Highlights of "Immersive Sciences" Research in the U.S.A. : Augmented/Virtual Reality and Human Surrogates

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1 INTRODUCTION

This article summarizes examples of Virtual/Augmented Reality (VR/AR) work supported by the United States Office of Naval Research (ONR) during the past decade, in particular work carried out in a particular “Immersive Sciences” research program under the direction of Dr. Peter Squire (ONR Code 30). While not a comprehensive look at VR/AR work in the United States during this period, the work includes examples in three principal areas of AR/VR: Augmented Reality (AR), Locomotion in Virtual Reality (VR), and Human Surrogates. The work was carried out at institutions located across the U.S.: the University of California Santa Barbara (Santa Barbara, CA), Columbia University (New York, NY), Lockheed Martin (Boston, MA), SRI International (Princeton, NJ), Virginia Tech (Blacksburg, VA), Stanford University (Stanford, CA), and the University of Central Florida (Orlando, FL). While most of the work presented here was being pursued in some fashion throughout the past decade, I focus on more recent work—work that is indicative of some current trends in Immersive Sciences.

2 AUGMENTED REALITY (AR)

The U.S. Department of Defense has been supporting research related to Augmented Reality (AR) since at least the 1960s when Ivan Sutherland et al. developed the first head-worn display system with funding from both the Advanced Research Projects Agency (ARPA) and the Office of Naval Research (ONR) [44]. While many think of this as the birth of Virtual Reality (VR), the system was actually an Augmented Reality system employing half-silvered mirror optics and miniature cathode ray tube displays.

From 1997–1999 I co-led a Defense Advanced Research Projects Agency (DARPA) project named “Geospatially Registered Information for Dismounted Infantry” (GRIDS), with Gary Bishop and Vernon Chi at at the University of North Carolina at Chapel Hill. This was a joint effort with Raytheon Defense Systems, Hughes Research Labs, and the University of Southern California aimed at AR outdoors. That effort led to years of AR research at the respective institutions—research that continues to this day. Around the year 2000, the U.S. Naval Research Laboratory began a program called “Battlefield Augmented Reality System” (BARS) [21]. The BARS project—initially led by Larry Rosenblum—supported a wide range of AR research around the U.S.—including some of the work mentioned later in this article. As with GRIDS, much of the BARS research continues to this day.

Here I summarize some VR/AR research supported by the Office of Naval Research (ONR) during the past decade, in particular AR research supported under the “Immersive Sciences” program led by Dr. Peter Squire (ONR Code 30). This includes research simulating AR head-worn displays, exploring AR for task assistance, locomotion in VR, and achieving AR outdoors for training purposes.

2.1 Simulating AR Head-Worn Displays

Even the best of today’s head-worn AR displays are limited in their field of view (FOV), compared to the human visual system. Indeed, the limitations of those displays have limited what researchers can do (have done)—and even limited our thinking about what we *might* be able to do. Prof. Tobias Höllerer et al. at the University of California Santa Barbara (Santa Barbara, CA) have been taking what might be the first steps toward exploring methods we *could* use if we had a wide FOV. To do so they are using their one-of-a-kind *AlloSphere* instrument [2]. The AlloSphere is a space containing a spherical front-projection screen system that is 10 meters in diameter, with stereo imagery, head tracking for one user, and multi-channel surround audio. Users experience the AlloSphere from a physical bridge suspended across the middle of the space. The bridge can accommodate up to 30 people.

Using the AlloSphere they have developed and tested wide-

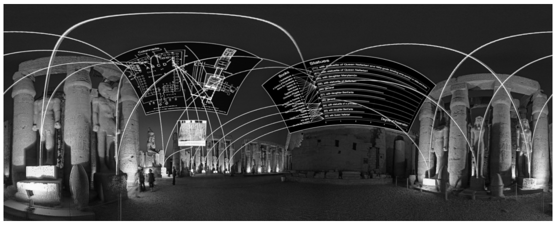

Figure 1: A reproduction of Figure 1 from [36] by Ren et al. at the University of California, Santa Barbara, © 2016 IEEE. Reprinted by permission. The figure depicts the Luxor Temple scene used in their experiments related to field of view (FOV) and tracking artifacts. The original stereo panorama of the Luxor Temple was provided by Tom DeFanti, Greg Wickham, and Adel Saad, with stereo rendering by Dick Ainsworth [1, 41].

