Decision Processes in Simulation-Based Training for ISAF Vehicle Patrols

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ABSTRACT

Gaining greater understanding of the requirements or needs of a commander or Operation Analysis Team for modeling human behavior, and the effectiveness of modelling and simulation for training for the Afghan mission, require a modelling process to make the structure of the decision domain explicit. As an initial knowledge elicitation step in this process, we have conducted a pilot study involving two field studies to create an initial model of how a team in a vehicle patrol operates within a training scenario implemented using a virtual training system at the Swedish Armed Forces International Centre (SWEDINT) at the Swedish Life Guard Regiment in Stockholm. The scenarios designed by the instructors at IntUtbE, the pre-deployment training for peace support operations unit within the Life Guard Regiment, are used to train and prepare teams for the real environment. Most importantly, the simulation-based training process creates an opportunity to train a team for specific possible events that can occur in the field, and how to act if those events arise.

The method used for modelling cognitive processes involved in this simulated (and real) operational environment began with the Belief, Desire and Intention (BDI) model of human decision-making. BDI has typically been used to model individual motivational factors and cognitive decision processes. Since patrol activities involve groups, the BDI model has been extended with several layers to bring the team aspect into focus.

The first field study within the pilot study involved observation of a simulated patrol and recording of the patrol session using voice recording, video, notes taken by an observer, and the screen history of the simulation together with captured eye gaze data upon the screen using an eyetracking system. The eyetracker provides tracking of objects of visual attention of the patrol leader, and dialogue between the patrol leader and driver can be analyzed in relation to these objects. The second field study omitted eyetracking for practical reasons.

The simulation used in the field studies has been developed by SWEDINT using Virtual Battle Space (VBS), a simulation engine developed by Bohemia Interactive. With this system, each team member has a health bar. One proposal following from this study is that it could be effective in improving and empowering the team aspect of training to provide a multidimensional `team radar´ to show the changing status of a team according to several measures of state and performance beyond a simple health bar. The team radar would consist of a graphical circle with different radius indicators for factors such as trust, physical state and courage, as well as the arsenal and equipment available for the team roles and the team as whole. Comparing a target team radar state with the evolving state during training would potentially provide an effective monitor of training progress. Such a display would also be interesting to investigate for operational applications, e.g. using augmented reality technology.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
OCT 2010	**N/A**	**-**

4. TITLE AND SUBTITLE
Decision Processes in Simulation-Based Training for ISAF Vehicle Patrols

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Blekinge Institute of Technology SWEDEN

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR’S ACRONYM(S)

11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADA564696. Human Modelling for Military Application (Applications militaires de la modelisation humaine). RTO-MP-HFM-202

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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**24**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

1.0 INTRODUCTION

With ISAF troops coming from approximately 50 countries, modelling and simulation (M&S) is a powerful tool for training in operational effectiveness and cultural awareness by providing safe synthetic experiences of situations prior to deployment in theatres of operation. M&S can mediate human support for small groups engaged in deep knowledge building. It can empower groups to construct forms of group cognition that exceed what the group members could achieve as individuals. However, the effectiveness of M&S systems needs to be validated and systems improved to take advantage of evolving technologies and understanding of human cognitive functions. This paper presents a pilot study including two field studies of current M&S training for ISAF staff and also of command and/or an Operation Analysis Team involved in modelling human behavior in training scenarios. The aim is modelling individual and group decision processes within the training scenario as a knowledge elicitation process. Such cognitive decision models can represent both intended and actual learning outcomes, e.g. for purposes of evaluating the effectiveness of M&S based training, and can also provide foundations for operational systems, e.g. for human support, group and organizational coordination, or as a foundation for decision-making by autonomous agents within operational systems.

In going from empirical investigation of M&S training situations to derived cognitive models, the starting point has been the AI modelling approach called the *Belief, Desire and Intention (BDI)* model invented by Bratman (1999/87). The initial BDI model has been enhanced with a planning layer by Georgeff and Ingrand (1989). Wooldridge (2000) uses the BDI model because it combines three important elements: 1) it is founded upon a well-known and highly respected theory of rational action in humans, 2) it has been implemented and successfully used in a number of complex fielded applications, and 3) the theory has been rigorously formalized in a family of BDI logics. However, critiques of the original model have included that it is lacking in both learning and social (here, primarily team) aspects of cognition (Wooldridge, 2000). The study reported here is a pilot study since it has been necessary to investigate the strengths of the BDI model and to specify potential extensions or modifications required for effectively modelling decisions within ISAF processes. The result is a series of cognitive modelling approaches derived from BDI, presented in the paper. Some potential uses of these models are also proposed. Actual implementation of the models could be based upon different cognitive architectural models such as SOAR (*S*tate, *O*perator *A*nd *R*esult, Laird et al, 1987), ACT-R (Adaptive Control of Thought—Rational, Anderson, 2007), or programming languages such as PROLOG, LISP, C++ etc.. However, the implementation of the models is beyond the scope of the research reported in this paper.

2.0 METHOD

Initial studies of gaze behavior in tactical simulations preceding the study reported here were concerned with details of visual cognition in relation to visual design during combat (see Sennersten, 2007). The two field studies documented here zoom out from this earlier work to understand how a group of people having different roles make decisions from within the framework they are operating in. Gaze logging is used again within the first pilot study and dialog analysis is added as a basis for analysing social interaction and team cognition with respect to roles and rules in typical training scenarios.

The operational situation chosen for the field studies is ground patrol operations in an Afghan village/town conducted with the use of one or more four wheel drive military ground vehicles. This scenario is part of a larger training process for people joining the International Security Assistance Force (ISAF) in Afghanistan. The first field study included two instructors operating the simulation as trainees, a person in charge of the simulation platform and one technician. This study was mostly a practical exercise to record gaze with a traditional set-up with an eyetracker without interconnecting it with the simulation engine. The simulation scenarios were created in VBS2™, see Fig.1. This study also contained sound and pulse recording to find out how the communication between the participants developed (pulse data is not considered in detail in this paper). This first study also had the aim of understanding via communication with instructors the detailed purpose and design of the scenario created by SWEDINT for IntUtbE simulation-based training of officers going to join the International Security Assistance Force (ISAF) in Afghanistan; the primary training would occur some weeks after the field studies reported here.

For the first field study, several conversations were held over several months between IntUtbE, the primary author of this paper and also SWEDINT staff in charge of their simulation platform. A couple of visits were arranged to meet staff and go through what kind of questions were of interest and why in relation to this research. Mail correspondence and phone calls were used to sort out the details and provide answers in between physical meetings. The field study examined training for two instructors who were new to the simulation system, prior to its use for training their own trainees.

The second field study observed 20 officers from Sweden and Norway participating in simulation-based training using the same simulation scenarios as in the first field study. This second field study was not visually recorded but concentrated more upon social interactions via observation and sound recording. The greatest value from this simulation-based training session was obtained from the answers to questions the participating officers gave retrospectively (the analysis of these questions can be found in Sennersten, 2010).

In terms of simulation design, the instructors design the scenarios together with the simulation platform staff and want to shape emergency situations so the officers can prepare themselves mentally for what can happen when they are in a real operational situation. The aim is also to practice with team members together where many have not met before, to practice navigation and radio communication and when to contact the Tactical Operational Centre (TOC). Evaluation happens routinely in the form of an After Action Review (AAR), retrospectively after a simulation-based training session. An emergency situation may occur due to language issues, so language and cultural differences with the context are also important to practice in a forgiving synthetic environment.

