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Applying Advanced User Models and Input Technologies to Augment Military Simulation-Based Training

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Gamer Preferences	Trainer Preferences
Entertainment Emotion	Learning Process Structure

Gamer Preferences	Trainer Preferences
Player Control	Learning Goals
Free Play	Instructor Control
Unpredictable Turn of Events	Standardization
Fantasy	Realistic Problems
No Boundaries	Effective and Efficient
Social Interaction	Transfer of Training
Surprise	Validity
Risk	Fidelity
Suspense	
Art and Beauty	

Simulators provide many advantages for training, including high fidelity to real-world operating environments. The main argument being that the closer the training environment is to the real world, the better will be the transfer of skills and knowledge acquired during training. However, it is now recognized that a simulator's fidelity must be measured not only by the physical appearance but also by its psychological and cognitive realism from the trainee's perspective [4]. Simulators also offer instructors the capacity to select specific training conditions, as well as detailed recordings of a trainee's performance for the purpose of performance comparison, diagnostic, and evaluation [5], with the capability of repeating a simulation scenario several times without the cost associated to live simulations. The availability of simulators is crucial to maintain readiness and avoid performance degradation [6, 7].

The training system development includes requirement and training objective specifications based on information collected and validated by course instructors and subject matter experts. The following sections will present the current state of development related to task analysis, cognitive modeling, and simulated firearm specifications. A systematic requirements specification process ensures that the training system is designed to meet the desired level of performance and readiness from soldiers.

2. TASK ANALYSIS

A task analysis was conducted in order to identify key performance objectives for training related to Close Quarter Battle (CQB). Different types of task analysis are possible, including hierarchical (also known as prerequisite task analysis), procedural (also known as an information-processing analysis) or cognitive task analysis. A procedural task analysis was used to flesh out the mental and/or physical steps that the learner (i.e., trainee in the IRET context) must go through in order to complete basic to more complex tasks related to CQB. In this context, soldiers are confronted with decision-making under the constraint of time and space, with minimum planning of the actions to be carried out after room entry. They must act

and react based on the situations they are confronted with. The criteria for each task may be listed in a hierarchical fashion but the soldier must not consciously run through a list of tactics or principles; he or she must act or react very quickly to the situation that is presented.

The first task analysis looked at simple quick aim shooting (QAS) tasks based on discussions with CQB instructors (DND). Table 2 presents a preliminary overview of variables (conditions), procedures, and possible performance measures for training quick aim shooting tasks.

Table 2. Fundamentals of QAS

Variables / Conditions	Procedural /Mental skills/ Rules	Evaluation: Possible performance measures
Number of participants: 2 men, 4 men	Hold weapon, ready, aim	Practice QAS: not timed
Room size: small, normal (12' x 12')	Identify threats	Entry drill assessment: Number of shots fired
Fire arms: 2 rifles, 2 pistols	Judge (only threats: perception /discrimination of threat level)	Type of injury (kill shots)
Targets: no target, single target, multiple targets	Shoot (only at threats)	Time (shots, between shots)
Threat behaviour: static, moving, readiness (low, med, high threat level), ability to impede (low, med, high threat level)	Other: Manage stress	Quality of performance: continuous movement, smoothness, accuracy
Mixed conditions x number of threats	Visual-motor coordination (eye-hand)	Other: personal awareness, safety, effective communication
Threat weapon -low potency -high potency (mixed conditions, number of threats)	Communication	
Distance to threat 1-3 meters 10 meters max.		
Room shape -L shaped -Square/rectangular -T shaped -Other		

These are some of the elements of a quick aim shooting task for "expected" or typical trainees with prior knowledge and capabilities (i.e., fundamentals of QAS, principals of tactical shooting, threat assessment) in a routine task. Simple tasks can easily be made more complex with any number of variations: for example, the number of threats, threat behaviours, reactions and their speed, or types of weapons and their potency.

Observations of actual training exercises were also conducted to better understand the types of tasks trainees perform in the course of typical urban operations training activities. Further clarification on performance objectives

and input on the first task analysis gave way to revisions based on feedback from instructors and reliance on urban operations training manuals.

