le jugement d'IDCbt pour un fantassin débarqué, mais que l'ajout d'un retard de 10 secondes à la mise à jour des données de localisation du SFB réduit sensiblement la capacité des sujets d'identifier les ennemis par rapport au SFB en temps réel. Les sujets avaient autant de chance de commettre un fratricide lorsqu'ils utilisaient le SFB avec retard que lorsqu'ils ne disposaient d'aucune aide à la décision, qu'ils soient avertis du retard ou non. La présence de civils dans l'environnement pourrait également perturber la capacité des participants de faire correspondre les cibles observées aux éléments amis indiqués sur l'affichage de SFB. Dans ce cas, les résultats d'IDCbt des participants, particulièrement pour ce qui est du fratricide, ne présenteraient qu'une amélioration faible ou nulle quand ces derniers utilisent le SFB par rapport aux résultats obtenus en l'absence d'aide à la décision.

Résultats : L'expérience a été réalisée pour étudier l'efficacité du SFB comme aide à la décision pour les fantassins débarqués dans un environnement simulé contenant des civils en plus des soldats amis et ennemis. Vingt-quatre sujets ont été mis dans cinq situations, soit : un essai de référence sans aide à la décision; un essai où le SFB fournissait des données de localisation en temps réel; un essai où les données avaient un retard de 10 secondes sans que les sujets soient avisés du retard sur le mouvement réel; un essai avec un retard de 10 secondes dans lequel les sujets étaient avertis du retard; un essai de référence final avec une mise à jour en temps réel du SFB. Quand ils utilisaient un appareil de SFB en temps réel, les sujets ont eu un taux de succès plus élevé et un taux de fausse alarme réduit par rapport aux essais où ils n'avaient pas d'aide à la décision. L'ajout d'un retard de 10 secondes à la mise à jour des données de localisation du SFB augmente sensiblement la probabilité que les sujets engagent un soldat ami par erreur, mais n'a pas d'effet sur la probabilité d'engager un civil par erreur. Avec un retard de 10 secondes, les sujets avaient un taux de fausse alarme pour les amis comparable à celui obtenu sans aide à la décision, qu'ils soient avisés du retard ou non. Le taux de fausse alarme pour les civils n'a pas été influencé par la présence ou l'absence de SFB et les taux de fausse alarme moyens pour les civils étaient à peu près équivalents lorsque les sujets disposaient du SFB en temps réel et lorsqu'ils ne disposaient d'aucune aide à la décision. En général, le retard de la mise à jour du SFB augmente sensiblement la probabilité que les sujets engagent un soldat ami par erreur, mais n'a pas d'effet sur la probabilité d'engager un civil par erreur.

Portée : Fournir un SFB en temps réel aux fantassins embarqués peut augmenter leur efficacité au combat, particulièrement en réduisant le risque de fratricide, même dans les environnements qui contiennent des civils. Toutefois, les avantages du SFB en temps réel sont moins importants

que ceux observés au cours d'études précédentes. La présence de civils pourrait donc réduire l'utilité du SFB pour les fantassins débarqués.

Recherches futures : Des expériences ultérieures étudieront l'effet de l'erreur temporelle et spatiale sur l'efficacité de l'aide à la décision du SFB ainsi que l'influence de différents types d'affichages sur les résultats. Les affichages qui donnent de l'information sur la fiabilité du système et l'incertitude des données pourraient réduire les effets négatifs des retards de mise à jour et de la présence de civils dans l'environnement.

Table of contents

List of figures

List of tables

Acknowledgements

The assistance of Sofi Blazeski, Tonya Hendriks, and Elaine Maceda was essential to the success of the research reported in this report.

1 Introduction

1.1 Combat Identification

Combat Identification (CID) is the capability to rapidly and accurately identify friendly, enemy, and neutral forces; manage and control the battlespace; and optimally employ weapons and forces [1]. Accurate CID increases combat effectiveness and overall operational success, but failure of CID can lead to fratricide (the inappropriate engagement of a friendly soldier or unit), neutricide (mistakenly engaging a civilian or non-combatant), and harm to oneself caused by failing to identify an enemy (see [2]). Other negative effects include decreased morale and unit cohesion, loss of initiative, disruption of tempo [3], and loss of the "hearts and minds" of the local population [4] [5].

Most instances of fratricide and neutricide can be related to either the loss of Situation Awareness (SA), misidentification of the target, or both [6] [7] [8]. Thus, there are three main approaches to improving CID performance. One is to address tactics, techniques, and procedures (TTPs) and training to increase soldier skill and discipline [9] [10] [11]. Another is to support target identification in some fashion, typically by outfitting friendly units with some reliable indicator such as an Identify-Friend-Foe (IFF) transponder [12] [13]. The third approach is to support SA, typically by providing so-called Blue Force Tracking (BFT) systems. One example is the Force XXI Battle Command Brigade and Below – Blue Force Tracking (FBCB2-BFT) system fielded by the U.S. Army on vehicles in Iraq during Operation IRAQI FREEDOM [14] [15]. The FBCB2-BFT system consists of a computer, satellite antenna, and Global Positioning System (GPS) receiver connected by line-of-sight radios and commercial L-band satellites. These systems form a tiered architecture using ground, airborne, and over-the-horizon relay to track friendly forces and collate their positions, information which is then transmitted to friendly units.

The Canadian Forces (CF) will, in the near future, acquire technologies to support BFT and position awareness, target designation capability, and SA for the dismounted infantry soldier. Such technologies have the potential to greatly enhance combat effectiveness and reduce risk. For example, integration of SA and target designation capabilities in command and control (C2) systems could enhance command capabilities at the section and platoon levels. Nevertheless, some specification is needed of the types of decision support that are effective and the performance characteristics (e.g., accuracy and timeliness of information) necessary for effective decision support.

IFF and BFT systems seem to be promising decision aids for CID, but research examining their impact on human judgment has been equivocal. In one study, Dzindolet, Pierce, Beck, Dawe, and Anderson [16] showed participants a series of pictures of a wooded terrain, of which 24% contained a camouflaged soldier, and asked them to indicate whether a soldier was present or absent in each. In an aided condition, subjects received the output (present/absent) of a "computer program routine" that emulated an IFF system by providing an indication of the presence of a soldier. Subjects were told that the decision aid could mistakenly indicate the presence of a soldier when one was not present or fail to indicate the presence of a soldier when one was present, and were given an estimate of the overall likelihood of an error. The researchers found that the decision aid did not significantly improve subjects' CID performance, even when the aid provided highly accurate outputs. When aided, subjects tended to over-rely on the system output, making more errors when the system gave incorrect feedback than when feedback was correct. In a similar study, Karsh, Walrath, Swodoba, and Pillalamarri [13] found that availability of an IFF system did not reduce the subjects' fratricide rate compared to a control condition, although it did significantly reduce instances in which subjects failed to identify enemy targets.

More recently, Bryant and Smith [17] compared the impact of a handheld BFT device and rifle-mounted IFF on CID judgments in a simulated combat environment. Subjects played the role of a dismounted infantry soldier in a dynamic, first-person-perspective gaming environment as friendly and enemy troops moved through the subject's area of responsibility. Subjects attempted to engage enemies in three conditions (with no decision support, with a rifle-mounted IFF, and with a hand-held BFT). Results indicated that subjects were both more accurate in engaging enemies and significantly less likely to mistakenly engage friends in both the IFF and BFT conditions. These results suggest, contrary to previous studies, that both an IFF and BFT system could improve CID judgments for the dismounted soldier.

The benefit of BFT to SA likely depends, in part, on the proportion of friendly units for which timely and accurate position information can be obtained. Although the goal for a BFT system is to provide real-time position information, in practice such systems typically suffer a lag of several minutes [18]. Any wireless, ad hoc network will be subject to periodic loss of connectivity, limited bandwidth, and variable latency [19]. Existing BFT systems depend on communication networks that can be adversely affected by weather, terrain, equipment failure, or interference by outside sources, including deliberate disruption by the enemy. Thus, some degree of lag in the updating of positional information can be realistically expected, and such delays could seriously reduce the usefulness of a BFT device [20].

