Spoken Dialogue: Extending Embedded Virtual Simulation with a Very Human Dimension

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ABSTRACT

Embedded virtual simulation, employed in many NATO training communities, is a key to addressing urgent training needs in areas that stretch the capabilities offered by conventional simulation techniques. Of particular relevance to NATO are training needs such communication and tactical team coordination. This paper will summarize some needs in training and mission planning that remain unmet, discuss the reasons why and propose some specific approaches that extend the reach of simulation in directions that directly address these gaps. We focus on communication and tactical team training. We will show specific examples of our approaches that are solving tangible training and rehearsal problems among NATO constituencies and discuss how this approach can be broadly applied across a spectrum of training settings.

1.0 INTRODUCTION/RELEVANCE TO THE WORKSHOP

Replicating unfamiliar areas of operation in a synthetic environment can expose NATO forces to a spectrum of tactical possibilities they may encounter in-theater. The use of simulation in training, mission planning and rehearsal is a long-accepted practice, but when forces deploy with little notice, or to locales with insufficient technology infrastructure, the benefits of virtual simulation remain beyond reach. Embedded virtual simulation can help mitigate these challenges faced by NATO forces when rapidly deploying to new locations, by providing training, mission planning and rehearsal capabilities along with the digital systems employed operationally.

Some skills have been overlooked in embedded simulation, namely, communication and team coordination. Such skills are gaining increasing importance, as forces are more multinational and as missions are increasingly conducted against an asymmetric adversary and complicated by proximity to and political reliance on non-combatants. This training gap is due largely to the complex and highly verbal interactions needed to incorporate spoken dialogue into synthetic environments. Nonetheless, this very human dimension remains a critical part of realistic training, planning and rehearsal. In this paper we report on work to embed speech-interactive synthetic agents into purpose-built training, mission planning and rehearsal systems.

2.0 RATIONALE

The most widely-practiced method for training effective coordination and communication is in the course of live or simulated exercises, where teams engaged in a tactical scenario learn to work together in pursuit of the mission. This technique has the advantage of realism, since the team members are interacting with a population very similar to what they will encounter in the field. Despite the belief that such techniques deliver effective training, there are cost and access penalties incurred by live or virtual team exercises.

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1. Many in the exercise may not be getting effective training. Such “role-players” are needed to perform the tasks necessary for the simulation to be credible and effective; in other words, to provide behavioral, aural, or visual cueing to the user to simulate how the team would be functioning;
2. It introduces variability that makes standardization of training difficult due to the human element influencing events in each scenario;
3. It interferes with performance assessment, since it is often the instructors themselves who are called upon to divide their attention between evaluating trainees and playing roles;
4. Costs arise from compensating, transporting and maintaining role-players at a training facility;
5. Availability is compromised because expert role-players can be exceedingly difficult to arrange.

The consequence is that access to team training is measured and scheduled and conducted only at dedicated facilities. Since such training is offered principally at home stations, deployed forces can suffer steep drop-offs in readiness, as any skills that are not practiced while deployed experience sharp decay (Chatham & Braddock, 2001). These challenges affect military training across a broad spectrum of skills but are especially salient in communication and coordination, which, broadly speaking, are under-represented in training as well as in the technology to support such training.

The application of simulation technology to training, mission planning and rehearsal has enabled realistic overhead 2-D and immersive 3-D “fly-through” capabilities that can help improve training and better prepare tactical teams for conducting missions in unfamiliar locales. Detailed terrain data can offer a preview of the relevant landmarks and hazards, and threat models can provide a more comprehensive glimpse of potential hot zones and safety corridors. A further extension of the utility of such techniques would allow users to perform the radio communications and team coordination planned for a mission; that is, the coordination that is critical to the success of NATO combat missions such as close air support (CAS). Such practice opportunities, while valuable, are limited by the inescapable scarcity of complete mission teams to gather in space and time during training, planning and rehearsal cycles. Below we discuss this gap as observed in two contexts: pilot communications training, and CAS planning and rehearsal.

2.1 Communications Training

Effective communication with team members is an essential element in accomplishing the mission. Opportunities to practice communication skills are limited to live or simulated team exercises, with the members of the team either present, or replaced by role-player surrogates. This approach is subject to the cost and access limitations described previously. As a result, training programs often suffer penalties due to ineffective use of team or simulator time, and/or poor student performance leading eventually to washout, due to the paucity of practice opportunities in team communication.

