The Use of Immersive Virtual Reality for the Test and Evaluation of Interactions with Simulated Agents

Gabrielle Vasquez(✉), Rhyse Bendell(✉), Andrew Talone(✉), Blake Nguyen(✉), and Florian Jentsch(✉)

University of Central Florida, Orlando, FL 32826, USA
{gvasquez, rbendell, atalone, bnguyen, fjentsch}@ist.ucf.edu

Abstract. We aim to better inform the scientific community regarding test and evaluation techniques for validating devices that will potentially be used by individuals interfacing with autonomous robotic teammates (particularly, members of the U.S. Military). Testing within immersive virtual environments (IVRs) similar to those experienced in military operations will be discussed with focus on the use of a commercial gaming engine for task development. Highlights of using commercial gaming engines will be illustrated throughout the paper to emphasize their utility for evaluating future technologies with attention given to testing efficiency and ecological validity. The study of interactions with simulated agents and future communication devices will be described in the context of the Robotics Collaborative Technology Alliance (RCTA) research program.

Keywords: Human-robot interaction · Immersive virtual reality
Simulation

1 Introduction

1.1 Purpose

Overall, our goal is to study human-robot interaction (HRI) topics (situation awareness, usability, trust) relevant to human-robot teaming involving interactions with highly autonomous unmanned ground vehicles (UGVs) and the use of tasks which incorporate principles of serious games and gamification within immersive virtual reality (IVR) environments for studying those topics. Specifically, we are focusing on the use of simulated agents and virtual representations of novel communication interfaces. Important benefits of experimentation in IVR will be emphasized with particular attention given to participant experience (immersion, engagement, learning, motivation), data collection scope (biomechanics, gaze, interaction times, perception reaction time, etc.), and the ability to replicate environments and scenarios that would otherwise be inaccessible.

D. N. Cassenti (Ed.): AHFE 2018, AISC 780, pp. 15–25, 2019.
https://doi.org/10.1007/978-3-319-94223-0_2

1.2 Robotic Collaborative Technology Alliance (RCTA) – Transitioning Robots from Tools to Teammates

As members of the Robotics Collaborative Technology Alliance (RCTA)-a consortium of university, industry, and government researchers seeking to enhance the state of the art in human-robot teaming-we have sought to identify useful methods for testing and evaluating human-robot communication interface designs intended for use with highly autonomous UGVs. The RCTA is primarily focused on advancing four key areas relevant to producing UGVs that move beyond simple tools to useful, autonomous teammates. These areas include: perception, artificial intelligence, mobility and manipulation, and human-robot interaction. If we seek to transition UGVs from their current use as tools to a new role as teammates, then advances in these key areas is essential to achieving this goal.

One key RCTA initiative is to investigate the utility of a multimodal interface (MMI) for optimizing communication and interactions with UGVs (specifically autonomous robotic teammates). Currently, human interactions with robotic teammates are characterized by: (a) a team of dedicated robot operators or "handlers", (b) a substantial amount of time spent "heads-down" viewing a visual display or graphical user interface (GUI), and (c) sustained attention needed to teleoperate, supervise, or manage the robot [1]. Taken together, these characteristics of current human-robot interactions with UGVs require substantial human resources that could be better utilized for other purposes (e.g., completing other critical tasks) [2]. The RCTA's vision for future human-robot teaming is one that involves UGVs communicating with humans in a manner that is similar to how human-human teammates communicate. Characteristics of human-human team communications include: natural, speech based communications, use of non-verbal signals (e.g., gestures), and utilization of both implicit and explicit communication. These characteristics can be incorporated into human-robot communication through the implementation of an MMI. MMIs provide users with the means to interact with a system via more than one sensory modality (e.g., visual and auditory, visual and tactile) [3].