To explore the impact such lag might have on the usefulness of a BFT system, Bryant and Smith [21] performed an experiment to contrast CID performance under real-time and lagged BFT. Subjects again played the role of a dismounted infantry soldier in a dynamic, first-person-perspective gaming environment as friendly and enemy troops moved through the subject's area of responsibility. In some conditions, subjects could access a real-time BFT device, whereas in two other conditions, subjects had access to a BFT device which provided data that was 10 seconds old. In one case, subjects were unaware of this lag, whereas in the other, subjects were alerted to the lag. Providing a real-time BFT device led subjects to exhibit a greater hit (H) rate and lower false alarm (FA) rate than observed when subjects had no decision support. Adding a 10-second delay to the updating of position information in the BFT significantly impaired subjects' ability to identify enemies relative to real-time BFT. Subjects were as likely to commit fratricide when using a lagged BFT as when they had no decision support, whether they were warned of the lag or not. In addition, subjects exhibited a strong response bias toward engaging targets in conditions with a lagged BFT device compared to essentially zero or small negative bias in real-time BFT conditions.

1.2 Objective

The results of Bryant and Smith [17] [21] show the potential benefit of providing soldiers with BFT devices, as well as the negative impact that update lag is likely to have on the effectiveness of such decision aids. Those experiments, however, employed simulated environments comprising only friendly and enemy soldiers. This is problematic in that Canada and its coalition partners find themselves participating in high tempo, non-linear operations with enemies who eschew traditional uniforms and employ diverse equipment. The so-called "three-block war" is likely to remain a strategic reality, with soldiers being called on to perform missions as diverse as support to an indigenous population, restoring stability/security, and fighting an armed opponent in force-on-force combat, these missions often performed simultaneously and in close proximity [22]. The presence of civilians is an important feature of such operations.

The presence of civilians in the battlespace could affect the utility of BFT. BFT facilitates CID by enhancing a soldier's SA. Thus, any factor that influences SA could potentially affect how BFT information is processed and used. Indeed, large civilian populations in urban areas contribute to loss of soldier SA, and BFT devices are not designed to mitigate this problem [23].

Within the operational context of the infantry soldier, SA is a spatial and temporal model of the local battlespace, including locations and types of potential hostile entities as well as friends [24]. SA affects the CID process in two ways [25]. First, it guides attention and can exert a large impact on where sensory processes are directed. Thus, knowledge of the environment and expectations lead perception to focus on some aspects of the environment at the expense of others [26] [27]. Second, the objects and areas within a soldier's spatial map serve as expectations concerning the true state of the battlespace and affect the level of evidence necessary to assign an identification to a target. Thus, an object presumed to be an enemy will have a lower threshold for identification as an enemy and a correspondingly higher threshold for identification as a friend or neutral. This trade-off reflects the general propensity for human judgment to be subject to expectation bias [28].

BFT contributes to SA by providing positional information about friendly entities. The soldier using the BFT must correlate locations indicated on a top-down map to locations in his/her field of view. This requires transformation of spatial frames of reference, which involves matching objects in the field of view to objects in the map display. In the transformation process, civilians are "distracters" because they are not displayed in the BFT map. Thus, civilians seen by a soldier have no corresponding object in the BFT display to which they can be matched. Instead, civilians act as potential matches to friends shown in the BFT and must be eliminated as candidates in order to correctly match friends in the field of view to friends indicated on the map. The greater the number of civilian distracters in the environment, the more difficult and cognitively demanding is this process.

The experiment reported here is intended to examine the effectiveness of BFT for dismounted soldiers operating in an urban environment containing civilians. The presence of civilians in the environment has the potential to interfere with participants' ability to spatially match observed targets with friends shown on the BFT display. In that event, participants' CID performance, particularly in terms of fratricide, would show little or no improvement with BFT than with no decision support.

2 Experiment

2.1 Method

2.1.1 Subjects

Subjects were 38 male and female volunteers who were employees of DRDC Toronto, students conducting research at DRDC Toronto, or individuals recruited from local universities. All subjects were aged 18 and older, had normal or corrected-to-normal vision, and were unfamiliar with the specific hypotheses and stimulus configurations of the experiments. All received stress remuneration for participating.

This study, approved by the DRDC Toronto Human Research Ethics Committee (HREC), was conducted in conformity with the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans* (2010).

2.1.2 Materials and Procedure

The experiment was conducted with Personal Computers (PCs), which presented stimuli, collected subject responses, and recorded data. The IMMERSIVE (Instrumented Military Modeling Engine for Research using SImulation and Virtual Environments) platform was used as a test bed simulating combat activities. The IMMERSIVE platform is a low-fidelity simulator but the environments and targets used in the experiments were developed with the support of people knowledgeable of CF doctrine and procedures. Subjects used the computer mouse to control the direction of facing and firing the weapon (by clicking the left mouse button).

The experimentation process comprised the set up, deployment, and management of the following experimentation components:

- Terrain: The simulated environment in which a scenario takes place;
- Scenario: A sequence of events representing a portion of battlefield action;
- Bots: RoBOTic computer-controlled entities play scenario characters;
- Participant: Volunteer subject who plays the role of a Canadian soldier and controls a simulated rifle that can be used to engage (shoot at) hostile entities; and
- Rules of Engagement (ROE): Rules that govern how the participant responds to different kinds of bots.

Subjects were provided with ROE at the beginning of the experimental session. The ROE distinguished friendly from potentially hostile bots according to four characteristics of the soldier: (1) the weapon carried, (2) the uniform worn, (3) the type of walk (crouched or upright), and (4) whether or not the soldier had his/her rifle aimed. Examples of friendly and enemy bots are shown in Figure 1. To establish a mission context, subjects were informed of the following:

> *"In this experiment, you are manning a critical checkpoint. Recent intelligence has indicated that enemy combatants are planning to attack a local orphanage in order to spark conflicts among various ethnic and political factions. It is crucial that they not be allowed to succeed. It is only by taking out enemy combatants who pass your checkpoint*

that we will be able to prevent the planned atrocity. As you monitor your area of operation, keep in mind the criticality of stopping all enemies as quickly as possible."

Figure 1: Examples of friendly and enemy bots

Subjects in previous pilot studies had expressed a great deal of concern with avoiding incidents of fratricide and were thus overly cautious. The urgency of engaging enemies was emphasized in the instructions to ensure that subjects concentrated on both engaging enemies as well as avoiding fratricide.

Subjects performed five blocks of trials as a dismounted infantry soldier manning a fixed location. In Figure 2, the subject's location is marked by a white box at the bottom. In a block, a number of bots were in motion, following pre-specified paths at pre-specified times. Two such paths are marked in blue and red in Figure 2. The bots traveled into and out of view sequentially, so that no two bots were visible to the subject at the same time.

To control for effects of position and path of movement, a friendly and enemy bot started at the same position and followed the same path in different trials in each block. Thus, subjects encountered a friend and an enemy following the same path under the same conditions. The directions in which bots moved through the environment followed one of two orders (forward and reverse).

In addition to friendly and enemy bots, civilian bots moved through the environment along pre-determined paths. Civilians wore several types of clothing but in all cases were readily distinguishable from friend and enemy bots. Civilians walked along different paths than friend and enemy bots. There were always civilians in the subject's area of responsibility.

