TRAINING TEAMS WITH SIMULATED TEAMMATES

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ABSTRACT

Training teams increasingly takes place in synthetic environments. However, team training is often still modeled after live team training, including the disadvantages of live training, such as instructor-intense performance monitoring, and the fact that all appropriate other teammates have to be available. This paper explores the latter issue: how to overcome the bottlenecks of the availability and drawbacks of human teammates in training teams in synthetic environments, while keeping the advantages: the opportunity to learn in a collaborative and cooperative fashion. Simulated teammates are a promising alternative to human teammates, because they are always available, may be modeled after experienced training personnel, and may be more cost effective in the long run. The research challenge lies in keeping the advantages associated with human teammates: simulated teammates should display the same collaborative and cooperative behavior typically associated with human teammates. This paper will review the relevant available research data, and will explore how intelligent teammates should be defined and modeled so as to take advantage of both worlds: optimizing the possibility of cooperative learning, as well as optimizing individual and team learning experiences.

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Alma Schaafstal studied Cognitive Psychology and Philosophy at the University of Groningen, The Netherlands, and the University of Manchester, UK. She wrote her dissertation (1991) on expert-novice differences in diagnostic skill in papermaking. In 1985-1986 she spent a year as a visiting scientist at Carnegie Mellon University, Pittsburgh, PA. She has been with TNO, the Dutch Organization for Applied Scientific Research since 1986, and since 1990 she is affiliated with TNO Human Factors , specializing in training complex skills in military environments, with a strong focus on team training. As part of an exchange program of the US and The Netherlands, she is currently working at the Naval Air Warfare Center Training Systems Division, in Orlando, FL, focusing on training teams with simulated teammates.

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1. INTRODUCTION

Training teams increasingly takes place in synthetic environments. However, team training is often still modeled after live team training, resulting in a very cost-intensive process in terms of both the time and resources required. Specifically, gathering all of the team members, instructors, and support personnel to conduct the training is very costly, let alone the costs involved with the lost productivity associated with the other tasks that those personnel are not doing while helping other teammates practice or while practicing themselves (Hicinbothom & Lyons, 1999). This issue becomes even more salient in cases where large-scale training of distributed teams is involved. For instance the exercise "Unified Endeavor" required 470 role-players with a total of 981 operators/controllers. These numbers are simply prohibitive in today's climate of decreasing military budgets and manpower.

The drawbacks of using human teammates in team training go beyond the cost issue, there is also a quality issue that should be considered. Analyzing current team training practices reveals that either training personnel, or other students from either the same or different classes take up the roles of various team members. Research on collaborative learning, learning individual tasks in interaction with other students, shows that training with fellow classmates may have some advantages over other approaches to learning. Collaborative learning basically claims that learning is a social process (Kaptelinin, 1999), and research has shown that collaborative learning results in more efficient use of higher level skills and knowledge, including reflection, planning and metacognitive processes, such as (self) explanation, internalization through verbal interaction, and sharing cognitive load (Dillenbourg and Schneider, 1995). From this perspective, one would imply that learning individual tasks is helped by the aid of collaborating with other students, with the necessity to communicate being a key issue, and is something we might take more advantage of in the future.

However, training teamwork skills with fellow teammates may not be as cost-effective and efficient, for a number of reasons:

1. Training personnel often have to take up various roles at the same time: playing roles of other team members, monitoring scenarios, and monitoring and diagnosing student performance. This is a difficult job to accomplish since the high workload involved can result in a decreased training effectiveness of the instructor or evaluator.

2. On other occasions, students of the same class are used for playing the roles of other teammates. The often heard advantage to this strategy is one of cross training: if students understand the roles of other teammates, they will become better in anticipating their needs. In fact, a synthetic team environment can be a powerful vehicle for cross training. Cross training has been shown to be an effective approach for building inter-positional knowledge (Blickensderfer, Cannon-Bowers, and Salas, 1998).However, quite often students have to assume roles of other teammates very early on in team training, when they have not yet acquired a thorough understanding of their own roles and tasks in the team, and, therefore, may not quite be in a position to look upon this job from the perspective of other teammates. Therefore, it is questionable whether the argument of cross training these students is a valid argument early in the training.