1.3 MMI Evaluation Considerations

Our team is interested in investigating human interactions with robots that have capabilities far beyond current robotic technologies and within environments not easily accessible to the research team. It is for these reasons that we employ other methods for investigating HRI topics. Wizard of Oz techniques are particularly useful, and involve creating illusions in place of some elements of experimental tasks which would otherwise require developing complex systems. This technique was implemented by our team in previous HRI research which used a scale Military Operations in Urban Terrain (MOUT) facility. The MOUT facility served to research HRI in the context of active, on-the-move military scenarios which are relevant for future use of robotics in the field [4]. Primarily, the MOUT facility was created to mimic the way UGVs and unmanned aerial vehicles (UAVs) were used by the military at the time; however, developing a system by which participants could interact with autonomous UVs during experimental tasks was not feasible. Rather than devote time and resources to developing actual autonomous robots, a Wizard of Oz solution was implemented by having one (or more) confederates (out of participant line-of-sight) control the UVs in response to participant commands. This technique proved to be straightforward and reliable which allowed the research effort to progress rapidly. Wizard of Oz methods do not always require an active confederate as the goal is simply to have participants believe that the events of the experiment are real. Given the case of interacting with remote robotic teammates, the illusion could be accomplished with something as low level as playing pre-recorded audio at specific times and letting participants believe that what they are hearing is being generated by an actual teammate completing a task. Our current work investigating human-robot interactions will employ a more complex manifestation by representing a virtual version of a MMI that will allow participants to receive and respond to messages purportedly generated by their remote teammate. By programming the behavior of the MMI and letting participants believe that the data it presents is from an active teammate we can create the illusion of dynamic interactions while maintaining experimental control and repeatability. Additionally tasks will take place in IVR to help engage participants and support the illusion.

As IVR has advanced rapidly in the last decade, consideration should be given to its utility for research in domains that seek to transfer findings into real world practice (the ultimate goal of fields such as HRI). What needs to be established is the ecological validity that using immersive simulation technologies can offer. Because it can be difficult to replicate certain functionalities and capabilities within a live simulation, an IVR environment paired with built-in Wizard of Oz techniques presents an ideal method for investigating human-robot (HR) teaming in a low cost, reliable, and ecologically valid manner.

2 Validity in IVR

2.1 Ecological Validity

Ecological validity describes the relevance of research findings to the real world, and is vital to consider for IVR studies [5]. Studies lacking ecological validity cannot transfer findings to practical applications, and are thereby useless to fields such as HRI (though not necessarily to basic research or the study of cognitive abstractions). It is possible to achieve adequate ecological validity with IVR studies by attending to elements of simulations such as visual realism, physics accuracy, interaction/input familiarity, locomotion, etc.; augmentation of the meaningfulness of findings in these studies may be achieved by additionally incorporating principles of serious games and gamification into experimental tasks. Consideration of such guidelines can help engage and motivate users in tasks so as to elicit reactions and behaviors that are similar to their tendencies in the real world (e.g. ecologically valid performance).

2.2 Gamification and Serious Games

Gamification is a general term used to describe the incorporation of task elements which are enjoyable and interesting to participants. The goal of implementing principles of gamification is to help participants behave as they would naturally, and not as a result of being in a laboratory completing a task (particularly when compensation is involved). An important aspect of gamification is the ability to elicit intrinsic motivation in participants by providing them with a reason to continue exerting effort and maintaining performance. An example of this is the utilization of badges for the Boy Scouts of America: this organization has been able to motivate young children to obtain a mastery of goals, reputation, and identity with the assistance of the extrinsic reward system provided by badges and ceremonies [6]. Additionally, Denny (2013) applied principles of gamification (i.e. rewarding students with badges) in an online, undergraduate course for completion of extra quizzes; this motivated students to go beyond the goals of the course to achieve a higher grade [7, 8]. These cases differ somewhat from experimental tasks as they are less constrained. Gamified IVR tasks must be minutely controlled for the maintenance of internal validity, and a balance must be struck between fun/interest and the production of meaningful results. Achieving the latter is the focus of tasks such as serious games which aim to maximize the applicability of outcomes to real world training, learning, and design [8–12]. Serious games have been shown in past research to help promote learning and knowledge acquisition [13], and elicit engagement, flow, immersion, and a sense of presence [14]. Normally, this is accomplished by gamifying aspects of training tasks to support the immersion and engagement of users [14]; this could be done with the use of badges, points, etc. By implementing dynamic feedback, rewards, into test and evaluation using an IVR simulation, we aim to maintain ecological validity. An example of how we have incorporated these elements is the implementation of a modified signal detection task: performance on this particular task will be automatically calculated during trials (i.e. correct hits and false alarm rates) to give participants an overall understanding of their performance; this will serve to provide immediate feedback and promote motivation in achieving the task objective. Our simulation studies will also achieve validity by replicating real world environments as accurately as possible, and implementing gamified tasks within those virtual realities. The development of the environments for instance will be accomplished by gathering images of urban and rural environments and using the features in the Unreal Engine (a commercial game engine) to recreate them.