Subsequent to the analysis of simple to more complex CBQ tasks, a more specific list of questions regarding basic training (and system) requirements was generated to engage CQB instructors, subject matter experts, and the lead IRET system developer in more in-depth discussion. Table 3 presents a summary of important parameters to consider in the current IRET training design, according to four instructors and one subject matter expert.

Table 3. Characteristics and parameters for baseline training

Drill type	Practice drills, entry drills, limited drills, step out drills, high/low or piecing the pie, around corners of buildings, barriers	
Basic scenario	2-man	Corner drills, simple room
Parameters to control	Features	Room (shape, doors, windows, multiple rooms)
		Distance to targets (5 meters, 7 meters or more)
		Threat/non threat elements (actions/reactions, threat level, number, speed)
		Rules of engagement (ROE), mission and related parameters to set (option: beforehand or control on the fly)
	Weapon (laser) tracking	Direction/location (where fire is coming from, kneeling or standing position, direction gun is facing, direction/speed gun is moving)
Quantitative/ qualitative measures	Time	Entering a room
	Steps	To get to corners
	Target sequence	Establishing priorities
	Weapon	Weapon goes through before clearing corner
Success indicators/out comes	Not making any mistakes and clearing the room Being thorough, speed, accuracy, ROE, element of threat removed, room cleared.	
Feedback from system	Shots	Placement Kill shots Appearance (hit as colored circle on target, bleeding)
	Time	To enter room Squaring up to the door To clear corner To detect target To engage target Between shots
	Location tracking	Engaging outside the door/range Weapon in relation to door

Features and options	Split screen, picture in picture Print out option Video inside-outside the room (increases observation capability). Replay for debriefing or after action review (AAR). Enhanced feedback/playback options (close up on shots, target specs, visual indicator of hit)—application in marksmanship practice under stress. Option to turn on/turn off feedback.
Level and amount of feedback	Depends on the aim of the scenario. Available time for AAR: a determining factor in amount of feedback provided (time for debriefing, wait time between groups, group size). Need to vary type of feedback as trainee progresses. Detailed feedback for extensive coaching in AAR (e.g., for missed shots). General recommendation: Feedback which takes away from the realism or creates a hindrance is discouraged.

It is anticipated that the IRET system development team will combine elements of the task analysis described here with verification and testing as part of an ongoing iterative process. The information gleaned from this task analysis will assist in articulating a clear set of scenarios that capture the flow and sequence of tasks to be trained in the IRET system. Since building new capabilities every time the threat profile changes disposition is both time consuming and costly, alternatively, the development of training standards and inherently adaptable training modules is both efficient and more cost effective. Other driving forces for the use of IRET in training soldiers include the demand for greater accountability and objectivity in performance measurement and the need for uniformity in training.

3. COGNITIVE MODELING

Associated to the task analysis, the project is also conducting a cognitive modeling activity to develop constructive simulations of the CQB skills. Constructive simulations are key elements in the development of training simulators [8]. They can be used to help in the acquisition process [9], as a foundation for the development of synthetic adversaries [10], as a mean to detail the skills to be acquired in a training simulator, or even to study the transfer of agent skills [11]. A broader access to game engines as well as the emergence of new or improved cognitive architectures [12,

13] has allowed the development of many simulation systems of military operations on urban terrain [14-20].

The cognitive modeling research activity within the IRET project has two principal objectives: a) develop high-fidelity cognitive modeling technology to be embedded as artificial intelligent agents in an immersive combat game; and b) develop detailed performance and learning models of the learners to support instructions. The next paragraphs will discuss the current state of development in achieving the first objective.

There are many definitions of what an agent is but the following characteristics seem to describe adequately what being an agent means [21]. An agent is an identifiable, discrete individual. It is autonomous and self-directed (goal driven); it is situated, living in an environment with which it interacts with other agents (having perceptual, motor, and communication capacities); and it is flexible, having the ability to learn and adapt its behaviors based on experience. Agent-based modeling is divided in two communities, one focused on large numbers of relatively simple and highly-interactive agents; and the other one focused on a smaller number of agents with more complex internal structures [22]. The current research falls into the second category, and uses the ACT-R cognitive architecture as a means to develop agents [23, 24], which has modules to implement goal driven behavior, perceptual and motor capabilities, and well as learning mechanisms.

