Criteria for Use of Synthetic Characters

Robert Hubal
RTI International
Research Triangle Park, NC, USA
rhubal@rti.org

ABSTRACT

The technology of synthetic characters (a.k.a. embodied agents) is no longer new: A great many of today's military training applications employ synthetic characters. Seven years ago when the author laid out in this forum directives for the use of synthetic characters for training, this observation was not true. In this paper the author broadly assesses current applications – not just training – regarding their use of synthetic characters. Examples of current applications where the use of synthetic characters makes sense include those for training interaction or cultural skills, for certain forms of therapy, for crowd modeling, and for assessing procedures within otherwise difficult to accomplish (logistically, safety-wise, or due to time or resource costs) role plays. Examples of current applications where the use of synthetic characters makes less sense include those that do not involve interactivity and those for training that could easily, and more effectively, be done using role plays.

A number of criteria are offered to guide synthetic character application development:

- Applications should reflect pressing current operational issues. Combat trauma assessment, understanding of cultural values, dealing with non-traditional (child, female) combatants, treatment of stress disorders, and conduct of support operations all may involve interpersonal interactions and warrant the use of synthetic characters.
- Applications that require repetition, replay, extensibility, standardization, safety, and/or parametric variability indicate a possible use of synthetic characters.
- Expert-derived models of behavior should underlie synthetic character behavior to make the applications realistic. Synthetic characters should engage, not detract.
- Synthetic character-based applications are not by themselves sufficient for all purposes. Instead they belong within a mix of virtual, constructive, and live environments.
- Applications using synthetic characters have merit if they lead to increased confidence, in addition to ability, before any live experiences.

ABOUT THE AUTHOR

Robert Hubal is in the Digital Solutions Unit at RTI International. He is interested in research focusing on development, presentation, and evaluation of learning materials and identifying approaches to improve learning and training effectiveness. For a little over a decade, he and his team have developed behavioral software that enables synthetic characters to act and behave realistically in controlled learning contexts, for interaction skills training and assessment. Applications include training civilian police officers in how to handle mentally disturbed individuals, assessing medical practitioners in history taking for both asthmatic and pediatric patients, and training telephone and field interview staff in obtaining respondent participation. He is interested in applying research results to both everyday and specialized domains. Dr. Hubal holds a masters degree in Computer Science and a doctorate in Cognitive Psychology.

Criteria for Use of Synthetic Characters

Robert Hubal
RTI International
Research Triangle Park, NC, USA
rhubal@rti.org

INTRODUCTION

Research involving synthetic characters is not new, but the number of applications that involve synthetic characters has risen dramatically over the past decade. Also called "embodied conversational agents" (Cassell, 2000) or "responsive virtual humans" (Hubal & Frank, 2001), among other descriptors, essentially synthetic characters are persons rendered on a monitor or screen with whom a user engages (e.g., in conversation) or that behave in such a way that the user must react to. A small sample of applications of synthetic characters includes:

- Mission rehearsal training to simulate conversation with civilians (Hill et al., 2003, 2006; Johnson, Vilhjálmsson, & Marsella; 2005);
- Military leadership and cultural training (McCollum et al., 2004; Raybourn et al., 2005; Solomon et al., 2008);
- Modeling of crowds and individuals comprising crowds, to represent civilians and computer generated forces (CGF) (Denny et al., 2008; Haynes et al., 2008; Pelechano et al., 2005);
- Interrogation and de-escalation training for law enforcement (Frank et al., 2002; Olsen, 2001);
- Tutoring (Graesser et al., 2000) of maintenance diagnostic skills (Guinn & Montoya, 1998; Rickel & Johnson, 1999);
- Training in clinical interaction skills for medical personnel (Deterding, Milliron, & Hubal, 2005; Kizakevich et al., 1998, 2003; Stevens et al., 2006);
- Obtaining informed consent from research participants (Hubal & Day, 2006);
- Training interviewers in skills to avoid non-response during field interviews (Camburn, Gunther-Mohr, & Lessler, 1999; Link et al., 2006);
- Simulation of dialog with a substance abuse coach (Hayes-Roth et al., 2004);
- Simulation within therapeutic sessions for various disorders and phobias (Klinger et al., 2005; Slater, Pertaub, & Steed, 1999; Takács, 2005; Tartaro & Cassell, 2006);
- Training and assessment of language (Prendinger & Ishizuka, 2001; Wideman & Sims, 1998);
- Training and assessment of other social competency skills (Bickmore, 2004; Paschall et al., 2005; Hubal et al., 2008);
- Game-like learning environments using animated pedagogical agents (André, Rist, & Müller, 1999; Conati, 2002; Johnson, Rickel, & Lester, 2000; Moreno et al., 2001; Moundridou & Virvou, 2002; Woods et al., 2007).