3 Immersive Virtual Reality Research Benefits

The principles of gamification may be applied to any simulation that requires human interaction; however, it is likely that incorporation of those principles will be particularly effective in IVR due to shared support of user engagement and motivation. Experiment design rarely takes participant experience into account beyond the consideration of the degree to which it aids the provision of accurate data. Accordingly experiments are designed to be rigid and repeatable, and tend to lose any semblance of enjoyable or familiar tasks that one might encounter in the real world. IVR tasks provide the ability to more accurately mimic complex activities experienced in the real world, and paired with the guidance of gamification can not only elicit real world behaviors from participants but can also promote that behavior by generating an intrinsic desire to continue. It is important for experimental research that participants remain engaged with administered tasks as boredom and disinterest can confound results as strongly as poor training or technical malfunctions.

3.1 Enhanced Presence and Engagement

Commercial hardware designed to present virtual realities can provide enough meaningful feedback to allow users to perform cognitive and manual tasks similarly to how they are performed in the real world. Currently feedback comes primarily in the form of high quality visuals (with high fidelity head tracking to allow for the illusion of motion), a simulation of 3D audio, and a limited amount of vibrotactile information via handheld controllers. While the sensory data provided by simulation tools is a reduced form of what the real world has to offer, it may be enough for most participants to develop a sense of presence and experience immersion in a virtual environment [15–17]. Presence can be considered a measure of the perception one has of physically being in an environment, real or virtual [18–20]. That perception is important for engaging participants and improving performance in IVR studies, and is most effectively created when the virtual reality accurately represents expected reality [21]. Accuracy is sometimes discussed in terms of breadth and depth of sensory stimulation; breadth describes the quantity of sensory modes and depth describes the resolution provided to each sense by virtual reality devices. The depth of current virtual realities is sufficient for creating many engaging tasks, and stimulators such as haptic gloves and displays that can match the resolving power of the human eye can be used to expand the depth range of current technologies. Breadth on the other hand would need to be addressed by more complex systems such as olfactory displays and virtual motion platforms. Interactions with virtual realities has also been shown to improve sense of presence and immersion, and more complex interaction types are an important factor in helping participants behave naturally in IVR. Additionally control over interactions through range of motion and input modes can be implemented at any level from having participants statically view and respond to scenarios to allowing them to move through and interact with a dynamic world. Advancements are being made regularly in the pursuit of improved immersive virtual realities, but their current state is already sufficient for supporting engagement as well as motivation [22].

3.2 Data Collection Benefits

Virtual reality devices both support the performance of natural behaviors and the collection of biomechanic, temporal, and some cognitive data regarding the execution of those behaviors. For example, the information required to match a user's motions to the associated representations in virtual reality is necessarily provided to the devices creating those simulations. That data may be combined with simulation output, and analyzed to reveal tendencies in the motion, input, gaze, task performance metrics, perception reaction time, etc. displayed by participants. One example of why this might be significant for researchers is shown by object identification and signal detection. Foremost the decision a participant makes regarding the identity of a particular object may be recorded as reliably as traditional present-absent signal detection trials, but that data alone may not be enough for researchers to determine which object features and environmental factors were most important in guiding that decision. IVR data collection can allow researchers to analyze the amount of time that participants spent looking at a particular object, which features they fixated on, how much time passed between their first fixation on the object and their decision input action, and even whether they displayed any hesitation when registering their input (provided some degree of motion is required as opposed to only a button press). An object in motion may also have its exact orientation, velocity, world location, and lighting data recorded for quantification of its projection on a participant's eye at every nanosecond of the identification process.

