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A training study of the Hercules Observer Trainer

Stuart C. Grant

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

Abstract

The Canadian Forces (CF) operates aircraft in theatres where they are threatened by missiles and gunfire. Timely, coherent and accurate reporting of the threats is vital to defeating them. A training device called the Hercules Observer Trainer (HOT) was developed to support the training of surface-to-air threat reporting. To validate the simulation and determine its training effectiveness, an experiment employing 16 CF air crewmembers was conducted at CFB Trenton. Half of the experimental subjects were qualified tactical aircrew and were deemed experts at making threat calls. The other half consisted of students on a CC-130 Basic Loadmaster course who had not yet qualified as loadmasters on the CC-130 and were deemed novices. Both groups of subjects completed two sessions of making threat calls against 26 surface to air missile and 24 anti-aircraft artillery threats. In the first session, experts made more accurate and more syntactically correct threat calls than novices. By the end of the second session, both groups showed improved accuracy and syntax over their earlier levels of performance, and the performance of the novices was equivalent to that of the experts. It is concluded that the HOT is a valid simulation of the threat call task, that students can use the HOT to learn the task, and that the training is transferrable to the operational environment. It is recommended that HOT be considered for operational training in the CC-130 community. It is further recommended that the training scenarios be adapted and the technology improved to best represent the current operational environment.

Résumé

Les Forces canadiennes (FC) utilisent des aéronefs qui, dans certains théâtres, sont menacés par des tirs de missiles et de l’artillerie. Des rapports rapides, cohérents et précis sur les menaces sont essentiels pour les contrer. Un appareil appelé observateur d’entraînement du Hercules (HOT) a été mis au point pour donner de la formation sur l’établissement de rapports et les façons d’intervenir en cas de menaces sol-air. Afin de valider l’appareil et d’établir l’efficacité de sa capacité de formation, une expérience a été réalisée à la BFC Trenton, à laquelle seize membres du personnel navigant des FC ont participé. La moitié des sujets de l’expérience faisaient partie de l’équipage aérien tactique et étaient considérés comme des spécialistes de la production de messages signalant une menace. L’autre moitié était composée de stagiaires du cours élémentaire d’arrimeur du CC-130. Ils n’avaient pas encore la qualification d’arrimeur et étaient considérés comme des novices. Les deux groupes de sujets ont participé à deux séances de production de messages signalant la menace de 26 missiles sol-air et de 24 tirs d’artillerie antiaérienne. Lors de la première séance, les spécialistes ont signalé les menaces de manière plus précise et plus exacte au plan syntaxique que les novices. À la fin de la deuxième séance, les deux groupes s’étaient améliorés et avait un rendement équivalent sur les deux aspects. On peut donc conclure que l’appareil HOT permet une simulation valide de la production de messages signalant une menace et que la formation peut être transférée dans un environnement opérationnel. On recommande donc l’appareil HOT pour l’instruction opérationnelle de la collectivité du CC-130. On recommande également l’adaptation des scénarios d’entraînement et l’amélioration de la technologie afin de mieux représenter le contexte opérationnel actuel.

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Executive summary

A training study of the Hercules Observer Trainer

Stuart C. Grant; DRDC Toronto TR 2009-008; Defence R&D Canada – Toronto; April 2009.

Introduction:

The Canadian Forces (CF) operates aircraft in theatres where they are threatened by missiles and gunfire. CC-130 transport aircraft operations in combat areas employ visual scanning by aircrew to detect and coordinate reaction to threats. The threats include small arms, anti-aircraft artillery (AAA), surface to air missiles (SAMs), helicopters (HELO), and fixed wing threats. Observers in the aircraft report the existence of the threats, provide advice on the required reaction, and report the location of the threat. Their reports must be fast, accurate, and consistent for their aircraft to respond in a timely and appropriate manner.

Currently, the CF has limited means to train aircrew in the recognition and avoidance of these threats. Computer simulation of ground threats is not currently available, live training is very primitive, and the measures of effectiveness are limited to instructor observations. The commander of 8 Wing therefore raised a Statement of Operational Capability Deficiency endorsed by 1 Can Air Div, to obtain training devices to address the deficiency. In parallel, the Canadian Forces Aerospace Warfare Centre (CFAWC) tasked DRDC Toronto with developing a prototype device to provide CC-130 loadmasters with threat reaction training. DRDC performed a task analysis, a training requirements analysis, and specified a technical solution that was implemented under a series of contracts. The experiment reported in this document provides an evaluation of the training effectiveness of the resulting Hercules Observer Trainer (HOT).

To validate the HOT and determine its training effectiveness, an experiment employing 16 CF air crewmembers was conducted at CFB Trenton. Half of the experimental subjects were qualified tactical aircrew and were deemed experts at making threat calls. The other half consisted of students on a CC-130 Basic Loadmaster course who had not yet qualified as loadmasters on the CC-130 and were deemed novices. Both groups of subjects completed two sessions, each of which involved making threat calls against 26 surface to air missile and 24 anti-aircraft artillery threats.

Results:

In the first session, experts made significantly more accurate and more syntactically correct threat calls than novices. Furthermore, both groups of subjects improved on both measures at the end of the second session. At the conclusion of the second session, performance of the two groups was equivalent on both measures. It is concluded that the HOT is a valid simulation of the threat call task, that students can use the HOT to learn the task, and that the training is transferrable to the operational environment.

Significance:

The experiment revealed that the HOT is a valid representation of the threat environment, shown by expert aircrew initially out-performing novices in the threat reaction task. The HOT demonstrated its ability to train and to lead to expert performance when the performance of novices improved and came to be indistinguishable from that of the experts. The HOT provides the CF with a device and Crown-owned intellectual property for training threat reaction where none existed before.

Future plans:

Several improvements can be made to the HOT to increase the utility of the existing version of the device. The visual imagery can be optimally rendered for the existing projection surface. Also, the time for a student to respond to a threat could be made available to the instructor in a reliable manner. Finally, the appearance of the tracer fire and missile trails can be made more realistic and variable.