The IMMERSIVE software logged subjects' actions pertinent to firing decisions. The software logged each instance of the subject firing the rifle, the identity of the bot fired upon, and the subject's accuracy (whether or not the shot hit the bot). The primary experimental measure was decision accuracy (i.e., whether or not the subject engaged a hostile or friendly bot). A subject could fire one or more shots at a bot without hitting it. To capture such events as intended engagements, the software logged for each shot fired whether it hit a bot and, if not, how close the shot was to a bot (i.e., minimal distance between shot and bot). Shots fired within a certain distance of a bot (approximately one meter in the simulated environment) were counted as engagements.[1]

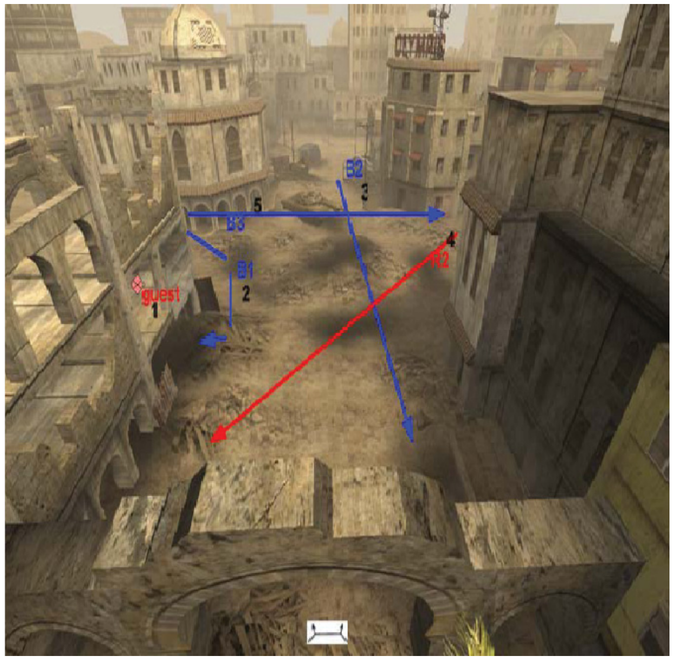

Figure 2. Example bot paths in a simulated environment.

Response times were not considered because it was impossible to distinguish the target detection and target identification aspects of the task. Subjects did not provide any observable indication that they had detected a target. Thus, overall response times measured from the first appearance of a target would contain varying amounts of time reflective of the presence but not detection of that target, making response times unreliable across targets.

In the No Decision Support System (No DSS) condition, subjects performed the task without access to any decision aid. In the remaining four blocks, subjects could call up a simulated BFT device as a decision aid (see Figure 3). The device, which was modeled on a Personal Digital Assistant (PDA), presented a top-down map of the local area. Superimposed on the map were blue dots representing the positions of friendly soldiers. Subjects could call up the BFT device at any time during the experiment by pressing a specified key on the computer keyboard but were not required to use it. Implemented as a PDA, the BFT was intended to be viewed periodically to ascertain positions of friendly units.

2.1.3 Design

The experiment employed a single-group, pretest–post-test design to control for potential effects of subject learning over the course of the experiment. Subjects performed the first block of trials

[1] Because the criterion for engagement was a fixed distance with respect to a bot, the angular displacement from rifle to bot varied somewhat with the distance of the bot to the subject's firing position. However, angular displacements were not computed for each shot because the range of firing angles associated with engagements was fairly small.

with no decision support system, to serve as an initial pretest of CID performance (No DSS). They performed the second block with access to a BFT that provided real-time data on friendly bots' positions (BFT). This was also a pretest to establish subjects' baseline performance with access to completely accurate positional information. The next two blocks served as experimental treatments in which the position information provided by the BFT lagged by 10 seconds after events in the simulated environment (i.e., positions indicated by the BFT were 10 seconds old). In the third block, subjects were not warned about the data lag (10s No Warning), whereas in the following block, subjects were told that BFT data lagged by 10 seconds (10s Warning). All subjects followed this order of blocks; otherwise, subjects who received the warning first would be cued to detect the lag in the unwarned condition. In the final block (End BFT), the BFT returned to real-time data, which served as a final baseline to determine whether any practice or fatigue effects had occurred.

Figure 3. Simulated BFT device available to subjects

The choice of a 10-second delay was somewhat arbitrary, but this time interval is a plausible update lag for BFT systems in an urban environment likely to contain various dead spots and interference affecting connectivity and available bandwidth [19]. Moreover, a 10-second delay would be a significant improvement over earlier systems. The U.S. Army, for example, set a target refresh rate of 10 seconds for an updated FBCB2-BFT system [29].

3 Results

Subjects' decisions to shoot or to not shoot were recorded for each bot in each condition. Decisions to shoot an enemy bot were termed *hits* and comprised correct recognition of an enemy, whereas decisions to not shoot an enemy bot were termed *misses* and comprised failures to recognize an enemy, leading to reduced mission effectiveness. Decisions to not shoot friendly bots were termed *correct rejections* and comprised the correct recognition of a friend, whereas decisions to shoot a friendly or a civilian bot were termed *false alarms* and comprised the incorrect determination of an enemy, leading to an instance of fratricide or neutricide. For the purpose of analysis, two types of false alarm were identified. *Friend false alarms* comprised instances in which the subject mistakenly engaged a friendly bot, and *civilian false alarms* comprised instances in which the subject mistakenly engaged a civilian bot.

3.1 Use of the BFT System

Every instance in which a subject called up the BFT system was recorded for analysis. Subjects inspected the BFT frequently in all conditions (except the initial baseline in which no BFT was available). Subjects averaged 5.0 inspections of the BFT per bot in the initial BFT condition, 4.4 in the 10s No Warning, 3.4 in the 10s Warning, and 3.6 in the End BFT conditions. Their use of the BFT was significantly affected by the condition [$F(3,111) = 10.42$, $MSE = 1.930$, $p<.05$.]. A series of Fisher's Least Significant Difference (LSD) post-hoc comparisons was performed to contrast subjects' mean number of inspections across all conditions. The results of the comparisons are summarized in Table 1.

Table 1. Fisher's Least Significant Difference (LSD) Test Results for Use of the BFT System

	Condition			
	BFT	**10s Delay (No Warning)**	**10s Delay (Warning)**	**End BFT**
BFT	N/A	0.070	***<0.001***	***<0.001***
10s Delay (No Warning)	-	N/A	***0.002***	***0.024***
10s Delay (Warning)	-	-	N/A	0.342
End BFT	-	-	-	N/A

Within *MSE* = 0.088; df = 144.

Contrasts which are significant to p<.05 are shown in ***bold italic***

The amount of time the BFT system was viewed was recorded for each instance in which the subject opened the device. Subjects' viewing times per BFT inspection tended to increase over the course of the experiment, but this effect was not statistically reliable [$F(3,111) = 1.31$, $MSE = 3.2\times10^4$, *n.s.*]. Subjects viewed the BFT, on average, for 597 msec/inspection in the BFT condition, 676 msec/inspection in the 10s No Warning, 789 msec/inspection in the 10s Warning, and 825 msec/inspection in the End BFT conditions

3.2 Hit (H) Data

Figure 4 shows mean hit (H) rates calculated for each condition. Hit rate was low in the No DSS condition but increased in all subsequent BFT conditions, including the delay conditions. A two-factor, mixed-design ANOVA indicated that hit rate varied significantly across BFT condition [$F(4,144) = 21.06$, $MSE = 0.009$, $p<.01$]. The order in which bots appeared did not have a significant effect on hit rate [$F(1,36) = 0.31$, $MSE = 0.036$, *n.s.*], but this factor did interact with BFT condition [$F(4,144) = 3.02$, $MSE = 0.009$, $p<.05$]. The interaction effect seems to reflect the fact that subjects' hit rates were slightly lower for the "reverse" than "forward" order in the No DSS and BFT conditions but slightly lower for the "forward" than "reverse" order for the 10s No Warning condition.