Certainly, as well, there are innumerable games, to include America's Army, DARWARS Ambush!, Full Spectrum Warrior, and a host of commercial off-the-shelf games.

The rise in use of synthetic characters can be attributed to several factors, including advances in synthetic character technology, the changing nature of military operations other than war, and a generalized interest in soft skills. Accompanying the rise in use of synthetic characters should be a greater understanding of when and how to involve them, but this understanding has not been carefully studied. This paper discusses how synthetic characters are used across a range of applications and provides a framework for describing most-appropriate use of synthetic characters.

RESPONSIVE SYNTHETIC CHARACTERS

At the author's institution, a series of desktop applications involve a user interacting with synthetic characters. Applications have ranged from trauma patient assessment to tutoring on tank maintenance diagnostic skills to gaining skills in avoiding non-response during field interviews. In these applications, the desktop simulates a person's behavior in response to user input. Users interact with the synthetic characters via voice, mouse, menu, and/or keyboard. As indicated above, many other groups are also developing training, assessment, operations, marketing, and other

synthetic character applications, with great breadth across domains and intended users of the applications.

One component underlying synthetic character technology is a behavior engine that holds expert-derived models of behavior to make the behavior realistic and transferable. The behavior engine accepts input from the user and employs cognitive, social, linguistic, physiological, and other models to determine synthetic character behaviors (André et al., 2000; Bates, 1994; Kizakevich et al., 1998; Magnenat-Thalmann & Kshirsagar, 2000; Wray & Laird, 2003). These behaviors may include recomputation of sub-goal states, changes in emotional state, actions performed in the simulated environment, gestures, body movement, or facial expressions to be rendered, and spoken dialog. Another component, the visualization component, renders the synthetic character and performs gesture, movement, and speech actions.

Evidence of Rising Use of Synthetic Characters

A stroll about the I/ITSEC exhibit hall highlights the rising use of synthetic characters, as seemingly every booth showing a simulation includes characters in the simulation. Similarly, an increasing number of presentations and papers at I/ITSEC and related conferences deal with synthetic characters. The pertinent issue here is to consider if all of these characters are necessary. I/ITSEC is merely one venue reflecting the increased attention to synthetic characters. A conference that was once called *Computer Generated Forces and Behavior Representation* (CGF-BR) has evolved into *Behavior Representation in Modeling and Simulation* (BRIMS) to reflect the move away from solely CGF. A number of journals, including *Educational Technology*, the *International Journal of Virtual Reality*, the *Journal of Applied Artificial Intelligence*, and *Künstliche Intelligenz* (the German artificial intelligence journal) have had synthetic character studies as bases for special issues. And a growing number of serious games have pushed into military areas, homeland security, and law enforcement that take advantage of extensive models of synthetic characters. The intent in this paper is not to critique any specific applications, but instead to present a framework suggestive of good practices for use of synthetic characters.

Synthetic Character Fidelity

Applications using synthetic characters are decidedly more realistic than ever, with increases in different types of fidelity. Like all kinds of simulations, synthetic characters can be simulated with a variable degree of fidelity, in this case, the degree to which the characters resemble people.

Appearance fidelity, the degree to which a synthetic character looks or, in some cases, sounds, like a real person, is an obvious variable. Some researchers suggest that high appearance fidelity creates unrealistic expectations for intelligence (Frank et al., 2002; Reeves & Nass, 1996). By contrast, some researchers strive for high appearance fidelity in an effort to capture the natural appeal of the human face and body movements (Harless et al., 2003; Olsen, 2001), while others cite the power of artful low-fidelity animation to create high believability, evoking strong user belief in the life and feelings of characters (Bates, 1994; Lester et al., 1999).

Despite the attention paid to appearance fidelity, however, characters also have important dimensions of psychological or behavioral fidelity, which may be equally or more important factors particularly within simulation training. In discussions of equipment fidelity for training procedures and motor skills, Patrick (1992) and others have made a similar distinction between engineering fidelity versus psychological fidelity and observed that the latter (not the former) determines transfer of learned skills to the performance environment. Several researchers cite different aspects of psychological fidelity of synthetic characters. Hayes-Roth and Doyle (1998) introduce the need for improvisational behavior in synthetic characters. Hubal and Guinn (2003) argue for animate characters that exhibit a range of human-like intelligence. Hayes-Roth et al. (2004) and Wray and Laird (2003) emphasize interaction fidelity with mixed-initiative natural language conversation. Cassell et al. (2000) and Prendinger and Ishizuka (2001) discuss social fidelity of a character's relationship with a user, while Frank et al. (2002) discuss interaction fidelity of the mixed initiative, such as degree of politeness, personalization, and tailoring of linguistic complexity. Cassell and Stone (1999) and Cassell and Thórisson (1999) focus on the gestural fidelity of a character, while Reynolds (1999) and Le Mentec et al. (1999) discuss motion behaviors. Gratch (2000) and others have looked at representing the goal-setting behaviors required during decision making and problem solving. Bates (1994), Conati (2002), Gratch and Marsella (2001), Hayes-Roth et al. (1998), Hubal et al. (2003), Lisetti et al. (2003), and Paiva (2000) all discuss emotional fidelity. Hayes-Roth, van Gent, & Huber (1997) introduce the concept of status fidelity, the degree to which a character's behavior reflects and reinforces his or her social status. Hubal et al. (2000, 2003b), and

Maldonado and Hayes-Roth (2003) identify role fidelity, comprising qualities specific to the job a character performs in a given application, and cultural fidelity, having to do with age and ethnicity of the synthetic character.