One example of a communication training need comes from USAF specialized undergraduate pilot training (SUPT), an intensive program that trains new pilots prior to assignment to an advanced training track. This initial phase presents student pilots with an array of complex skills to acquire and integrate in a high-pressure, time-sensitive programme. Current approaches that augment the minimal flying hours with simulation devices have not succeeded in providing the interactivity required for some skills (particularly those requiring communication). As a result, training gaps have emerged in the SUPT syllabus that include pattern operations and radio communications (AFRL, 2002). The consequence is that training benefit from time in the airplane is compromised whenever an instructor is obliged to review skills and concepts (like communication) that might have been mastered if appropriate simulation technology were available.

2.2 Tactical Team Mission Planning

Tactical team mission planning and rehearsal, though a ubiquitous practice, is typically conducted with live or virtual teams, with few opportunities to practice mission coordination skills outside of scheduled runs. The need to pre-arrange members of the team or role-player surrogates introduces cost and access limitations described previously. An instance of this gap is in mission planning and rehearsal for coordination-intensive missions such as CAS. With friendly forces and non-combatants in close proximity to targets, mission success requires effective verbal interactions between the air assets and the observers on the ground. In previous work we have demonstrated the use of speech-capable synthetic teammates for CAS training (Bell, Johnston, Freeman & Rody, 2004). Mission planning and rehearsal require similar capabilities, and should allow users to practice the radio communication along with the other aspects of mission performance. In CAS, for instance, the air-ground coordination is critical to the success and safety of the mission and should be represented in walk-through/fly-through activities. Unfortunately this is seldom the practice, due largely to the separation in time and space of the respective staffs in the air and ground elements planning and rehearsing the mission.

3.0 DESCRIPTION OF METHODS EMPLOYED AND RESULTS OBTAINED

In order to meet the challenges summarized above, traditional simulation must be augmented with robust, verbally-interactive synthetic agents. Such agents must possess capabilities that extend well beyond conventional computer-generated forces (CGFs), semi-automated forces (SAFs), and game-based artificial intelligence, or "AI"s – largely scripted entities with limited abilities to respond to events beyond a predefined range of simple behaviors. Entities driven by CGFs, SAFs, or AIs cannot model the real-world complexities necessary to provide training value at the level of individual interaction. To provide interaction effectively for team training, synthetic teammates require the following capabilities:

1. simultaneous execution of: taskwork (e.g., flying the aircraft, working the console); teamwork (interacting with other members of the team); and instruction (providing assessment and feedback);

2. interaction via spoken language (required for team training in verbal environments); and

3. modulating behaviours to replicate various error modes, to allow for varying the proficiency of the synthetic team members (important in team training).

These generic requirements extend well beyond conventional computer-generated forces (CGFs), semi-automated forces (SAFs), and game-based artificial intelligence, or "AI"s – largely scripted entities with limited abilities to respond to events outside a predefined range of simple behaviors. CGF/SAF technologies do have an important role to play, but for our purposes they fall short of addressing specific needs that remain unmet. To meet these needs, we are employing cognitive modeling using CHI Systems' computational development tool, iGEN®, for encapsulating human expertise and behavior in synthetic agents (Zachary, LeMentec & Ryder, 1996). Sophisticated agents, such as those which may be built using iGEN, can provide dialogue-capable synthetic teammates to reduce reliance on human role-players and make training, mission planning and rehearsal more accessible, less costly, and more standardized. Below we summarize two recent implementations of this technique, addressing the needs presented above: communications training, and tactical team mission planning and rehearsal, respectively.

3.1 Communications Training

USAF Joint Primary Pilot Training (JPPT) teaches flying principles and techniques to student pilots at dedicated training bases, where, due to the number of aircraft operating in proximity to the field, there is a standard traffic pattern and established procedures for requesting the overhead pattern to maximize opportunities to practice landings. Pilot-controller radio communications in the traffic pattern follow a specific protocol to minimize radio congestion and enhance comprehension. It is important for the students to learn and use standard phraseology for these purposes. Furthermore, the communications between other pilots and the controllers provide an important source of situational awareness as they include position reports and clearance requests. Thus, part of learning radio communications is learning to develop situational awareness from listening to radio calls of other pilots in the pattern.

