Mission Integrated Simulation – A Case Study

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ABSTRACT

Currently available modeling and simulation technology has the potential to increase capability of military units. The purpose of this study was to explore the potential benefit of 3D modeling and simulation as mission integrated tools for preparing, executing and evaluating a ranger mission. The study was undertaken during an eight day exercise in which two ranger squads were tasked to ambush a communication hub. Access to an interactive 3D model of the mission area was expected to enhance planning and task force performance and also provide means for better debriefing. During the planning, virtual mission rehearsals and reconnaissance were undertaken in a virtual 3D model of the target area in the simulation system Virtual Battlespace 2. The execution in the real target area was documented by observers, questionnaires, GPS, voice recording, helmet mounted video cameras and interviews. Results indicated that “virtual reconnaissance” was a more appreciated function compared to “virtual mission rehearsal”. Results also indicated that the 3D model had given the rangers a spatial mental model which enhanced their execution. Finally, replaying the mission in the model enhanced the possibility to draw conclusions. One conclusion is that mission integrated simulation does not replace, but rather complements conventional tools or procedures. Possibly an urban terrain would render the “virtual mission rehearsal” more valuable compared to this case of forest with a limited number of significant artefacts. Still, a virtual 3D model which is “good enough” in terms of adequate level of detail in the mission area gives a supplementary perspective which increases the understanding of the limitations of 2D maps. Consequently, the concept of mission integrated simulation will be explored further. By utilizing already available tools and platforms and focusing on solutions that might be realized within 5-10 years it should be possible to enhance mission performance with limited investments.

ABOUT THE AUTHORS

Per Wikberg (PhD) is a senior scientist and project manager at the Swedish Defence Research Agency. His primary focus is the development and implementation of research methodology in non-laboratory settings such as exercises or large scale case studies. The work includes modeling experimental designs and approaches for efficient data-collection, analysis and documentation; interdisciplinary studies focusing on a wide variety issues such as decision making, situation awareness, access to real-time information; multi-agency decision making; CBRN-response etc. Besides his PhD. in Cognitive Science from Linköping University, he is also a former commissioned army officer and currently holds a position in the Swedish Defence Force as a Lieutenant (Res.).

Mirko Thorstensson (Lieutenant, Army Res.) is a senior scientist and project manager at the Swedish Defence Research Agency, where he has worked with the development of unit training and mission rehearsals utilizing Modeling and Simulation. He has also expanded his work beyond the military services with applications for other agencies as well. He has specialized in using observers for data collection in the fields and how to use observer data in computerized evaluation systems and lessons learned processes. Mr. Thorstensson holds an MSc in Computerized Automation and a Tech. Lic degree in Computer Science from Linköping University.

Peter Hammar (PhD) is a scientist and project manager at Swedish Defence Research Agency in the field of Modeling and Simulation. The work has focused on game-based training for soldier as well as command level, regarding development of both methods and simulation systems.

Gustav Tolt (PhD) is a senior scientist and project manager at the Swedish Defence Research Agency, where he has worked with development of methods and techniques for 3D sensor data analysis, sensor fusion, 3D terrain modeling and geoinformatics. His main current research interest is methods and techniques for automated 3D terrain analysis to enhance planning, training and M&S capabilities.

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INTRODUCTION

Scope of the Case Study

The scope of this case study was to test and evaluate modeling and simulation (M&S) tools as support to planning, rehearsal, execution, debriefing and evaluation of a mission. The vision is to use modeling and simulation technology to increase a military unit's capability to execute a mission. In a series of case studies, the methodological approach is to adapt currently available, but immature and not fully integrated, solutions and use them in an operational context. Consequently, the scope is primarily not on using M&S for training purposes. Instead, the scope is on integrating M&S in real missions, thus "Mission Integrated Simulation." This study, the first in the experiment campaign and undertaken at the Swedish Ranger Battalion (AJB), has been restricted to some representative M&S tools and models with a focus on planning, rehearsal and debriefing.

The Concept of Mission Integrated Simulation

As a preparation for the study, a concept of how M&S can be implemented in a ranger mission was outlined together with officers from AJB (personal communication, November 2012 - May 2013). Up-to-date geographic information, specific intelligence data and other mission critical conditions can be collected and used to construct a three-dimensional (3D) computer model of the mission area. This model, in combination with M&S tools, can subsequently be used for mission planning as well as mission rehearsal in the actual geographical area with the latest available information about conditions, enemy location, and other important criteria. The use of 3D models, together with real-time data from the mission, can also be used for enhanced command and control tools as well as for re-planning in the field. Furthermore, the 3D model together with collected mission data can be used to support After Action Review (AAR; Rankin et al., 1999) and form the basis for Lessons Learned. Subsequently, the model together with the recorded course of actions can constitute a validated training scenario. Figure 1 depicts the concept on how different M&S tools can be integrated in the preparation, execution and analysis of a ranger mission.