Hayes-Roth (2004) elaborates the concept of behavioral fidelity, articulating seven qualities (conversational, intelligent, individual, social, empathic, variable, and coherent) and operationalizing each in terms of observable features of behavior. For example, behavioral fidelity increases to the extent that a character's behavior is more conversational, exhibiting mixed-initiative, multi-threaded dialogue and multiple layers of meaning.

Going outside of the character per se, following theories of situated learning (Brown, Collins, & Duguid, 1989; Greeno et al., 1993; Lave & Wenger, 1991), context fidelity is the degree to which the context in which a user interacts with a character resembles the actual performance setting.

CRITERIA TO GUIDE THE USE OF SYNTHETIC CHARACTERS

Examples of current applications where the use of synthetic characters makes sense include those for training interaction or cultural skills, for certain forms of therapy, for crowd modeling, and for assessing procedures within otherwise difficult to accomplish (logistically, safety-wise, or due to time or resource costs) role plays. Such synthetic character applications are representative of the simulations developed in the author's R&D division. These technology assisted lifelong learning applications are for jobs requiring complicated knowledge and skills, complex material, a high cost of on-the-job training or failure on the job, jobs where safety or situation awareness is essential, and for large student throughput requirements (Frank, Helms, & Voor, 2000; Hubal & Helms, 1998; Wilson & Helms, 2003). The use of synthetic characters in practice sessions that meet these challenges has merit, and as a bonus can lead to increased confidence in a student's skills, in addition to the skills themselves, before any live experiences.

Examples of current applications where the use of synthetic characters makes less sense include those that do not involve interactivity and those for training or assessment that could easily – and perhaps more cost-effectively – be done using questionnaires, interactive videos, or role-plays (Hubal, Fishbein, & Paschall, 2004). For instance, an application for learning procedural skills generally would involve equipment or other physical systems, and unless the learning of the skills requires communication with team members, and unless that communication *has to* be represented as face-to-face, then the use of synthetic characters is probably not warranted. Similarly, if the intent is to assess how an individual would behave in a given situation that involves others, then in general situating that individual in a synthetic character scenario would seem to make sense. However, if beforehand it is known or presumed that individuals would have a good understanding or awareness of how they would behave, then a simulation might be an example of more technology than is necessary.

Some additional (overlapping) criteria that may be used to understand when and how to involve synthetic characters are these:

- If the application should reflect pressing current operational environment issues, then synthetic characters may be appropriate to use. Combat trauma assessment, understanding of cultural values, dealing with non-traditional (child, female) combatants, treatment of post-traumatic stress disorder, and conduct of military operations other than war all involve interpersonal interactions and warrant the use of synthetic characters. Military operations other than war, such as full spectrum operations (Chiarelli & Michaelis, 2005) and stability, security, transition and reconstruction operations (SSTR; DoD, 2005), present dynamic environments that are inherently different from pure kinetic military operations environments, but are increasingly critical elements of warfighters' skills. In an SSTR environment, the mission evolves into a "wicked" (Pierce & Dixon, 2006) problem of rebuilding or maintaining peace in a society or country during political instability, hostile actions such as counterinsurgency, terrorism, and criminality, and sometimes conflicting ethical and cultural orientations of military, multinational force, governmental, nongovernmental, commercial, tribal, religious, and civilian entities (Brinkerhoff, 2000; DoD, 2006). Depending on the application, diplomatic, informational, military and economic actions (Taylor et al., 2008) or detailed dialogs that elicit intelligence (Frank & Hubal, 2008) may be used to influence political, military, economic, social, infrastructural, and informational effects.

- If the application requires repetition, replay, extensibility, standardization, safety, and/or parametric variability, then this suggests a possible

use of synthetic characters. Certainly such an application demands a simulation, so that scenarios can be repeated, replayed, and extended using defined parameters so as to be safe and meet set standards. Practicing skills in such an environment, with entities that have sufficient levels of fidelity, allows a student to learn flexible approaches. Flexibility is critical for interaction skills and for performing well under time constraint, information-poor, and other difficult conditions (Frank et al., 2002). The consistency that is gained by practicing in simulated environments leads directly to good decisions on the job (McMaster et al., 2002). By practicing interaction or soft skills in safe, simulated setting, and interacting with synthetic characters, students have the opportunity to develop practical experience and skills which would otherwise be difficult to acquire.