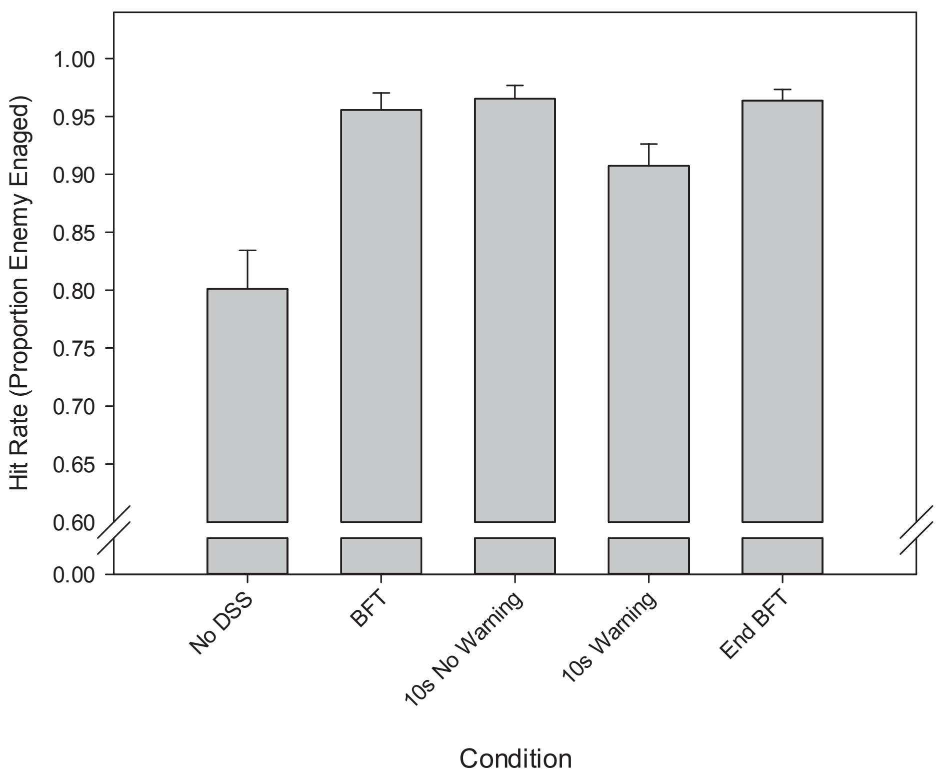

Figure 4. Hit rates (correct engagement of enemy) across BFT condition

To better understand how hit rate varied across blocks, a series of Fisher's LSD post-hoc comparisons was performed to contrast each block with every other block. The results of the comparisons are summarized in Table 2 (first row). These analyses confirmed that the hit rate in the No DSS condition was significantly lower than that of all other conditions. In addition, the hit rate in the 10s Warning condition was significantly lower than that of the 10s No Warning and End BFT conditions but not the BFT condition. Hit rate in the BFT condition did not differ from

Table 2. Fisher's Least Significant Difference (LSD) Test Results for All Measures of Performance

		Condition				
		No DSS	**BFT**	**10s Delay (No Warning)**	**10s Delay (Warning)**	**End BFT**
Hit Rate	**No DSS**	N/A	***<0.001***	***<0.001***	***<0.001***	***<0.001***
	BFT	-	N/A	0.651	***0.027***	0.711
	10s Delay (No Warning)	-	-	N/A	***0.008***	0.935
	10s Delay (Warning)	-	-	-	N/A	***0.010***
	End BFT	-	-	-	-	N/A
Within *MSE* = 0.088; df = 144.						
Friend FA Rate	**No DSS**	N/A	***0.009***	0.860	0.510	***0.028***
	BFT	-	N/A	***0.015***	0.051	0.679
	10s Delay (No Warning)	-	-	N/A	0.629	***0.043***
	10s Delay (Warning)	-	-	-	N/A	0.121
	End BFT	-	-	-	-	N/A
Within *MSE* = 0.206; df = 144.						
Civilian FA Rate	**No DSS**	N/A	0.188	0.238	0.476	0.663
	BFT	-	N/A	0.891	0.543	0.376
	10s Delay (No Warning)	-	-	N/A	0.638	0.455
	10s Delay (Warning)	-	-	-	N/A	0.782
	End BFT	-	-	-	-	N/A
Within *MSE* = 0.102; df = 144.						
d'	**No DSS**	N/A	***<0.001***	***0.001***	0.070	***<0.001***
	BFT	-	N/A	0.191	***0.006***	0.784
	10s Delay (No Warning)	-	-	N/A	0.134	0.301
	10s Delay (Warning)	-	-	-	N/A	***0.012***
	End BFT	-	-	-	-	N/A
Within *MSE* = 1.346; df = 144.						
c	**No DSS**	N/A	***<0.001***	***<0.001***	***0.002***	***<0.001***
	BFT	-	N/A	0.111	0.330	0.915
	10s Delay (No Warning)	-	-	N/A	***0.011***	0.137
	10s Delay (Warning)	-	-	-	N/A	0.280
	End BFT	-	-	-	-	N/A
Within *MSE* = 0.350; df = 144.						
Contrasts which are significant to p<.05 are shown in ***bold italic***						

that of the 10s No Warning and End BFT conditions but was significantly greater than that of the 10s Warning condition. No other contrasts yielded significant differences.

3.3 Friend False Alarm (FA) Rate

Figure 5 shows Friend False Alarm (FA) rates calculated for each block. The Friend FA rate was relatively high in the No DSS condition but dropped substantially in the first BFT condition (real-time data). It then climbed in both 10s Delay conditions to almost the No DSS level before dropping again in the End BFT condition. A mixed-design ANOVA confirmed that mean Friend FA rate varied across conditions [$F(4,144) = 2.93$, $MSE = 0.021$, $p < .05$]. The order in which bots appeared to subjects did not have a significant effect on Friend FA rate [$F(1,36) = 0.05$, $MSE = 0.083$, *n.s.*], nor did this factor interact with BFT condition [$F(4,144) = 0.78$, $MSE = 0.021$, *n.s.*].

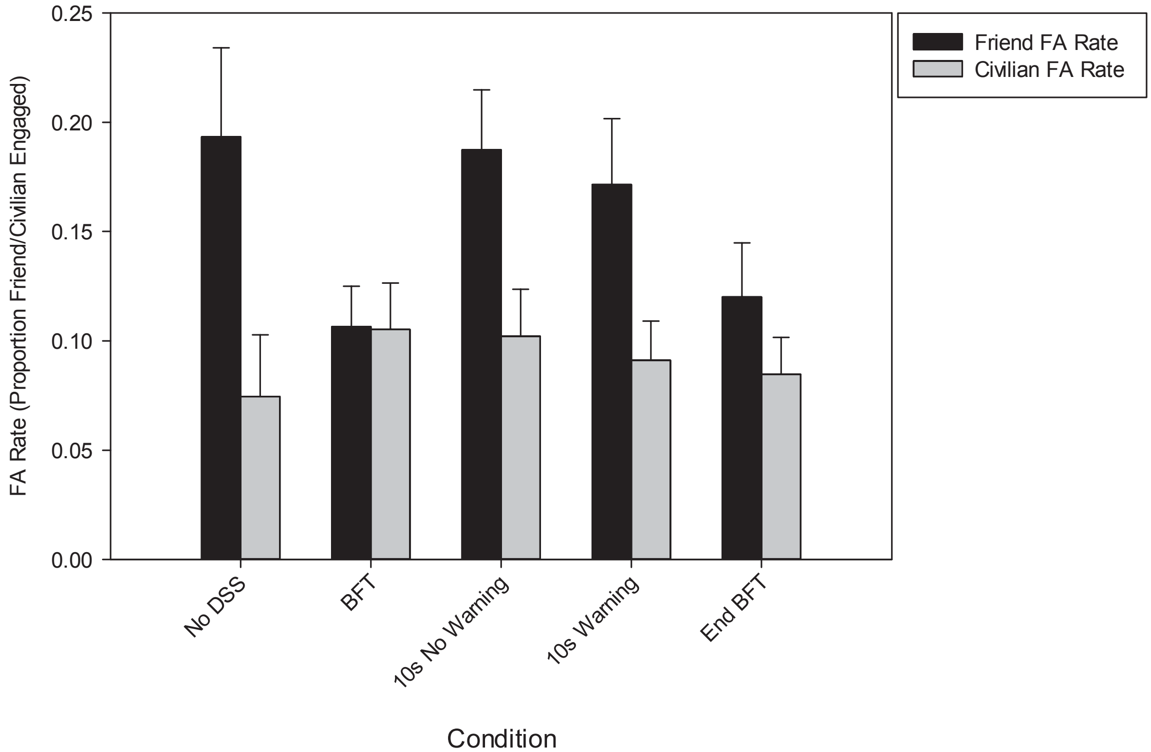

Figure 5. Friend and civilian FA rates (incorrect engagement of friend or civilian) across BFT condition