3.3 Real World Scenario Accessibility

Participants' actions in IVR are taken in response to whatever scenario is presented to them, and is not limited by the practicality of running an experiment in the real world. While exciting possibilities exist for basic perceptual research (presenting scenarios with altered physical laws, creating visual illusions in three dimensions, testing audio source localization ability), this capability is extremely relevant for human interaction research as many of the scenarios that are of real significance simply cannot be replicated for testing purposes. A bomb squad searching buildings in a real town for instance has no resources to spare for participation in a research study, and is an overly hazardous and volatile situation for research. Data may be passively collected in special cases for analysis after missions are complete, but repeatability of conditions and events cannot be achieved. IVR can present identical search-and-dispose missions to as many participants as needed and replicate experiences for each one. Though the effects of being in a life-threatening situation may not all manifest due to participants' awareness that they are in a simulation, risk may be induced through gamification and adequate story-telling for generating motivation. The limitations of imposing real risk may be outweighed by the opportunity to conduct tests in dynamic environments requiring large numbers of personnel and technologies such as robotic teammates: conducting research in such scenarios would be impractical for a single participant let alone with sample sizes large enough to reveal meaningful effects.

A particularly useful aspect of using simulations for administering experimental tasks is the ability to present prototypes of technologies that have only been conceptualized. Modeling functionalities and designing a technology's visual appearance are the major requirements for informing a virtual representation that hasn't been physically prototyped. For test and evaluation purposes functionalities and resulting capabilities for future robotic teammates could be developed within a virtual reality simulation, and would not require having to physically build a robot with those features already functioning. For example, experiencing a robot call and respond to reports given by a human could be accomplished with an input button that is programmed to execute the appropriate behavior in the simulation without having to solve the problem of implementing complex hardware.

Because developing new technology takes time and effort, especially in the test and evaluation stage, developing them in simulation can reduce cost and time; developers can determine and implement functionalities and capabilities that can be adjusted as designs are iterated. Such test and evaluation methods can reduce the time and cost that would otherwise be required for fabricating real world prototypes. The field of robotics is a prime example of how simulated prototypes reduce resource requirements: the cost of fabricating a novel robot (excluding the costs of producing designs) includes sensors, computing systems (and typically proprietary programming), locomotion actuators, chassis components, batteries, custom mechanical parts (especially for robots with manipulators), etc. as well as the time and effort of a build team that is skilled enough to assemble parts and problem solve when real world issues arise. The combined costs of manifesting a novel robotic system that is usable for field testing can be tens of thousands of dollars, but the cost of representing that same system in virtual reality can range from under a hundred to several hundred dollars depending on developer pay. Additionally whereas assembling (and debugging) a novel robotic system may take weeks or months, virtually representing a physical appearance and vital functionalities of a robot can be accomplished in a single week by a capable 3D modeler and a VR programmer. Therefore, IVR testing lends support toward the iterative prototyping process that is employed in the development of technologies as it can augment the scope of early model iterations, inform the design of real world interactions, and minimize the resources required for the prototyping phase.