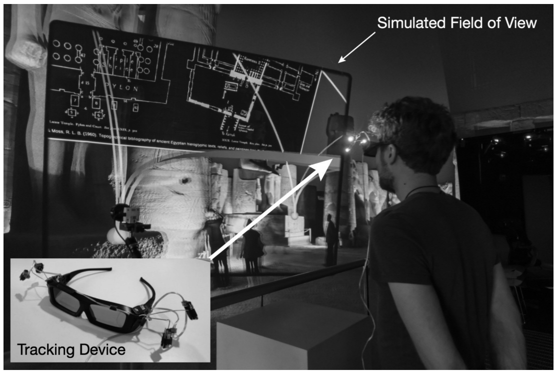

Figure 2: A reproduction of Figure 2 from [36] by Ren et al. at the University of California, Santa Barbara, © 2016 IEEE. Reprinted by permission. The figure depicts a simulation of a head-worn display with a fixed FOV, indicated by the border of the viewport (annotation "Simulated Field of View"). In such a case the user is presented with only a subset of the annotations, compared to the full field of regard indicated in Figure 1.

FOV annotations that link elements far apart in the visual field, and used this to simulate head-worn display devices with varying fields of view and head tracking characteristics. See for example Figure 1. In [37] they presented a basic framework for simulating different mobile display devices for use in Mixed/Augmented Reality. In [36] they share methods for and results from a specific study comparing user performance in a scenario aimed at using the simulated AR interface for an information-seeking task in an archaeological tourism application. As depicted in Figure 2, they compared two different FOVs, with/without tracking artifacts. Perhaps not surprisingly, a constrained FOV (comparable to today's head-worn displays) significantly increased the task completion time. Counterintuitively, they appear to have seen worse performance in terms of success (correctness) in the task for the full FOV condition—an increase in unsuccessful attempts at seeking the information, and increased time in those unsuccessful searches.

Despite the questions re. this phenomena, and how (or whether) we will ever enjoy head-worn devices with such large (unconstrained) FOVs, this work is noteworthy in that very few other researchers in the world could carry out such research. I have personally experienced the unconstrained (full field of view) AR experience and it is remarkable—for the first time I actually felt as if the annotations were anchored and suspended in the world around me. The experience reminded me of similarly compelling experiences I have had in the Digital Immersive Showroom (DISH) developed by Mark Mine at Walt Disney Imagineering [11].

Ironically, while *increasing* the FOV can increase presence and task effectiveness, *decreasing* the FOV can decrease "simulator sickness" often resulting from VR/AR experiences [23, 9]. Fernandes and Feiner at Columbia University (New York, NY) have been exploring ideas for addressing this tradeoff by imperceptibly changing a person's FOV as they move throughout a virtual environment [10] (*Best Paper* award, 3DUI 2016). To explore this idea, the researchers carried out a controlled experiment comprising stationary users wearing a stereoscopic head-worn display that did or did not (two conditions) incorporate FOV-modifying capabilities. The researchers' results suggest that by "strategically and automatically" manipulating the FOV one can reduce the occurrences or severity of sickness without decreasing their perceived level of presence, with minimal awareness of the FOV-modifying intervention.

2.2 Task Assistance in AR

For many years Prof. Steve Feiner et al. at Columbia University (New York, NY) have been exploring the use of AR for "task assistance" between remote collaborators. See for example [18, 17]. Figure 3, a reproduction of Figure 1 from [31], shows two approaches allowing an expert remote user to guide a novice local user to place the top of an aircraft engine combustion chamber relative to its bottom, by interacting with a virtual replica of the top. On the left is an example from their VR-based system to be used by a remote expert advisor, and on the right an example of an AR approach to be used by a local novice user. In [31] the researchers describe the methods and a user study designed to assess the effectiveness. The subjects carried out a task involving the six degree-of-freedom (6DOF) alignment of two parts of an aircraft engine combustion chamber as shown in Figure 3. Oda et al. compared their VR/AR approaches to an approach where the expert used a 2D tablet-based drawing system. The researchers found the VR/AR approach shown in Figure 3(b) to be faster than both the 2D tablet approach and the approach shown in Figure 3(a). (The expert could also work in remote video see-through AR, though that was not tested in the user study.)