A series of Fisher's LSD post-hoc comparisons (see Table 2, second row) indicated that the mean Friend FA rate was significantly higher in the No DSS than the BFT and End BFT conditions. Mean Friend FA rate, however, did not differ between the No DSS and 10s No Warning and 10s Warning conditions. The BFT and End BFT Friend FA rates did not differ significantly, indicating no learning effect across the course of the experimental session. Both the BFT and End BFT Friend FA rates were significantly lower than that of the 10s No Warning condition. Although Friend FA rates in the BFT and End BFT conditions were lower than that of the 10s

Warning condition, these differences did not achieve statistical significance. Friend FA rates were not different in the 10s No Warning and 10s Warning conditions.

3.4 Civilian False Alarm (FA) Rate

Figure 5 shows Civilian False Alarm (FA) rates calculated for each block. The Civilian FA rate was roughly the same in each condition. A mixed design ANOVA indicated no effect of BFT condition [$F(4,144) = 0.59$, $MSE = 0.010$, *n.s.*], the order in which bots appeared [$F(1,36) = 1.04$, $MSE = 0.047$, *n.s.*], or the interaction of these factors [$F(4,144) = 0.76$, $MSE = 0.010$, *n.s.*].

3.5 Sensitivity (*d'*)

In the context of the CID task, sensitivity refers to subjects' psychological discrimination between friends and foes, or their ability to correctly classify a friend as a friend and a foe as a foe [30]. As a statistical measure, sensitivity (d-prime or *d'*) is defined in terms of *z* (i.e., the inverse of the normal function) and the observed hit (H) and FA rates by the formula [31]:

$$d' = z(H) - z(FA) \quad (1)$$

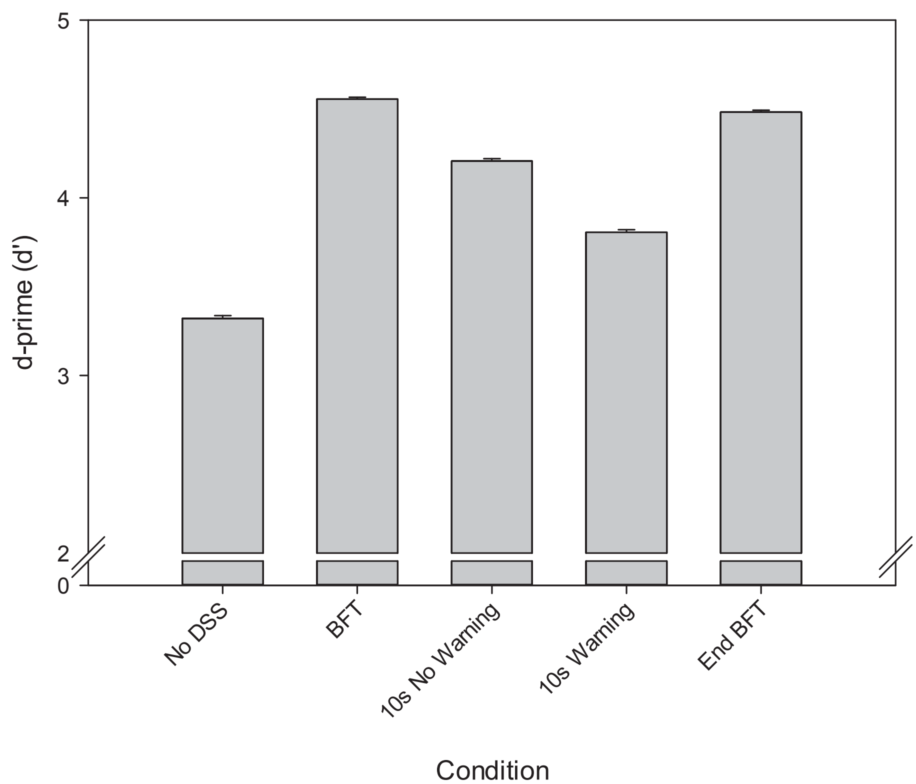

Figure 6. Mean *d'* values (sensitivity) across BFT conditions

A *d'* value of zero corresponds to a complete inability to distinguish friend from foe, with increasingly positive values indicating progressively greater ability to discriminate friend from foe. Sensitivity takes into account correct engagements of enemy bots and correct non-engagements of friendly bots and is thus a more complete measure of performance than hit rate or FA rate alone. For the purposes of this experiment, *d′* was calculated using the combined FA rate (i.e., Friend FA and Civilian FA).

Subjects' mean *d′* values are shown in Figure 6. Sensitivity varied significantly across conditions [$F(4,144) = 7.46$, $MSE = 1.346$, $p<.01$]. The order in which bots appeared to subjects did not have a significant effect on *d′* [$F(1,36) = 0.20$, $MSE = 6.005$, *n.s.*], nor did this factor interact with trial block [$F(4,144) = 0.62$, $MSE = 1.346$, *n.s.*].

A series of Fisher's LSD post-hoc comparisons (see Table 2, fourth row) revealed that *d′* was significantly lower in the No DSS than all conditions other than 10s Warning. Mean *d′* in the BFT condition significantly exceeded that of the 10s Warning condition but did not significantly differ from that of the 10s No Warning and End BFT conditions. In addition, *d′* did not differ between the 10s No Warning and 10s Warning conditions. Thus, subjects exhibited somewhat greater sensitivity when using the lagged BFT compared to no decision support. Sensitivity in the lagged BFT conditions was somewhat lower than or, at best, equivalent to, the level of sensitivity conveyed by real-time BFT.

3.6 Response Bias (*c*)

Response bias (*c*) is a measure of a subject's general tendency to respond positively to a target. In the case of the current experiment, it measures the general tendency to report a foe regardless of the actual identity of the target. Like sensitivity (*d′*), response bias (*c*) is defined in terms of *z* and the observed hit (H) and FA rates:

$$c = -0.5 \bullet [z(H) + z(FA)] \quad (2)$$

Positive values of *c* indicate a tendency to classify a target as foe regardless of its true identity, whereas negative values indicate a tendency to classify a target as a friend. For the purposes of this experiment, *c* was calculated using the combined FA rate (i.e., Friend FA plus Civilian FA).

Subjects' mean *c* values are shown in Figure 7. Subjects exhibited a negative *c* value in the No DSS condition, indicating bias against engaging bots, and positive bias to engage in all other conditions. A mixed-design ANOVA indicated that the BFT condition had a significant effect on subjects' mean *c* values [$F(4,144) = 9.02$, $MSE = 0.350$, $p < .01$]. The order of friendly and enemy bots did not have a significant effect on *c* values [$F(1,36) < 0.001$, $MSE = 1.525$, *n.s.*], nor did this factor interact with trial block [$F(4,144) = 2.13$, $MSE = 0.350$, *n.s.*].

A series of Fisher's LSD post-hoc comparisons (see Table 2, fifth row) showed that the No DSS *c* value was significantly lower than that of all other conditions. The *c* value in the 10s No Warning condition significantly exceeded that of the 10s Warning condition. No other comparisons yielded significant results.