4 HRI Research in IVR

4.1 HRI Relevant Scenarios

Natural behaviors and meaningful performance data can only be elicited from participants if the virtual environment they are experiencing is adequately realistic. This stipulation is necessarily vague as user requirements are not consistent across features of immersive virtual realities. Visual realism for instance has been shown to reach adequate levels of realism for supporting performance far before photorealism or even accurate texturing are achieved [23]. Users tend to expect more realism from functionalities on the other hand: if a lever does not move as anticipated, an item seems like it can be picked up but cannot, or a virtual tool malfunctions or does not behave according to physics users quickly lose their sense of immersion and reject the virtual reality. Achieving adequate realism with simulated robotic agents requires identifying and optimizing the features that users are most likely to require for maintaining engagement and natural interactions. The required features, and their level of realism, will change for any given task set depending on the interaction modes available to users. Given a scenario in which participants are asked to interact with a remote robotic teammate, it is likely that the physical appearance, appearance of locomotion, and essentially all visual elements regarding the physical robot do not require attention. While the stipulation that the teammate is remote (or at least out of line-of-sight) exempts consideration of visual factors, representations of the data and output allegedly generated by the actions of the robot are still necessary. Determination of the form communications should take may be informed by research questions and the relevance of particular data types to the scenario that participants will experience. Examples of the sorts of considerations that may be appropriate for HRI research are discussed below in the context of our current research.

4.2 Use Case: RCTA Experiments

The testing environment we have implemented in IVR is based on a rural, Middle Eastern setting that is meant to replicate a setting similar to a possible modern military operation. This was chosen for the sake of maintaining ecological validity while taking into consideration ability of our chosen development engine, Unreal Engine 4 (UE4), to realistically render such environments. Due to hardware limitations it was determined to be preferable to present relatively simple, uncluttered environments and avoid introducing latency or visual lag to the participant experience. Within the rural environment, participants will be performing tasks that are similar to those that might be executed by dismounted soldier teams. Our primary interests with the study currently in development is the effect of situational awareness and mental workload (with attention to multiple resource theory) on the performance of mission critical tasks. These factors are of interest to the future of human-robot team interactions as effective utilization of autonomous robots implies not interfering with other duties.

Situational awareness describes one's awareness of surroundings, events, objectives, and the changes that occur within relevant environments over time [24]. Given our experimental scenario this includes awareness of what is occurring during a visual search task as well as of the whereabouts, activities, and decisions of remote robotic teammate. The measurement of situational awareness is not consistent in the literature, so we have chosen to distribute verbal SA probes throughout the mission to measure the abilities of users to stay aware of their teammate's actions.

Mental workload is an important consideration for tactical scenarios as overloading can result in serious performance decrements and mission failure. It is considered in the context of mental resources that may be drawn upon for the processing of information and completion of tasks [25]. Multiple Resource Theory (MRT) is a useful method of pinpointing the contribution of various tasks and task elements to experienced workload as it considers the processing capacity and demands on particular sensory modalities [26]. Because there will be an element of time -sharing and a dual-task performance in our experimental design, MRT will allow us to closely investigate the impact of loading (and overloading) audio and visual pathways as well as resulting effects on task performance and situational awareness.

It is very likely that workload impacts situational awareness, and the interaction between the two constructs must be quantifiable for rigorous analysis of either. A simulated commanding officer will be communicate with participants at planned intervals, and inquire about the state of the participant's environment, task, and teammate; responses to these probes will accurately represent a participant's situational awareness during the mission and can be quantified by coding for stratified correct and incorrect responses. While situational awareness will be quantified by the accuracy and speed of participant responses to awareness probes, quantification of workload will be accomplished by detailed performance metrics and validated post trial workload measures. In the mission, the user will be required to perform a signal detection task that will involve selecting potential threats (characters carrying weapons) entering an area, and performance on this task will be considered in tandem with workload measure outcome. As shown in Fig. 1, UE4 is used to create the immersive virtual environment which participants experience through an HTC Vive head mounted display;

participants will be using the HTC Vive controllers to select potential targets for the signal detection task, and provide input to communications from their robotic teammate.