However, these very skills were identified as training gaps in an AFRL study (AFRL, 2002). Not surprisingly, the high-fidelity training devices employed in primary pilot training make no accommodation for communications training, other than a helpful simulator instructor issuing occasional commands to simulate a controller, nor is there simulated radio traffic. To address this gap, AFRL and CHI Systems developed the Virtual Interactive Pattern Environment and Radiocomms Simulator (VIPERS).

VIPERS offers users opportunities for guided practice and feedback in radio communications skills and decision making in a simulated pattern environment (Bell, Ryder & Pratt, 2008). The format of this practice is simulation-based training with intelligent software agents performing in both tutoring roles and synthetic teammate roles, in a laptop-based portable application for anytime/anywhere training enrichment. The core training technique in VIPERS is scenario-based guided practice (Fowlkes, Dwyer, Oser & Salas, 1998; Schank, Fano, Bell & Jona, 1994) in a simulated traffic pattern. Specifically, VIPERS provides three types of speech-interactive synthetic entities:

1. a synthetic instructor that provides coaching and feedback during scenarios and makes assessments to be used in a debrief;

2. a synthetic controller that maintains knowledge of all aircraft in the pattern and verbally responds to clearance requests and issues directives to all aircraft in the pattern; and

3. synthetic pilots/aircraft in the pattern behaving appropriately and making radio calls.

Figure 1 illustrates the display during a VIPERS scenario. The mission display is a top-down schematic view of the pattern with aircraft icons representing the pattern traffic. In the mission, the user commands the aircraft and makes radio calls as if flying the airplane. The user controls the aircraft using high-level controls indicated by buttons that the user can select either via mouse or keyboard. In addition, the user has a headset with microphone for transmitting and receiving radio communications.