3.7 Summary

Providing a real-time BFT device led subjects to exhibit greater hit rate and lower FA rate than observed when subjects had no decision support. Adding a 10-second delay to the updating of position information in the BFT had an inconsistent effect on subjects' ability to identify enemies relative to real-time BFT. Subjects exhibited significantly greater hit rates and sensitivity (*d′*) in the BFT and End BFT than the 10s Warning condition but not the 10s No Warning condition. The 10-second delay significantly increased subjects' friend FA rates but not their civilian FA rates, as compared to the real-time BFT. Subjects exhibited friend FA rates comparable to the No DSS condition in both the 10s No Warning and 10s Warning conditions. Subjects' civilian FA rates were not affected by BFT condition and mean civilian FA rates were roughly equivalent when subjects had real-time or lagged BFT or no decision support at all. Finally, subjects exhibited a negative bias (against engagement) in the No DSS condition but positive bias (toward engagement) in all other conditions. This bias was significantly smaller in the 10s Warning condition. Overall, a delay in BFT updating made subjects significantly more likely to mistakenly engage a friend but did not affect the likelihood of mistakenly engaging a civilian.

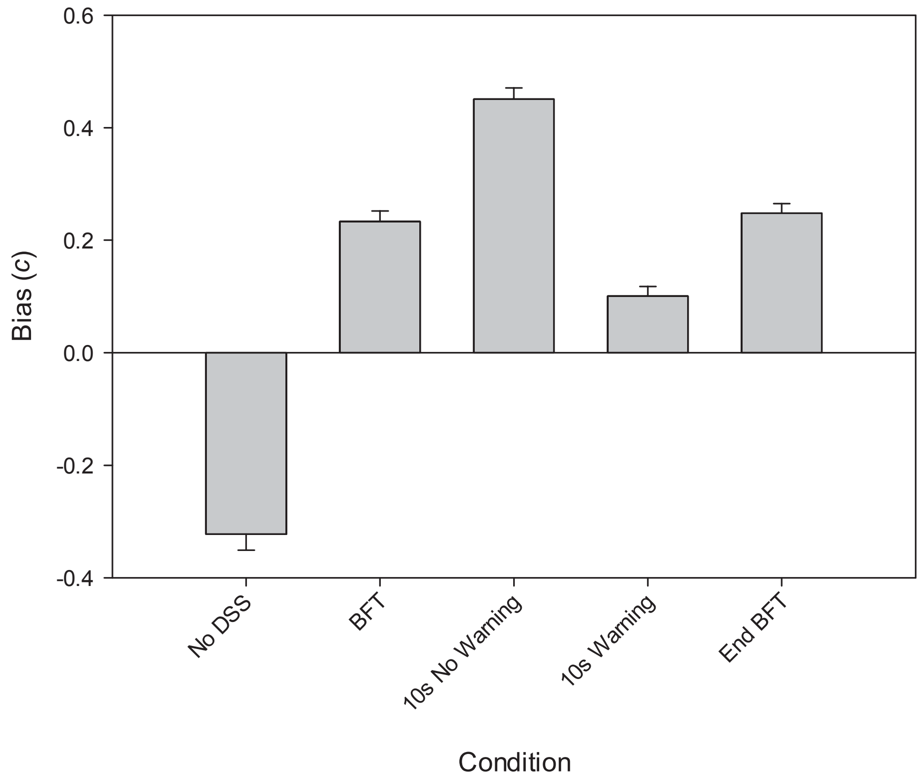

Figure 7. Mean *c* values (response bias) across BFT conditions

3.8 Comparison to Bryant and Smith [21]

Bryant and Smith [21] performed a version of the current experiment in which only enemies and friends appeared. Their FA results, reproduced below, show the same general pattern as the friend FA results of the current experiment. Inspection, however, suggests that the positive effect of real-time BFT in reducing FA rate was larger in Bryant and Smith's experiment. It is possible that the presence of civilians in the current experiment reduced the effectiveness of real-time BFT as a decision aid to avoid fratricide.

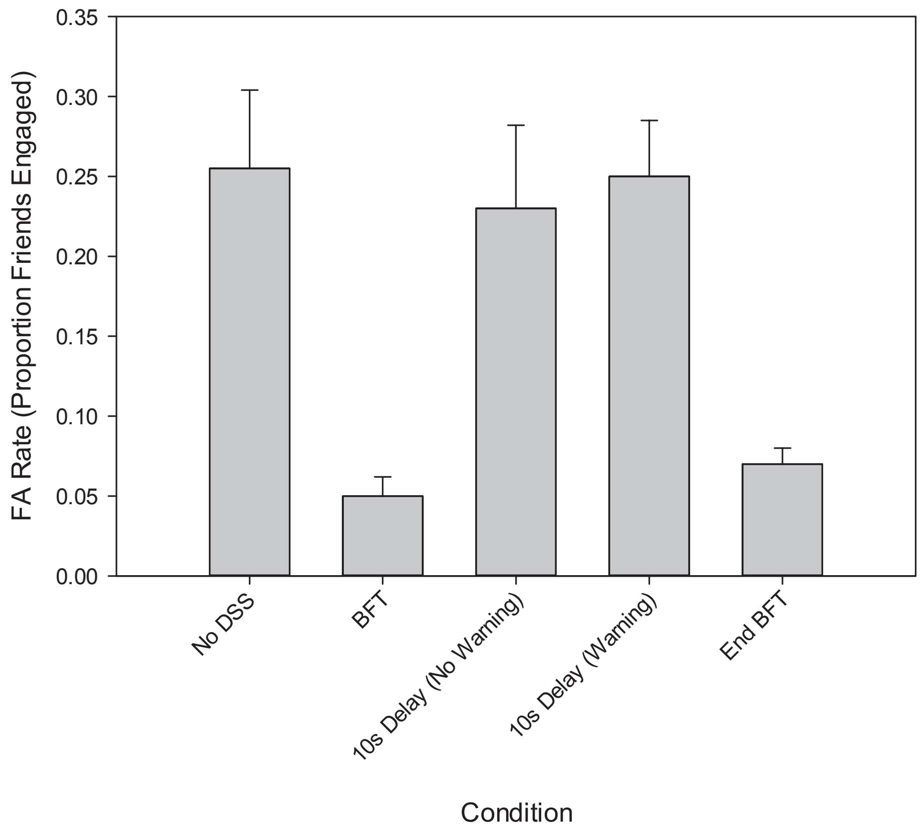

Figure 8. FA results from Bryant and Smith [21]

To verify that subjects' improvement in friend FA rate was in fact smaller in the current experiment where civilians were present in the environment, the effect sizes of the post-hoc comparisons between the BFT and End BFT conditions with the No DSS, 10s No Warning, and 10s Warning conditions were assessed by Hedges' *g* statistic [32]. Hedges' *g* measures the magnitude of a treatment effect. For comparison between two within-subjects groups, Hedges' *g* is calculated by the formula [33]

$$g = \frac{\bar{y}_a - \bar{y}_b}{\sqrt{2 \bullet MSE_{a\times b}}} \bullet \frac{N-3}{N-2.25} \bullet \sqrt{\frac{N-2}{N}} \quad (3)$$

where

$\bar{y}_a$ = mean for treatment group *a*,

$\bar{y}_b$ = mean for treatment group *b*,

$MSE_{a\times b}$ = Mean Square Error term for the comparison between treatment groups *a* and *b*, and

N = number of subjects in the comparison.

Hedges' g was calculated for the key comparisons between the two experiments. These values are shown in Table 3. In all cases, the effect sizes observed in Bryant and Smith's [21] experiment exceeded those observed in the current experiment. To understand the implication of an effect size, Cohen [34] proposed rules of thumb that designated an effect size of .20 a *small effect*, an effect size of .50 a *medium effect*, and an effect size of .80 a *large effect*. Following this convention, the differences between the BFT and End BFT conditions and the No DSS and lagged BFT conditions in the present experiment can be considered small. In contrast, those differences in Bryant and Smith's [21] experiment are of medium size. Thus, it appears that the presence of civilians in the simulated environment did lead to a reduction in the beneficial effect of real-time BFT on subjects' FA rates.