3. It will be very difficult for fellow students to assume other team roles in realistic ways, since in many occasions, they never had experience in carrying out this teammate's task before. They can therefore not be the realistic teammate the learner needs to train teamwork skills.

There are also some other disadvantages to this strategy, one of them being that training with fellow class members changes the team's informal organization: having a classmate, of about the same age and experience level as the student, assuming a role that in real life would be played by for example a much more experienced and senior person, changes the way tasks will be divided between the two of them, and will presumably also change instances of leadership.

4. Another disadvantage, perhaps the most important one, is that having to assume someone else's role implies that this person is not being trained on his own position. Though they spend a lot of time on training, these role players do not get as many structured learning experiences as would have been optimal.

Additionally, in recent years it has been shown that a good approach to training teams is linking training goals to events in training scenarios in a controlled fashion (event-based approach to training; Hall, Dwyer, Cannon-Bowers, Salas & Volpe, 1993; Johnston, Smith-Jentsch, & Cannon-Bowers, 1997). However, it will be very difficult to train along those lines if other trainees are role playing the various positions in the team, since they will not as likely show controlled behavior, and make controlled mistakes, a necessity for linking training goals and training performance to specific events? obtaining optimal training effectiveness.

Initially, the development of synthetic team members (SYNTHERs) was proposed to decrease the cost and increase the accessibility of training (Hicinbothom &

Lyons, 1999). We have identified an equal driving factor: to improve the quality of training. This paper addresses an approach toward defining SYNTHER behaviors that can improve the cost effectiveness, while at the same time improve the quality of training.

2. A CONCEPTUAL FRAMEWORK FOR SYNTHETIC TEAMMATES FOR TEAMTRAINING

Teamwork is one of the major contributing factors of success in the military domain. On top of that, the realization grows that just putting together a team of individual experts does not make an expert team (Salas, Cannon-Bowers, & Johnston, 1997). In recent years, it has been shown that a good approach to training teams with complex training technology is linking training goals to events in training scenarios in a controlled fashion. This is called the 'event-based approach to training' (EBAT) (Hall, Dwyer, Cannon-Bowers, Salas, & Volpe, 1993; Johnston, Smith-Jentsch, & Cannon-Bowers, 1997). The primary goal of EBAT is to systematically provide opportunities for a training audience to develop critical competencies by receiving practice in simulated environments that are representative of actual operational conditions, and receiving feedback linked to specific events that occur during training. EBAT tightly links trainee needs, critical tasks, learning objectives, scenario design, performance measurement, and feedback. The general assumption of EBAT is that without a systematic linkage among these components there is no way of knowing or ensuring--with any degree of certainty--that the exercise training will have its intended effect.

Figure 1 shows that the EBAT framework supports the design, development, execution, and evaluation of exercises.

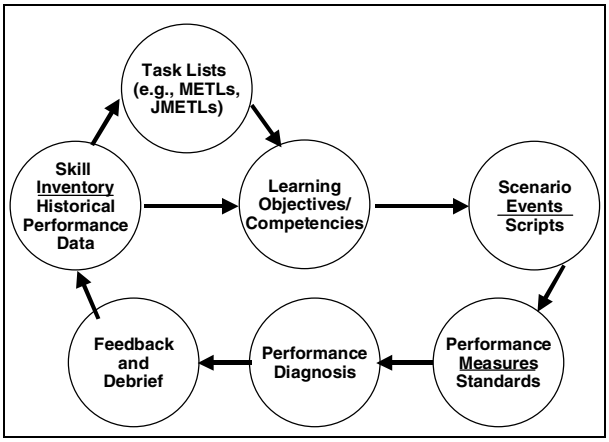

Figure 1. Components of an EBAT Framework (Adapted from Zachary et al., 1998)

The EBAT-approach provides a good starting point for the development of a conceptual framework for training teams with synthetic teammates. It shows us where synthetic teammates could possibly play a role in training teams: they could act as fellow teammates, as collateral forces, or as enemy forces. Second, it shows that, as much as scenario events are scripted, synthetic teammates should behave scripted too. This does not mean that their behavior has to be strictly 'canned', but it does imply that their behavior is predictable for the scenario designer, but not necessarily predictable for the trainee.