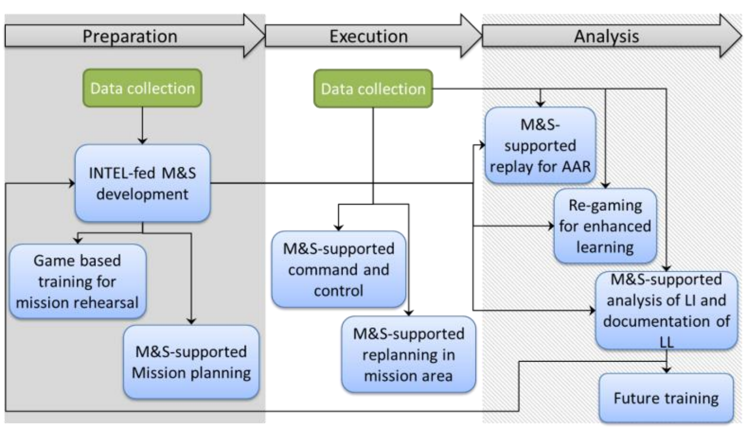

Figure 1. Possible Components in a Modeling and Simulation Supported Mission Concept

M&S Tools for Planning, Training and Analysis Used in the Case Study

This study has focused on three aspects of the concept described in Figure 1: game-based mission rehearsal, planning and AAR. As an example of how to increase the usage of existing and procured M&S technology, Virtual

Battlespace 2 (VBS2) from Bohemia Interactive (Bohemia Interactive, 2012) was chosen as the M&S tool for exploring the use of 3D virtual models for planning and mission rehearsal. VBS2 is a 3D simulation training system for dismounted soldiers, operated from the first person perspective on standard desktop computers. One of the features of VBS2 is the possibility to import real-world terrain areas and create and configure new 3D models. Presumably, this gives the possibility to use the system not only for training but also to support planning and execution of real missions by importing a 3D model of the mission area as well as the possibility to feed recorded data from the real mission back into the system for debriefing and lessons learned. For the context of national defense in Sweden a lot of terrain data are available, including elevation models and a large amount of data regarding tree positions, type and density. This kind of data can be used to create a high fidelity 3D model for VBS2 or other systems.

In order to address the use of M&S tools to support AAR, a tool developed at Swedish Defence Research Agency (FOI) was utilized for replay and analysis of recorded data using Global Positioning System (GPS) data, and voice and video recordings. The tool “FOI Reconstruction and Exploration” (F-REX) is a toolset developed to support evaluation by constructing mission histories and exploring them through a multimedia presentation in a time synchronized manner (Andersson, Pilemalm, & Hallberg, 2008; Andersson, 2009). The tool also contains several applications for recording and collecting necessary data including – but not limited to – GPS tracks, computer screenshots and radio communication. F-REX supports replay of the entire mission history from the start to the end, with elementary functions such as pause, resume, rewind and fast forward. This, together with the filtering functionality, enables the analysts to shift between different foci and observe the chain of events in a meaningful context to make extended conclusions from simultaneous incidents occurring at different locations by multiple actors. Figure 2 shows a screenshot of F-REX.