Future generations of the HOT that provide night viewing conditions and night vision goggle simulation (or night vision goggle stimulation) must be subject to a validation study.

Sommaire

A training study of the Hercules Observer Trainer

Stuart C. Grant; DRDC Toronto TR 2009-008; R & D pour la défense Canada – Toronto; Avril 2009.

Introduction :

Les Forces canadiennes (FC) utilisent des aéronefs qui, dans certains théâtres, sont menacés par des tirs de missiles et de l'artillerie. Lorsque les avions de transport CC-130 survolent les zones de combat, on fait appel au balayage visuel des membres du personnel navigant pour détecter les menaces et coordonner les mesures pouvant les contrer. Précisons notamment la menace des armes légères, de l'artillerie antiaérienne (AAA), des missiles sol-air (SAM), des hélicoptères (HELO) et des aéronefs à voilure fixe. Les observateurs à bord des avions signalent la présence d'une menace, donnent des conseils sur les mesures à prendre et précisent d'où elle provient. Leurs rapports doivent être rapides, précis et cohérents afin que l'avion puisse réagir en temps opportun et de manière appropriée.

À l'heure actuelle, les FC disposent de moyens limités pour entraîner des équipages navigants à reconnaître et à éviter ces menaces. La simulation informatique des menaces terrestres n'est pas encore disponible, l'entraînement en situation réelle n'est qu'au tout début et les mécanismes servant à mesurer l'efficacité sont réservés aux observations de l'instructeur. Le commandant de la 8e Escadre a donc formulé un énoncé d'insuffisance de capacités opérationnelles, appuyé par la 1 DAC, afin d'obtenir des appareils d'entraînement pour pallier les lacunes. Parallèlement, le Centre de guerre aérospatiale des Forces canadiennes (CGAFC) a chargé RDDC Toronto de mettre au point le prototype d'un appareil qui permettrait de donner aux arrimeurs du CC-130 une formation sur la façon de réagir en cas de menaces. RDDC a procédé à une analyse des tâches et des exigences en matière de formation, et a déterminé une solution technique qui a été mise en œuvre dans toute une gamme de contrats. L'expérience dont il est question dans le présent document renferme une évaluation de l'efficacité de la formation que permet l'observateur d'entraînement du Hercules (HOT).

Afin de valider l'appareil et d'établir l'efficacité de sa capacité de formation, une expérience a été réalisée à la BFC Trenton, à laquelle seize membres du personnel navigant des FC ont participé. La moitié des sujets de l'expérience faisaient partie de l'équipage aérien tactique et étaient considérés comme des spécialistes de la production de messages signalant une menace. L'autre moitié était composée de stagiaires du cours élémentaire d'arrimeur du CC-130. Ils n'avaient pas encore la qualification d'arrimeur et étaient considérés comme des novices. Les deux groupes de sujets ont participé à deux séances de production de messages signalant la menace de 26 missiles sol-air et de 24 tirs d'artillerie antiaérienne.

Résultats :

Lors de la première séance, les spécialistes ont signalé les menaces de manière beaucoup plus précise et plus exacte au plan syntaxique que les novices. En outre, à la fin de la deuxième séance, les deux groupes s'étaient améliorés et leur rendement était équivalent sur les deux aspects. On

peut donc conclure que l'appareil HOT permet une simulation valide de la production de messages signalant une menace, que les stagiaires peuvent utiliser l'appareil pour apprendre ce qu'ils ont à faire et que la formation peut être transférée dans un environnement opérationnel.

Importance :

L'expérience a révélé que l'appareil HOT permet une représentation valide d'un environnement de menace, illustrant comment des spécialistes du personnel navigant ont d'abord déclassé des novices relativement aux actions à prendre dans une situation de menace. L'appareil HOT a montré sa capacité de formation et sa capacité à obtenir un rendement de spécialiste en améliorant celui des novices, au point où il est impossible de le distinguer de celui des spécialistes. L'appareil HOT fournit aux FC une propriété intellectuelle de la Couronne destinée à former du personnel à réagir en situation de menace, alors qu'aucun mode de formation dans ce domaine n'existait auparavant.

Plans futurs :

Plusieurs améliorations peuvent être apportées à l'appareil HOT afin d'accroître l'utilité de la version actuelle. L'imagerie visuelle peut être rendue, de façon optimale, en fonction de la surface de projection existante. De plus, le temps que met un stagiaire à réagir à une menace peut être soumis à l'instructeur de façon plus fiable. Enfin, l'apparence des balles traçantes et des traînées de missiles peut être plus réaliste et plus diversifiée.

Les futures générations de l'appareil HOT offrant des conditions de vision nocturne et une simulation de vision nocturne à l'aide de lunettes (ou une stimulation de vision nocturne) doivent faire l'objet d'une étude de validation.

Table of contents

List of figures

List of tables

Acknowledgements

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1 Introduction

The Canadian Forces (CF) operates aircraft in theatres where they are threatened by missiles and gunfire. Skilled operation of the aircraft is a key element in mitigating these threats. In particular, timely, coherent and accurate reporting of the threats is vital to defeating them. Accordingly, the Hercules Observer Trainer (HOT) was developed to support the training of surface-to-air threat reaction and reporting. This document reports an evaluation of the training effectiveness of the HOT.

1.1 Project background

Aircrew operating the CC-130 transport aircraft in combat areas visually scan their environment to detect and coordinate reaction to threats. The threats include small arms, anti-aircraft artillery (AAA), surface to air missiles (SAMs), helicopters (HELO), and fixed wing threats. Observers in the aircraft report the existence of the threats, provide advice on the required reaction, and report the location of the threat. Their reports must be fast, accurate, and consistent for the crew and aircraft to respond in a timely and appropriate manner [1].