Another function synthetic teammates may serve is as an aid in diagnosing the team's or teammember's performance. If this is taken somewhat further, teammates may also serve a function in providing intelligent on-line feedback. In summary, synthetic teammates can serve a number of different roles in training teams: as fellow teammates, collatoral forces, enemy forces, observer/evaluator, or as an instructor/coach.

The behavior of synthetic teammates is linked to scenario events, and scenario events in the EBAT-framework are linked to learning objectives and competencies. This implies that the behavior of synthetic teammates should be linked to training objectives and competencies as well. What are the training objectives that are focal to training teams? An important distinction that resulted from research on team training is the concept of 'taskwork' and 'teamwork' skills underlying team performance (Cannon-Bowers, Tannenbaum, Salas, & Volpe, 1995; Cannon-Bowers & Salas, 1997). Taskwork consists of the position-specific requirements of the job, which are usually technical in nature (such as operating a certain workstation), and are geared towards individuals. Teamwork has more to do with processes that individuals use to coordinate their actions. Both taskwork and teamwork skills are important in any given team member.

Smith-Jentsch, Johnston and Payne (1998) have further delineated the skills underlying teamwork. They found evidence for four dimensions underlying teamwork:

- Information exchange
  - Seeking information from all available sources
  - Passing information to the appropriate persons before being asked
  - Providing "big picture" situation updates
- Communication
  - Using proper phraseology
  - Providing complete internal and external reports
  - Avoiding excess chatter

- Ensuring communications are audible and ungarbled

- Supporting behavior
- Correcting team errors
- Providing and requesting backup or assistance when needed

- Team initiative/leadership
- Providing guidance or suggestions to team members
- Stating clear team and individual priorities

Thus, in training teams, with or without the use of synthetic teammates, we should focus on training task- and teamwork skills. Automatically evaluating taskwork skills and providing feedback has already proven to be successful in the past, for example in the Advanced Embedded Training System (Zachary, Cannon-Bowers, Burns, Bilazarian, & Krecker, 1998). However, using synthetic teammates for training teamwork skills is a new, fairly unexplored, area, but one in which synthetic teammates could potentially play an excellent role in providing opportunities for trainees to practice their teamwork skills. For example, training teamwork skills such as 'supporting behavior' (correcting team errors, and providing/requesting backup or assistance when needed), or 'team initiative/leadership' (providing guidance or suggestions to team members, and stating clear team and individual priorities), require opportunities to practice those skills. If in a particular scenario everything runs smoothly and the team is at a certain level of proficiency, opportunities for practicing skills such as error correction will be rare. At appropriate times in a scenario, synthetic teammates can introduce errors which the trainees have to correct. Introducing these errors can provide opportunities for practicing teamwork skills that would hardly exist otherwise.

One of the implications of this line of reasoning is that we propose a layered model of scenario-events for describing the behavior of a variety of synthetic teammates in training. On the first layer, the 'normal' scenario-events occur: the behavior of entities external to the team (such as a target approaching with a certain speed at a certain altitude). A second layer consists of the behavior of the synthetic teammate(s). A third layer may consist of training strategies linked to team performance measurement and providing on-line feedback. In any given training system, the second or third layer does not have to be present. All three layers are connected by their relationship to training objectives/competencies, but they will each contribute to achieving these goals in different ways. The first layer defines events external to the team. The second layer defines when and how the synthetic teammates will provide opportunities for training certain (teamwork) skills. The third layer defines how intelligent performance evaluation and on-line feedback could be provided by a synthetic teammate. The three layers can be linked in various ways: by time (when will a certain event at each of the three layers occur), based on the contingency of events (e.g. the synthetic teammate will provide an opportunity for practicing error correction at specific targets), or based on a combination of both.