The simulation platform staff design scenarios beforehand and also creates simulation details on the fly during simulation sessions. Following a training session, instructors summarize performance and discuss certain hardships and successes during the simulation session(s) with trainees, what kind of scenarios the teams met, the roles and interpersonal interactions involved. Video-captured material from VBS2™ can also provide additional information. In relation to BDI and plans it is good to know what initial plan, in the form of a flap sheet and certain pre-specified routines the staff are asked to perform, so the plan can be the basis for debriefing and for determining what was learned during the simulation session. SWEDINT technical staff and the person in charge of Simulation, Modeling and the Practical Platform see these training environments as providing two major outcomes[1]: i) to support command exercises and to provide stimuli for international Brigade Staff courses and ii) training for future international peacekeeping missions. A foremost aim is to train and exercise cultural awareness, language (i.e. English), and collaboration with an interpreter and team during decision making. Visualization helps to understand and to comprehend dialog when a different language is being used in contact with local inhabitants. Hence visualization helps to unify participants when describing what is happening and also in aiding participants in more quickly shaping a collective mental comprehension together.

2.1 Experiment

Two experiments were conducted with the same scenarios designed by SWEDINT based upon an operational idea specified by IntUtbE and implemented by SWEDINT´s technical staff at the Simulation, Modeling and Practical Platform.

[1] Data from field study.

Figure 1: Screenshots of UK MoD in VBS2 v1.22.

2.1.1 Tools and Equipment

The tools and equipment set-up (see Fig.2) available for the field studies reported in this paper include:

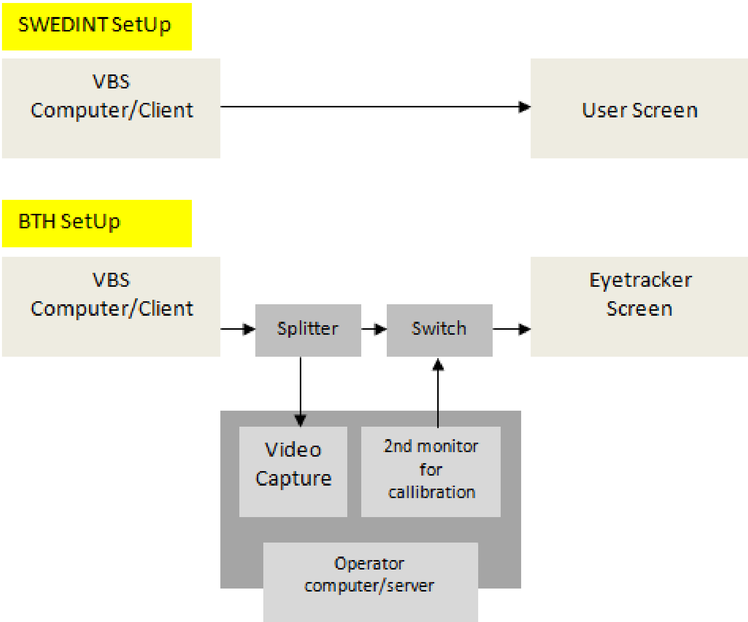

Figure 2: Connection scheme for VBS server/client + screen and VBS server/client + eyetracking screen.

Tobii Eyetracker T60
Simulation/Game Engine Virtual Battle Space 2, VBS2™running on 3 PC´s
Sound recording freeware
Simulation scenarios in VBS2™ editor
POLAR pulse watch
Keyboards
Extra interaction devices: Steering wheel and pedals
Analogue (paper) map
Walkie Talkies
Microphones
Control room with instructors role playing and making simulation design on the fly
Excel, Word

2.1.2 First Field Study

In the first field study, training staff were selected who were able to evaluate the simulation and its value as a training environment. To look at decision making, the Patrol Leader (PL) is the natural choice for eyetracking because s/he is responsible for the group and its decisions. Communication tasks within the vehicle, outside and via radio make this role the key to the effective performance of the whole group. Of course, every other role has its own responsibilities and challenges, but will be carried out in accordance with a main decision by the PL. The PL shall not only secure her or his own survival, but also that of the team, and achieve the patrol objectives and treat people with respect and optimism so survival is reinforced for all.

Two people are in the patrol vehicle, one driver and one PL. For the training session, each role is played by separate participants, who sit next to each other in the simulation room, as shown in Fig.3. In the control room there are two instructors and some other people voice acting in dialog when digital characters/ avatars are approached in the simulation (see Fig 4).

Figure 3: Officers preparing for simulation-based training, instructor in the middle.

2.1.3 Experimental Task

The experimental task was to gather gaze data, audio recording, video, and make observations in support of subsequent cognitive modeling of decision processes involved in the operational patrol task.

Figure 4: The team in this study was limited to the patrol leader (who is also the navigator) and the driver.

In a computer simulation with stimuli on a screen, the team members gaze upon the screen in order to navigate and meet challenges in the simulated environment. Fig. 5 shows the distribution of PL gaze behavior over a simulation session.

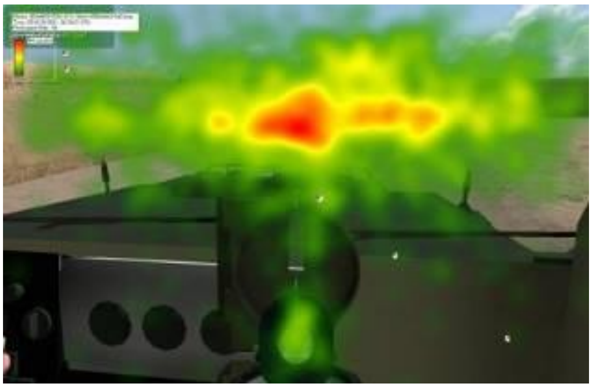

Figure 5: Heat map of visual attention from within the car, for the patrol leader.

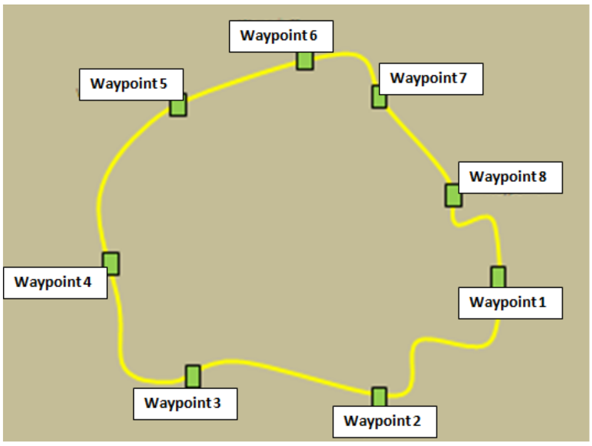

Figure 6: A predesigned route here contains 8 waypoints.

Figure 7: PL´s first person view of the driver.

2.1.3.1 Scenarios

The simulation scenario includes an accurate landscape and layout of the environment. The full scenario is a fictive event chain that is simulated and mediated in VBS2™ (see the driver visualization in Fig. 7). The group starts at the CAMP and then follows a predefined pathway (Fig.6) and reports position coordinates the patrol chooses when going to patrol target X (the governor) in the area, in a town somewhere in Afghanistan.

2.1.3.2 Training Sessions

There is no time limit to the training scenario – the purpose for the groups is to train themselves out of problems arising in the simulation while physically being in the home arena. Teams sit separately from each other to ensure intercommunication via the simulation. All objects are representations. 8 training scenarios, or cases, A1-A8, are shown on Figure 8.