Currently, the CF has limited means to train aircrew in the recognition and avoidance of these threats. Computer simulation of ground threats is not currently available, live training is very primitive, and the measures of effectiveness are limited to instructor observations. The commander of 8 Wing therefore raised a Statement of Operational Capability Deficiency (SOCD), endorsed by 1 Can Air Div, to obtain training devices to address the deficiency [2]. In parallel with this SOCD, the Canadian Forces Aerospace Warfare Centre (CFAWC) tasked DRDC Toronto with developing a prototype device to provide CC-130 loadmasters with threat reaction training [3].

In response to the CFAWC tasking, DRDC conducted an analysis of the training system deficiencies facing CC-130 operators. The analysis confirmed the high priority of the threat reaction training [4]. Following from that, DRDC performed a task analysis and training requirements analysis to set the requirements. DRDC specified a technical solution that was implemented under a series of contracts using CFAWC funds [5 – 8].

The tasking required that the ensuing prototype be evaluated for its training effectiveness. The experiment reported in this document provides an evaluation of the training effectiveness of the HOT.

1.2 HOT description

Analysis of the training requirement and meetings with CC-130 operators led to the design of the training device. The HOT consists of three components: the trainee station; the instructor / operator station (IOS); and the synthetic environment.

The trainee station presents a visual display of computer-generated imagery depicting the view from the CC-130 paratrooper door. The display enables the trainee to view any objects that are visible from the windows of the aircraft. To enable the reporting of the threats and dialogue with the instructor / operator, the student station has an intercom for voice communication. Figure 1 shows the trainee station with a simple paratrooper door and window mock-up that serves to orient and constrain the observer's view.

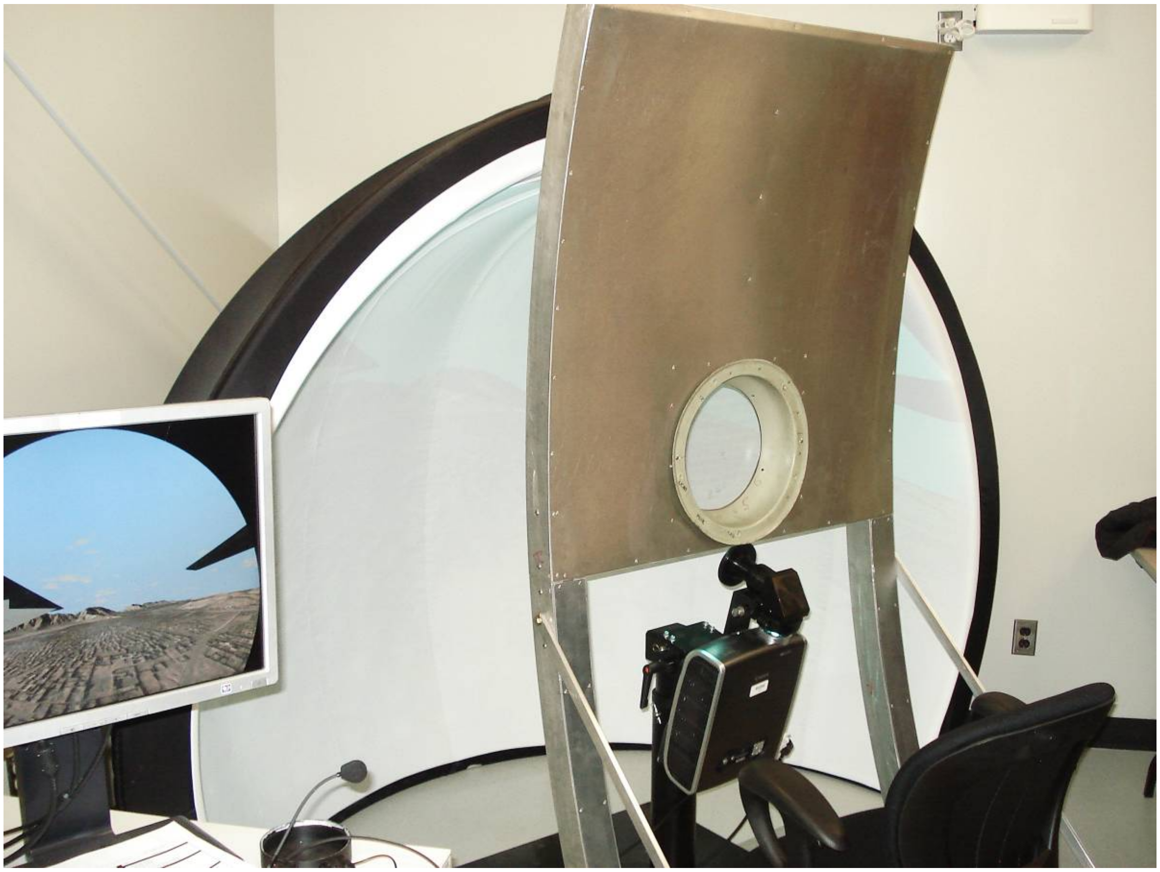

Figure 1 The HOT Trainee Station

The IOS provides the functions to start the trainer, load and edit scenarios, control execution of the simulation, and monitor performance. The instructor / operator has voice communications with the trainee and can control the threat reaction of the trainee's aircraft. The IOS also includes a briefing and debriefing capability. Using this capability, the instructor / operator can provide briefings on the training scenario and the anticipated threats as well as debriefing performance by replaying the scenario, and providing feedback in terms of effectiveness and performance. Figure 2 shows the IOS as it appears during a simulation run.