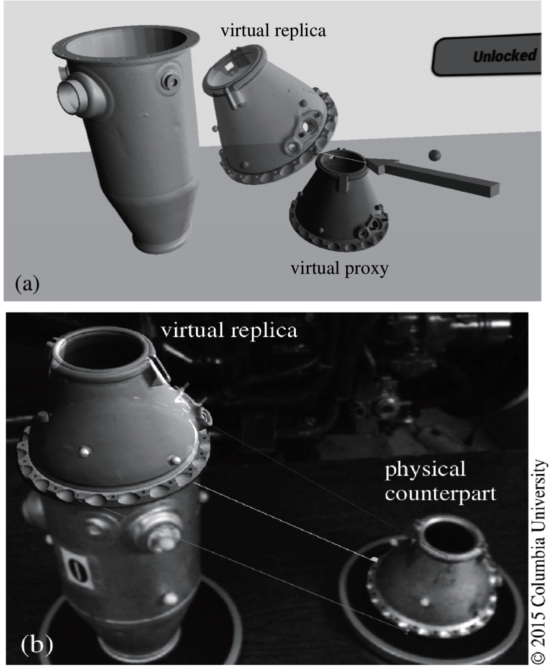

Figure 3: A reproduction of Figure 1 from [31] by Oda et al. at the Columbia University (New York, NY), © 2016 Association for Computing Machinery, Inc. Reprinted by permission. The figure depicts two approaches allowing an expert remote user to guide a novice local user to place the top of an aircraft engine combustion chamber relative to its bottom, by interacting with a virtual replica of the top: (a) an example from the VR system to be used by a remote expert advisor, and (b) an example of an AR approach to be used by a local novice user.

2.3 Outdoor AR

The U.S. Department of Defense has been sponsoring research related to AR outdoors for decades, and continues today with efforts such as the DARPA ULTRA-Vis project [26]. Since 2011, researchers from multiple organizations have been working on an ONR project called Augmented Immersive Team Training (AITT). The AITT project was specifically created to advance the state of the art in outdoor AR to a point where one could realistically simulate battlefield effects, such as munitions explosions, such that the simulations would be useful to U.S. Marines engaged in what is called "force-on-force" training. In particular here we look at work led by Richard Schaffer at Lockheed Martin (Boston, MA) and Dr. Rakesh "Teddy" Kumar at SRI International (Princeton, NJ). Their efforts have been remarkably successful. Relevant publications include [38, 34, 33, 32], which are complemented by an official video summarizing project results [45].

The U.S. Marine Corps Program Manager for Training Systems (PM TRASYS) has been developing a system called I-TESS, that builds on related OneTESS technology originally developed by the U.S. Army. A principal use of the I-TESS system is for training *forward* observers involved in *call-for-fire* and *close-air support* tasks. The OneTESS hardware includes sensors that attach to a real mortar[1] allowing the system to determine the mortar's deflection and elevation angles. The system is designed such that when a simulated mortar round is dropped into the mortar, it would compute the round's simulated impact location and time, and display the simulated impact point on a tablet computer on a 2D map that used various symbols to indicate the objects and fire effects. The goal of the AITT program was to replace the relatively limited tablet-based symbolic representation of mortar detonations with a more natural display of 3D virtual detonations on the trainee's view of the real terrain using real equipment that is modified to support an AR simulation of the outdoor scene, including static and moving objects (friend or foe), and all of the battlefield effects including realistic explosions, fire, and smoke. See for example the military binoculars shown in Figure 4 and the system demonstration results shown in Figure 5—both from [38].

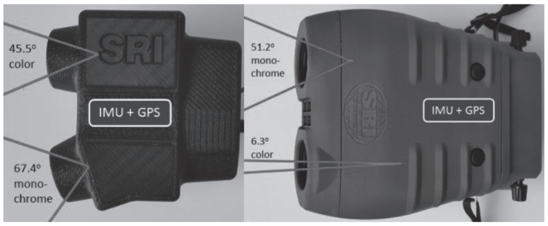

Figure 4: A reproduction of Figure 6 from [38]. Reprinted by permission. Left: a helmet-attached unit. Right: a hand-held unit. Each included a wide field-of-view (FOV) monochrome camera for coarse tracking, and a narrower FOV color camera for augmentation and fine tracking. (Image credit: SRI International, Lockheed Martin, and the U.S. Office of Naval Research.)