Case 1:	Leave CAMP	
Case 1-2:		Navigation-Follow Flap sheet
Case 2:	Civil Accident	
Case 2-3:		Navigation
Case 3:	ANP, Afghan National Police -Control	
Case 3-4:		Navigation
Case 4:	Communication with Local Inhabitant (practice functions)	
Case 4-5:		Navigation
Case 5:	Roundabout with motorcyclist	
Case 5-6:		Navigation
Case 6:	ANA, Afghan National Army -Tank	
Case 6-7:		Navigation
Case 7:	IED-Bomb	
Case 7-8;		Navigation
Case 8:	Return CAMP	

Figure 8: The ISAF simulation scenario cases.

2.1.2 Second Field Study

The second field study had around 25 people in training using the same scenario as the first field study.

The leader group in the control room (this time including two technicians and two instructors) received a Flap Sheet (patrol waypoint list) from the teams. The teams can be followed via a big screen in the simulation room in front of where the leader group sits in the control room. Communication regarding decisions was via radio.

A team consists of 4-5 people, with one lead patrol of 2-3 officers and one following vehicle with 2-3 officers. The lead vehicle has the PL for the whole team. The second field study had two full teams in the morning and also two full teams in the afternoon. All sessions were audio recorded and retrospectively all officers answered a questionnaire. The analysis of the data has first involved transcribing visual data and sound, including communication between the participants.

3.0 RESULTS

Detailed results presented here are from field study 1, while the cognitive models developed later are based upon both field studies. This simulation took approximately 1 hour after instructions and guidelines presented by the main instructor and technical staff. There were two major simulation restarts, one back to the beginning and inside the camp area and the second one to a certain place within the simulation environment.

The initial instructions by the instructor included: “The task is to do the vehicle patrol in relation to the predefined route we have made, here [specified on the] flap sheet. If something is happening along the road and you both decide to make a march re-plan, then you do this concerning your decision. We do not have to think about things as we have to do out in the field and this is what this method´s strength is. You choose the way you want to go, report your re-plan over radio, and in relation to where you are we can move the event scenarios we want you to go through irrespectively what direction you have chosen. You do not have to think about any constraints like -didn´t he say that we had to follow the colored line?, no." The distribution of the instructions and its main content are shown on Fig. 9.

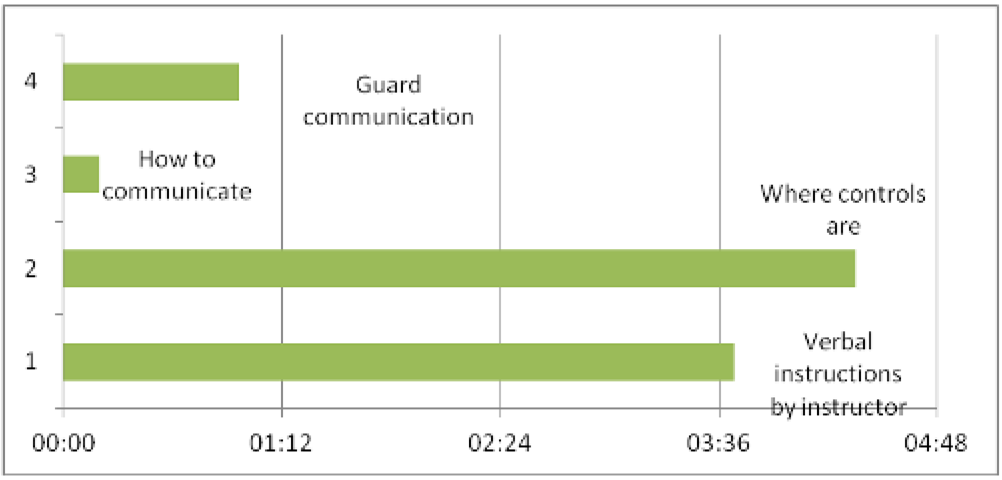

Figure 9: Categories of instructions before the start of the simulated patrol.

3.1 Observation

External observation consists of seeing the external environment and being able to say when conditions are normal and when there are special occurrences of different kinds. Inside each vehicle there is a team which we can call the internal team and every person in a team functions as an observer. For one team member, observation contains many gaze fixations, exemplified by red disks in the figures in this section; lines are saccades, i.e. eye movements between fixation points.

Individual fields of view are combined to become one that is documented after the patrol, a common field of view. The PL role is in charge of the team and is the main channel in contact with the TOC, also s/he is in charge of communication with people in the local community while patrolling as well as being the navigator in a two-man team.

The following are examples of typical events within the ISAF simulation training scenarios.

A1 Leave Camp; ISAF guard soldiers control Vehicle Patrol, has left Flap Sheet copy in TOC. Opens the gate and own staff drives out in Area of Responsibility (AoR).

A2 Follow Flap Sheet; Own staff passes (meets) traffic, local inhabitants and animals along the streets.

Figure 10: PL and driver pass a woman in a burqa.

A3 Incident along the road; Own staff meets a local accident. There are people around the local vehicle, and they are searching for help.

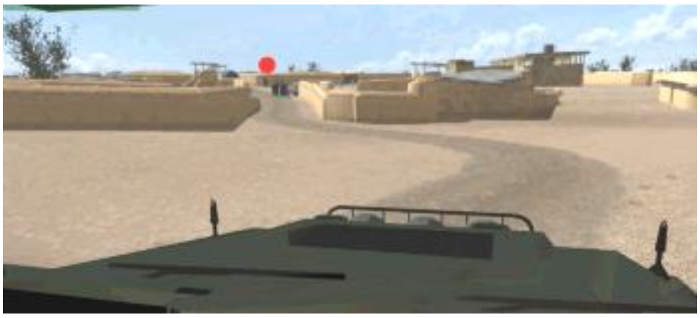

Figure 11: PL fixates above an accident at distance.

Figure 12: Fixations on one of the men. A man is lying on the ground.

Figure 13: Driver looks at PL. PL is looking at the man outside.

A4 Afghan National Police (ANP) Checkpoint; Own staff is stopped at checkpoint. The reason is first said to be fire in some of the quarters but the real reason is due to checking vehicles for weapons and if they carry criminals. The security aspect makes it not possible for ISAF to proceed here so re-planning has to be done by the trainees.

Figure 14: A sign saying “SLOW” and it seems like a police control.

Figure 15: PL fixates two of the ANP staff.

Figure 16: PL fixates the two ANP staff while communicating with the third policeman. Middle-ground is also attended.

A5 Re-plan; Own staff chooses a new road, it is reported to TOC so there will be a check-up.

Figure 17: Measuring distance by gaze.

Figure 18: Motorcycle accident in a roundabout and communication with the motorcyclist.

A6 Afghan National Army (ANA) in wrong place; Own staff sees ANA with vehicle. Questions arise about what they are doing there?

A7 Improvised Explosive Device (IED) observed; Own staff sees what is comprehended as being an explosion. This happens close to the camp that sends out support; Own Flap Sheet is interrupted.

Figure 19: A car waiting for the ISAF vehicle to pass.

Figure 20: The same car is overtaking the patrol.