Figure 2 The HOT Instructor Operator Station

The synthetic environment has two chief functions. The first is to create the flight dynamics of the trainee’s aircraft, thus providing the trainee station with the visual experience of inhabiting the aircraft reacting to the threats. The HOT provides for two sources of flight dynamics. One source is a computer-generated forces (CGF) software package integral to the HOT that simulates the flight of the CC-130. When the HOT is operating in stand-alone mode, the trainee’s viewpoint is anchored to the side of the CC-130 simulated by the CGF system. Through the use of distributed simulation technologies, the flight dynamics controlling the trainee station viewpoint can also come from sources external to the HOT. When operating in this networked mode, the trainee’s viewpoint can be controlled by another CGF, a flight simulator, or even a real aircraft. The synthetic environment is also responsible for presenting the threats. The dynamics of the threats and the events of the scenario are controlled by the synthetic environment. The threats can be generated by the CGF integral to the HOT, or by other external sources.

2 Experiment

As called for in the tasking, an experiment was conducted to evaluate the HOT. The goal of the experiment was to determine if the HOT is an effective device for training threat reaction. Specifically, answers to three questions were sought.

Is the HOT a valid simulation of the threat reaction environment in the CC-130?

A valid simulation of the threats, the observer's situation, and the aircraft movements is sought so that the experience provided by the HOT is representative of the actual threat reaction situation. It is important to note that the validity of the simulation components is relevant to the extent that they affect the perceptions and actions required to properly perform the threat reaction. For example, the trainee's viewpoint should be within the target aircraft so that the dynamics and perspective of the threats in consistent with that found in the real world. On the other hand, the colour of SAM rocket motor smoke, for example, does not have bearing on the reaction (vice recognition) to the threats.

To answer this validity question, an experimental technique called backward transfer was employed [9] in which the performance of experienced CC-130 loadmasters, referred to as experts in this report, were compared to new loadmasters, referred to as novices. If the simulation is a valid depiction of the threat reaction environment, expertise in threat reaction should be evident in performance. The experts should initially outperform the novices.

Does the HOT support learning?

A training device must foster development of its targeted skill. To answer this question, the changing performance of the novices will be examined. If the novice's performance is observed to improve with use of the HOT, this will be evidence that learning is occurring.

The performance of experts will also be monitored for improvements but conclusions may be harder to draw. A lack of improvement by the experts could be attributable to a ceiling effect. In this case, a lack of improvement would occur because they already know all that the HOT is capable of training. On the other hand, if expert performance is seen to improve, this could arise from improved proficiency at making threat calls or to learning of discrepancies between performing the task in the simulator and in the aircraft.

Does learning in the HOT transfer positively to the operational environment?

The purpose training devices is to improve performance in the operational environment. If training with the device does not transfer, or leads to worse performance (negative transfer), then the device should not be used for training. From the standpoint of experimental logic, the most straightforward and compelling way to answer this question would be to compare the performance of trained and untrained crew members in a live-flying environment exposed to real threats. Obviously, there are many reasons why this cannot be done. Instead, the validity of the device will be used to argue that the skills should transfer to the operational environment. The backward transfer of training logic will be used to argue that if the device allows experts to show their expertise in the simulator, then one should expect that novices who acquire skills in the simulator should be able to demonstrate them in the operational environment [9].

2.1 Methodology

An experiment to answer the above questions was conducted in February and March 2008, at CFB Trenton. An exercise run director from DRDC Toronto oversaw the running of the trial. A contracted technician, trained on the operation of the HOT, controlled the simulation. An instructor from 426 Squadron provided instruction to the experimental subjects.

2.1.1 Subjects

Sixteen members of the CF served as subjects in the experiment. Eight of the subjects were experienced CC-130 aircrew, qualified for the tactical airlift mission and familiar with making threat calls. In addition, most of them were also instructors at the Operational Training Unit, 426 Squadron. These subjects were defined as the experts. Eight additional CF members were drawn from the population of aircrew attending the CC-130 Basic Loadmaster Course at CFB Trenton. These subjects were not yet qualified for the CC-130 tactical airlift mission and they had not completed the threat call training included in the course they were attending. These subjects were defined as the novices.

The subjects were tasked by 426 Squadron to participate. However, their data were used only if they provided informed consent for its use. In addition, all subjects were informed of their ability to withdraw from participation in the trial without consequences. All subjects provided their consent and none withdrew from the trial.

2.1.2 The task

Threat call standard operating procedures are published in the Standard Manoeuvre Manual [1]. This publication identifies the terminology and syntax for a variety of threats. Although not explicitly addressed in the published standard operating procedures, consideration of the tactical situation and consultation with subject matter experts reveals that the calls must be prompt and accurate.

This experiment considered only SAM and AAA threats. Tables 1 and 2 present the threat call criteria for SAM and AAA threats in this experiment. Each call provides four (in the case of SAMs) or five (in the case of AAA) types of information, followed by updates as the tactical situation allows. The threat is reported either as a SAM or AAA with no addition detail on type. The threat direction is given relative to the aircraft as facing toward the nose of the aircraft. The clock position is a horizontal frame of reference, with 12 o'clock being at the nose of the aircraft. Distance is given in nautical miles from the aircraft. An example of a SAM call would be "SAM right 4 o'clock 3 miles – overhead". An example of an AAA call would be "JINK AAA left 9 o'clock 1 mile – still firing – still firing- cease firing".

Type of Information	Possible Values
Threat	SAM
Direction	LEFT or RIGHT
Clock Position	1 - 12 O'CLOCK
Distance	x MILES
Update clock position and distance	1 - 12 O'CLOCK and x MILES or OVERHEAD

Table 1 SAM Threat Call

Type of Information	Possible Values
Action	JINK
Threat	AAA
Direction	LEFT or RIGHT
Clock Position	1 - 12 O'CLOCK
Distance	x MILES
Update	STILL FIRING or CEASE FIRING

Table 2 AAA Threat Call

2.1.3 Apparatus

Vega Prime ™ visual simulation software with the FX ™ special effects module rendered the imagery at 60 Hz for the trainee station. The geometric field of view generated by the software provided a scene 180˚ wide by 135˚ high. The imagery was displayed using an OmniFocus ™ HAL SX-3 projector with a 1400 × 1050 resolution and an Immersive Display Solutions Immersive Dome ™ 200C 2.2 meter inflatable hemispherical projection screen. The subjects viewed the screen through a hole cut in a plywood screen that constrained their view to that available through the CC-130 paratrooper door normally used by loadmasters watching for threats The screen shown in Figure 1 is a subsequent metal version. An example of the imagery presented to the subjects is presented in Figure 3. The image in Figure 3 has a "fish-eye" appearance because it is intended to be projected on a hemispherical screen. The scene appears undistorted when projected on the hemispherical screen and observed from the design eyepoint.