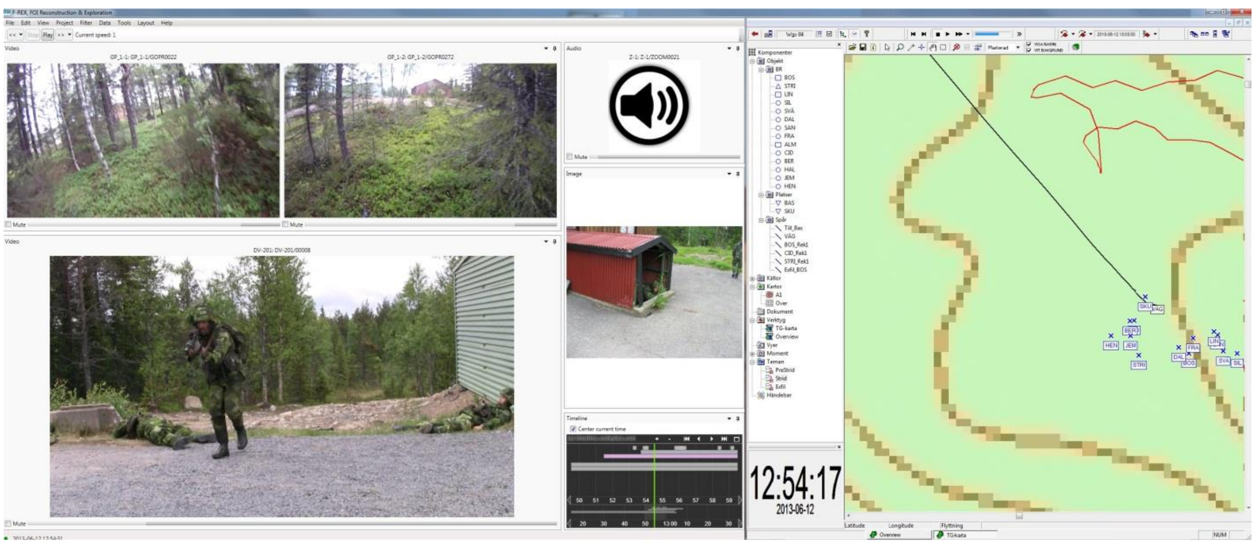

Figure 2. Screenshot Illustrating the F-REX Visualization

Swedish Army Ranger Battalion

The study was performed at the Swedish Army Ranger Battalion (AJB). The Ranger Battalion is a unit capable of combat and intelligence gathering far behind enemy lines where other units could not operate or achieve the same effect. The core unit of the battalion is the ranger platoon, formed around five squads. The platoons are organized in a flexible way in order to allow for adaptation to the mission-specific requirements (Swedish Defence Force, 2013).

Execution of a ranger mission follows a five step mission cycle, including (1) planning, (2) infiltration to mission area, (3) execution, (4) exfiltration and (5) reorganization. The planning phase includes two important functions: to *imagine a desired outcome* and to *arrange a configuration of possible actions* in time and space to obtain that outcome. The infiltration phase includes transportation to a location as close as possible to the target and the subsequent approach by foot or on skies to the target area. The execution phase includes *establishment* in the area in form of a base to enable on-site planning, preparations and recovery; *reconnaissance* by the collection of additional intelligence about the target in order to assess whether the plan is possible to execute; *execution* of task by realizing the plan; and finally *withdrawal* from the target area. The exfiltration phase includes movement by foot or on skies from the target area to a location where it is possible to use other means of transportation. The reorganization phase includes *debriefing* of the task force in order to review the mission in chronological order; *maintenance* of equipment; and *recovery*. Potential solutions for implementing mission integrated simulation (Figure 1) includes support planning based on 3D data of target objects and surrounding environment, support command and control during execution, re-planning in the mission area, After Action Review and Lessons Learned database (Wikberg et al, 2003, 2004).

Hypotheses

The case study was set to probe a number of assumptions developed as a part of the work of outlining the concept (AJB, personal information, November 2012 - May 2013). In general it was envisaged that for the task force's execution of the mission cycle, having access to an interactive 3D-model of the mission area would add value to the planning process, enhance performance during the execution and focus the debriefing. The following list summarizes the expectations.

- Virtual reconnaissance during planning (regarding advance routes, deployment areas etc.) was expected to give an accurate picture of the mission area, additional information compared to 2D-maps and diminish the need for re-planning due to substantial differences between the model and reality.
- Interactive mission rehearsal during the planning phase was expected to strengthen the final plan by the ability to test different alternative tactical behavior as well as to give a set of rehearsed alternative chain of actions as fall back. Ideally the executed mission should correspond to the plan selected after the virtual rehearsal.
- Using the 3D-model for planning and rehearsing raised concerns regarding unrealistic expectation on the 3D-model, and for being too time and resource consuming since the analysis using the 3D-model was not expected to replace any existing activities.
- In the execution phase, the actual chain of events should correspond to challenges and the enemy behavior as expressed beforehand by the platoon commander. In case the plan fails, the unit should fall back on one of the alternatives rehearsed in the 3D-environment. It was expected to be a correspondence between how the soldiers perceived the execution of the virtual mission rehearsal and the live mission execution in terms of a number of measures, such as realism, difficulty, how they performed and acted and how motivated they were as well as some "core success factors" including planning, access to updated intelligence, soldier competence, communication and level of training in coordinated teamwork.
- Replay the mission in the model during debriefing was expected to give a better overview of the chain of events and thus enhance the possibility to draw event-based conclusions from the mission. A concern was however that the debriefing might focus on details that are less relevant.