Another implication of this conceptual framework is that synthetic teammates do not necessarily have to behave as experts in the task, since their role is not necessarily being a 'normal', proficient teammate, but they should rather be defined as entities that serve certain training goals. Therefore, the mission of synthetic teammates could be to provide opportunities for practicing certain skills, instead of being expert performers in the task itself.

In our research, we will focus on the requirements for synthetic teammates in training teamwork skills, in particular 'supporting behavior' and 'team initiative/leadership'. These skills are difficult to train otherwise, and, therefore, this seems a good opportunity for showing how synthetic teammates can help in reducing the cost while at the same time enhancing the quality of team training.

3. AN EXAMPLE: TRAINING OF THE AAWC

Now that we have conceptually defined a framework for training teamwork skills with simulated teammates, we will provide an example of how this can be applied to training in a particular context: Anti Air Warfare on board of Navy ships, and more in particular, training of the Anti Air Warfare (AAW) Commander. Within the Combat Information Center on board of Navy ships, the AAW team concentrates on many roles that deal with specific parts of the AAW problem, such as identifying tracks, observing and interpreting electronic emissions from tracks, and controlling combat air patrol. The activities of all the individual roles are integrated and organized by the AAW coordinator (AAWC). The AAWC works under the command of the ownship Commanding Officer (CO)/Tactical Action Officer (TAO), and under control of a battle group AAW commander in battle group AAW operations. At any given time, the AAWC must choose which of many tracks or tasks to attend to, internalize implications of decisions and actions of others on the AAW team, and infer the intents and implications of the enemy and the overall tactical situation as shown on screen. The AAWC has been modeled extensively at mainly the taskwork level in the TADMUS-program (Zachary, Ryder, and Hicinbothom, 1998). The taskwork

involved in this task may be summarized as learning to make decisions under time pressure, on the basis of incomplete information and uncertainties. The teamwork involved consists roughly of supervising the AAW-team, setting priorities and communicating them to the team, providing situational updates to the team, and, on the other hand receiving timely information from other team members. In supervising the team, the AAWC has to show leadership, and may be in the position to detect and correct errors the team made. On top of that, the AAWC has to coordinate with the AAW commander, the CO and TAO.

Simulated teammates could play a role in training this officer both at the taskwork level and at the teamwork level. At the taskwork level, depending on the training goals, the simulated teammate could aid in providing opportunities for practicing taskwork skills, such as delivering information that the AAWC has to work on, and in performing the actions or implementing decisions made by the AAWC. In this case, the simulated teammates act as members of the AAW-team. We could also envision a simulated teammate acting as CO/TAO or AAW commander, and presenting changes in plans on which the AAWC has to react, or requesting information from the AAWC.

At the teamwork level, there are manyways in which simulated teammates could be envisioned, again dependent upon the training goals. If the goal is to coordinate activities within the team, then the simulated teammate(s) could provide opportunities for coordination by asking about priorities if not already given, or by (not) passing information to the AAWC when needed. They could also intentionally make errors, as such providing opportunities for the AAWC to notice and possibly correct them.

Both in training task- and teamwork skills, simulated entities could help in automatic performance evaluation and aid in preparing feedback. Another notion that could be implemented is a synthetic teammate acting as a coach, looking over the shoulder of the trainee, giving on-line comments on the trainees performance, and providing guidance on how to improve this performance.