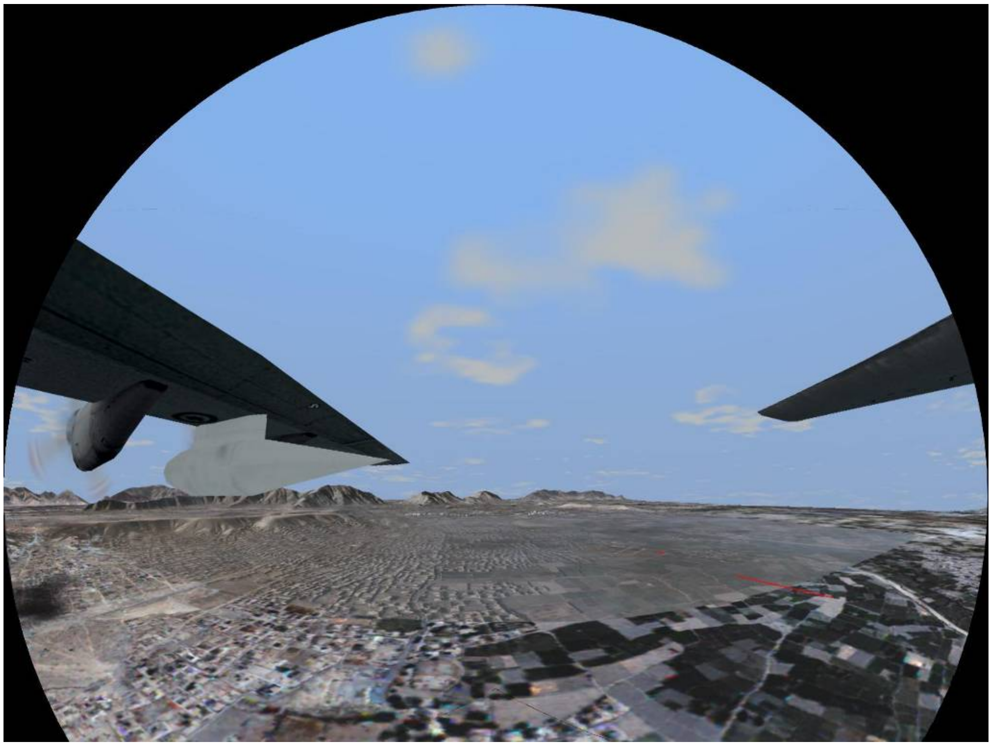

Figure 3 Example of imagery at the student station before projection onto the dome.

To use the intercom to make their threat reports, the subjects wore a headset with a boom microphone. To report, subjects depressed a push-to-talk switch. They could hear instructions and corrective feedback through the headset.

2.1.4 Experimental design

The experiment was a mixed design where each subject attended two experimental sessions that were separated by one to two weeks. At the start of the first session, the run director explained the purpose of the experiment, informed the subject that he could withdraw from the experiment at any time without repercussions, and obtained informed consent for the use of the subject's data. The HOT system operator and the instructor then provided a briefing on the HOT, reviewed the correct threat calls, and demonstrated two examples each of SAM, AAA, and helicopter (HELO) threats using the HOT. The structure of the blocks of trials was then explained to the subject and any questions raised were answered. The subject then completed six blocks of trials. The structure of the trials is presented in Table 3. The first two blocks consisted entirely of SAMs to facilitate learning of the calls. The AAA threats, which require a slightly more complicated call, were introduced in Blocks 3 and 4. The final two blocks consisted of a mix of SAM, AAA, and HELO threats. The subjects were not trained on reporting the HELO threats and were therefore instructed that no call was required.

The position of the threats relative to the aircraft was varied to both ensure that the subjects had to make every possible call and to encourage them to scan the full extent of their assigned arc. The threats appeared at three different clock positions and three different ranges. The combination of three ranges at three locations resulted in 9 threats in each block. In the blocks 5 and 6, the mixed blocks, the HELO threats appeared in two of the nine threat locations. Because threat calls were not required for the HELO threats, two of the possible locations were not the subject of threat calls in these blocks.

Due to the complexity of defining each simulation scenario, each subject saw the same block. The threats within a block occurred one at a time and were spaced between 10 and 60 seconds apart. Completion of a block required approximately 7 minutes and the overall session ran under 90 minutes.

Table 3 Blocks of trials

Block	Threat	Details
1	SAM	9 SAM
2	SAM	9 SAM
3	AAA	9 AAA
4	AAA	9 AAA
5	MIX	4 SAM, 3 AAA, 2 HELO
6	MIX	4 SAM, 3 AAA, 2 HELO

The initial block of each set of threats (i.e. blocks 1, 3, and 5) were unscored tutored blocks. In these blocks the instructor would halt the simulation and coach the subject on the threat call, as required. In the other blocks, the subject completed the block without instructor intervention.

One to two weeks after the first session, the time varying according to the availability of the subject, the subjects completed a second experimental session. The second session omitted the introduction and collection of consent but was otherwise identical to the first session.

The accuracy and syntax of the subject's threat reports were graded by the run director. The programmed nature of the threats allowed the run director to know the correct reports in advance. It was therefore possible to compare the subject's report to the geometrically and syntactically correct report required during run time. The subject's report and score for each trial were recorded on paper.

The accuracy of the call was scored against the known true values. A trial was scored as accurate if all values were correct ± one value. For example, if a threat was located at 3 o'clock, the call would be scored as accurate if the subject reported 2, 3, or 4 o'clock. Other values would be scored as incorrect.