METHOD

Participants

The task force was formed by two ranger squads with six soldiers in each and two officers as unit CO and deputy. For the first squad and the CO, the exercise was the final test after completing one year of training to obtain ranger status. The other squad came from the mountain ranger unit and had already completed the ranger training. The first squad was the primary focus group for this study. It is important to note that the mountain ranger unit could not be used as a reference group as it only participated in selected parts of the exercise. For example they did not participate in the planning phase and the exfiltration phase.

Most soldiers in the first squad had one year of service. However, the CO and the deputy had served five years as officers before entering the one year ranger program. Reported field experience varied between 3 and 6 on the seven degree scale where 1 corresponded to no experience at all and 7 to very experienced. Reported experience relevant for the task had a similar spread. Two thirds of the first squad reported having experience in using PC games. Typically they estimated to have spent 20 hours a week but most also reported that they in general have not played after they entered the ranger course. Only one of the soldiers had experience of using VBS2.

The Exercise

The eight day long exercise took place in a scenario in which the ranger unit was given the mission to destroy an antenna at an enemy communication hub. Three days were allocated for the planning phase. Transportation to the mission area and establishing the troops in the area was performed on the fourth and fifth days, including reconnaissance. On sixth day the mission was executed, and the subsequent two days was used for leaving the area, transportation back to the regiment and a hot wash-up and AAR.

3D Model

A VBS2 3D model of the mission area was prepared in advance of the exercise. The model, covering an area of 400 km^2 (20×20 km), was based on an elevation model with a resolution between the elevation points of about 5 m, draped with color aerial orthophotos. A generic Nordic woodland terrain model was used. In close proximity of the target object, in an area of approximately 5×5 km, the model was refined additionally based on photos, videos and GPS-coordinates from an on-site reconnaissance. The average tree height was adjusted to fit the actual area. Exact location of a road as well as of the target object were manually fitted in the VBS2-model, as well as for example tree types, tree density, under vegetation, rocks, smaller lakes, creeks and swamp terrain. Despite this, small trees and bushes, typical for subarctic terrain, were missing in the model. Moreover, smaller variations in elevation were missing, like ditches, holes and stone cairns. In addition, swamps were modelled by fitting a photo to a flat surface.

Data Collection

Observations. Observations were undertaken by the military umpires from AJB who followed the task force during the preparation and execution. The instructors used two different protocols to document their observations. One protocol was based on AJB normal observation protocol for documenting the execution of a mission cycle. For each sub-phase of the mission cycle, a number of actions, judged necessary for a successful execution are listed. For this study, the protocol included a sub-phase for the tactical mission rehearsal in VBS2.

The other protocol was also based on the mission cycle. At the initiation of each phase, the umpire interviewed the platoon commander on his expectations on the phase regarding enemy behavior and what would be the major challenges. In addition, the umpire also documented whether any of these concerns were conclusions based on the outcome from the use of VBS2. Subsequently, the umpire judged whether the commander's assessment corresponded to the actual chain of events after each phase. In addition he also judged the unit's performance regarding a number of features. Overall performance, preparedness in details, preparedness for alternatives, risk taking, tactically correct behavior and influence from external factors were judged on a seven degree Likert scale, ranging from 1=complete failure to 7=complete success. In addition, any enemy engagements were documented in terms of reason for engagement and outcome. Finally, any unexpected events were characterized.

Questionnaires. Three different questionnaires were distributed during the exercise and answered primarily by the first team. The second team, the mountain ranger squad, only answered one survey which captured their experience. The questionnaires were (1) *background (pre-exercise) questionnaire*, completed at the initiation of the exercise and included questions on the participants experience, expectations on the exercise, judgments on the importance of factors for the successful execution of a mission and expectations on VBS2 and F-REX; (2) *questionnaire after the game-based mission rehearsal*, answered by the first team directly after using VBS2 in order to document their opinion on the system and the task, and (3) *post-exercise questionnaire*, answered directly after the debriefing. The post-exercise questionnaire included the same questions as the questionnaire after the mission rehearsal. The focus of the questions was the participants' opinions in hindsight of having executed the mission. It also included questions on whether the replay of the mission had focused on the relevant factors and if it had enhanced the possibility to draw conclusions.

