DEVELOPING EFFECTIVE VIRTUAL REALITY TRAINING FOR MILITARY FORCES AND EMERGENCY OPERATORS: FROM TECHNOLOGY TO HUMAN FACTORS

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ABSTRACT
The use of Virtual Reality (VR) for training is increasingly common in the military and in emergency operator fields. One of the main problems with the use of VR for training is the fact that the technology, although advanced, is not enough on its own. Technological aspects like fidelity and sensorial realism are certainly important in developing effective training techniques, but there are others that need to be considered. Focusing on human factors from the earliest stages of designing VR training can increase effectiveness and reduce the possibility of ineffective or even harmful effects of the training. This approach, called "Human-Centered VR Training Design," is characterized by being both multimodal (i.e., oriented to several aspects of user experience) and multilevel (i.e., based on the integrated use of technical and methodological solutions); it has undergone preliminary testing by Selex ES within the project Minerva in collaboration with psychological researchers at the University of Milano-Bicocca.

Keywords: Virtual Reality, Training, Military, Emergency Operators, Human Factors

1. VIRTUAL REALITY FOR THE TRAINING OF MILITARY FORCES AND EMERGENCY OPERATORS
The use of Virtual Reality (VR) for training is increasingly common in the military (Koźlak, Kurzeja, & Nawrat, 2013; Reist et al., 2013; Rizzo et al., 2011; Rizzo et al., 2013; Seidel & Chatelier, 2013; Summers, 2012) and in the emergency operator fields (Brady, Lee, Pearce, Shintaku, & Guerlain, 2015; Farra, Miller, Timm, & Schafer, 2013; Hsu et al., 2013; Pucher et al., 2014). This level of endorsement is linked mainly to the possibility offered by VR to simulate complex, highly stressful scenarios in a safe, customizable and dynamic environment (e.g., flight simulator, simulations of battlefields or emergency scenarios) (Seidel & Chatelier, 2013; Wilkerson, Avstreih, Gruppen, Beier, & Wooliscroft, 2008). In addition, training in a virtual world has been reported to be a good compromise between the traditional alternatives of classroom-based training and real-world training exercises (Hsu et al., 2013; Rizzo et al., 2011).

VR has been adopted by both the military and emergency operators for the training of physical (e.g., the repetition of the steps to follow during an emergency helicopter landing) and mental skills (e.g., managing a health-related emergency situation).

The three main areas of application of VR within these fields can be summarized as follows:

1) Procedural training: focuses on the training of single procedural skills. Some examples are military flight simulation (An, Li, Xu, & Shi, 2011; Zhao, Xu, Ye, & Li, 2011) and emergency medicine simulations (Bartoli et al., 2012; Ferracani, Pezzatini, Seidenari, & Del Bimbo, 2014);
2) Management of complex situation training: relates to contextual or relational skills, including team communication and decision making (Hoch & Kozlowski, 2014; Pucher et al., 2014), battlefield simulations (Rizzo, Parsons et al. 2011) and disaster preparedness training (Freeman et al., 2001; Kizakevich et al., 2007; Wilkerson et al., 2008);
3) Emotion and stress management training: concerns coping with stress. Examples include stress management training for military forces (Cosenzo, Fatkin, & Patton, 2007; Rizzo et al., 2012) and PTSD management training (Rizzo et al., 2015; Rizzo et al., 2012; Cosenzo, Fatkin, & Patton, 2007) and PTSD management training (Rizzo et al., 2015).

2. IS TECHNOLOGY REALLY ENOUGH? THE IMPORTANCE OF HUMAN FACTORS
A few years ago there was a "technology rush", with the aim of developing the most effective VR system for training; in particular, a VR system with the maximum level of sensory realism, or "physical fidelity," which is

the objective level of sensory realism that a VR system provides. More specifically, physical fidelity refers to the degree to which the physical simulation looks, sounds and feels like the operational environment in terms of the visual displays, controls, audio and haptic devices, as well as the physics models driving each of these variables (Becker, Warm, Dember, & Hancock, 1995; Rinalducci, 1996).

But how realistic does a VR system need to be in order to fulfill its training goals? On the one hand, it is possible that unrealistic situations may lead to ineffective or even harmful effects of training. For example, the enhancement of haptic fidelity has been shown to be a fundamental element for surgical training when fine motor skills, accuracy and delicate tool control are required (Basdogan et al., 2004). On the other hand, because of the learning abilities and perceptual limitations of the sensory, motor and cognitive systems of users, a perfect VR system is not always necessary (Scerbo & Dawson, 2007). A number of studies have even demonstrated that a high transfer of learning can be achieved with simple simulators when training soft and hard skills (Scerbo & Dawson, 2007).