The syntax of the call was scored as correct if the threat information was provided in the correct order and used the correct terminology, as described in Table 1. Additional information before the call, omission of information, information out of order, or incorrect terminology resulted in the syntax for the trial being scored as incorrect. Updates to the calls were not scored.

2.2 Data analysis

The collected data were analyzed to answer questions of the validity of the HOT, the achievement of learning in the HOT, and whether there is evidence of training transfer. All collected data were used in the analyses. One expert was unable to complete the second session and those data were therefore not available to include in the analyses.

First, a multivariate analysis of variance (MANOVA) was conducted to determine if any differences existed amongst the experimental conditions. Using a significance level of $\alpha = .05$, a three-way MANOVA (expertise × session × threat) indicated that there were significant effects of the experimental conditions. Wilk's Lambda and associated F values for the effects of expertise ($F_{3, 34} = 3.82$, $p = .018$), session ($F_{3, 34} = 5.30$, $p = .004$), and threat type ($F_{3, 34} = 6.55$, $p = .001$), justified closer examination of the data using univariate methods.

A repeated measures analysis of variance (ANOVA) performed on the syntax data detected effects significant at the .05 level. Specifically, syntax improved in the second session ($F_{1, 61} = 12.27$, $p = .004$). The same analysis performed on the accuracy data also detected significant effects. Accuracy improved in the second session, ($F_{1, 61} = 22.05$, $p < .001$), and AAA threats were reported more accurately than SAM threats ($F_{1, 61} = 8.59$, $p = .011$). The interaction of expertise and session also produced a significant effect on accuracy, ($F_{1, 61} = 5.00$, $p = .043$).

Given the significant effects in the syntax and accuracy data, these data were then examined using planned comparisons. The research questions regarding validity and learning could be answered with a comparison to the novice performance in the first session. To answer these questions, the first session novice performance was therefore treated as the control condition in a Dunnett's multiple comparisons with a control condition [10]. In each case it was predicted that performance would be better than performance in the first session of novices, so the results were evaluated against a one-sided criterion of $\alpha \leq .05$. The result in these comparisons was that the other conditions were significantly better than the first-session novice performance. These results are discussed in more detail below.

2.2.1 Evidence of validity

The data were analyzed for evidence that the HOT is a valid simulation of calling threats in the CC-130. Specifically, the performance of experts and novices were compared in the first session of training. If performing threat calls in the HOT is not representative of making threat calls in a tactical setting, the performance of the experts and novices should not differ. However, if it is representative, then one should expect experts to outperform the novices. The syntax and accuracy data collected in the first training session, collapsed over threat type and analyzed with the Dunnett's multiple comparison with the control, both showed that the experts indeed significantly out-performed novices in the first session at the $\alpha \leq .05$ level. The difference between novices and experts in the first session is readily visible in Figure 4 and Figure 5.

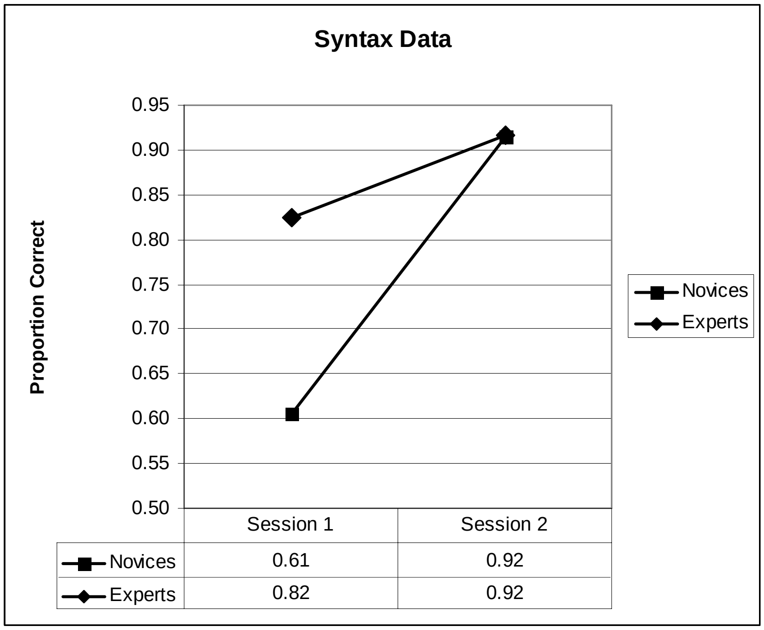

Figure 4 Syntax Data

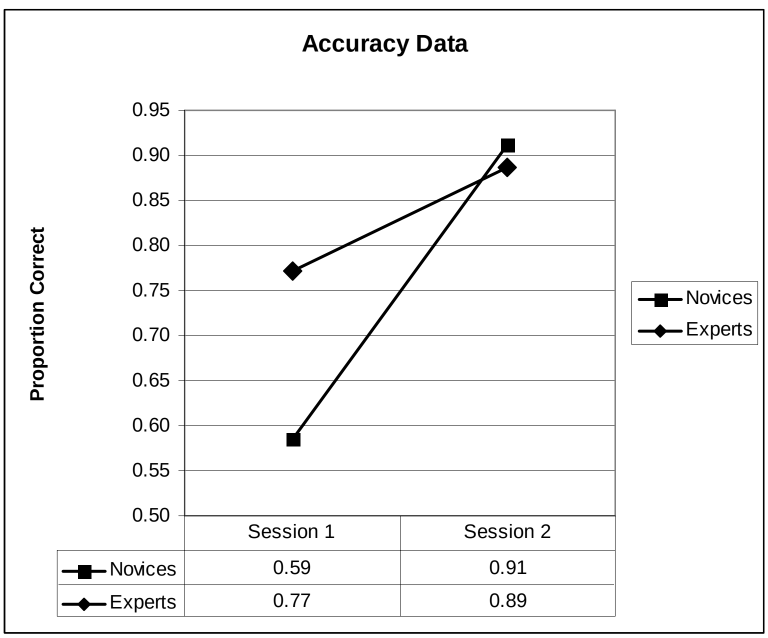

Figure 5 Accuracy Data

2.2.2 Evidence of learning

Next, the data were examined to confirm that learning was occurring. The specific comparison tested whether the novices improved over the course of the two sessions. The analyses were planned to conserve statistical power by only considering the data from the novices and forgoing examination of the expert data because of the ambiguities associated with the possible outcomes, as described in section 2.0.