Tracking of the AR devices was particularly challenging. On the one hand, because the AR content and associated real world objects would be seen at a distance, the requirements for translation precision and accuracy were less demanding than would be the case for nearer real/virtual objects. On the other hand, whether focusing on near or far objects, the orientation-related challenges remain. Making things even more challenging, the ONR goal was for the equipment to actually be used by real U.S. Marines. As such the AR imagery needed to appear and be registered instantly when the device (e.g., the binoculars) was picked up, and properly appear to move in and out of the field of view as the user moved around a 50 meter by 50 meter area. This presented difficult challenges related to tracking in particular. The

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[1] A short, smoothbore gun for firing projectile munitions at high angles.

Figure 5: A reproduction of Figure 4 from [38]. Reprinted by permission. Images from field tests at the U.S. Marine Corps Base in Quantico during November of 2014 and May of 2015. The top and bottom images reflect augmentation of 1x and 7x views (respectively) with renderings of technical vehicles and munition detonations. (Image credit: SRI International, Lockheed Martin, and the U.S. Office of Naval Research.)

overall tracking approach is to use an error-state Extended Kalman Filter (EKF) [14] to combine inputs from an Inertial Measurement Unit (IMU), Global Positioning System (GPS), and wide and narrow Field of View (FOV) cameras to estimate the navigation state (location, orientation, velocities, accelerometer and gyroscope biases) at a regular rate given sensor measurements arriving at different times.

3 LOCOMOTION IN VR

Another area of interest in the ONR Immersive Sciences portfolio is that of human *locomotion* in Virtual Reality (VR)—how users move from one place to another in a virtual environment. As a part of that effort, this has most recently been explored by Prof. Doug Bowman et al. at Virginia Tech (Blacksburg, VA). In particular that group has recently been experimentally comparing *hyper-natural* locomotion techniques, *semi-natural* locomotion techniques, traditional *non-natural* techniques (using a game controller), and a fully natural technique (real walking).

For many applications, VR developers would wish for a real environment that was as large as the virtual environment, thus allowing the users to naturally walk around at a one-to-one scale. However usually that is not possible, and sometimes not desired. Many semi-natural alternatives with moderate interaction fidelity have been explored over the history of VR, including walking-inplace [40, 46], the use of transitional environments [42], and redirected walking such as pioneered at the University of North Carolina at Chapel Hill (Chapel Hill, NC) and more recently [3, 35].

3.1 Hyper-Natural Techniques

In [28] Nabiyouni and Bowman focus on what they call *hyper-natural* locomotion techniques—techniques that enhance a user's real-world abilities—comparing natural walking with a particular hyper-natural technique based on Seven League Boots introduced by Prof. Victoria Interrante et al. at the University of Minnesota (Minneapolis, MN) [19]. The Seven League Boots technique scales (typically increasing) a user's movement, enabling them to move faster and travel farther with the same physical movement. Nabiyouni and Bowman found that hyper-natural real-virtual transfer function can improve locomotion speed and some aspects of user satisfaction, but that this can come at the expense of accuracy, which could cause a problem for tasks involving precision localization or path following. In [28] they also explored *biomechanical* symmetry—the degree of similarity of the virtual body movements (used in the interaction technique) compared to the real body movements for performing the same task. To explore biomechanical symmetry they ran a user study that employed biomechanical assistance via a specific spring-based athletic shoe—the Kangoo Jumps™ boots. One of the study participants is shown in Figure 6. Perhaps surprisingly, the technique they implemented to provide biomechanical assistance exhibited lower performance and user acceptance than those based on natural walking.

Figure 6: A reproduction of Figure 2 from [28] by Nabioyuni and Bowman at Virginia Tech, © 2015 The Eurographics Association. Reprinted by permission. The figure depicts an experimental subject wearing a tracked head-worn display and a pair of Kangoo Jumps™ boots, which are claimed to provide an effective method for improving aerobic capacity compared to normal running shoes.