Physical fidelity and sensorial realism are certainly important elements to be considered during the design and development of a VR training system, but there is more to the story. The concept of fidelity, in fact, is not limited to that of sensorial realism; more generally, it refers to the extent to which the virtual environment emulates the real world (Alexander, Brunyé, Sidman, & Weil, 2005; Lintern, Roscoe, Koonce, & Segal, 1990). The level of fidelity of a VR system includes a large number of subcategories (Stoffregen, Bardy, Smart, & Pagulayan, 2003) related not only to its technological features, but also to the users' subjective characteristics, or "human factors" (Riva & Mantovani, 1999; Wann & Mon-Williams, 1996). Due to the close bond between the user and the system within virtual environments, it may be impossible to segregate human factors from design issues when striving to achieve the potential of VR technology. It is the capabilities and limitations of the user that often times will determine the effectiveness of virtual worlds.

3. DEVELOPING VIRTUAL REALITY TRAINING THROUGH A "HUMAN-CENTERED DESIGN"

Designing usable and effective interactive virtual worlds is a new challenge for system developers and human-factors specialists. An understanding of human-factors issues can thus be used to provide a systematic basis by which to direct future VE research efforts aimed at advancing the technology to better meet the needs of its users. This need is best articulated by Shneiderman, 1992), who stated that "analyses of VR user-interface issues may be too sober a process for those who are enjoying their silicon trips, but it may aid in choosing the appropriate applications and refining the technologies" (p. 224).

Thus, an interdisciplinary approach including users, trainers, designers, psychologists and technology experts can define concrete guidelines that may support strategic choices and training design activities evaluation. Human-factors practitioners such as psychologists and trainers can assist in making significant contributions to the theoretical understanding of human-virtual environment interaction (HVEI). Focusing on the users' characteristics and needs from the earliest stages of the design of a VR can increase its effectiveness.

This can be done by adopting a "Human-Centered VR Training Design" that provides an understanding of issues related to the subjective experience of the user and to the particular aims of the training from the early stages of development. Knowing the different elements involved in the task means that VR scenarios are tailored to the user, adopting the most suitable technology selected according to the needs of fidelity dictated by the specific task. This is possible through an analysis of the specific task to be trained, not only from a procedural point of view but also from a cognitive one (see Figure 1).

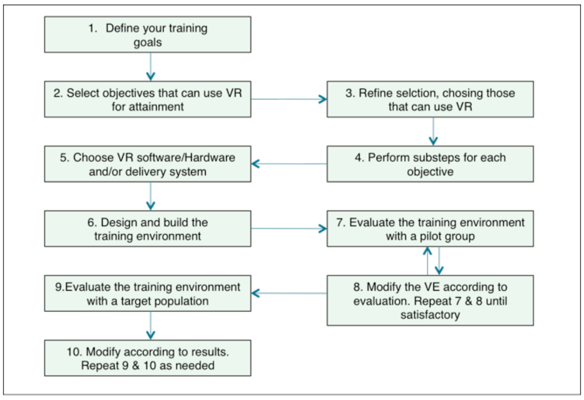

Figure 1: "Human-Centered VR Training Design Model" (adapted from Pantelidis, 1995)

4. A PRELIMINARY INVESTIGATION OF THIS APPROACH AND FUTURE DIRECTIONS

This approach, that could be defined as a "Human-Centered VR Training Design," is characterized by being both multimodal (i.e., oriented to several aspects of user experience) and multilevel (i.e., based on the integrated use of technical and methodological solutions). It has undergone preliminary testing by Selex ES within the project Minerva in collaboration with psychological researchers at the University of Milano-Bicocca. The interdisciplinary approach proposed could contribute to the definition of concrete guidelines that may support future strategic choices and training design activities in the development of VR training for military and emergency operators. Future studies will replicate the preliminary test conducted in order to thoroughly investigate the usefulness of this new integrated approach in the design and development of effective VR training.

This innovative approach has been tested by Selex ES within the project Minerva in collaboration with psychological researchers at the University of Milano-Bicocca and five staff members at the Scuola Interforze di Aerocooperazione di Guidonia. Testing sessions were the first opportunity to give a preliminary demonstration of how academic methods and know-how can be adopted to improve the efficacy of specific VR training scenarios.