The syntax and accuracy data, collapsed over threat type and analyzed with the Dunnett's multiple comparison with the control, both showed that the novices improved in session 2 relative to session 1 at the $\alpha \leq .05$ level. Again, the difference between novice performance in sessions 1 and 2 is visible in Figure 4 and Figure 5.

2.2.3 Evidence of transfer

The best measure of transfer of training would be improved performance in the operational environment. Collecting that sort of data was not an option for this study. Therefore, the performance of the novices was examined to determine whether training in the HOT would result in their performance resembling that of experts. The comparison reported in the Evidence of Validity sections found that experts were significantly better than novices initially. During training, the experts improved, as did the novices. At the end of training, the novices were making syntactically correct and accurate threat calls as frequently as the experts (the superior accuracy of the novices is not statistically reliable at the $\alpha \leq .05$ level). In Figure 4 and 5, one can see the novices overcome an initial deficit in the first session, finishing the training session with performance equal to that of the experts.

2.3 Discussion

The experiment was conducted to determine the validity of the HOT, whether subjects learned from the HOT, and whether the learning in the HOT was transferable. The experiment provided two 90-minute training sessions to novices and experts. Each training session provided structured training and feedback to the subjects, allowing them to learn and practice making threat calls against 26 SAM and 24 AAA threats.

The syntax and accuracy data generated statistically significant and consistent results. The data suggest that the HOT is tapping the skills involved in making threat calls. This is demonstrated by the reliably better syntax and accuracy exhibited by the experts at the start of training. If the HOT did not depend on the skills involved in making threat calls, one would expect no difference between experts and novices. It is also apparent that learning is possible through the use of the HOT. The syntax and accuracy of the novices' threat calls were observed to improve through training. Finally, training with the HOT enables the novices to deliver expert performance. Following the two sessions of training, their syntax and accuracy was indistinguishable from that of the experts.

2.3.1 Limitations of the trial

The results of the trial are reliable, but the trial was subject to limitations caused by unexpected circumstances, practical considerations, and trade-offs made in the experimental design. These limitations temper the conclusions drawn and suggest where additional HOT development or instructional methods could increase the benefits possible with the HOT.

The threats did not accurately depict any particular threat weapon system. The use of real threats against real aircraft was not practical and the use of classified data was judged by the author to be unnecessary to determine the training value of the HOT. The modelling of the surface to air threats was medium fidelity, with only one SAM and one AAA threat presented in different locations. This reduced variability may have lead to somewhat faster learning than might be found with greater variety of threats. Any overestimation of the speed of learning is likely to be small, however, given the high degree of commonality in the appearance of AAA and SAM threats. On a related note, the training of threat reaction should not be confused with threat recognition. The HOT was not configured or tested to train the recognition of specific threat types, but rather the recognition of the existence of a threat class and the appropriate response.

The claim that learning in the HOT transfers to the operational environment depends on argument rather than data collected from live flight exposed to real threats. The argument goes as follows: Given that the simulation has been shown to be a valid representation of the operational environment, data showing that training leads to novices and experts performing equivalently in the simulation is synonymous with showing that the training leads to novices and experts performing equivalently in the operational environment. This experimental tactic of analogical transfer is perhaps necessary in high-risk situations [11], but its necessity does not make it compelling. Nevertheless, the live data that would be ideal from a scientific standpoint (live threats in a live flying) are not available due to cost and safety concerns. Additional support for transfer might be obtained if the HOT is employed by aircrew who subsequently experience these threats.

The inability of the tested version of the HOT to reliably capture the time to respond to the threats compromises estimates of the device's training benefit. There may be a speed – accuracy tradeoff. Specifically, the subjects might be responding more slowly to improve the syntax and accuracy of their responses [12, 13]. It did not appear to be the case to the instructors, operators, or experimenters; rather the opposite was their belief. Nevertheless, without solid data, this criticism cannot be positively refuted. It can be pointed out, however, that even such a result would demonstrate learning and sensitivity to conditions and their performance. Furthermore, it would still count as improvement in accordance with the current training manuals since they mandate only correct syntax and not a performance standard.

The training sessions were structured to gather evidence bearing on the experimental questions. Structuring the training sessions differently might lead to better training. For example, subjects were trained one at a time. In an operational training setting, students typically benefit from watching one another perform, and learning from other's successes and failures. Also, throughout the training sessions, the subjects were denied any coaching or feedback during the second block of any threat type. In an operational training setting, subjects who failed to master the threat call in the first block would be given additional coaching.

Also, not all threats were presented in the trial. Rotary and fixed wing threat calls were not evaluated. Lasers are also not represented. The HOT hardware and software has the potential to present these threats and can evaluate responses to them. However, until such functionality is fully implemented and training scenarios developed, the HOT is unable to address all threat call training.

Finally, this trial did not attempt to represent all threat situations and environments. All engagements were in daylight over a desert terrain. The subjects were not trained how to perform the task when wearing night vision goggles or during degraded atmospheric conditions. It should not be assumed that the HOT can train the performance of the task under these because these conditions can change the appearance of the threats. Misrepresentations of the threats could lead to no training or even negative training. Modifications to the HOT might be required to deliver this training.