Team interviews. Two team interviews were undertaken with the first team, the platoon commander and the umpires. The first one was undertaken after the game-based mission rehearsal during the planning phase. The interview focused on the impact from the 3D model on planning. The second team interview was undertaken during the debriefing session, directly after filling out the post-exercise questionnaire. It was conducted as a discussion focusing on the hypotheses defined in this study which were presented in bullet format.

GPS positioning. Garmin eTrex Legend HCx outdoor GPS receivers were used for logging soldier's position over time, with an interval of 20 seconds, for the whole live exercise. Once every 24 hours the log from each receiver was collected and batteries replaced. Hence, a complete position history for each individual solider could be obtained.

Video and voice recording. During the assault element of the live exercise, head mounted video cameras (HMC) as well as voice recorders on the vests were used on Platoon and Squad commanders and their deputies along with the machine-gunner. Two video cameras were operated in the target area by two observers, and one hand-held video camera was used by an umpire following the unit. One additional sound recorder was mounted in the target area, and each data collection devise was time-synchronized manually before mounting.

Analysis

Quantitative data from the Likert scale ratings were primarily analyzed with descriptive statistics. However, the questions, which recurred over questionnaires, were analyzed from repeated measures using multivariate analysis of variance (MANOVA) or analysis of variance (ANOVA) tests in order to identify any indications on changes over time in opinions. Consequently, expectations in advance of the exercise were compared with perceptions directly after the M&S enhanced planning and the opinions in hindsight after completing the mission.

Qualitative data put forward in the questionnaires were analyzed by identifying comments which were similar in content. Each comment was given a brief summary. If comments of the same type were given by several participants, they were summarized together.

RESULTS

This section first outlines the chain of events from the exercise, where after the results from data collection and analysis are presented in regards to the hypotheses for the planning, execution and debriefing phases.

Chain of Events and Precondition for Conclusions

Planning phase. Before using the 3D model, a framework for a plan was developed. The target object was located on a hilltop, and the road up to the object as well as the object was missing in the printed map. However, the road up the hill to the object and a fictitious representation of the target object on the correct position was present in the virtual model. Although not an effect of the 3D representation, this information enabled a more detailed planning than what would have been possible using only the map.

The unit started using the 3D model for terrain inspection as soon as access to VBS2 was given. This occurred four hours after receiving the mission task. The initial planning phase had until then been performed by using available paper maps over the area. The most used feature in VBS2 was the possibility to navigate the model from a bird's eye perspective. After getting more familiar with the terrain, the soldiers who were involved in the planning started to define insertion points, march routes and bivouac areas using a combination of the VBS2 model and paper maps.

After the plan was developed, the first squad together with one commander rehearsed the mission in VBS2. This was performed twice: once at the end of the second day of the planning phase when the main plan was rehearsed; and once at the beginning of the third and last day of the planning phase, when a backup plan was rehearsed. Only the assault element of the mission was played in VBS2, each game session lasting between 10 and 20 minutes. The first game session was preceded by an introduction to VBS2 and allowed testing the game controls for about an hour. Apart from the two mission rehearsals, the participants were allowed to use VBS2 during the days of planning.

Infiltration. Advancement to and establishment of the bivouac followed the plan into detail and the rehearsed route was used. After arriving in the area two reconnaissance patrols were sent out the first night. Results from detailed object reconnaissance showed that the terrain to the west of the object was unsuitable for the planned assault due to gravel piles and debris protecting the object from supportive fire. The plan needed to be adjusted and further reconnaissance detailed out a plan to attack from the east in cover of dense woods.

Execution. During the assault the unit ended up with time pressure because of choosing a relatively long distance for the initiation point. This forced the commander to alter the plan to an alternative very similar to one of the back-up alternatives developed during the VBS2 mission rehearsal. Since this alternative was not well scouted and the unit had to move swiftly due to time pressure, it ended up in tactical disadvantage. About 150 m from the object one soldier set of an alarm charge and the element of surprise was lost. However, the unit fought their way into the object, very much as rehearsed in VBS2, and solved their mission objectives.

Exfiltration. Initially the exfiltration was very slow when the unit faced an enemy patrol watching a road they had to cross in order to escape the area. After detailed reconnaissance of the area they found the most protected spot for a road cross and awaited a lull in the patrol awareness. A quick dash over the road was successful and the unit could then take advantage of the vast wooded areas between roads. Enemy patrols mostly used vehicles on the roads the first night after the assault and was not able to get reinforcements to support the pursuit. In the morning after the assault, the enemy used a dog patrol to search an expected road crossing.