Table 3. Effect Sizes for Key Post Hoc Comparisons of Conditions in the Current and Bryant and Smith's [21] Experiments

	Post Hoc Comparison					
	No DSS vs. BFT	**No DSS vs. End BFT**	**BFT vs. 10s No Warning**	**BFT vs. 10s Warning**	**End BFT vs. 10s No Warning**	**End BFT vs. 10s Warning**
Current Experiment	0.406	0.342	0.379	0.304	0.315	0.240
Bryant & Smith (in press)	0.732	0.660	0.644	0.715	0.572	0.643

Effect sizes: 0.2-0.5 (small); 0.5-0.8 (medium); > 0.8 (large)

4 Discussion

This experiment was performed primarily to determine whether provision of real-time BFT to dismounted soldiers would enhance combat effectiveness, in particular, reduce the risk of fratricide, in operational environments containing civilians. Subjects exhibited smaller FA rates for friendly forces when they had access to a real-time BFT device relative to no decision support, suggesting that real-time BFT continues to provide a benefit when soldiers operate in environments containing civilians. Access to a BFT device did not affect subjects' FA rates for civilians, which is to be expected because BFT does not provide information about civilians. Civilian FA rates, however, were lower than friendly FA rates, suggesting that access to BFT does not affect the likelihood that a civilian will be mis-identified as an enemy. Thus, BFT continues to have a beneficial effect on CID performance in environments containing civilians.

A second objective of this experiment was to assess the degree to which BFT aided CID judgments. The presence of civilians in the battlespace could complicate the process of mapping friends in the environment to friends displayed on the BFT top-down map. Civilians could act as distracters that increase the cognitive difficulty of and time required for the matching process. By assessing the effect sizes of key comparisons in the current experiment to the corresponding comparisons of Bryant and Smith [21], it was observed that all effects were smaller in the current experiment. Thus, the real-time BFT conditions in the current experiment produced smaller decreases in friend FA rate than those observed by Bryant and Smith [21]. Friend FA rates in the BFT and End BFT conditions were also larger than those observed by Bryant and Smith [21]. These results suggest that BFT will not provide as great a benefit to dismounted soldiers when they operate in asymmetric environments containing civilians or other non-combatants.

Soldiers will likely continue to operate in operational environments containing civilian and other non-combatant populations. Consequently, it will be important to develop systems to enhance soldier SA, reduce the risk of fratricide, and reduce the risk of injury and death to non-combatants. Providing real-time BFT to dismounted soldiers can enhance combat effectiveness, in particular, reduce the risk of fratricide, even in environments containing civilians. However, real-time BFT produced smaller benefits than those previously observed. Thus, the presence of civilians has the potential to reduce the usefulness of BFT to dismounted soldiers.

References

[1] Defense Science Board. (1996). *Defense Science Board Task Force on Combat Identification* (Report No. 20301-3140).

[2] Harris, M. J., & Syms, P. R. (2002). *Land fratricide and IFF OA review*. Farnborough, Hampshire, U.K.: Defence Science and Technology Laboratory.

[3] Regan, G. (1995). *Blue on blue: A history of friendly fire*. New York: Avon Books.

[4] Dean, D., Vincent, A., Mistry, B., Hossain, A., Spaans, M., & Petiet, P. (2008). Representing human decision making in constructive simulations for analysis. *The International C2 Journal, 2*, 1–32.

[5] U.S. Congress, Office of Technology Assessment. (1993). *Who goes there: Friend or foe?* (Office of Technology Assessment Report OTA–ISC–537). Washington, D.C.: U.S. Government Printing Office.

[6] Allegretti, B. P. (2000). *Situational awareness data requirements for a combat identification network.* (Master's thesis, Naval Postgraduate School, Monterey, CA).

[7] Snook, S. A. (2002). *Friendly fire: The accidental shootdown of U. S. Black Hawks over northern Iraq*. Princeton, NJ: Princeton University Press.

[8] Wilson, K. A., Salas, E., Priest, H. A., & Andrews, D. (2007). Errors in the heat of battle: Taking a closer look at shared cognition breakdowns through teamwork. *Human Factors, 49*, 243–256.

[9] Briggs, R. W., & Goldberg, J. H. (1995). Battlefield recognition of armoured vehicles. *Human Factors, 37*, 596–610.

[10] Greitzer, F. L., & Andrews, D. H. (2010). Training strategies to mitigate expectancy-induced response bias in combat identification: A research agenda. In D. Andrews, R. Herz & M. Wolf (Eds.), *Human factors issues in combat identification* (pp. 173–190). Surrey, U.K.: Ashgate Publishing.

[11] Wood, D. (2001, December 10). Study: Lack of training, equipment causes errant bombs. *Air Force Times*.

[12] Cruz, E. E. (1996). *Fratricide in air-land operations* (Unpublished Master's thesis, Naval Postgraduate School, Monterey, CA).

[13] Karsh, R., Walrath, J. D., Swoboda, J. C., & Pillalamarri, K. (1995). *Effect of battlefield combat identification system information on target identification time and errors in a simulated tank engagement task* (Technical Report ARL-TR-854). Aberdeen Proving Ground, MD: Army Research Lab.

[14] Bitar, I., & Felsman, B. L. (2005, Fall/Winter). Blue force tracking in Operations ENDURING FREEDOM and IRAQI FREEDOM. *Technology Review Journal,* 79–97.

[15] Rider, T. L. (2004, September/October). Blue force tracking to expand across force. *Army AL&T,* 2–5.

[16] Dzindolet, M. T., Pierce, L. G., Beck, H. P., Dawe, L. A., & Anderson, B. W. (2001). Predicting misuse and disuse of combat identification systems. *Military Psychology, 13*, 147–164.

[17] Bryant, D. J., & Smith, D. G. (2009). *Comparison of identify-friend-foe and blue-force tracking decision support for combat identification* (DRDC Technical Report TR 2009-214). Toronto, Canada: Defence Research and Development Canada – Toronto.

[18] Boyd, C. S., Collyer, R. S., Skinner, D. J., Smeaton, A. E., Wilson, S. A., Krause, D. W., Dexter, R. M., Perry, A. R., & Godfrey, J. (2005). Characterisation of combat identification technologies. In *Proceedings of TENCON 2005 – 2005 IEEE Region 10 Conference* (pp. 568–573). Piscataway, NJ: Institute of Electrical and Electronics Engineers.

[19] Suri, N., Benvegnù, E., Tortonesi, M., Stefanelli, C., Kovach, J., & Hanna, J. (2009, October). Communications middleware for tactical environments: Observations, experiences, and lessons learned. *IEEE Communications Magazine,* 56–63.

[20] Penny, P. H. G. (2002). Combat identification: Aspirations and reality. *Military Technology, 5*, 50–55.

[21] Bryant, D. J., & Smith, D. G. (2013). Impact of blue force tracking on combat identification judgments. *Human Factors, 55,* 75–89.

[22] Glenn, R. W., Paul, C., Helmus, T. C., & Steinberg, P. (2007). *People make the city: Joint urban operations observations and insights from Afghanistan and Iraq* (Report to the United States Joint Forces Command). Santa Monica, CA: Rand Corporation.

[23] Rasmussen, R. E. (2007). *The wrong target: The problem of mistargeting resulting in fratricide and civilian casualties (*Unpublished Master's thesis, Joint Advanced Warfighting School, Norfolk, VA).

[24] Looney, C. G., & Liang, L. R. (2003). Cognitive situation and threat assessments of ground battlespaces. *Information Fusion, 4*, 297–308.

[25] Bryant, D. J. (2012). *Sequential Evidence Accumulation for Combat Identification (SEACID)* (DRDC Technical Report TR 2012-046). Toronto, Canada: Defence Research and Development Canada – Toronto.