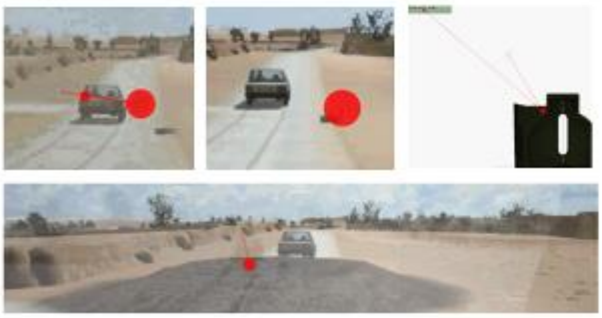

Figure 21: Sequence when IED is thrown from the car in front of ISAF vehicle.

A8 Return to CAMP; Patrol over.

Figure 22: Ground vehicle with PL and driver sees ISAF guard soldiers again.

3.1.1 Objects

Visually fixated objects measured using eyetracking include people met on the street, animals, stationary vehicles, garbage piles, overtaking cars, motorcycles and bicycles driving towards a patrol, stands with fruit and vegetables, own staff, etc.. For all of these simulation agents/objects there are related actions that can be actions of the objects themselves or dialog actions between the team members. So to understand the dialog, the object is the smallest common denominator here in this study.

Figure 23: Women, children, men, animals, and vehicles are passing by.

3.1.2 Dialog

Dialog is taken to be primarily a description or discussion about states where objects are the basis for the dialog, even if not directly (this is a simplifying assumption for modelling). Dialog can be divided into three main categories:

- Dialog between the team (patrol leader) and the TOC
- Dialog between the team(patrol leader) and local inhabitants
- Internal dialog within the team, here the driver and the patrol leader (e.g. for navigation)

Figure 24 shows communication times with locals during different kinds of meetings, as well as internal communication.

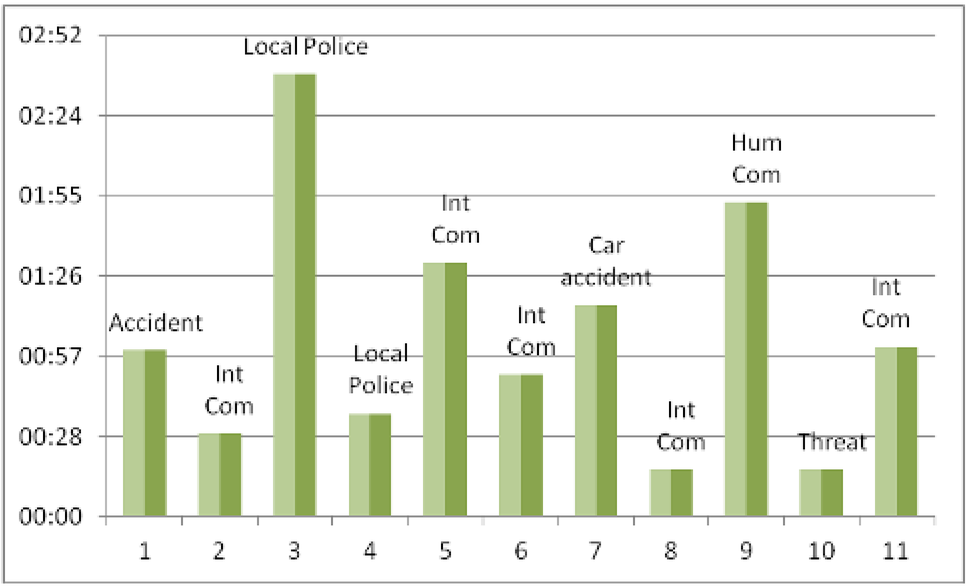

Figure 24: Human communication takes around 12 minutes in total for the first field study.

The PL communicated in total 08:38 minutes with TOC. The communication is formal and changes in form when special events occur and help of some kind is needed. Help can consist of getting support in a special decision or choosing an alternative waypoint.

The graph below, Fig. 25, shows the distribution of duration in radio contacts with TOC. Communications have to be short, formal and substantial, so everybody understands what is communicated if any disturbances interfere.

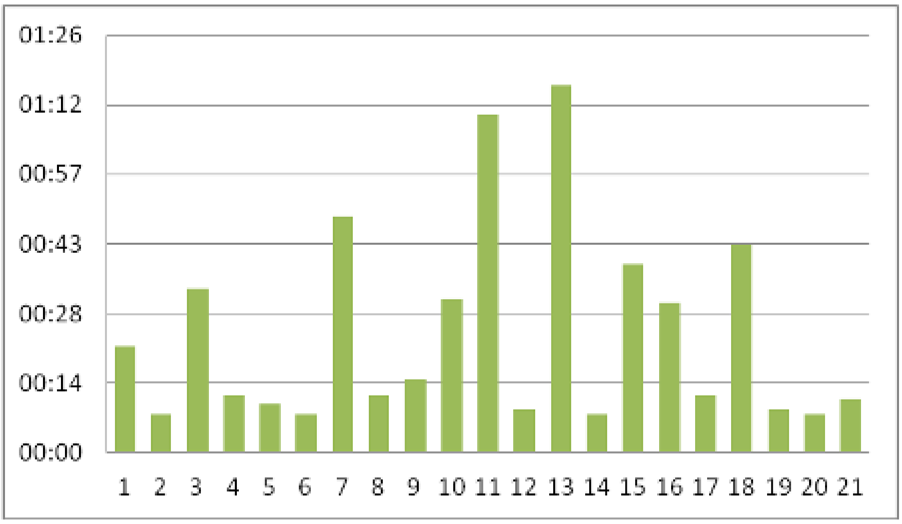

Figure 25: Radio communication with TOC during a Vehicle Patrol (time in minutes and number of contact)

The total time of communication between the Patrol Leader and Driver is 24:34 minutes, see the distribution between PL and D in Fig.26.

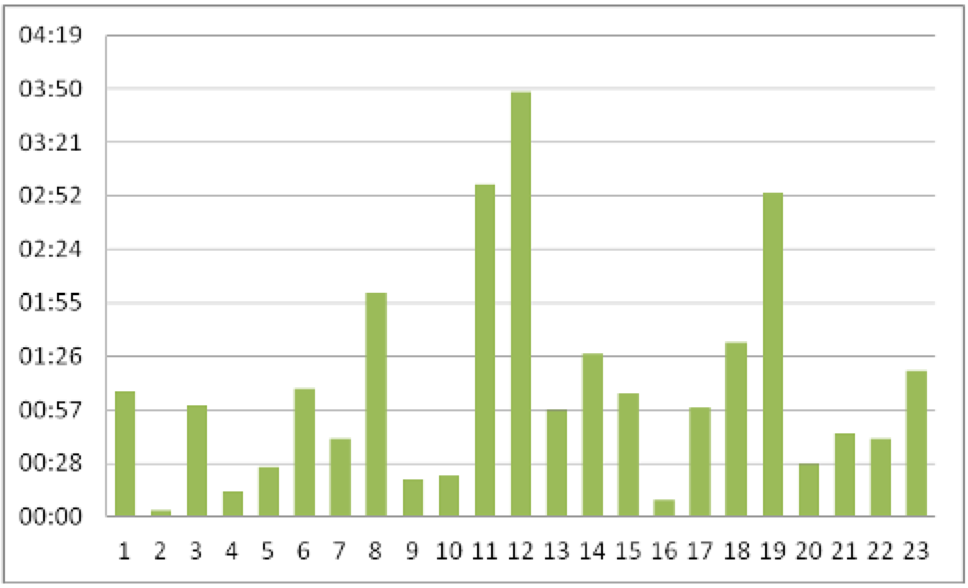

Figure 26: The number of verbal communications and their length in time (in minutes) between the Patrol Leader and the Driver.