Debriefing. A hot wash-up was performed in the same way as it is usually done, i.e. the team gathers for half an hour and through an open discussion notes things done well and issues for improvement. This hot wash-up was complemented a couple of hours later by a one hour AAR in which data from the case study was presented using F-REX. This was subsequently followed by the post-exercise questionnaire and the second team interview.

Summary of results regarding chain of events. The judgment is that the obtained data on the chain of events indicate no major deviations from the ranger mission cycle. Consequently, the conclusion is that the exercise has given an adequate context for analysis of the collected data. However, due to the limited number of participants, the basis for statistical results is limited. Hence, quantitative results should be viewed with some caution before any conclusions are drawn.

Impact of Using VBS2 for Planning

VBS2 reportedly enabled reconnaissance in the virtual world as well as mission rehearsal of the plan. The three level Repeated Measures MANOVA indicated no difference between expectations in advance, perception after planning and the perception after execution regarding these factors. In the final team interview it was noted that the virtual planning created a reconnaissance plan in terms of more specified information needs. The plan was also subsequently used in the mission area to prepare for the execution. The participants stressed that it would have been beneficial with an improved model although it was judged to be “good enough” to prepare for the on-site reconnaissance. Some changes were also made compared to the virtual planning based on information collected on-site. The major change was to exclude the fire support from the machine gun due to low visibility. Still it was stressed that the participants did not feel deceived by the 3D model. They were aware that they could not expect the model to fully correspond to reality. Finally, they agreed that the possibility to do virtual reconnaissance was more valuable than game-based mission rehearsal. High scores (Mean Value between 5.0 and 6.0 out of 7) were obtained in the questionnaire after the planning regarding perception of whether it was beneficial to use VBS2 for the planning process and whether the participants would like to use VBS2 (with its current functionality) again if they were assigned a similar task in the future.

Only one of the two groups did participate in the planning and mission rehearsal in the virtual model, but this was in the team interview not expressed as having a negative influence. Still, it was anticipated that it would have been better if all the participants would have had this experience. The participants’ assessment indicated that the soldiers in the group that had planned and trained in the virtual model were more confident. In case of traditional planning, it is also common that only part of the team have seen the model.

In the final team interview, it was agreed that the virtual planning had taken some additional time and resources, especially as the unit had to be trained on the system as well. Still it had the benefit of creating a better mental model of the target area. It was also perceived by the participants that this enhanced the possibility to discuss the plan with those who did not participate in the reconnaissance patrol. However, on the question in the post-exercise questionnaire regarding whether realism and resolution of the 3D model was insufficient this was found to be the case. In their comments to this assessment, they especially mentioned terrain details such as vegetation, height differences and line of sight. The same issues were also raised during the final team interview. Nevertheless, it was also noted that aerial photography in combination with the 3D model gave a good perception of the conditions in the target area.

Results indicate that the possibility to do a "virtual reconnaissance" was a valuable asset. However, the resolution seemed to be insufficient and only provided the unit with a rough overview of the target area. Additional information was needed besides the 3D model, for example it would have been beneficial to have a very recent high resolution aerial photo to be incorporated in the model. Consequently, the expectation regarding virtual reconnaissance was only partly met. Also, the unit did a re-planning of the mission based on information collected in the mission area. This indicate that the expectation that it should not be necessary to do any re-planning due to substantial differences between the terrain model and the real target area was not met. However, it is also important to note that the final solution for the execution was the one defined in the simulation-supported planning.

Results also indicate that the possibility to do an interactive virtual mission rehearsal was less valuable. The possibility to identify the strengths and weaknesses of different alternatives and thus have an impact on the selection of a final plan was limited. Instead, the benefit of using VBS2 for mission rehearsal was rather creating a better mental model of the target area. Still, the plan outlined after the mission rehearsal corresponded to the final plan selected for the execution in the mission area. Consequently, the expectation as formulated before the case study was not fully met.

The results give no support to the concerns that there would be unrealistic expectations on the 3D model and that simulation-supported mission planning might be too time and resource consuming.

Performance During Execution

After completion of mission planning, the assessment from the umpire was that the unit had performed slightly below average regarding efficient use of time, relevant focus and quality of plan.

The expectations of the commander before the infiltration were that the enemy would be established in the area patrolling the object perimeter. After completion of the infiltration phase, the umpire judged that the commander's assumptions about expected enemy behavior had been correct. He also judged the unit's performance as 6 on a 7 degree Likert scale. The infiltration had gone according to plan with minimal friction.