Each scenario has been evaluated from a multilevel point of view, and in particular:

1) Subjective user's experience level: interviews, focus groups and the administration of self-report questionnaries (e.g., SUS, STAI-Y1). In particular, the following aspects of the VR experience were evaluated:
- Sense of presence (i.e., user's subjective sensation of "being there" in the scene depicted) (Riva & Mantovani, 2000);
- Usability (i.e., the extent to which users can achieve specified goals with effectiveness, efficiency and satisfaction (McMahan, Bowman, Zielinski, & Brady, 2012; Sutcliffe & Kaur, 2000);
- Cybersickness (i.e., user symptoms similar to the common symptoms experienced when people get motion sickness, like headache, nausea and vomiting) (Kennedy & Fowlkes, 1992; LaViola Jr, 2000);
- Experienced emotions.
2) Behavioral-observational level: observations and video recording of the non-verbal (e.g.,facial expressions, posture, gestures) and verbal (e.g., evaluation of communication flows) behaviors of the users;
3) Physiological level: assessment of the physiological response in order to give objective indexes of the emotional and cognitive states experienced by individuals during the VR scenarios. In particular, during VR sessions skin conductance response, heart rate and facial muscle activation have been recorded.

Collected data are being analyzed and will be used to develop hypotheses of improvement and redefinition of the tested VR training scenarios. In general, the interdisciplinary approach proposed could contribute to the definition of concrete guidelines that may support future strategic choices and training design activities in the development of VR training for military and emergency operators. Future studies will replicate this preliminary test in order to investigate the usefulness and effectiveness of the proposed approach in the design and development of VR training.

REFERENCES

Alexander, A. L., Brunyé, T., Sidman, J., & Weil, S. A. (2005). *From gaming to training: A review of studies on fidelity, immersion, presence, and buy-in and their effects on transfer in pc-based simulations and games.* Paper presented at the The interservice/industry training, simulation, and education conference, Orlando, Florida.

An, X., Li, G., Xu, L., & Shi, Y. (2011). A Survey on Application of Virtual Reality Technology in US Military Simulation Training. *Electronics Optics & Control, 10*, 010.

Bartoli, G., Del Bimbo, A., Faconti, M., Ferracani, A., Marini, V., Pezzatini, D., Seidenari, L., Zilleruelo, F. (2012). *Emergency medicine training with gesture driven interactive 3D simulations*.

Basdogan, C., De, S., Kim, J., Muniyandi, M., Kim, H., & Srinivasan, M. (2004). Haptics in minimally invasive surgical simulation and training. *Computer Graphics and Applications, IEEE, 24*(2), 56-64.

Becker, A. B., Warm, J. S., Dember, W. N., & Hancock, P. A. (1995). Effects of jet engine noise and performance feedback on perceived workload in a monitoring task. *International Journal of Aviation Psychology, 5*, 49-62.

Brady, D., Lee, A., Pearce, A., Shintaku, N., & Guerlain, S. (2015). *Intelligent Cities: translating architectural models into a virtual gaming environment for event simulation.* Paper presented at the Systems and Information Engineering Design Symposium (SIEDS).

Cosenzo, K. A., Fatkin, L. T., & Patton, D. J. (2007). Ready or not: enhancing operational effectiveness through use of readiness measures. *Aviation, Space, and Environmental Medicine, 78*(1), B96-B106.

Farra, S., Miller, E., Timm, N., & Schafer, J. (2013). Improved training for disasters using 3-D virtual reality simulation. *Western journal of nursing research, 35*(5), 655-671.

Ferracani, A., Pezzatini, D., Seidenari, L., & Del Bimbo, A. (2014). Natural and virtual environments for the training of emergency medicine personnel. *Universal Access in the Information Society*, 1-12.

Freeman, K. M., Thompson, S. F., Allely, E. B., Sobel, A. L., Stansfield, S. A., & Pugh, W. M. (2001). A virtual reality patient simulation system for teaching emergency response skills to U.S. Navy medical providers. *Prehospital Disaster Medicine, 16*, 3-8.

Hoch, J. E., & Kozlowski, S. W. (2014). Leading virtual teams: Hierarchical leadership, structural supports, and shared team leadership. *Journal of applied psychology, 99*(3), 390-403.

Hsu, E. B., Li, Y., Bayram, J. D., Levinson, D., Yang, S., & Monahan, C. (2013). State of virtual reality based disaster preparedness and response training. *PLoS currents, 5*, PMC3644293.

Kennedy, R. S., & Fowlkes, J. E. (1992). Simulator Sickness Is Polygenic and Polysymtomatic: Implications for Research. *International Journal of Aviation Psychology, 2*(1), 23-38.

Kizakevich, P. N., Culwell, A., Furberg, R., Gemeinhardt, D., Grantlin, S., Hubal, R., & Dombroski, R. T. (2007). Virtual simulation-enhanced triage training for Iraqi medical personnel. *Studies in Health, Technology and Informatics, 125*, 223-228.

Koźlak, M., Kurzeja, A., & Nawrat, A. (2013). Virtual reality technology for military and industry training programs *Vision Based Systemsfor UAV Applications* (pp. 327-334).