- If the application involves sensitive or dangerous topics, it might be a candidate for involving synthetic characters. Perhaps in part the questioning is directed towards members of the other gender who are wary of responding due to cultural values of propriety. The questioning may be proactive but involve sensitive topics likely to trigger concerns on the part of the individual: "Have you seen anyone you suspect of planting IED's in this area?" "Where are arms caches kept?" Or, given the potentially increasing role of soldiers as civil affairs and law enforcement officers (Sheffe, 2007), the questioning may be of health-related concern, such as asking about health practices, domestic abuse, and sexually-transmitted diseases. In these kinds of situations, it would be best for students to first acquire and then practice their interaction skills in a repeatable, extensible, safe environment, with characters who respond with high fidelity in appearance, linguistic responses, and expressions and gestures.

- If the application requires learning or assessment or practice of physical activities, or of strategies or higher-level awareness that is not easily simulated, then it may not be a good candidate as a synthetic character application. Simulated environments that involve engagement with synthetic characters ***can*** be instrumented so that a user's physical movements are captured (Bickmore, 2004; Hill et al., 2003), however, these are typically expensive environments to set up, and it is often likely that more common situations such as role plays and demonstrations would suffice for the learning or assessment or practice. On the other hand, if the situation to be presented is difficult to set up as a role play, or expensive or time-consuming or demanding of too many resources (e.g., other role players) or dangerous or unethical, then a simulated environment involving synthetic characters ***would*** be a good candidate for the training, assessment, and practice.

- If the appearance fidelity of the application is such that a high level of realism is demanded, for example to learn to identify subtle emotional or deceptive signals (Harless et al., 2003; Olsen, 2001), then only specific forms of synthetic characters, such as video-based characters, would be appropriate. Generally, the cost of making a computer generated character behave validly (e.g., in terms of facial expressions and gestures) would be more than the cost of using video technology and hiring actors. On the other hand, if the application demands the possibility of rapid regeneration of scenarios, then computer generated characters may make more sense than video-based characters. As an example, for training it can help students to practice soft skills against characters varying in gender, ethnicity, age, personality, and other characteristics. Implementing these variations in generated environments is generally simpler than doing so using videos.

- If the implementation of the application requires that users be taken out of their normal situation and placed into a simulated environment, and this placement is not in line with their normal activities, then it is ***not*** a good candidate as a synthetic character application. As an example, if soldiers are working together as a team, conversing and interacting and using physical tools such as whiteboards and sand tables, even if using electronic tools such as cell phones and e-mails, a simulated environment is likely inappropriate, as it removes the soldiers from their normal activities hence does not represent an intelligent use of technology. The occasional paper or presentation will describe how soldiers use a given simulation for training or practice, without describing the impact on their day-to-day activities.

- If the application requires the presentation of crowds, for instance within simulations of behavior of first responders to natural or man-made disasters, then the use of synthetic characters is sensible. The appearance fidelity of these characters generally would not need to be high, but other behavioral components, such as the movements the characters make individually and in groups, ***would*** be important.

- If the application demands any kind of character fidelity then the use of synthetic characters is appropriate. For instance, some applications require

the student to note or identify emotional or deceptive expressions (Hill et al., 2003; Olsen, 2001). Others require the student to interpret gestures (Wideman & Sims, 1998) or overt actions (Frank et al., 2002) or identify the activities of crowds. When the application involves an embodied tutor (Johnson et al., 2000; Graesser et al., 2000; Hubal, 2008) certainly a synthetic character is necessary.

Synthetic Character Applications in Context

Even if necessary for training, assessment, or other purpose, given the suggestive criteria just listed, synthetic character-based applications are rarely if ever by themselves sufficient for that purpose. Instead they typically belong within a mix of virtual (i.e., simulated), constructive, and live environments. Hence they must fit (i.e., not be dissonant) with other training. One good example of the use of synthetic characters is in medical training, where medical practitioners and first responders can acquire and practice interviewing and diagnostic skills with trauma patients (Kizakevich et al., 1998, 2003) and patients presenting in clinic (Hubal et al., 2000; Kenny et al., 2007; Stevens et al., 2006). These skills are commonly assessed in a standardized patient scenario (Swygert et al., 2003), a kind of constructive environment. On the other hand, there are some less positive uses of synthetic characters. For instance, Marshall et al. (2008) found that CGF controlled by the Modular Semi-Automated Forces (ModSAF) package produced unrealistic opponent force behaviors during a constructive dismounted operations exercise. Similarly, the author found in several studies (Frank et al., 2002; Link et al., 2006; Hubal et al., 2008) that users of an application were engaged in the simulations, and gave some leeway in how relevant the verbal responses of the character needed to be, but as soon as a synthetic character acted wholly inappropriately, by words or actions, the users disengaged from the scenario. Synthetic characters, then, must engage, not detract.