As shown on Fig. 24, the total communication time with local civilians is around 7-9 minutes, while the remaining time outside the team is communication with local police. We have a threat scenario following the motor cycle accident that is very short, just 16 seconds, where the driver tells the PL to immediately return to the vehicle so the driver can reverse. Just after this, two men throw stones at the vehicle and TOC is contacted directly afterwards. They are instructed by TOC to head back to the camp.

3.2 Objects and Dialog

The communication carried out in this context seems to build on the stimulus of a gazed object with dialog following gaze behavior. The dialog concerns situation estimation, deliberation over what to do (actions), and how to approach inhabitants on the spot. Not all objects have any importance but still many gazed objects have to be deliberated in case they may hide information, can be of harm, etc.

Time	Distance	Eyetracked Object	Role	Dialouge
0:23:16	75m	ACCIDENT IN DISTANCE		
0:23:17			PL	Continue along this road.
0:23:18			PL	There is something ahead.
0:23:19		CAR1 left side	PL	Do you see that in the alley?
0:23:20		MAN1	PL	
0:23:21		MAN2	PL	
0:23:22		TOWER	DRIVER	Yah.
0:23:23		MAN on ground		
0:23:24		CAR2 on the side		
0:23:25			PL	What kind of accident?
0:23:27			PL	Guess?
0:23:28			PL	Lets go ahead and see what
0:23:29			PL	is happening?
0:23:30			PL	Does it look any hostile?
0:23:32			DRIVER	No
0:23:35	20m		PL	Yah.
0:23:38		MAN 1 is coming to the car		
0:23:40			PL	Okej.
0:23:41		PEDAL S	PL	There is one man coming.
0:23:45			PL	How do you get out?
0:23:47			DRIVER	"U"
0:23:48			T	"U"
0:23:50			PL	Salam ali cum!

Figure 27: An example of how objects and dialog (including meta-controls!) are related in this context.

Figure 28: This is the situation with the moped and the man claiming $500. In the background quite many people appear to be lining up to support the man.

3.3 Cognitive Models

The previous section has provided examples of the data obtained primarily in field study 1. This data, together with audio recordings and answers from field study 2, is the basis for cognitive modelling foundations summarized in this section. The primary aim here is not to present detailed cognitive models. Rather, the outcome of this pilot study is the identification of the abstract form of models (more accurately, the cognitive modelling *metamodels*) required for comprehensive modelling of decision processes within this domain.

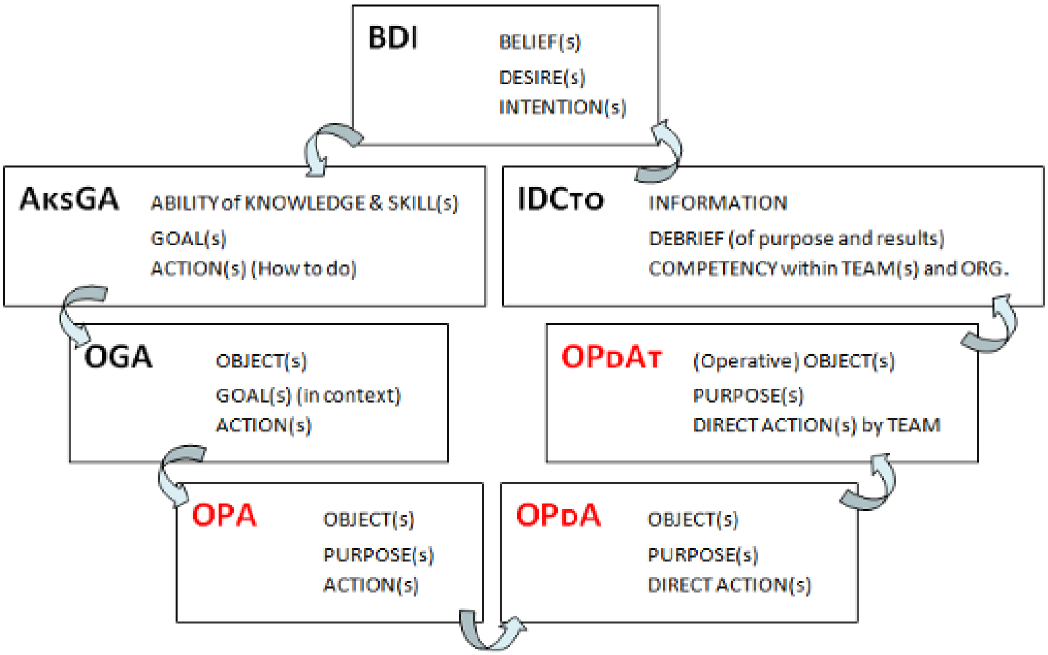

Figure 29: BDI, a cognitive reasoning model, and its modification over several steps from individual and organizational points of view, education through operational missions in teams, to retrospective performance evaluation. The last step is gathered competency that can feed back into the high level BDI model of the system and organization again.

The cognitive modelling methodology and software called Beliefs, Desires and Intentions (BDI, Wooldridge, 2000) functions as the starting point for cognitive modeling in this pilot study. However, BDI has not been found to be sufficient for modeling all aspects of decision processes in the military application domain. Hence the process models shown on Fig. 29 begin with BDI, but then present a series of variants resulting from working with BDI and interpreting it from points of view of: the military organization, education, instructors, simulation-based training, operational scenarios in the field, teams, and debriefing situations. The resulting BDI-derived cognitive modeling methods developed in this study are (Fig. 29):

- The original BDI and its framing
- The AKSGA model for training in military education
- OGA, a simulation-mediated perspective
- OPA/OPDA and OPDAT using VBS2 and eyetracker/adaptation emphasizing object perception and taking advantage of rapid eye gaze
- IDCTO where shared imperfect experience and debriefing are major cornerstones

These models are interrelated and are understood to operate in parallel where many levels of operational and training environments and systems are considered. Note in particular that these are *not* implementation models; the question of the best architectures and/or languages for the implementation of the models is not within the scope of this paper. Rather, the models are abstractions of distinct decision processes within the application domain, derived from the field studies. Application of all of these models (which has not yet been done, and therefore remains to be validated) is a suggestion for how to contribute to system development where learning, sociability, time issues and technology can provide tools to meet requirements for decreasing gaps in training, and/or increasing safety and security in open and closed worlds, or a mix of both.

3.3.1 BDI

In this study it has been found that the original BDI model has been found to stand for the organizational framework within which simulation-based training is conducted and how the framework and rules are formed over many years such that the organization stands for certain values and rules, that all individual activities within the organization are supposed to conform to. So we can say it is an *intrapersonal*[2] as well as an *organizational*[3] model.

The word *desire* here is about motivation[4] of goal-oriented behavior, a thought that leads to action. The thought can vary depending on what kind of situation we may meet. Desires do not really have a functional place when it comes to fast action in operational tasks in a changing environment, since fast action responses are reflexive, prebuilt during training; the routines and the intensions of a certain framework are worked out beforehand and discussed so they should not need elaboration while performing varied tasks in the field that are not necessarily routine, but at least anticipated.

Beliefs, desires and intentions are therefore perceived here as a model that lies as a background for an organization, where frameworks are developed over long periods of time and also where documentation and negotiation are important processes for forming a stable framework. The pathos of the organization and its contribution to a peace process is of high importance.