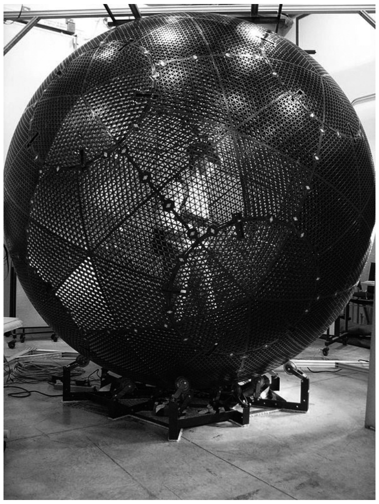

Figure 7: The Virtusphere simulator used in [29]. The Virtusphere is a three-meter hollow sphere placed on a special platform that allows the sphere to rotate freely as a user walks around inside [47]. Here Paul Monday demonstrates a Virtusphere at the Mounted Warfare TestBed, Ft Knox, KY [48].

3.2 Natural, Semi-Natural, and Non-Natural Techniques

The U.S. Army and Navy (Office of Naval Research) have also supported investigation of a device called the Virtusphere—a three-meter hollow sphere placed on a special platform that allows the sphere to rotate freely as a user *inside* the sphere walks around [47, 48]. See Figure 7 for an example. Because results from prior use of the Virtusphere had primarily been anecdotal, Nabiyouni and Bowman et al. undertook a controlled study comparing the Virtusphere and natural walking for tasks involving walking in both straight and multi-segment paths. The researchers found that walking in the Virtusphere was significantly slower and less accurate than virtual locomotion via a joystick (a game controller) or real walking. Based on their results and analyses of experiments published by others, Nabiyouni et al. speculate that either *high*-fidelity (high interaction fidelity) locomotion techniques or well-designed *low*-fidelity locomotion techniques are likely to result in better task performance than *moderate*-fidelity locomotion techniques [29].

4 HUMAN SURROGATES

A surrogate or “stand-in” for a human can be realized by a real human such as an actor, or a technological human such as a virtual human. Such surrogates can assume roles of unavailable humans for purposes such as medical, military, or teacher training. They can appear in a virtual environment or can share physical space [24]. Since 2009 we have been exploring the effects of various characteristics of human surrogates in general, and since 2014 we have been focusing more on effects related to a real human’s senses of social presence and *co-presence* with the surrogate. Lombard and Ditton define presence as the sense of non-mediation, which means that one can perceive presence via a technological medium if one can be totally oblivious to the existence of the medium [25]. There are many interpretations of the terms *social presence* and *co-presence*, e.g., see [7]. Goffman et al. indicate that *co-presence* exists when people sensed that they were able to perceive others and that others were able to actively perceive them [13]. Blascovich et al. define social presence both as a “psychological state in which the individual perceives himself or herself as existing within an *interpersonal* environment” (emphasis added) and “the degree to which one believes that he or she is in the presence of, and interacting with, other veritable human beings” [6, 5]. Harms and Biocca illustrated *co-presence* as one of several dimensions that make up social presence, and they evaluated the validity of their social presence measures by questionnaire [16]. While there is no universal agreement on the definitions of these terms, we generally consider social presence to be one’s sense of being socially connected with the other, and co-presence to be one’s sense of the other person’s presence.

Most research related to social presence with virtual humans has focused primarily on the virtual human itself, e.g., its appearance [12, 43], intelligence [15, 30], and verbal and nonverbal behaviors [27, 12, 4]. While we too have explored these virtual human characteristics, we also believe the contextual surroundings where social interactions take place, and peripheral events—even seemingly inconsequential or imperceptible events, have the potential for indirectly increasing social presence with virtual humans.

In the following three subsections I describe several areas of interest and related experiments. While a team of several people contributed to each of the experiments, they were primarily led by UCF graduate students Kangsoo Kim, Myungho Lee, and Salam Daher respectively. The experiments and some of the explanations below were formulated with them.

4.1 Joint Gaze Behavior

One area of interest to us has been that of the apparent awareness of a virtual human to events associated with the real human. One such example is that of *joint gaze*—the shared gaze by the individuals toward a common object/point of interest. Such joint gaze offers important non-verbal cues that allow interlocutors to establish *common ground* in communication between collocated humans. Joint gaze is related to but distinct from *mutual* gaze—the gaze by the interlocutors towards each other such as during eye contact, which is also a critical communication cue.