SUMMARY

The technologies behind synthetic characters continue to advance rapidly; today's computer-generated characters in many ways match the fidelity of video-based characters. Given these advances, important issues arise regarding when and how to employ synthetic characters in simulation training, assessment, and other applications. This paper outlines a number of guidelines for intelligent use of synthetic characters in these types of applications, including considering the fidelity needed, the nature of skills being trained or assessed (e.g., military operations other than war; sensitive topics; deception), and the need for simulation in general and characters in particular.

ACKNOWLEDGEMENTS

Some of the key ideas in this paper stem from discussions between the author and the following individuals, among a great many others: Steve Baumann, Steve Clyman, Ruth Day, Robin Deterding, Randy Dupont, Paul Feltovich, Geoff Frank, Curry Guinn, Barbara Hayes-Roth, Jerry Heneghan, Paul Kizakevich, James Lester, Dale Olsen, Zach Rosenthal, Jim Spira, and Bob Wray.

REFERENCES

(2005). Military support for stability, security, transition, and reconstruction (SSTR) operations. Washington, DC: Department of Defense Directive 3000.05.

(2006). Military support to stabilization, security, transition, and reconstruction operations: Joint operating concept. Washington, DC: Department of Defense.

André, E., Rist, T., & Müller, J. (1999). Employing AI methods to control the behavior of animated interface agents. *International Journal of Applied Artificial Intelligence*, *13*(4-5), 415-448.

André, E., Rist, T., van Mulken, S., Klesen, M., & Baldes, S. (2000). The automated design of believable dialogue for animated presentation teams. In J. Cassell, J. Sullivan, S. Prevost, & E. Churchill (Eds.), Embodied conversational agents (pp. 220-255). Cambridge, MA: MIT Press.

Bates, J. (1994). The role of emotion in believable agents. *Communications of the ACM*, *37*(7), 122-125.

Bickmore, T. (2004). Unspoken rules of spoken interaction. *Communications of the ACM*, *47*(4), 38-44.

Brinkerhoff, D.A. (2000). Assessing political will for anti-corruption efforts: An analytic framework. *Public Administration and Development*, *20*(3), 239-253.

Brown, J.S., Collins, A., & Duguid, S. (1989). Situated cognition and the culture of learning. *Educational Researcher*, *18*(1), 32-42.

Camburn, D.P., Gunther-Mohr, C., & Lessler, J.T. (1999). Developing new models of interviewer training. Proceedings of the International Conference on Survey Nonresponse, Portland, OR.

Cassell, J. (2000). Embodied conversational interface agents. *Communications of the ACM, 43*(4), 70-78.

Cassell, J., & Stone, M. (1999). Living hand to mouth: Psychological theories about speech and gesture in interactive dialogue systems. Proceeding of the AAAI Fall Symposium on Narrative Intelligence.

Cassell, J., & Thórisson, K.R. (1999). The power of a nod and a glance: Envelope vs. emotional feedback in animated conversational agents. *Applied Artificial Intelligence, 13*, 519-538.

Cassell, J., Bickmore, T., Vilhjálmsson, H., & Yan, H. (2000). More than just a pretty face: Affordances of embodiment. In Proceedings of the Intelligent User Interfaces Conference. New York: ACM Press.

Chiarelli, P.W., & Michaelis, P.R. (2005). Winning the peace: The requirement for full-spectrum operations. *Military Review, LXXXV*(4), 4-17.

Conati, C. (2002). Probabilistic assessment of user's emotions in educational games. *Applied Artificial Intelligence, 16*(7-8), 555-575.

Denny, M., DeSmedt, B., Gella, K., Hiles, M., May, D., Natarajan, S., Waisel, L., & Wass, J. (2008). Force behavior agents. Proceedings of I/ITSEC (pp. 643-654). Arlington, VA: National Defense Industrial Association.

Deterding, R., Milliron, C., & Hubal, R. (2005). The virtual pediatric standardized patient application: Formative evaluation findings. *Studies in Health Technology and Informatics, 111*, 105-107.

Elliott, C. (1993). Using the affective reasoner to support social simulations. Proceedings of the International Joint Conference on Artificial Intelligence (pp. 194-200), Chambery, France.

Frank, G., Guinn, C., Hubal, R., Pope, P., Stanford, M., & Lamm-Weisel, D. (2002). JUST-TALK: An application of responsive virtual human technology. Proceedings of I/ITSEC (pp. 773-779). Arlington, VA: National Defense Industrial Association.

Frank, G.A., & Hubal, R.C. (2008). Bias inoculation advanced simulation (BIAS) training. Proceedings of BRIMS. Orlando, FL: Simulation Interoperability Standards Organization.