This belief-desire-intention framework is what an individual is `accepting´ when deciding whether to join an organization or not. The values and the ideology in the case of the UN charter and peacekeeping missions stand for hope, good and human peace (United Nations, 2008). On the intrapersonal level, beliefs are elaborated and, depending on private status concerning being single, divorced, married, having any children, kind of religion or not, it may be easier or harder to take a decision to join and commit to the organization. Desires probably play a major part in this and can include: attending deployment again

[2] http://www.mypersonality.info/multiple-intelligences/intrapersonal/, accessed 2010-05-05

[3] http://www.cognitivebehavior.com/management/concepts/organizationalmodels_table.html, accessed 2010-05-05

[4] http://en.wikipedia.org/wiki/Motivation, accessed 2010-05-05

because it was a former good experience, to earn money, to make a contribution to a messy world, to go away from a family situation, to join because other colleagues have decided to do so, career advancement, etc. The intension then is actually to go on a mission (or not).

Once a person has joined a military organization, from the organizational and intrapersonal layer they will be trained and prepared by the organization. Instructors and staff will train their future staff before they leave their home country. Officers joining have former schooling in the military and an awareness of the organization, but maybe have not been operating in an international mission before, or with ISAF forces. Hence the BDI organizational layer frames the whole organization and mission, and mission training includes training in the values of this layer.

The BDI model has constraints if we use it for operational purposes in fast paced decisions. BDI is perfectly fine from an organizational and an intrapersonal point of view, but when it comes to operational tasks in situations of observation with ROE as a framework, we have to think of a model of another kind.

3.3.2 AκsGA

A stands for Ability, κs for Knowledge and Skill(s), G stands for Goal and A for Action. The abilities officers are to practice have to function as background knowledge, a backbone plan, which will be used in most activities carried out in an international operational mission. The trained AκsGA plans are those the officer applies to know how to act in certain situations.

AκsGA includes the *ability model* used in the military education in Sweden *(*Försvarsmakten, 1988, 2006). The ability model is used for educating military staff both for national and international missions, with the aim of making education effective at least in part by having people use the same concepts and having a collective language for goal formulations in qualitative terms. The ability model is used to shape a comprehension of simulation-based training sessions for upcoming missions.

Bratman's BDI model (Bratman, 1999/87) is captured in IntUtbE's principle of HOW TO DO which could be said to be based in Belief plus Desire which then gives the Intention to perform or to do something. However, the result of the training process is to combine APPLICATION (ability) as KNOWLEGDE and SKILL with educational goals so the trainees know how to act in different situations, e.g. how to stop blood pumping out from an artery or how to shoot, how to use a vehicle, a weapon, a system, etc.. The educational model means that a trained person has done an action before and can do it independently and also that time pressure can come into the picture without being a problem. Hence these learning outcomes are more suitably modelled using AκsGA as an extension of the BDI model.

On a group level, AκsGA models collective action of people with different experiences after formal education about a certain area or context. From an educational point of view, the aim is to have everybody up to a common collaborative lowest level in/for a context. So with AκsGA, we move from the organizational and intrapersonal BDI to personal and group training outcomes concerning action-oriented abilities and skills. The AκsGA model in its context helps to clarify performance qualities and quality levels for an individual as well as for a team. The description and use of the ability model "…is especially useful in goal formulations as well as planning, performance, analysis and evaluation of education" (Försvarsmakten, 1988). AκsGA is an abstraction of the structure and functions of the ability model.

3.3.3 OGA

The Object, Goal (in context) and Action (OGA) stage operates in a training or adjustment phase where there are no real world consequences. The original BDI model has its percept layer outside the model, while in OGA this is lifted into the model as "O", the object layer. This layer replaces Belief with tangible object perception. The object can of course be any object including vehicles or weapons one is educated to handle. "G (in context)" adds the dimension of what kind of world and regional situation holds, so the team knows how to behave and in relation to the general state they can elaborate what actions they are permitted to take. Goal development involves typically long term interaction and a bridge from ability training and long term negotiations into every day operations, a state of peacekeeping operations where the OGA can be a prolongation of the BDI and where also both models can work in parallel.

We have now gone from BDI to AᴋѕGA to OGA (Object, Goal and Action), where Belief is replaced with Object as the source of information, Desire is replaced with Goals and Intention is replaced with Action. This means that certain tasks in relation to `the state of the world´ change. In simulation-based training this model is more accurate when the updates of the engine with its rendering shape another, faster pace for exercising decisions than for the BDI or AᴋѕGA models. The officer observes the world, in this case scenarios in VBS2, and the simulation world contains objects of various kinds. An OGA model provides the mapping from these observations to chosen (and potential) actions according to relevant goals.

The OGA model brings the 3D percept into the model instead of keeping it external. One argument for building the percept layer into the model is to save time for people working in time critical situations and that can mean to save lives. To earn seconds or fractions of seconds can be critically important for individuals, teams and organizations. This kind of model can of course log what is gazed in a fast paced environment, but if you can log then you can also steer by gaze if you are occupied, etc.. This could be used, for example, as a help device in negotiation, life critical situations, or if your hands are occupied and you have to act fast with maybe no help, etc.. This functionality can be used both for training and for operational purposes where technology for augmentation can support and enhance human performance. But of course, this is far too much detail for higher level concerns of the organization, which here, it is proposed, are better modelled using BDI, while AᴋѕGA is more concerned with learning social collaboration and providing a map of different kinds of abilities, knowledge and skills as training targets, without necessarily going into the details.

The question arises of how committed an agent should be when the agent has selected an action. This may involve two questions: 1) how committed, and 2) for how long? There are different kinds of commitments (Wooldridge, 2000): i) blind commitment/fanatical commitment, ii) single-minded commitment, and iii) open-minded commitment. The OGA level allows for some extended deliberation in order to resolve these kinds of issues and obtain a decision.

3.3.4 OPA and OPᴅA

Some actions have purposes that may not drive deliberative action selection by individuals or teams, for example, routines, such as reporting reaching waypoints to TOC. Routines are trained for and performed often enough that they are performed automatically and with little deliberation, and without being driven by detailed conscious goals. They relate to specific objects, have purposes, and consist of highly familiar actions. This can be modelled using Objects (O), Purposes (P) and Action (A). This is referred to as an OPA model.

It is also necessary that at least some training aims for direct and rapid action selection under circumstances that are not routine (although they may be heavily trained for) without any extended deliberation[5]. Hence, while an *action* in OGA can be regarded as a deliberatively chosen behavior in response to certain stimuli, *interaction* (as in AᴋѕGA) is more of a dialog, and *direct action*, ᴅA, is more or less reacting with highly automated responses and little or no deliberation. To accommodate this we introduce the Object, Purpose, (direct)Action, or OPᴅA, model. (Actions in OPA have less urgent time requirements than in OPᴅA.) OPᴅA, stands for a level of direct action that may be modified by a deliberative context.

[5] This means a spine decision, or reflex reaction, achieved by training.

In the field studies, statements were observed that were about scenarios testing cognitive decision-making and judgment rather than skills, which should eventually lead to the capacity for skill-based direct action when there is no room for cognitive decision-making in the actual moment, or direct action responses may be trained in a way that does not rely upon higher level cognitive processing other than an understanding of the context. In direct action, cognitive procedures and allocations have been trained and built up over many hours and possibly years. Reaction can mean survival and is a fast response. This can also be to rescue others, and all roles within military mission training (including for health and emergency staff) are given weapon education as a common ground for self-defence situations. The object and its value are what an agent sees (O), the information about the world, and the purpose (P) of action (ᴅA) is to meet that object and its value in a way that achieves higher level goals, but without deliberative action selection.