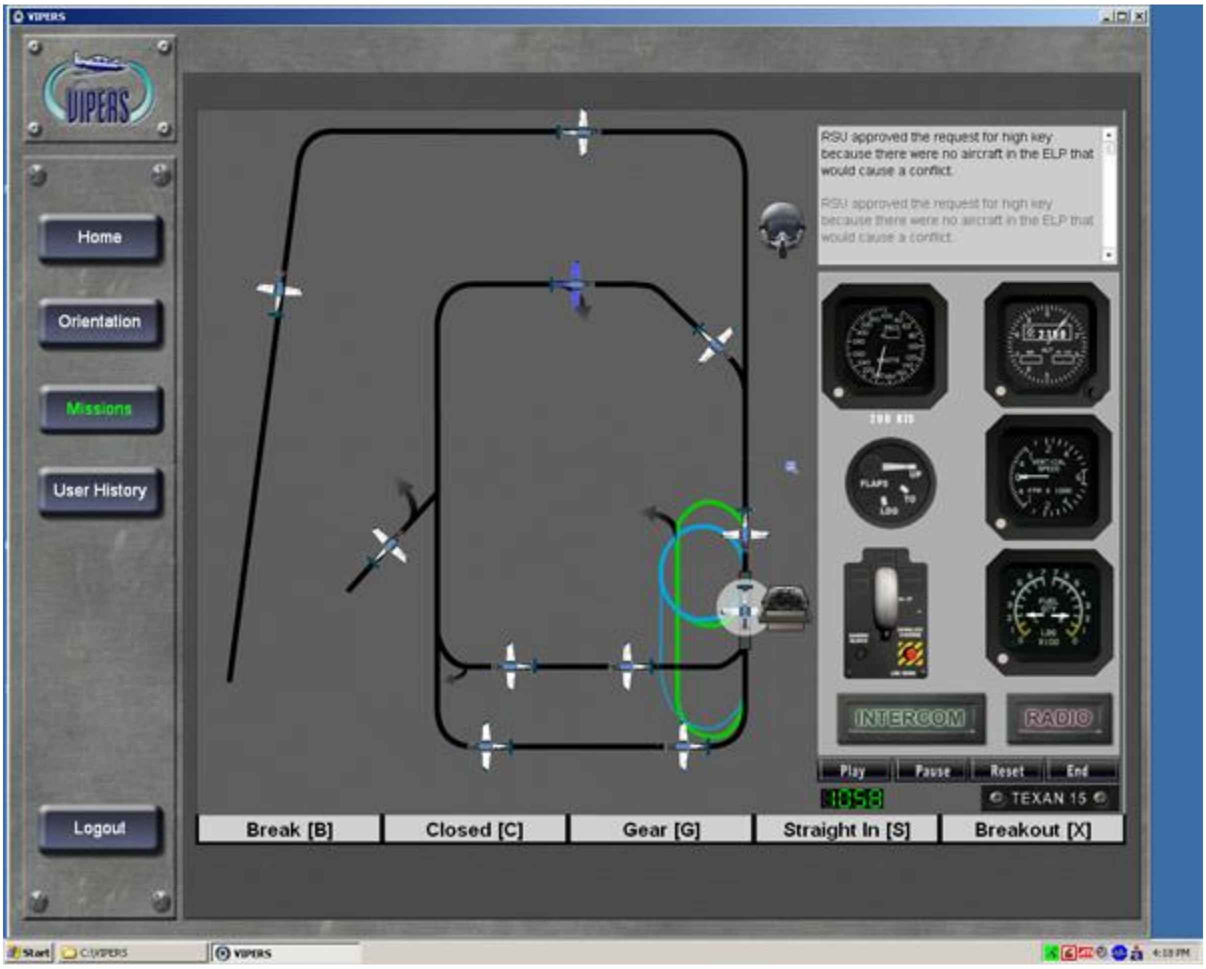

Figure 1: Example screen from the VIPERS communications training program.

The simulation includes synthetic aircraft flying in the pattern (represented by aircraft icons on the display) with synthetic pilots making the appropriate radio communications. It also includes a synthetic controller responding to clearance requests and issuing directives to all aircraft in the pattern. The synthetic instructor provides coaching and short feedback as appropriate, reminding the user to make missed calls, and assuming temporary control of the aircraft if needed. At the conclusion of the mission, a debrief is provided to the user, reviewing the user's performance on the following four performance measures: (1) making correct radio transmissions; (2) proper performance of in-flight checks; (3) taking appropriate actions in decision situations; and (4) complying with directives. A representative transcript is shown in Figure 2.

VIPERS provides instructor-optional guided practice and feedback in radio communications skills and decision making in the JPATS pattern. The combination of PC-based simulation, intelligent speech-interactive synthetic teammates, and speech interaction increases training availability and reduces dependence on instructors. Data collected from 70 users over a five-month period show statistically-significant training gains from using VIPERS. Specifically, VIPERS use correlated (significantly) with reduced time to achieve a rating of "good" on flown sorties for all three measures (situational awareness, communications, and in-flight checks) identified by the Air Force as being relevant. This program is thus a convincing illustration of how speech-interactive synthetic teammates can offer solutions for training tactical communications skills.

User:	Texan one-five request closed	*RSU:*	*Closed Approved*
		IP:	*You need to call closed downwind*
User:	Texan one-five closed downwind		
SSP_1:	*Tiger two-three initial request high key*	*RSU:*	*Report high key*
User:	Below one-fifty, gear clear	*IP:*	*Clear*
User:	Texan one-five gear down		
User:	Handle down, three green, flaps take-off	*IP:*	*Confirm*
SSP_2:	*Lush four-two, two miles, gear down*		
User:	Gear up, lights out, flaps up by one-fifty		
User:	Texan one-five breakpoint straight through	*IP:*	*Disregard*
User:	Texan one-five request closed	*RSU:*	*Negative closed*
		IP:	*I have the aircraft*

Figure 2: Representative dialogue among Texan one-five (user), and synthetic agents: RSU (controller), student pilots (SSP) and instructor pilot (IP)

3.2 Tactical Team Mission Planning and Rehearsal

In related work we are applying some of the capabilities we developed in the training domain to explore more realistic and more accessible mission planning and rehearsal tools. Our focus was on users in high OPTEMPO contexts, engaged in missions requiring a great deal of teamwork. We looked particularly at cases where teams are distributed and where verbal communication enjoys a key role in mission coordination, selecting CAS for this study. To accelerate our research, we employed a fielded mission planning and rehearsal tool, so that we could devote our attention to investigating the utility of speech-interactive synthetic teammates rather than on creating a suitable testbed. The tool we employed is called the Combined Arms Gateway Environment (CAGE). Developed by AeI, CAGE is a mission support tool that enables operators to plan, rehearse and then conduct missions under a wide variety of operational conditions. CAGE allows planners to employ the rehearsal capability to create routes, inspect and deconflict airspace, view corridors and define threat cones. Planners and mission personnel can view the mission in 2-D (top-down) and 3-D. The 3-D view provides dynamic lighting (sun, shade, moonlight) to assess the tactical implications of time of day and visibility effects (fog, haze, cloudbase) to project the visibility under the forecast weather conditions.