Frank, G.A., Helms, R.F., & Voor, D. (2000). Determining the right mix of live, virtual, and constructive training. Proceedings of I/ITSEC (pp. 1268-1277). Arlington, VA: National Defense Industrial Association.

Graesser, A., Wiemer-Hastings, K., Wiemer-Hastings, P., Kreuz, R., & the Tutoring Research Group (2000). AutoTutor: A simulation of a human tutor. *Journal of Cognitive Systems Research, 1*, 35-51.

Gratch, J. (2000). Modeling the interplay between emotion and decision making. Proceedings of CGF-BR, May 16-18, 2000, Orlando, FL.

Gratch, J., & Marsella, S. (2001). Tears and fears: Modeling emotions and emotional behaviors in synthetic agents. In Proceedings of Agents (pp. 278-285).

Greeno, J.G., Chi, M.T.H., Clancey, W.J., & Elman, J. (1993). *Cognitive Science, 17*, Special Issue on Situated Action.

Guinn, C.I., & Montoya, R.J. (1998). Natural language processing in virtual reality. *Modern Simulation & Training, 6*, 44-45.

Harless, W.G., Zier, M.A., Harless, M.G., & Duncan, R.C. (2003). Virtual conversations: An interface to knowledge. *IEEE Computer Graphics and Applications, 23*(5), 46-52.

Hayes-Roth, B. (2004). What makes a character life-like? In H. Prendinger & M. Ishizuka (Eds.), Life-like characters: Tools, affective functions and applications. Berlin: Springer-Verlag.

Hayes-Roth, B., & Doyle, P. (1998). Animate characters. *Journal on Agents and Multi-Agent Systems, 1*, 195-230.

Hayes-Roth, B., Amano, K., Saker, R., & Sephton, T. (2004). Training brief intervention with a virtual coach and virtual patients. In B.K. Wiederhold & G. Riva (Eds.), Annual Review of CyberTherapy and Telemedicine (pp. 85-96). San Diego, CA: Interactive Media Institute.

Hayes-Roth, B., Ball, G., Lisetti, C. Picard, R.W., & Stern, A. (1998). Affect and emotion in the user interface, Proceedings of the Intelligent User Interfaces Conference. New York: ACM Press.

Hayes-Roth, B., van Gent, R., & Huber, D. (1997). Acting in character. In R. Trapple & P. Petta (Eds.), Creating personalities for synthetic actors. Berlin: Springer-Verlag.

Haynes, J., Zbylut, M., Wason, T.D., & Maloor, P. (2008). "The play's the thing": Teaching high level skills through dramatic simulations. Proceedings of

I/ITSEC (pp. 750-759). Arlington, VA: National Defense Industrial Association.

Hill, R., Belanich, J., Lane, H., Core, M., Dixon, M., Forbell, E., Kim, J., & Hart, J. (2006). Pedagogically structured game-based training: Development of the ELECT BiLat simulation. Proceedings of the Army Science Conference, November 27-30, 2006, Orlando, FL.

Hill, R.W., Gratch, J., Marsella, S., Rickel, J., Swartout, W., & Traum, D. (2003). Virtual humans in the mission rehearsal exercise system. *Künstliche Intelligenz (KI Journal), Special issue on Embodied Conversational Agents*, *17*(4), 5-10.

Hubal, R., & Guinn, C. (2003). Interactive soft skills training using responsive virtual human technology. Proceedings of the Interactive Technologies Conference. Arlington, VA: Society for Applied Learning Technologies.

Hubal, R.C., & Day, R.S. (2006). Informed consent procedures: An experimental test using a virtual character in a dialog systems training application. *Journal of Biomedical Informatics*, *39*(5), 532-540.

Hubal, R.C., & Frank, G.A. (2001). Interactive training applications using responsive virtual human technology. Proceedings of I/ITSEC (pp. 1076-1086). Arlington, VA: National Defense Industrial Association.

Hubal, R.C., & Helms, R.F. (1998). Advanced learning environments. *Modern Simulation & Training*, *5*, 40-45.

Hubal, R.C., Deterding, R.R., Frank, G.A., Schwetzke, H.F., & Kizakevich, P.N. (2003). Lessons learned in modeling virtual pediatric patients. *Studies in Health Technology and Informatics*, *94*, 127-130.

Hubal, R.C., Fishbein, D.H., & Paschall, M.J. (2004). Lessons learned using responsive virtual humans for assessing interaction skills. Proceedings of I/ITSEC (pp. 989-999). Arlington, VA: National Defense Industrial Association.

Hubal, R.C., Fishbein, D.H., Sheppard, M.S, Eldreth, D.L., & Hyde, C.T. (2008). How do varied populations interact with embodied conversational agents? Findings from inner-city adolescents and prisoners. *Computers in Human Behavior*, *24*(3), 1104-1138.