LaViola Jr, J. J. (2000). A discussion of cybersickness in virtual environments. *ACM SIGCHI Bulletin, 32*(1), 47-56.

Lintern, G., Roscoe, S. N., Koonce, J. M., & Segal, L. D. (1990). Transfer of landing skills in beginning flight training. *Human Factors, 32*, 319-327.

McMahan, R. P., Bowman, D., Zielinski, D. J., & Brady, R. B. (2012). Evaluating display fidelity and interaction fidelity in a virtual reality game. *Visualization and Computer Graphics, IEEE Transactions on, 18*(4), 626-633.

Pucher, P. H., Batrick, N., Taylor, D., Chaudery, M., Cohen, D., & Darzi, A. (2014). Virtual-world hospital simulation for real-world disaster response: design and validation of a virtual reality simulator for mass casualty incident management. *Journal of Trauma and Acute Care Surgery, 77*(2), 315-321.

Reist, C., Difede, J., Rothbaum, B. O., Lange, B., Koenig, S., & Talbot, T. (2013). Virtual reality applications to address the wounds of war. *Psychiatric Annals, 43*(3), 126.

Rinalducci, E. J. (1996). Characteristics of visual fidelity in the virtual environment. *Presence: Teleoperators and Virtual Environments, 5*(3), 330-345.

Riva, G., & Mantovani, G. (1999). The ergonomics of virtual reality: human factors in developing clinical-oriented virtual environments. *Studies in Health, Technology and Informatics, 62*, 278-284.

Riva, G., & Mantovani, G. (2000). The Need for a Socio-Cultural Perspective in the Implementation of Virtual Environments. *Virtual Reality*(5), 32-38.

Rizzo, A., Cukor, J., Gerardi, M., Alley, S., Reist, C., Roy, M., Rothbaum, B. O., Difede, J. (2015). Virtual Reality Exposure for PTSD Due to Military Combat and Terrorist Attacks. *Journal of Contemporary Psychotherapy*, 1-10. doi: 10.1007/s10879-015-9306-3

Rizzo, A., Parsons, T. D., Lange, B., Kenny, P., Buckwalter, J. G., Rothbaum, B., Difede, J., Frazier, J. , Newman, B. , Williams, J., Reger, G. (2011). Virtual reality goes to war: a brief review of the future of military behavioral healthcare. *Journal of Clinical Psychology in Medical Settings, 18*(2), 176-187.

Rizzo, A. A., Buckwalter, J. G., Forbell, E., Reist, C., Difede, J., Rothbaum, B. O., Lange, B., Koenig, S., Talbot, T. (2013). Virtual reality applications to address the wounds of war. *Psychiatric Annals, 43*(3), 123-138.

Rizzo, A. A., John, B., Williams, J., Newman, B., Koenig, S. T., Lange, B. S., & Buckwalter, J. G. (2012). *Stress resilience in virtual environments: training combat relevant emotional coping skills using virtual reality* Paper presented at the 9th Conference on Disability, Virtual Reality & Associated Technologies.

Scerbo, M. W., & Dawson, S. (2007). High fidelity, high performance? *Simulation in Healthcare, 2*(4), 224-230.

Seidel, R. J., & Chatelier, P. R. (2013). *Virtual Reality, Training's Future?: Perspectives on Virtual Reality and Related Emerging Technologies* (Vol. 6): Springer Science & Business Media.

Shneiderman, B. (1992). *Designing the user interface* Reading, MA: Addison-Wesley.

Stoffregen, T. A., Bardy, B. G., Smart, L. J., & Pagulayan, R. J. (2003). On the nature and evaluation of fidelity in virtual environments. *Virtual and adaptive environments: Applications, implications, and human performance issues*, 111-128.

Summers, J. E. (2012). Simulation-based military training: An engineering approach to better addressing competing environmental, fiscal, and security concerns. *Journal of the Washington Academy of Sciences*, 9-12.

Sutcliffe, A. G., & Kaur, K. D. (2000). Evaluating the usability of virtual reality user interfaces. *Behaviour & Information Technology, 19*(6), 415-426.

Wann, J., & Mon-Williams, M. (1996). What does virtual reality NEED?: human factors issues in the design of three-dimensional computer environments. *International Journal of Human-Computer Studies, 44*(6), 829-847.

Wilkerson, W., Avstreih, D., Gruppen, L., Beier, K. P., & Wooliscroft, J. (2008). Using immersive simulation for training first responders for mass casualty incidents. *Academic Emergency Medicine, 15*, 1152–1159.

Zhao, K. R., Xu, S., Ye, Q., & Li, Y. (2011). *Design and realization of flight simulation system* *based on Virtual Reality technology*. Paper presented at the Control and Decision Conference (CCDC).