4. WHAT CAN BE DERIVED FROM THIS EXAMPLE?

On the basis of this example, a number of requirements can be formulated for ideal synthetic teammates:

a) The ability to perform the task at the taskwork level, from the perspective of the individual team member. What this implies will vary from task to task.

b) The ability to interact and communicate with other members of the team: receiving and interpreting visual and auditory information and acting appropriately on the basis of this information. This implies that the simulated teammates have abilities for communication itself.

c) The ability to flexibly and intelligently adapt itself to a changing scenario.

d) The ability to interact and communicate with both humans and other simulated team members.

e) The ability to behave as a believable, worthy teammate, instructor, coach or combinations thereof.

f) The ability to demonstrate both taskwork and teamwork skills

g) The ability to analyze trainee performance, and provide appropriate feedback, possibly coupled with instructional strategies. This is important in those instances in which the role of the simulated teammate is that of the instructor/coach.

h) The ability to diagnose trainee performance. This is important, for example, in those cases where simulated teammates will provide opportunities for practicing teamwork skills such as error correction and providing/requesting backup, since providing opportunities for practicing those skills relies on an extensive diagnosis of the trainees behavior (knowing and deciding when and how to interrupt the ongoing behavior. However, this argument does not apply to training all of the teamwork skills through simulated teammates: using proper communication styles, situational updates etc. relies on a much more superficial level of performance diagnosis.

An important implication of this framework is that simulated teammates should provide opportunities for training, instead of just being experts in the task. They should provide opportunities for practice, which may be hard to obtain in the real world.

Finally, the requirements for synthetic teammates depend upon the training goals and upon their roles in the scenario: if the synthetic teammate will act as a fellow teammate for practicing teamwork skills, without any coaching tasks, then the requirements will be different from an instance in which the synthetic teammate should act as a coach, providing opportunities for error correction and commenting on the outcome of this event. If this notion is linked to the Event-Based Approach to Training, as outlined before, it calls for the definition of an extra layer in the scenario: when and how should the simulated teammate act?

5. DISCUSSION

Previous reports have identified the need for improved software architectures for simulating higher-order processes in computer generated forces (CGFs) including decision making, intent, deception, adaptability, creativity and problem solving for a wide range of applications such as training, mission rehearsal, analysis and acquisition (Lyons & Hawkins, 1999). Such lofty goals can be as elusive as "The Holy Grail", particularly when stated as general desires. However in training applications, prioritizing improved CGF behaviors should be driven by the expected improvement to training effectiveness. A structured approach towards this goal would include:

1. Precise experimentation into development of methodologies for training teamwork skills with simulated teammates. The effectiveness of these methods may originally be evaluated with human confederates, in constrained training situations, before implemented in expensive models of simulated teammates.
2. Expansion of Human Behavioral Modeling architectures to accommodate the abilities of synthetic teammates identified above.
3. Development of guidelines for scenario generation for training teamwork skills with simulated teammates. This may include expanding the 'Event Based Approach to Training' (EBAT) to include linking the behavior of synthetic teammates to training objectives and competencies.
4. Development of guidelines for implementing instructional strategies with synthetic teammates. Should the teammate be acting in a coaching or mentor role? If so, it should exhibit somewhat expert behavior, which the trainee is encouraged to model. However, if the synthetic teammember is providing an opportunity for the trainee to practice a particular teamwork dimension, i.e. error-correcting, the synthetic teammate should not only perform a task incorrectly, the scenario should be of an appropriate difficulty that the error would seem reasonable.
5. Starting with the conceptual framework presented here, and as further research is conducted, the development and prioritization of requirements for the behavior of synthetic teammates can be refined.

We have started collaborative experimentation along the lines sketched above, and so far, it has been promising to see that we really can envision in great detail how training teamwork skills with simulated teammates in a synthetic environment should be envisioned. It has clearly shown us that we can push automatic, on-line measurement of teamwork skills towards its realization, and it has also shown us that there will be in fact a clear interaction between events in the scenario and teammate-events. Therefore, we see a need to expand current event-based approaches to training with a teammate-level of scenario-events. Future references will detail these results further.

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