Figure 8: Virtual human exhibiting mutual gaze (left) and joint gaze (right) as depicted in Figure 1 of [20].

In 2014–2015 we conducted a user study to compare real human perceptions of a virtual human (VH) with their *expectancy* of the VH's gaze behavior [20]. The experiment was based on what we believe would be a common expectation related to joint gaze. As shown in Figure 8 we structured the experiment such that subjects were exposed to a virtual human playing the role of a new student on campus who is lost and urgently needs directions to get to a new student orientation session. Normally (in reality) if you attempted to explain directions to such a lost student, while pointing toward and looking at features on a map, you would expect the student to also look at the map. If the student does not look at the map, you might be puzzled and wonder whether they are paying attention. Such an occurrence could be characterized as an *expectation violation*. A positive (or negative) expectation violation in this case would correspond to when the subject initially has a low (or high) expectation for the student's joint gaze, and then later evaluates the student more positively (or negatively) after they actually interact with a student who exhibits (or does not exhibit) joint gaze. We hypothesized that an expectation violation related to a VH's joint gaze in this scenario would influence one's perceptions of the VH.

Our experiment included two conditions associated with the VH's gaze behavior: (i) *mutual gaze only* and (ii) *mutual gaze with joint gaze*. While the VH always looked at the subject's face without looking down to the map in "mutual-only" condition, he looked at the map occasionally in the "mutual+joint" condition. In both conditions, the VH exhibited small natural upper-torso movement and eye blinks. In a between-subjects fashion the subjects experienced both conditions and evaluated both versions of the VH. We found evidence of positive responses when the VH exhibited joint gaze, and preliminary evidence supporting the effect of expectancy violation, i.e., more positive perceptions when participants were presented with VH's gaze capabilities that exceeded what was expected. In some sense a negative expectation violation could be related to the need for plausibility in immersive virtual environments as reported by Mel Slater in 2009 [39]. In other words, an absence of joint gaze behavior might seem implausible or at least puzzling, leading to a reduced sense of presence with the avatar.

4.2 The Wobbly Table

Beyond the direct behavior of the surrogate (e.g., virtual human) as illustrated in the joint gaze experiment described above, we have developed a growing interest in the power of peripheral events— even seemingly inconsequential or imperceptible events—to indirectly affect social presence with virtual humans. This belief is based on an expected increase in mutual awareness [13] and the sense of a shared interpersonal environment [6, 5].

One class of potentially impactful peripheral events are those related to joint physical contact. For example, while performing everyday interactions, humans often mutually or simultaneously touch and move objects, often in subtle or imperceptible ways. For example, when one person hands a drink to another, at some point both individuals will be touching the glass, and consequently exerting small (often unnoticed) forces on the other person. Similarly if two people are simultaneously using a (shared) piece of furniture, e.g., a table or a couch, movement of one person might be detected by the other person. The awareness might be conscious or sub-conscious.

To explore this idea we ran an experiment to assess how presence and social presence are affected when a subject experiences subtle, incidental movement through a real-virtual table that they share with a virtual human across from them [22]. Specifically we constructed a real-virtual room with a table that spanned the boundary between the real and virtual environments as shown in Figure 9. The participant was seated on the real side of the table, which visually extended into the virtual world via a projection screen, and the VH was seated on the virtual side of the table. The real and virtual humans interacted by playing a simple guessing game.

Figure 9: The physical and virtual setting of our "wobbly table" experiment with the virtual human in view [22].

During the game, half of the subjects experienced subtle "wobbly" movements of the real-virtual table: the entire real-virtual table tilted slightly away/toward the subject when the virtual/real human leaned on it, and after several such wobbles the virtual human exhibited basic awareness via her body language as shown in Figure 10. Those who experienced the shared wobbling of the table felt higher presence and social presence with the virtual human in general, with statistically significant increases in presence, co-presence, and attentional allocation. In [22] we present the experiment and results, and discuss some potential implications for virtual human systems and some potential future studies.

Figure 10: Example gestures used by the Virtual Human in [22].