[26] Endsley, M. R., & Smith, R. P. (1996). Attention distribution and decision making in tactical air combat. *Human Factors, 38*(2), 232–249.

[27] Gugerty, L. (1998). Evidence from a partial report task for forgetting in dynamic spatial memory. *Human Factors, 40*(3), 498–508.

[28] De Martino, B., Kumaran, D., Seymour, B., & Dolan, R. J. (2006). Frames, biases, and rational decision-making in the human brain. *Science, 313*, 684–687.

[29] Osborne, K. (2008). Superfast blue-force tracking. *Defense News*. Retrieved from http://www.defensenews.com/story.php?i=3767827&c=FEA&s=CVS

[30] Green, D. M., & Swets, J. A. (1966). *Signal detection theory and psychophysics*. New York: Wiley.

[31] Macmillan, N. A., & Creelman, C. D. (1991). *Detection theory: A user's guide*. Cambridge, U.K.: Cambridge University Press.

[32] Hedges, L. V. (1981). Distribution theory for Glass's estimator of effect size and related estimators. *Journal of Educational Statistics, 6*, 107–128.

[33] DeCoster, J. (2009). *Meta-Analysis Notes*. Retrieved from http://www.stat-help.com/notes.html.

[34] Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

This page intentionally left blank.

List of symbols/abbreviations/acronyms/initialisms

ANOVA	Analysis of Variance
BFT	Blue Force Tracking
bots	roBOTic computer controlled entities
c	Response Bias
C2	Command and Control
CF	Canadian Forces
CID	Combat Identification
d′	d-prime, Response Sensitivity
DRDC	Defence Research & Development Canada
DSS	Decision Support System
FA	False Alarm
FBCB2-BFT	Force XXI Battle Command Brigade and Below – Blue Force Tracking
GPS	Global Positioning System
H	Hit
Hedges’ *g*	Measure of statistical effect size
HREC	Human Research Ethics Committee
IFF	Identify-Friend-or-Foe
IMMERSIVE	Instrumented Military Modeling Engine for Research using SImulation and Virtual Environments
LSD	Least Significant Difference
MSE	Mean Square Error
PC	Personal Computer
PDA	Personal Digital Assistant
ROE	Rules of Engagement
SA	Situation Awareness
TTPs	Tactics, Techniques, and Procedures
US	United States

Distribution list

Document No.: DRDC TM 2012-100

	LIST PART 1: Internal Distribution by Centre
2	
2	TOTAL LIST PART 1
	LIST PART 2: External Distribution by DRDKIM
1	Library and Archives Canada
	DJCP
1	LCol Rick Johnston (Richard.Johnston@forces.gc.ca)
1	Cdr Robert Edwards (Robert.Edwards2@forces.gc.ca)
	DRDC Valcatier
1	Dr. Eloi Bossé (Eloi.Bosse@drdc-rddc.gc.ca)
	DST C4ISR 4
1	Dr. Benny Wong (Benny.Wong@forces.gc.ca)
	CTC
1	Col Steve Bowes (Steve.Bowes@forces.gc.ca)
1	Maj Michael Standish (Michael.Standish@forces.gc.ca)
	DGLS/COS Land Ops
1	Shawn Hoag (Shawn.Hoag@forces.gc.ca)
	SJS
1	LCol Alan Smith (Alan.Smith@forces.cgc.ca)
1	Maj John Whalen (John.Whalen2@forces.gc.ca)
	ADM(S&T)
1	LCol Peter Scott (Peter.Scott@forces.gc.ca)
	DSTA
1	Luc Lefebvre (Luc.Lefebvre@forces.gc.ca)
	DRDC Atlantic
1	Dr. Mark Gammon (Mark.Gammon@forces.gc.ca)
13	TOTAL LIST PART 2
15	**TOTAL COPIES REQUIRED**

DOCUMENT CONTROL DATA

(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 sp onsoring 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 APRIL 2011

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)

Impact of Civilians on the Effectiveness of Blue Force Tracking (U)
(U)

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

David J. Bryant

5. DATE OF PUBLICATION (Month and year of publication of document.) October 2013	6a NO. OF PAGES (Total containing information, including Annexes, Appendices, etc.) 35	6b. NO. OF REFS (Total cited in document.) 34

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.)

Technical Memorandum

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

Sponsoring:
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.) 14dq	9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.)
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) DRDC Toronto TM 2012-100	10b. OTHER DOCUMENT NO(s). (Any other numbers under which may be assigned this document either by the originator or by the sponsor.)

11. DOCUMENT AVAILABILITY (Any limitations on the dissemination of the document, other than those imposed by security classification.)

Unlimited distribution

12. DOCUMENT ANNOUNCEMENT (Any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11), However, when further distribution (beyond the audience specified in (11) is possible, a wider announcement audience may be selected.))

Unlimited announcement

DOCUMENT CONTROL DATA

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

13. ABSTRACT (A brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual.)

(U) Blue Force Tracking (BFT) systems seem to be promising decision aids for Combat Identification (CID) although their effectiveness is reduced by lag in data updating. Previous studies have evaluated BFT for dismounted soldiers in environments containing only friendly and enemy forces but the presence of civilians has the potential to reduce the usefulness of BFT. An experiment examined the effectiveness of BFT decision support for dismounted infantry soldiers in a simulated environment containing civilians in addition to friendly soldiers and enemies. Twenty-four subjects performed five conditions: a baseline with no decision support, a condition with BFT providing real-time positional information, a 10 second delay condition with no warning that the BFT data would lag actual movement, a 10 second delay condition in which subjects were told of the delay, and a final end baseline with real-time update of the BFT. Providing real-time BFT greatly improved subjects™ CID performance. Adding a 10 second delay to the updating of position information in the BFT resulted in subjects being significantly more likely to mistakenly engage a friend but did not affect the likelihood of mistakenly engaging a civilian. Providing real-time BFT to dismounted soldiers can enhance combat effectiveness, in particular a reduction in the risk of fratricide, even in environments containing civilians. However, real-time BFT produced smaller benefits than those previously observed.

(U) Les systèmes de suivi de la force bleue (SFB) se présentent comme des aides à la décision prometteuses pour l™identification au combat (IDCbt), même si le retard de la mise à jour des données réduit leur efficacité [17] [21]. Des études précédentes ont évalué le suivi de la force bleue pour les fantassins débarqués dans des environnements ne contenant que des forces amies et ennemies. La présence de civils pourrait cependant réduire l™utilité du SFB. Une expérience a été réalisée pour étudier l™efficacité du SFB pour l™aide à la décision des fantassins débarqués dans un environnement simulé contenant des civils en plus des soldats amis et ennemis. Vingt-quatre sujets ont été mis dans cinq situations, soit : un essai de référence sans aide à la décision; un essai où le SFB fournissait des données de localisation en temps réel; un essai où les données avaient un retard de 10 secondes sans que les sujets soient avisés que le SFB était en retard sur le mouvement réel; un essai avec un retard de 10 secondes dans lequel les sujets étaient avertis du retard; un essai de référence final avec une mise à jour en temps réel du SFB. Le SFB en temps réel améliore considérablement les résultats d™IDCbt des sujets. L™ajout d™un retard de 10 secondes avant la mise à jour des données de localisation du SFB augmente sensiblement la probabilité que les sujets engagent un soldat ami par erreur, mais n™a pas d™effet sur la probabilité d™engager un civil par erreur. Le SFB en temps réel peut augmenter l™efficacité au combat des fantassins débarqués, particulièrement en réduisant le risque de fratricide, même dans les environnements qui contiennent des civils. Toutefois, les avantages du SFB en temps réel sont dans ce cas moindres que ceux observés dans des études précédentes.

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; Blue Force Tracking

Defence R&D Canada

Canada's Leader in Defence
and National Security
Science and Technology

R & D pour la défense Canada

Chef de file au Canada en matière
de science et de technologie pour
la défense et la sécurité nationale

DEFENCE R&D DÉFENSE

www.drdc-rddc.gc.ca