The HOT's visual system is not able to provide all the visual cues present in the real world. It cannot provide the same resolution, brightness variability, and terrain detail that are seen in the real world, for example. Thus, although threat reaction can be trained using the HOT, threat detection and the time to respond in the HOT are not necessarily representative of what will be obtained in the real world.

2.4 Conclusions

The HOT was developed to provide simulation-based threat reaction training to CC-130 loadmasters and others who work in the CC-130 cargo compartment. The HOT utilizes a simulated crew station to provide students with a simulated view from a CC-130 being engaged by AAA and SAMs. Structured training materials and scenarios enable instructors to teach threat calls to the students in a dynamic, interactive, and controlled simulation. The experiment revealed that the HOT is a valid representation of the threat environment, as shown by expert aircrew initially out-performing novices in the threat reaction task. The HOT demonstrated its ability to train and to lead to expert performance when the performance of novices improved and came to be indistinguishable from that of the experts.

3 Recommendations

- The HOT has demonstrated the ability to improve the threat call performance of novices to that of experts in the course of two 90- minute sessions. The HOT should therefore be considered for use in the training of CC-130 loadmasters. The timing and structure of the training sessions used in this trial should be revised by the CC-130 training community, taking into consideration the current threat scenarios, prevailing administrative constraints, and local knowledge. It should be anticipated that different training regimens will be required for users with different levels of experience, such as novices versus pre-deployment refresher training for operational crews.
- The CC-130 community should consider establishing performance standards for threat calls. Standards for timeliness, accuracy of the calls, and the syntactical correctness should be considered. The availability of such standards will provide guidance to the development of training scenarios and the amount of HOT training required.
- Several improvements should be made to the HOT to increase the utility of the existing version of the device. The visual imagery should be optimally rendered for the existing projection surface. Also, the time for a student to respond to a threat should be made available to the instructor in a reliable manner. Finally, the appearance of the tracer fire and missile trails should be made more realistic and variable.
- If the HOT is taken into use for operational training, opportunities for confirming the positive transfer of learning from training to operations should be sought. Although it is not expected that enough data could be collected for a statistical analysis to have sufficient power to show a quantitative training effect, interviews could be recorded that would at least document striking qualitative effects.
- Any future generations of the HOT that provide night viewing conditions and night vision goggle simulation (or night vision goggle stimulation) should be subject to a validation study.

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List of symbols/abbreviations/acronyms/initialisms

[Enter list here, if applicable. If not, delete the page.]

AAA	Anti – Aircraft Artillery
ANOVA	Analysis of Variance
CF	Canadian Forces
CFAWC	Canadian Forces Aerospace Warfare Centre
CGF	Computer Generated Forces
DRDC	Defence Research & Development Canada
DRDKIM	Director Research and Development Knowledge and Information Management
HELO	Helicopter
HOT	Hercules Observer Trainer
IOS	Instructor Operator Station
MANOVA	Multivariate Analysis of Variance
R&D	Research & Development
SAM	Surface to Air Missile
SOCD	Statement of Operational Capability Deficiency

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The Canadian Forces (CF) operates aircraft in theatres where they are threatened by missiles and gunfire. Timely, coherent and accurate reporting of the threats is vital to defeating them. A training device called the Hercules Observer Trainer (HOT) was developed to support the training of surface-to-air threat reporting. To validate the simulation and determine its training effectiveness, an experiment employing 16 CF air crewmembers was conducted at CFB Trenton. Half of the experimental subjects were qualified tactical aircrew and were deemed experts at making threat calls. The other half consisted of students on a CC-130 Basic Loadmaster course who had not yet qualified as loadmasters on the CC-130 and were deemed novices. Both groups of subjects completed two sessions of making threat calls against 26 surface to air missile and 24 anti-aircraft artillery threats. In the first session, experts made more accurate and more syntactically correct threat calls than novices. By the end of the second session, both groups showed improved accuracy and syntax over their earlier levels of performance, and the performance of the novices was equivalent to that of the experts. It is concluded that the HOT is a valid simulation of the threat call task, that students can use the HOT to learn the task, and that the training is transferrable to the operational environment. It is recommended that HOT be considered for operational training in the CC-130 community. It is further recommended that the training scenarios be adapted and the technology improved to best represent the current operational environment.

Les Forces canadiennes (FC) utilisent des aéronefs qui, dans certains théâtres, sont menacés par des tirs de missiles et de l’artillerie. Des rapports rapides, cohérents et précis sur les menaces sont essentiels pour les contrer. Un appareil appelé observateur d’entraînement du Hercules (HOT) a été mis au point pour donner de la formation sur l’établissement de rapports et les façons d’intervenir en cas de menaces sol-air. Afin de valider l’appareil et d’établir l’efficacité de sa capacité de formation, une expérience a été réalisée à la BFC Trenton, à laquelle seize membres du personnel navigant des FC ont participé. La moitié des sujets de l’expérience faisaient partie de l’équipage aérien tactique et étaient considérés comme des spécialistes de la production de messages signalant une menace. L’autre moitié était composée de stagiaires du cours élémentaire d’arrimeur du CC-130. Ils n’avaient pas encore la qualification d’arrimeur et étaient considérés comme des novices. Les deux groupes de sujets ont participé à deux séances de production de messages signalant la menace de 26 missiles sol-air et de 24 tirs d’artillerie antiaérienne. Lors de la première séance, les spécialistes ont signalé les menaces de manière plus précise et plus exacte au plan syntaxique que les novices. À la fin de la deuxième séance, les deux groupes s’étaient améliorés et avait un rendement équivalent sur les deux aspects. On peut donc conclure que l’appareil HOT permet une simulation valide de la production de messages signalant une menace et que la formation peut être transférée dans un environnement opérationnel. On recommande donc l’appareil HOT pour l’instruction opérationnelle de la collectivité du CC-130. On recommande également l’adaptation des scénarios d’entraînement et l’amélioration de la technologie afin de mieux représenter le contexte opérationnel actuel.

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simulator; simulation; Hercules; CC-130; training

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