Cognitive models and agents will be considered synonymous. However, because the modeling approach is based on the ACT-R cognitive architecture, when a reference is made to a cognitive model, the internal structure of the model is the point of interest, such as the perceptual and motor modules, or the declarative and procedural memory modules. On the other hand, when the point of interest is not the internal but the individual and discrete nature of an entity, then the term agent will be used.

Figure 1 presents a flow diagram of the cognitive modeling methodology spanning from task analysis to model verification and validation. Processes are represented as ellipses and products as rectangles. A first distinctive feature of the approach is the development of an environment model in parallel to the cognitive model. The environment model is a piece of software with which a cognitive model or a human user can interact. Only relevant characteristics of the environment for the tasks that need to be performed are included in the environment model. The same executable environment model can be used to collect data on human performance, and provides the perceptual and motor environment for the cognitive model. The figure also shows that model verification proceeds by comparing simulated performance data to the task formal model, while model validation proceeds by comparing simulated to human performance data.

Figure 1. The cognitive and environment modeling process.

The interdependency between simulated agents and the environment they interact with put forward the need for cognitive model specifications to include both cognitive elements such as perceptual and motor skills, as well as environment affordances. As the Figure 2 suggests, a constructive simulation needs to identify the high-level primitive perceptual and motor representations essential for a cognitive model to interact with a simulated environment. These primitives constitute the first set of modeling requirements.

Figure 2. Information flow between a device and a cognitive architecture

The intermediate layer [25, 26] between a cognitive architecture and devices, such as a desktop application or a game engine, can be described by functions transforming internal device data into high-level perceptual constructs feeding in the cognitive model perceptual modules. In the same manner, motor actions get executed in the external device by translating high-level action representations in the cognitive model into device input.

Initiative based tactics are driven by the actions and initiative of the individual soldiers. Proper actions must conform to the doctrine and fundamentals of close quarter battle (CQB), but the actions success is highly dependent on the application of skills directed by the challenges of the immediate and specific conditions of a CQB situation. Communication and coordination with teammates, efficient body movements, as well as rapid threats assessment from environmental cues important building blocks of initiative-based tactics skills.

Prior research in CQB tasks analysis and cognitive modeling applications [10, 27, 28] provide an initial identification of key perceptual and motor primitives. Table 4 summarizes some of these primitives. The table is divided perceptual and motor modalities. Most of the categories and labels should be relatively easy to understand, such as location and end-points (defined in an egocentric spatial coordinate system), volume, and type. The people category however identifies environmental affordances that are crucial to the assessment of a threat level. Acquired-visual-object and weapon-target for example are the respective projections of the line of sight and weapon pointing direction onto agents in the room. Weapon readiness and potency are also other perceptual factors in threat assessment. A person can also exhibit composition of course and heading variations produce different kinds of body motion such as steering (aligned course and heading); canted (fix alignment offset between course and heading), oblique (constant heading position), and scanning (free heading movement from the course) [28].

All of the primitive perceptual, cognitive and motor elements presented in Table 4 can be physically measured with some level of accuracy using sensors located in a training room or worn by the participants. Sensor data (ex. tracking body movements) associated with trainee performance assessments by experts would allow a refined performance analysis that would create mathematical behavior models based on real-world actions. During the requirement specifications stage, one of the purposes of a cognitive model is to provide an initial mapping between simulated physical measurements, model performance, and cognitive operations, which are then represented as a set of production rules; within these production rules, perceptual, cognitive, and motor operations can be linked to observable objects and behaviors.

Table 4. Perceptual, cognitive and motor constructs required to operate in a CQB situation. ^A [27]; ^B [10]; ^C [28].