A high-level needs analysis was performed for a CAS scenario. This was limited, in alignment with the exploratory nature of this research, and so focused specifically on voice interaction. This entailed performing a Hierarchical Task Analysis (HTA) for the scenario, and reviewing each relevant step[1] to identify:

- The objective for that step.
- How to gauge that the objective has been achieved, *i.e.* the measure of effectiveness (MoE);
- The required inputs for that step (what the instructor has to include over and above the synthetic agent component in order to accomplish the step);
- The specific benefits that the synthetic agent provides, which would not have been achieved by other means (*e.g.* by displaying the dialogue as text on a screen);
- What the technology must be able to do in order to provide the required benefit.

[1] By 'relevant step' we mean those steps that involve the user doing something, as the HTA also covers the actions of the Joint Terminal Attack Controller (*i.e.* the actor being 'played' by the synthetic agent).

The results of the HTA were captured against the following criteria (example outcomes shown in brackets):

- Task: [Look for described area and features].
- Objective: [Rapidly and accurately identify areas based on description of the visual scene].
- MoE: [Identify target within elapsed time parameters].
- Required inputs: [A representation of the visual scene that relates to the descriptions being provided].
- Benefit: [Synthetic agent allows natural interaction between user and JTAC, with correct sensory input (auditory) and output (speech)].
- Requirement for agent: [able to provide descriptions that relate to the visual scene provided].

To bound our initial experiment, we created a set of CAS scenarios, focusing on dialogue between the pilot and a Joint Terminal Attack Controller (JTAC), allowing for alternative dialogue branches and error correction. The complexity of the scenarios determines the necessary sophistication of the grammar, synthesized voice, and agent model. For this exploratory effort, the scenarios were limited to specific phases of a representative CAS mission. We created an iGEN model to play the role of the JTAC.

The implemented scenario demonstrates a mission rehearsal where the user takes on the role of lead CAS pilot, interacting with a synthetic JTAC agent. When a scenario is started, the components load their required data (CAGE loads its scenario data, the speech components load the grammar and voice data, and iGEN loads the JTAC model) and each initializes the appropriate communication channels. The user selects a call sign from a set of nominal identifiers and two-digit suffixes. The user then begins the mission and initiates communication by checking in with the chosen call-sign. Figure 3 shows a representative display at this point
in the mission, with a 3-D view on the left and the 2-D view on the right.

Figure 3: Representative rehearsal display in CAGE

The JTAC agent transmits a 9-line brief, based on information given to it by CAGE (the user can request a re-transmit at any point during the mission). The user then repeats the 9-line and this read-back is checked by the synthetic JTAC for accuracy. If an error is found in the readback, the user is asked to repeat any incorrect portions of the communication until it is correct (and only the incorrect portions). Following accomplishment of the 9-line, the JTAC agent directs the user to the target, who must read back the targeting information, which is again checked for accuracy. Following an accurate read-back, the JTAC clears the user for attack. After attack the JTAC responds with a battle damage assessment, and the user signs off. During each exchange in the dialogue the JTAC waits for the appropriate response from the user, and asks the user to repeat any communication that is incorrect or unrecognizable. A representative transcript is shown in Figure 4.