From a BDI organizational perspective the information about the world and its framework is quite stable, while a decision under pressure (at the OPᴅA level) brings us to the question of how to quickly process the information at hand to arrive at an action while staying within the framework of rules and negotiations. The VBS2™ simulation-based training data, gaze recording and the field studies at SWEDINT provide a basis for detailed descriptions of the components required to develop more detailed OPA/ OPᴅA models. These are described in Sennersten (2010).

3.3.5 OPᴅAᴛ

From OPA and OPᴅA we have a comprehension of how Object(s), Purposes and Actions function and are thought of. These models have been derived from observations of individual roles, but we must also consider how a team may function. This leads to a team extension to the OPᴅA model, leading to OPᴅAᴛ, where ᴛ stands for Team. There are different kinds of teams and here the term *team* will be used with the meaning of "A group organized to work together and a group on the same side (as in a game)"[6].

OPᴅAᴛ captures training for the ability to constitute a team in relation to operational tasks. The team participants are required to understand individual roles and their prerequisites, leading to a cognitive team model[7] . As a result of this training, "job performance (task performance) is related to cognitive ability and not to personality" (LePine & Dyne, 2001)[8]. OPᴅAᴛ allows modelling of individual and possible collective "observation" tasks that can result in a common cognitive model for specific kinds of decisions. Direct action here means to act and know what to do in a coordinated way among team members without long thought processes or individual or collective deliberation. Coordination among team members may involve terse verbal or nonverbal signs. The major difference among members of a patrol team is the role allocation and the distribution of observation areas between roles, with one person being in charge overall for decisions.

3.3.6 IDC$_{TO}$

Information, Debrief and Competency within Team and Organization (IDCᴛᴏ), refers to collective cognitive processing where after training and debriefing the team has developed an imperfect competency together that can be of further use for later team collaboration in improving understanding. The competency is an interpersonal shared mental model based upon experience of situations. It is important here to understand the difference between imperfect post-experiential information and information needed in ongoing task performance in the present. Debriefing is about role- and team-shaped *postscripts* in

[6] http://www.thefreedictionary.com/team, accessed 2010-05-05

[7] http://www.google.com/books?hl=sv&lr=&id=U_8GVml_6IMC&oi=fnd&pg=PA221&dq=cognitive+team+model&ots=VqYPanRJ86&sig=fTHogFsjChPo1P0vYk-PRlC1hgE#v=onepage&q=cognitive%20team%20model&f=false, accessed 2010-05-05

[8] http://www.personalityresearch.org/papers/neubert.html, accessed 2010-05-05

relation to former initial *prescripts*. The pre- and postscripts form learning/comprehension outcomes. The simulation-based training scenarios carried out provide a basis for case studies in debriefing and also provide a ground for in-simulation team dialog.

4.0 POTENTIAL APPLICATIONS OF COGNITIVE MODELS

4.1 Training Evaluation

The cognitive (meta) models presented above identify different levels and forms of cognitive decision processes involved in military simulation-based training. Detailed models at these levels can provide a basis for: i) analysing and understanding cognitive processes both within training environments and real operational theatres, including evaluation of the effectiveness of different operational decision models, ii) expressing target cognitive processes for training, and iii) evaluating the effectiveness of training systems by comparison of target models with models achieved via training systems. These three uses represent a development sequence, of first identifying cognitive decision model variants and possibilities, then prioritizing and selecting from these to specify detailed cognitive training targets, and then using these targets for evaluating and improving training processes. Of course, fully developing comprehensive models at all levels for a given operational environment would be an enormous and perhaps impossible task, so actual use of the models will require more selective application.

4.2 Training and Operational Enhancement

A team in a simulation-based training environment interacts with visual content produced by simulation and rendering engines via devices and sensors. Having an explicit representation of target cognitive models for training leads to the possibility of implementing those models within the training system. This could support real-time mapping and analysis of trainee performance against those target models, providing feedback for instructors to adapt the simulation to provide more training in less developed areas of trainee cognitive ability. After the simulation, mapping performance against a target model can provide detailed information on trainee performance for feedback, discussion and ongoing training. Such a model could also be used to automatically adapt the simulation in real time, for example, by providing more examples for areas where further training is needed and progressively increasing task difficulty as trainee ability increases (a common principle of computer game design).

More significant enhancements can be expected if various psychophysiological inputs can also be included in simulation interaction. In principle these could include galvanic skin response (GSR) measuring arousal, electromyography (EMG) measuring emotional valence, heart rate/pulse, and electroencephalography (EEG) measuring approach/avoidance, attention, etc. (see, for example, Andreassi, 2006). Such inputs can provide data about emotional states and their role in cognitive decision processes, including the effectiveness of approaches to minimizing the influence of emotions on instrumental task performance and decisions that need to be driven by operational needs.

A training system taking psychophysiological measures into account at the same time as pre-plans, actual plans and carried out plans can be tracked, can make the team members more aware of themselves and each other, and also support decisions in situations where the world update changes rapidly. A possible interface proposed here for providing such feedback is a `team radar´ (see Fig.30), that can function for training support and cross correlate important states of action. A team radar implemented, for example, in VBS2™, (see Fig. 31), would graphically represent initial personal data like weight, pulse (rest-pulse), age, mood and emotion (derived from psychophysiology data), role, trust thresholds, skill(s) etc.. The outcome of this feedback can be increased awareness of the status of the group, and individual soldiers and officers can be empowered in their roles when taking hard decisions when they arise, by mapping action decisions to optimal performance models at the different cognitive levels described above.

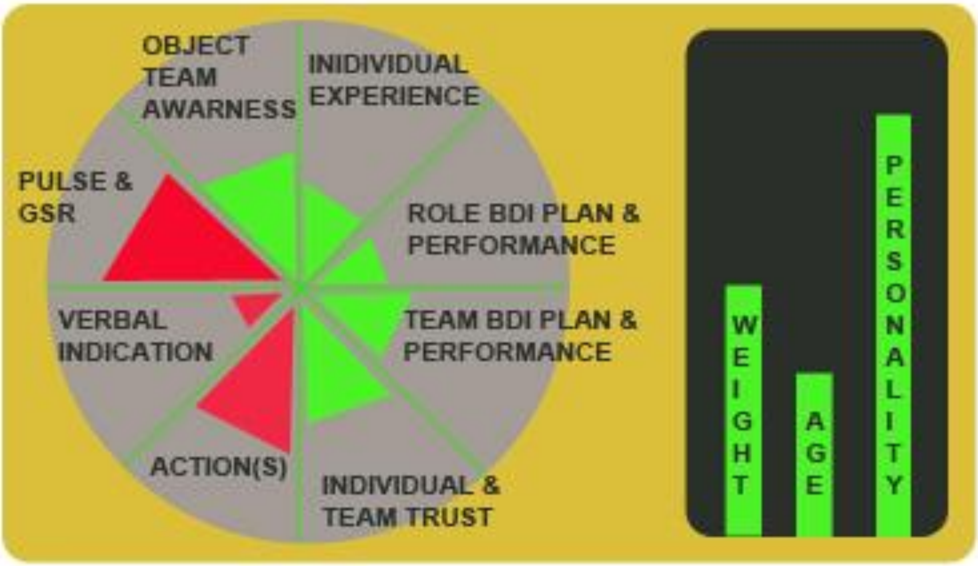

Figure 30: Proposed `Team Radar´.