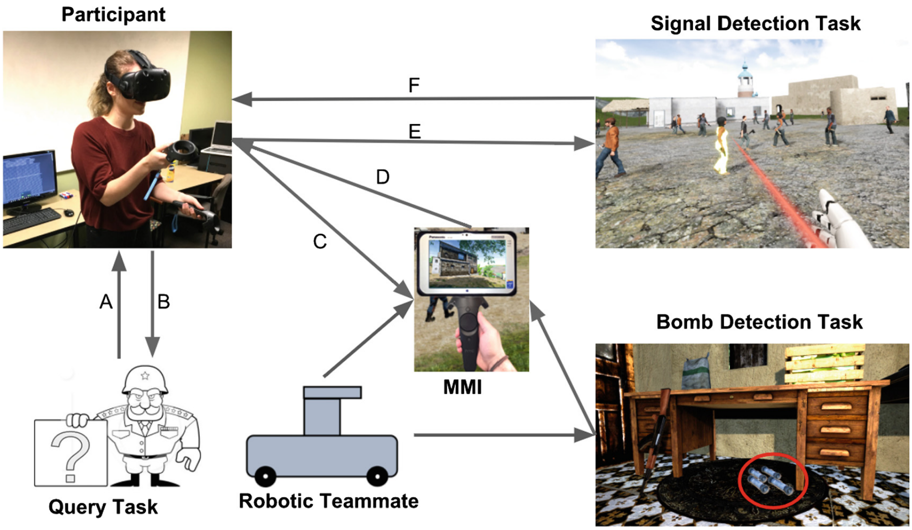

Fig. 1. The three tasks that will be completed by participants for the evaluation of cognitive workload and situational awareness are a signal detection task, a bomb detection task, and a query task. The signal detection task will require participants to view an environment (F) and make input (E) to identify characters who are carrying guns, whereas the query task will require listening to (A) and verbally responding to (B) pre-recorded situational awareness probes. Answers to the probes (B) will derive from information sent to the participant by their simulated robotic teammate (D) via the MMI using visuals or synthetic speech. The bomb identification task will require viewing images (D) and providing input (C) through the simulated MMI. The Wizard of Oz method will be used to generate the robotic teammate, bomb detection, MMI loop that ostensibly feeds into the data sent to participants (C) and reacts to their input (D).

5 Conclusion

The goal with our current projects is to continue using simulations to test HRI topics along with evaluating aspects and functionalities of the MMI and to validate its use for field studies and further research. Others interested in studying HRI topics may considering utilizing simulations developed similarly to the task set described above in order to:

- Ensure their research is able to maintain ecological validity
- Take into account engagement and immersion of users
- Control variables of interest and maintain internal validity

With technology continuously changing and more state-of-the-art technology being released, test and evaluation tools can potentially be implemented in IVR for users to better evaluate the usefulness and efficiency of emerging and near future technologies.

Acknowledgments. The research reported in this document was performed in connection with Contract Number W911NF-10- 2-0016 with the U.S. Army Research Laboratory. The views and conclusions contained in this document are those of the authors and should not be interpreted as presenting the official policies or position, either expressed or implied, of the U.S. Army Research Laboratory, or the U.S. Government unless so designated by other authorized documents. Citation of manufacturers or trade names does not constitute an official endorsement or approval of the use thereof. The U.S. Government is authorized to reproduce and distribute reprints for Government purposes notwithstanding any copyright notation hereon. Support for this endeavor was additionally provided by the University of Central Florida's Office of Research and Commercialization in the form of financial assistance via Mr. Bendell's ORC fellowship.