4.3 Social Presence Priming

When you encounter a second human in real life, for example at an airport information desk, that second human is often times already engaged in idle conversation with yet another (third) human. Generally (hopefully) they will interrupt or finish their ongoing idle second-third human conversation to attend to you. A scenario like this seemed to offer another potentially interesting peripheral or incidental event to explore. We were curious about whether exposure to a VH participating in a socially engaging discussion with a real human—i.e. exhibiting apparent social presence—could cause the subject to perceive the VH as being more socially engaging during a subsequent conversation.

To explore this question we carried out a human subject experiment as described in [8]. Specifically, we used the same shared environment described above and shown in Figure 9. Half the subjects (the experimental group) were briefly exposed to an engaging social interaction between a VH and a nearby real human, after which the real human departed. The other half of the subjects (the control group) were not exposed to the prior VH-real human interaction. All subjects were (then) asked to play the same (as described above) simple guessing game with the VH. The procedure is depicted in Figure 11. During the Preparation phase shown in Figure 11(a) the subjects in both groups filled in questionnaires before entering the room. During this time, only the experimental group heard "Katie" (the VH) and "Michael" (the real human) having a muffled conversation. The control group was not exposed to such a conversation. During the Priming phase shown Figure 11(b), subjects in the experimental group were exposed to Michael and Katie ending their conversation as the subject entered the room. We characterized that brief interaction between Michael and Katie as a form of *social presence priming* of the subject. In the control group Michael was not present so the subject did not witness the conversation. The Interaction phase shown in Figure 11(c) was the same for both groups. Michael was not present for the control group, while for the experimental group Michael left the room first then the simple guessing game between the subject and Katie started. In our preliminary experiment, both attention and affective attraction for the VH were found to be significantly higher for the experimental group compared to the control group.

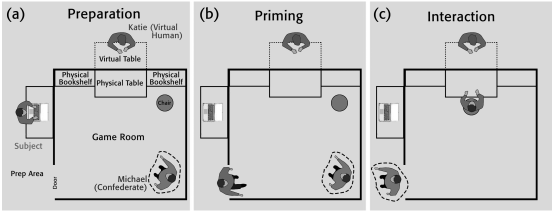

Figure 11: A depiction of the three phases of the experimental space during the experimental interaction: (a) Preparation, (b) Priming, and (c) Interaction. The dotted line around Michael (blue shirt) indicates that he was optionally present: he was present for the experimental group and not present for the control group.

We also examined the etiquette subjects followed at the end of the guessing game interaction. Our expectation was that people who felt a greater social connection to the VH would end the conversation in a polite manner. To that end we reviewed video of each subject looking for polite conversation endings such as "Good bye" or "See you later" or "Thank you," or some form of an appropriate non-verbal acknowledgement. We found that subjects in the experimental group were more likely to end the conversation with the VH politely, compared to those in the control group. As an additional measure we caused the VH to sneeze and noted the response of each subject. Specifically, after the completion of the post questionnaires, subjects were asked to return to the room and face the virtual human again. When they did so, the virtual human sneezed violently in the direction of the subject. (Because this was done after the post-questionnaire, there was no impact on those measures.) We reviewed the videos of the subjects to see if they said "Bless you" or somehow indicated polite concern after the sneeze. We found that subjects in the experimental group were more likely to politely acknowledge the VH's sneeze compared to those in the control group.

We plan to carry out a further experiment to investigate whether similar effects can be obtained from the use of a virtual human for the social presence priming, i.e. to see if two VHs conversing with each other could be as effective as a VH conversing with a real human. If so, that could be a relatively easy way to improve interactions with virtual humans.

5 CONCLUSIONS

While this article was focused on examples of "Immersive Sciences" research supported by the U.S. Office of Naval Research (ONR), I believe that the work offers a diverse sample of AR/VR research being carried out at institutions located across the United States during the past decade. Each of these projects has produced new researchers (e.g., PhD students) in the past—and will continue to do so in the future—both in the U.S. and internationally.

It is also worth noting that the projects I summarize here present examples of good opportunities for joint collaboration with interested international researchers via support from the U.S. Office of Naval Research Global (ONR Global). ONR Global is a separate organization from ONR in the U.S., and is primarily focused on building and fostering international (global) research, including possibly (though not required) connections with ONR-supported researchers in the U.S. A primary mechanism for fostering international global research is through research grants by ONR Global to the international collaborators at their home institutions. I personally have experienced the effects of such support to international colleagues.

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