By the time of the initiation of the execution, the commander expected the enemy to have low morale and static behavior. The major challenge was expected to be enemy patrols coming in from the side during the assault. These expectations were not specifically gained from VBS2. After completion of the execution phase, the umpire judged that the commander's expectations on enemy behavior had not been completely correct. The enemy had been more alert than expected. The overall judgment on mission success was judged as 5 on the Likert scale.

At the initiation of the exfiltration, the commander expected the enemy to use search patrols, dogs and surveillance lines. He thought that the major challenge would be enemy posts along the major roads. These expectations did not come as a conclusion from using VBS2 as a support tool for planning. After completion of the exfiltration phase, the umpire judged that the commander's expectations on enemy behavior had not been completely correct. The major challenges were not standing patrols along the roads. Instead, the enemy had used their dog patrols in a more active and persistent way than expected. The umpire's overall impression of whether the unit had solved the task successfully was 2 on the seven degree Likert scale.

A Repeated Measures MANOVA comparing questionnaire data on perceived "realism", "difficulty", "performance" and "tactical correct behavior" showed no overall differences between data obtained from the questionnaire after planning and the one from after the exercise. However, the real mission was perceived as significantly more difficult ($p \leq 0.01$, $F=27.3$) than the virtual mission rehearsal ($MV=5.5$, $SD=0.6$ as compared to $MV=2.7$, $SD=1.0$). In addition, there was no overall difference when all three occasions were compared in a three level repeated measure. However, there was a significant difference regarding whether the participants perceived the exercise as motivational between pre-exercise and post-planning questionnaires.

Results indicate that expected enemy behavior and other challenges expressed by the commander did not fully correspond to the subsequent chain of events. However, the result is somewhat inconclusive as much of the commander's expectations did not stem as a result from the simulation-supported planning. Instead, and not surprisingly, other experiences largely formed his expectations.

The ranger unit did fall back on a plan developed during the mission rehearsal in the 3D model, which was according to expectation. However, without the game-based mission rehearsal the unit would still fall back on a planned alternative, which makes the interpretation of the expectation inconclusive. Still, the participants reported that the 3D model had given them a spatial mental model which presumably should have enhanced the execution compared to a situation in which they would have relied exclusively on a model based on maps.

Results also indicate that the execution of the virtual mission rehearsal and the real mission was perceived as equal in terms of realism, how the unit performed and acted and how motivated the participants were. However, this was not the case regarding perceived difficulty. Consequently, expectation on how the participants perceived the different executions was not fully met.

In addition, there should be a similar correspondence regarding the relative importance of some "core success factors" for the virtual and real execution. Such factors include planning, access to updated intelligence, soldier competence, communication and level of training in coordinated teamwork. The participants' perception regarding these factors for the virtual and real execution largely corresponded. However, this was not the case for "a well-executed tactical and technical mission rehearsal" when expectations were compared to opinions after the exercise. Consequently, expectations were not fully met.

Using F-REX for Debriefing

The two-level repeated MANOVA showed no differences regarding whether F-REX enhanced the possibility to focus on relevant aspects of the mission and whether it increased the possibility to draw conclusions when the pre-exercise questionnaire and the post-exercise questionnaire was compared. Scores were in general high (MV=5.5-6.3). This result was also supported by the team interview. There it was stressed that the in hindsight perspective and the possibility to allocate time to analyze was appreciated. This possibility would be valuable in other exercises as well. It is important to have sufficient quality of voice recording in order to evaluate the commander's actions. Presumably, the after action replay will give an idea of the limitations of simulation-supported planning which in turn would be beneficial the next time. The unit found that the effort was well worth the time.

Consequently, the results support the expectations that replaying the mission in the model was expected to give a better overview of the chain of events and thus enhance the possibility to draw event-based conclusions from the mission. In addition, there were no indications that the debriefing focused on details which were less relevant.

CONCLUSIONS

General Conclusions

The support for virtual reconnaissance was considered more valuable than interactive mission rehearsal. Subsequently, the planning had limited effect on the unit's perceived performance on the defined performance indicators during execution. The largest value of having access to a virtual model of the mission area seems to be the enhanced ability to create mental models. This also increases the ability to refer to features of the target object and terrain once in the mission area, also in communication with team members that have and not have been on reconnaissance in the real terrain. Moreover, the access to the game and the 3D model did provide a help to think through the mission, element by element.