References

1. Yanco, H.A., Drury, J.L.: Rescuing interfaces: a multi-year study of human-robot interaction at the AAAI robot rescue competition. Auton. Robots **22**(4), 333–352 (2007)
2. Chen, J.Y.C., Haas, E.C., Barnes, M.J.: Human performance issues and user interface design for teleoperated robots. IEEE Trans. Syst. Man Cybern. Part C: Appl. Rev. **37**(6), 1231–1245 (2007)
3. Perzanowski, D., Schultz, A.C., Adams, W., Marsh, E., Bugajska, M.: Building a multimodal human-robot interface. IEEE Intell. Syst. **16**(1), 16–21 (2001)
4. Evans III, A.W., Hoeft, R.M., Rehfeld, S.A., Feldman, M., Curtis, M., Fincannon, T., Ottlinger, J., Jentsch, F.: Advancing robotics research through the use of a scale MOUT facility. Proc. Hum. Factors Ergon. Soc. Ann. Meet. **49**(6), 742–746 (2005)
5. Rizzo, A., Buckwalter, J.: Virtual reality and cognitive assessment and rehabilitation: the state of the art. Stud. Health Technol. Inf. **44**, 123–145 (1997)
6. Deterding, S.: Gamification: designing for motivation. Interactions **19**(4), 14–17 (2012)
7. Denny, P.: The effect of virtual achievements on student engagement. In: Proceedings of CHI 2013: Changing Perspectives, pp. 763–772 (2013)
8. Landers, R.N., Armstrong, M.B.: Enhancing instructional outcomes with gamification: an empirical test of the technology-enhanced training effectiveness model. Comput. Hum. Behav. **71**, 499–507 (2017)
9. Michael, D.R., Chen, S.: Serious games: games that educate, train, and inform. Muska & Lipman/Premier-Trade. Thomson Course Technology, Boston (2006)
10. Abt, C.C.: Serious Games. University Press of America, Boston (1987)
11. Landers, R.N.: Developing a theory of gamified learning: linking serious games and gamification of learning. Simul. Gaming **45**(6), 752–768 (2014)
12. Roth, S.: Serious gamification: on the redesign of a popular paradox. Games Cult. **12**(1), 100–111 (2017)
13. Connolly, T.M., Boyle, E.A., MacArthur, E., Hainey, T., Boyle, J.M.: A systematic literature review of empirical evidence on computer games and serious games. Comput. Educ. **59**(2), 661–686 (2012)
14. Boyle, E., Connolly, T.M., Hainey, T.: The role of psychology in understanding the impact of computer games. Entertain. Comput. **2**(2), 69–74 (2011)

15. Heeter, C.: Being there: the subjective experience of presence. Presence: Teleoper. Virtual Environ. **1**(2), 262–271 (1992)
16. Snow, M.P., Williges, R.C.: Empirical modeling of perceived presence in virtual environments using sequential experimentation techniques. In: Proceedings of the Human Factors and Ergonomics Society, 41st Annual Meeting, pp. 1224–1228 (1997)
17. Witmer, B.G., Singer, M.J.: Measuring presence in virtual environments (Tech. Rep. No. 1014). U.S. Army Research Institute, Washington, DC (1994)
18. Barfield, W., Sheridan, T., Zeltzer, D., Slater, M.: Presence and performance within virtual environments. In: Barfield, W., Furness, T.A. (eds.) Virtual Environments and Advanced Interface Design, pp. 473–513 (1995)
19. Barfield, W., Weghorst, S.: The sense of presence within virtual environments: a conceptual framework. In: Salvendy, G., Smith, M. (eds.) Human–Computer Interaction: Software and Hardware Interfaces, pp. 699–704 (1993)
20. Steuer, J.: Defining virtual reality: dimensions determining telepresence. J. Commun. **42**, 73–93 (1992)
21. Bowman, D., McMahan, R.: Virtual reality: how much immersion is enough? Computer **40**, 36–43 (2007)
22. McMahan, R.P., Bowman, D.A., Zielinski, D.J., Brady, R.B.: Evaluating display fidelity and interaction fidelity in a virtual reality game. IEEE Trans. Vis. Comput. Graph. **18**, 626–633 (2012)
23. Slater, M.: Place illusion and plausibility can lead to realistics behaviour in immersive virtual environments. Philos. Trans. R. Soc. B **364**, 3549–3557 (2009)
24. Endsley, M.R.: Design and evaluation for situation awareness enhancement. Proc. Hum. Factors Soc. Ann. Meet. **32**, 97–101 (1988)
25. Moray, N.: Mental Workload: Its Theory and Measurement. Plenum, New York (1979)
26. Wickens, C.D.: Multiple resources and mental workload. Hum. Factors **50**, 449–455 (2008)