User: Widow 76 this is Vader 28 checking in as fragged
JTAC: Vader 28, Widow 76 Loud and clear, this is a Type 1 control, call ready to copy.
User: Vader 28 Type 1 control, ready copy
JTAC: IP U278, Heading 055 magnetic, Distance 9260 meters, Elevation 70 feet. Target is a Helicopter parked on western edge of dispersal. Location North 51 00.89 West 002 38.01. Mark Laser 1111 LTL 355 Magnetic. Friendlies 1000 South, Egress North to Bad Wolf. Advise when ready for remarks
User: Ready to copy remarks
JTAC: Final attack heading 055 through 030
User: Elevation 70 feet , Location North 51 00.89 West 002 38.01. Friendlies 1km South. Laser 1111 LTL 355 magnetic. Attack heading 055 through 030 magnetic
JTAC: Readback correct, report leaving IP
User: Leaving IP, abort alfa romeo sierra
JTAC: Widow 76, abort alfa, romeo, sierra your target is one of 2 helicopters on the western edge of a dispersal.
User: Helicopter, western edge, dispersal. Vader 28 leaving IP.
JTAC: Short of target, airfield
User: Short of target, airfield
JTAC: North of runways, group of 8 hangars. From there, 12 o'clock 500, further set of 3 hangars, North East corner airfield. Laser on. Friendlies to South of all runways.
User: Contact 10 seconds. Further 3 hangars Laser on. Visual friendlies
JTAC: Right of hangars is large dispersal, in sunlight, target is helicopter on right hand side
User: Contact Target, left of target further helicopter against building.
JTAC: Affirm, cleared hot
User: In hot. Rifle away. Terminate
JTAC: Terminate, Vader 28, widow 76, Delta Hotel, helicopter destroyed, End of mission.
User: Target destroyed, Delta Hotel, End of Mission.

Figure 4: Representative dialogue between aircraft (user) and JTAC agent

An important design consideration is the degree of variability in whether user utterances are treated as "legal". Too restrictive an approach erroneously emphasizes syntax over semantics, frustrates users, and undermines mission planning and rehearsal objectives. Too accommodating an approach not only adds complexity to the recognition process but could introduce non-doctrinal phraseology. There is no quick-fix solution; striking a proper balance depends on thoughtful, comprehensive consultations with subject matter experts, guided by a principled cognitive task analysis methodology (*e.g.*, Zachary, Ryder & Hicinbothom, 2000). For our exploratory study we employed a CAS-rated RAF pilot and implemented logic in the JTAC agent that permits lexical and syntactic variations based on the tactical context. Each communication spoken by the user can thus be phrased in different ways; optional wording can be omitted and some alternate wordings are accepted.

This flexible grammar, combined with the selective requests for read-back (*i.e.*, only incorrect portions of the 9-line need be repeated) afford the user a transparent dialogue capability. For the initial work reported here, we developed a speaker-independent demonstration that required no training to a specific voice. Our testing team consisted of both U.K. and U.S. speakers and there were no noticeable differences in recognition rates among them.

Initial results showed that there was an immediate benefit to being able to practice techniques as they would be performed for real while remaining in a benign environment. For early-stage training, this removes the stress of the real situation in order to put the trainee at ease; for planning and rehearsal the realism is sufficient to provide the necessary situational awareness to adequately exercise the plan and measure an individual's performance in executing it.

Early feedback from end-users also indicates the scaleability of this technology. There is significant potential to increase the richness of the training experience, including using the synthetic agent to increase the user's exposure to operational stress; to augment the simulated environment with more diverse players and to provide voice interaction in situations where it is not currently available.

4.0 CONCLUSIONS

The investigations reported here provide support for the utility of speech-interactive synthetic teammates for training, mission planning and rehearsal. We are currently planning to develop more comprehensive and more complex scenarios in these domains, which will require behavioral, speech and grammar components with additional sophistication. This will require more robust speech recognition and discourse management. We will address this need by employing a dynamic grammar, where an intelligent agent activates and de-activates sub-grammars as the tactical situation changes, an approach we have reported in previous work (Bell, Johnston, Freeman & Rody, 2004). Our work has indicated that there is significant training benefit to be gained from using speech interactive agents through increased richness or improved efficiency of the training environment (Bell, Ryder & Pratt, 2008).

New simulation capabilities that extend the benefits of synthetic training can yield parallel advances in mission rehearsal and mission planning. For missions that rely on effective communication and coordination, though, the verbal exchange among tactical teammates is trained, planned and rehearsed only if and when suitable role-players are available, co-located in time and place. By employing the knowledge encapsulated in an intelligent agent, we can overcome many of the challenges faced in human-computer dialogue, and continue to enrich synthetic training while migrating the benefits of this approach into the realms of mission planning and rehearsal. The research summarized in this paper offers evidence that agents of sufficient cognitive fidelity to support spoken dialogue can extend embedded virtual simulation to achieve a new level of readiness for NATO forces deploying to new locales with little advance preparation time.

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