The higher perceived value of the virtual reconnaissance as compared to virtual mission rehearsal might be described by the difference in functionality. For the virtual reconnaissance, it is most interesting to get a picture of the overall situation, the terrain. Consequently, for the virtual reconnaissance it is the overall experience that is of interest and the important thing in the 3D model is to be able to see how to get to the target object in order to do reconnaissance on the site.

For the interactive mission rehearsal, high levels of details and accuracy of the geographical model is important close to the target object. That means to be able to determine how far one can see and decide how to exploit minor differences in elevation, density in foliage, ditches, culverts, and details in these objects. The terrain model used in this case study represented a fairly low fidelity since it was based on a 5 m elevation grid with vegetation rendered from built-in VBS2 models based on the orthophotos. Since accurate intelligence information regarding the target object was missing the simulation tool gave limited added value for the planning during this study.

Perhaps the context of this study – a ranger mission in a forest terrain with a limited number of artifacts – was less suitable for having use of the interactive mission rehearsal. The difference between different forest areas is less apparent compared to a terrain with more artifacts and buildings. Consequently, the mission rehearsal might have been perceived as more valuable if the mission had been executed in an urban environment. If the mission would offer a setting where it is easier to perceive the relations between the virtual representation and the real mission environment, the virtual mission rehearsal might be more efficient compared to live mission rehearsal in an unrealistic terrain or terrain similar to that of the mission. In such a case it is presumably easier to consider the action with the reference of virtual reality.

Another aspect to consider is the relative uncomplicated scenario with a quite independent and small ranger unit. Coordination between the subunits close to the target is perhaps to large extent of routine character. A more complex mission including Close Air Support, artillery, other kind of units, etc. might have enhanced the value of virtual mission rehearsal.

The enhanced debriefing and AAR functionality added by the case study was appreciated. This included the greater ability to get a hindsight perspective as well as increased time allocated for debriefing. F-REX enhanced the possibility to focus on relevant aspects of the mission. The replay gave a good overview of the chain of events and thus enhanced the possibility to draw event-based conclusions.

In summary, it is believed that mission integrated simulation does not replace any conventional tools or procedures. An adequate level of detail in the model of the mission area is necessary. Still, a virtual 3D model which is "good enough" gives a supplementary perspective which increases the understanding of the shortcomings of any representation of reality (2D map or 3D virtual world). The 3D model offers a more intuitive way of thinking of distances and angles compared to a traditional 2D map. Given a more complex mission context, the usage of the virtual model is expected to reduce the amount of time that needs to be spent on other planning preparations. It is also believed to reduce the amount of time needed for reconnaissance in the mission area. The support for debriefing/AAR was assessed as an effort well worth the time. Consequently, the conclusion is that the concept of mission integrated simulation is worth exploring further. By utilizing already available tools and platforms and focusing on solutions that might be realized within 5-10 years it should be possible to enhance efficiency and ability with limited investments.

Aspects to Investigate Further

Integration of a wider scope of exercise and mission activities between different kind of units and platforms. The underlying geographical data can be used for various analyses to support mission planning beyond reconnaissance and mission rehearsal. For example, to create route hypotheses, detect inaccessible areas, support orientation in low visibility environment or to identify suitable observation positions.

Import of real-time data to the virtual model in order to enhance command and control. By importing GPS tracks to the simulated environment, it is possible to visualize the simultaneous motion of avatars representing the different units, platforms and soldiers.

Images collected with a UAV can also be geographically linked with the simulated environment, so that intelligence gathered from those images (IMINT) can be visualized and analyzed within the environment, e.g. the enemies' current state and activities at the target area and the current status of the terrain.

Efficient utilization of high resolution terrain data. From standard geographical content, that may be delivered by a national mapping authority (regularly or on demand), one can get the general view and a basic understanding of the area of interest. Today it is possible to get a 3D model that is ready for employment in a tool like VBS2 within a day with commercial (civilian) UAVs. With a designated system these time lags can be shortened even further. Such a highly detailed 3D model can be combined with a larger, less accurate terrain data model in order to get a unified virtual terrain for both large-scale and more detailed analysis.

Procedures for implementing mission integrated simulation. The perceived border between mission supported simulation and simulation for entertainment in terms of commercial first person games might be vague. A distinct procedure and routine is presumably a prerequisite in order to create the adequate mind set. In this context it is important to realize that the corresponding mission rehearsal in a real terrain similar to the one in the target area is also a simulation.

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