Hubal, R.C., Frank, G.A., & Guinn, C.I. (2003). Lessons learned in modeling schizophrenic and depressed responsive virtual humans for training. Proceedings of the Intelligent User Interface Conference. New York: ACM Press.

Hubal, R.C., Kizakevich, P.N., Guinn, C.I., Merino, K.D., & West, S.L. (2000). The virtual standardized patient–Simulated patient-practitioner dialogue for patient interview training. *Studies in Health Technology and Informatics*, *70*, 133-138.

Johnson, W.L., Rickel, J.W., & Lester, J.C. (2000). Animated pedagogical agents: Face-to-face interaction in interactive learning environments. *International Journal of Artificial Intelligence in Education*, *11*, 47-78.

Johnson, W.L., Vilhjálmsson, H., & Marsella, S. (2005). Serious games for language learning: How much game, how much AI? *Frontiers in Artificial Intelligence and Applications*, *125*, 306-313.

Kenny, P., Parsons, T.D., Gratch, J., Leuski, A., & Rizzo, A.A. (2007). Virtual patients for clinical therapist skills training. *Lecture Notes in Artificial Intelligence*, *4722*, 197-210.

Kizakevich, P.N., Lux, L., Duncan, S., Guinn, C., & McCartney, M.L. (2003). Virtual simulated patients for bioterrorism preparedness training. *Studies in Health Technology and Informatics*, *94*, 165-167.

Kizakevich, P.N., McCartney, M.L., Nissman, D.B., Starko, K., & Smith, N.T. (1998). Virtual medical trainer: patient assessment and trauma care simulator. *Studies in Health Technology and Informatics*, *50*, 309-315.

Klinger, E., Bouchard, S., Légeron, P., Roy, S., Lauer, F., Chemin, I., & Nugues, P. (2005). Virtual reality therapy versus Cognitive Behavior Therapy for social phobia: A preliminary controlled study. *CyberPsychology & Behavior*, *8*(1), 76-88.

Lave, J., & Wenger, E. (1991). Situated learning. New York: Cambridge.

Le Mentec, J.C., Glenn, F., Zachary, W., & Eilbert, J. (1999). Representing human sensory and motor action behavior in a cognitive modeling architecture. In Proceedings of CGF-BR, May 13, 1999, Orlando, FL.

Lester, J.C., Stone, B.A., & Stelling, G.D. (1999). Lifelike pedagogical agents for mixed-initiative problem solving in constructivist learning environments. *User Modeling and User-Adapted Interaction*, *9*, 1-44.

Link, M.W., Armsby, P.P., Hubal, R.C., & Guinn, C.I. (2006). Accessibility and acceptance of responsive

virtual human technology as a survey interviewer training tool. *Computers in Human Behavior*, *22*(3), 412-426.

Lisetti, C., Nasoz, F., LeRouge, C., Ozyer, O., & Alvarez, K. (2003). Developing multimodal intelligent affective interfaces for tele-home health care. *International Journal of Human-Computer Studies*, *59*, 245-255.

Magnenat-Thalmann, N. & Kshirsagar, S. (2000). Communicating with autonomous virtual humans. Proceedings of the TWENTE Workshop on Language Technology (pp. 1–8). Enschede, Universiteit Twente, October 2000.

Maldonado, H., & Hayes-Roth, B. (2003) Cross-cultural believability in character design. In R. Trappl & P. Petta (Eds.), Agent culture: Designing synthetic characters for a multi-cultural world. New York: Lawrence Erlbaum Associates.

Marshall, H., Garrity, P., Roberts, T., & Green, G. (2008). Initial real-world testing of dismounted soldier embedded training technologies. Proceedings of I/ITSEC (pp. 377-387). Arlington, VA: National Defense Industrial Association.

McCollum, C., Deaton, J., Barba, C., Santarelli, T., Singer, M., & Kerr, B. (2004). Developing an immersive, cultural training system. Proceedings of I/ITSEC (pp. 635-644). Arlington, VA: National Defense Industrial Association.

McMaster, L., Cooper, G., McLin, D., Field, D., Baumgart, R., & Frank, G. (2002). Combining 2D and 3D virtual reality for improved learning. Proceedings of I/ITSEC (pp. 246-254). Arlington, VA: National Defense Industrial Association.

Moreno, R., Mayer R.E., Spires, H.A., & Lester, J.C. (2001). The case for social agency in computer-based teaching: Do students learn more deeply when they interact with animated pedagogical agents? *Cognition and Instruction*, *19*, 177-213.

Moundridou, M., & Virvou, M. (2002). Evaluating the persona effect of an interface agent in an intelligent tutoring system. *Journal of Computer Assisted Learning*, *18*(3), 253-261.

Olsen, D.E. (2001). The simulation of a human for interpersonal skill training. Proceedings of the Office of National Drug Control Policy International Technology Symposium, San Diego, CA.