Psychophysiological interaction does not require any efforts by the trainee because sensors gather physiological data without any conscious input from the user. Software tools can categorize and cross-correlate data so it can become usefully displayed and/or used in real-time, as well as logged and analysed retrospectively.

Eye gaze interaction, physiological tracking and team-based cognitive modelling and execution software such as JACKTeam™ can create the basis for comprehension of interaction patterns that help in debriefing and how to build safer and more effective operational systems for people in missions. The AOS company has implemented CoJACK™ within VBS2™. CoJACK can model human cognition, including the effects of moderators (e.g. fatigue, fear) on human performance, with JACKTeam™ supporting autonomous teams. Each team exists as an entity with separate beliefs from those of its constituent agents. The software supports different teaming algorithms and allows the representation of social relationships and co-ordination between team members. Team-oriented programming is presented as an intuitive paradigm for engineering group action in multi-agent systems. The software can then specify what a team is capable of doing and which components are needed to form a particular type of team, and then provide coordinated behavior among the team members and team knowledge.

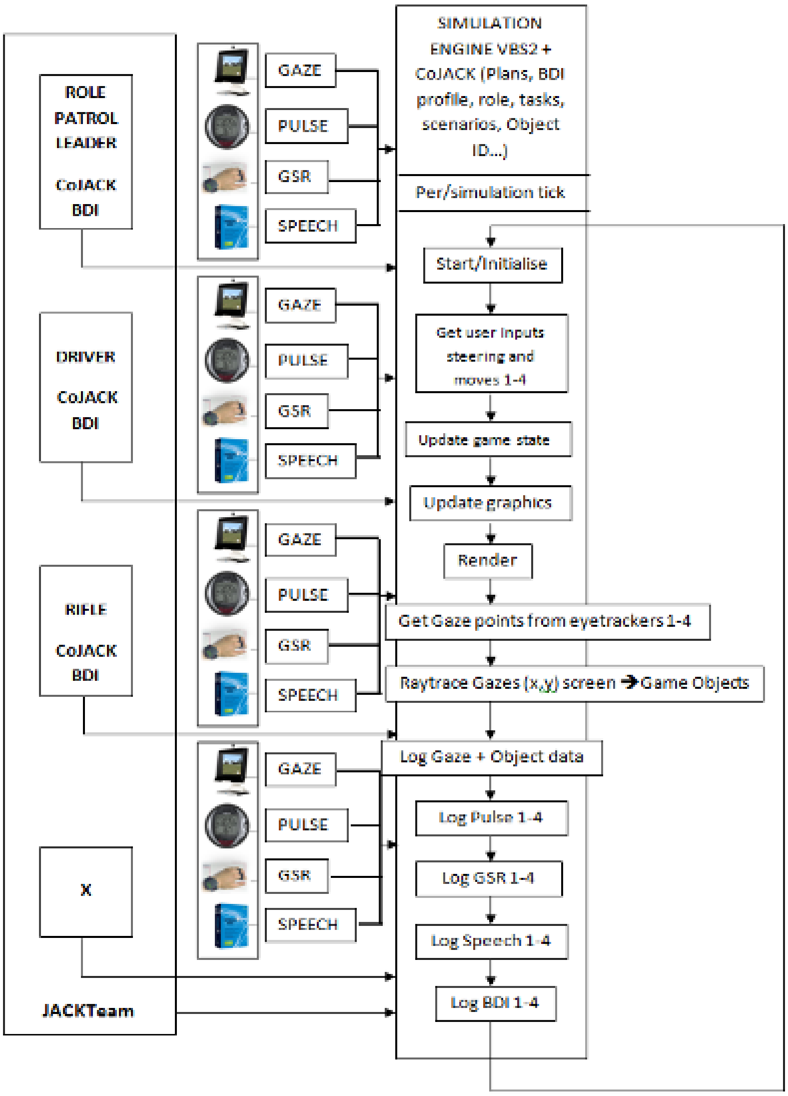

Figure 31: Instruments interconnected to the VBS2 engine, with CoJACK™, JACKTeam™, an eyetracker, GSR, pulse, and speech inputs.

In the simulation-based training environment proposed in Fig. 31, before starting, and depending upon the physical constraints of the operational or training environment, all team members place themselves in front of an eyetracker which then is interconnected with the VBS2™ engine, CoJACK™ and JACKTeam™, and are also provided with a pulse watch, GSR electrodes, and a microphone for speech recognition. During activity, gaze, objects, and audio will stand for transformations through or depending on every participant's physiological reactions. How actions conform or not to prior training can be assessed and fed back, both to the individual and the team so that team self-regulation becomes an explicit cooperative goal for the group.

5.0 CONCLUSION

We have presented a pilot study of simulation-based training developed by SWEDINT for IntUtbE for ISAF troops in preparation for ground vehicle-based patrols in Afghanistan. The pilot study involved two field studies and resulted in a metamodel providing a representation paradigm for the more detailed kinds of cognitive models required to represent decision processes and their context both for training and in the target theatre of operations. This metamodel provides a more specific foundation for ongoing detailed modelling, both for evaluation of simulation effectiveness and potentially for enhanced functions within both simulation-based training and actual operations. It has further been proposed in this paper that greater benefits may be realized, both in training and in operations, by the introduction of real-time psychophysiological monitoring and feedback for troops, instructors and commanders, integrated with cognitive models. Extensions of this concept could involve augmented reality systems for direct feedback of group state, e.g. using a team radar. The deployment of both centralised and distributed cognition models is fundamental for enhanced operations, and for the successful integration of both manned and unmanned combat agents. Such a vision is fully compatible with, and in fact heavily dependent upon, the heavily internetworked architecture of modern western combat systems; the aim of this paper has been to use this architecture as a foundation for enhanced training effectiveness by providing and representing new dimensions of situational awareness in terms of cognitive state, and effective synchronization of the cognitive foundations of operations at multiple levels of organizational, temporal and spatial resolution.

REFERENCES

Anderson, J. R. (2007). *How can the human mind occur in the physical universe?* New York, NY: Oxford University Press.

Andreassi J. L. 2006 *Psychophysiology: Human Behavior and Physiological Response*, Lawrence Erlbaum Associates Inc.

Bratman, M. E. (1999/87). *Intention, Plans, and Practical Reason*, Harvard University Press, USA.

Georgeff, M. P. and Ingrand, F. F., (1989). “Decision-making in embedded reasoning system”, in *Proceedings of the 11th international joint conference on Artificial intelligence – Volume 2*, pages 972-978, Seattle, Washington.

Laird, J., Rosenbloom, P. and Newell, A. (1987). "Soar: An Architecture for General Intelligence". *Artificial Intelligence*, 33: 1-64.

Sennersten, C. (2010) *Model based Simulation Training supporting Military Operational Processes*, PhD Thesis, School of Computing, Blekinge Institute of Technology (BTH), Sweden.

Sennersten C., Alfredson J., Castor M., Hedström J., Lindahl B., Lindley C. and Svensson E. (2007). *Verification of an Experimental Platform Intergrating a Tobii Eyetracking System with the HiFi Engine*, Swedish Defence Research Agency –FOI, FOI-R—2227—SE, Sweden.

United Nations. (2008). *Peacekeeping Operations: Principles and Guidelines*. http://pbpu.unlb.org/pbps/Library/Capstone_Doctrine_ENG.pdf