Perception Audition	
Verbal messages	Location; Volume; Sender ^A ; Content ^A
Weapon fire	Location ^A ; Volume ^A ; Type ^A
Ricochets	Location ^A ; Volume ^A ; Type ^A
Flash bang	Location; Volume

Footsteps	Location ^A ; Volume ^A ; Direction
Perception Visual	
Non-verbal messages	Sender; Content
Walls	End-points ^A ;
Corners	Location ^A ;
Pathways	End-points ^A ;
Doors	End-points; Hinges-location; Open-state;
Weapons	Location ^A ; Type ^A
Objects	Location ^A ; Type ^A
People	Location ^A ; Type ^A ; Speed ^{A,C} ; Course ^{A,C} ; Heading ^C ; Acquired-visual-object; With- weapon; Weapon-potency; Weapon-orientation; Weapon- readiness; Weapon-target
Motor Communication	
Speech	Receiver; Content; Volume
Non-verbal messages	Receiver; Content
Motor Body	
Weapon handling	Type; Trigger-arm&hand; Readiness ^B ; Orientation; Pull- Trigger; Throw ^B ;
Body displacement	Course ^C ; Heading ^C Speed ^C ; Modality
Body rotation	Heading ^C ; Speed ^C

4. SIMULATED FIREARMS

In addition to the task analysis and cognitive modeling activities, simulated firearms and the related user interface technology are also developed to provide trainees with realistic input devices for the training simulator. In order to create them, we use models of firearms with the same shape and weight as the real ones. To track the shots from those firearms in the simulated environments, the system must be able to record both the moment when they occur as well as their point of impact. For CQB where several soldiers are engaged, the system must also be able to identify the source of the shots, i.e. associate a shot to a specific soldier.

To achieve these goals, we are using simulated firearms mounted with lasers that are activated by a trigger press. Video cameras are then used to track the laser spots projected on the walls of the virtual training room. The information extracted (points of impact as well as associated timestamps and IDs) is used both as input to the simulation and as a record for performance analysis of the trainees. Performance metrics consist of number of bullet shots, the accuracy of the shots and the response time to specific events. The specific training scenarios will be determined through task analysis with the senior instructors.

5. CONCLUSION

The paper presented a brief overview of some components of a project aimed at developing a virtual

training environment using advanced user input technologies. The main intention of the project is to allow trainees to acquire initiative-based tactics skills in an environment as similar as possible to the operational conditions. The project explores the impact of targeted simulation-based interventions in producing effective training outcomes while future papers will report in depth on the scientific theories and empirical results underlying the IRET system and training program. The training system development includes requirements specification and training objectives based on information collected and validated by course instructors and subject matter experts. A systematic requirements specification process will ensure that the training system is designed to meet the desired level of performance and readiness from soldiers.

The task analysis identifies key performance objectives for training related to Close Quarter Battle (CQB) and what is expected of typical trainees with prior knowledge and capabilities. Tasks run from simple to complex very quickly with several characteristics and parameters involved in baseline training, and features in the IRET environment instructors will need to control to ensure trainee progression. The information gleaned from this process will ensure that the training system is designed to meet the desired level of performance and readiness from trainees, with requirements that have been collected and validated by course instructors and subject matter experts.

Constructive simulations are key elements in the development of training simulator. They can be used to help in the acquisition process, as a foundation for the development of synthetic adversaries, as a mean to detail the skills to be acquired in a training simulator, or even to study the transfer of agent skills. The present cognitive modeling approach focuses on the development of an environment model in parallel to the cognitive model. The environment model is a piece of software with which a cognitive model or a human user can interact. Only relevant characteristics of the environment for the tasks that need to be performed are included in the environment model. The same executable environment model can be used to collect data on human performance, and provides the perceptual and motor environment for the cognitive model. Prior research in Close Quarter Battle tasks analysis and cognitive modeling applications provided an initial identification of key perceptual and motor primitives for the development of constructive simulations. The cognitive modeling section reported on some of these initial requirements.

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Jean-François Lapointe: Dr. Lapointe is a Research Officer at the National Research Council of Canada's Institute for Information Technology since 1998. He holds a B.Eng. and M.Eng. in mechanical engineering specialized in robotics and a Ph.D. in electrical engineering specialized in human factors, all from École Polytechnique de Montréal. He is pursuing research on the design, realization and evaluation of interactive technologies for training, supervisory control and entertainment purposes. He worked on several research projects involving the use of virtual reality technologies in the forestry, mining, space robotics, cultural (media art, heritage, museum) and military sectors. His contributions to science and technology focused on the improvement of human-machine communication when using visual information technologies.