Paiva, A. (2000). Affective interactions: Towards a new generation of computer interfaces. Berlin: Springer-Verlag.

Paschall, M.J., Fishbein, D.H., Hubal, R.C., & Eldreth, D. (2005). Psychometric properties of virtual reality vignette performance measures: A novel approach for assessing adolescents' social competency skills. *Health Education Research: Theory and Practice*, *20*(1), 61-70.

Patrick, J. (1992). Training: Research and practice. San Diego: Academic Press.

Pelechano, N., O'Brien, K., Silverman, B.G., & Badler, N.I. (2005). Crowd simulation incorporating agent psychological models, roles and communication. Proceedings of the International Workshop on Crowd Simulation (pp. 21-30), Lausanne, Switzerland, November 24-25, 2005.

Pierce, L., & Dixon, M. (2006). Improving multicultural teamwork to combat terrorism. Proceedings of the Tactical Decision-Making and Situational Awareness for Defense Against Terrorism, North Atlantic Treaty Organization Systems Concepts and Integration (SCI) Panel Workshop SCI-174, Turin, Italy, May 1, 2006.

Prendinger, H., & Ishizuka, M. (2001). Let's talk! Socially intelligent agents for language conversation training. *IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans*, *31*(5), 465-471.

Raybourn, E., Heneghan, J., Deagle, E., & Mendini, K. (2005). Adaptive thinking & leadership simulation game training for Special Forces officers. Proceedings of I/ITSEC (pp. 789-796). Arlington, VA: National Defense Industrial Association.

Reeves, B. & Nass, C. (1996). The media equation. New York: Cambridge University Press.

Reynolds, C.W. (1999). Steering behaviors for autonomous characters. Proceedings of the Game Developers Conference (pp. 763-782), San Jose, CA.

Rickel, J., & Johnson, W.L. (1999). Animated agents for procedural training in virtual reality: Perception, cognition, and motor control. *Applied Artificial Intelligence*, *13*, 343-382.

Sheffe, R.C. (2007). The development of the J9: An operational level directorate for stability and security operations for the military. Newport, RI: Naval War College.

Slater, M., Pertaub, D.P., & Steed, A. (1999). Public speaking in virtual reality: Facing an audience of avatars. *IEEE Computer Graphics and Applications*, *19*(2), 6-9.

Solomon, S., van Lent, M., Core, M., Carpenter, P., & Rosenberg, M. (2008). A language for modeling cultural norms, biases and stereotypes for human behavior models. Proceedings of BRIMS. Orlando, FL: Simulation Interoperability Standards Organization.

Stevens, A., Hernandez, J., Johnsen, K., Dickerson, R., Raij, A., Harrison, C., DiPietro, M., Allen, B., Ferdig, R., Foti, S., Jackson, J., Shin, M., Cendan, J., Watson, R., Duerson, M., Lok, B., Cohen, M., Wagner, P., & Lind, D.S. (2006). The use of virtual patients to teach medical students history taking and communication skills. *American Journal of Surgery*, *191*(6), 806-811.

Swygert, K., Margolis, M., King, A., Siftar, T., Clyman, S., Hawkins, R., & Clauser, B. (2003). Evaluation of an automated procedure for scoring patient notes as part of a clinical skills examination. *Academic Medicine*, *78*(10 Suppl), S75-77.

Takács, B. (2005). Special education & rehabilitation: Teaching and healing with interactive graphics. *IEEE Computer Graphics and Applications, Special Issue on Computer Graphics in Education*, *25*(5), 40-48.

Tartaro, A., & Cassell, J. (2006). Using virtual peer technology as an intervention for children with autism. In J. Lazar (Ed.), Towards Universal Usability: Designing Computer Interfaces for Diverse User Populations (pp. 231-262). New York, NY: John Wiley & Sons, Ltd.

Taylor, G., Bechtel, R., Knudsen, K., Waltz, E., & White, J. (2008). PSTK: A toolkit for modeling dynamic power structures. Proceedings of BRIMS. Orlando, FL: Simulation Interoperability Standards Organization.

Wideman, C.J., & Sims, E.M. (1998). Signing avatars. Proceedings of the Technology & Persons with Disabilities Conference, California State University Northridge, March, 1998.

Wilson, W.R., & Helms, R.F. (2003). A business model for lifelong learning. Proceedings of I/ITSEC (pp. 1089-1098). Arlington, VA: National Defense Industrial Association.

Woods, S., Hall, L., Dautenhahn, K., & Wolke, D. (2007). Implications of gender differences for the development of animated characters for the study of bullying behaviour. *Computers in Human Behavior*, *23*(1), 770-786.

Wray, R.E., & Laird, J.E. (2003). Variability in human behavior modeling for military simulations. Proceedings of BRIMS. Orlando, FL: Simulation Interoperability Standards Organization.