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TARGET ARTICLE

Immersive Virtual Environment Technology as a Methodological Tool for Social Psychology

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Historically, at least 3 methodological problems have dogged experimental social psychology: the experimental control–mundane realism trade-off, lack of replication, and unrepresentative sampling. We argue that immersive virtual environment technology (IVET) can help ameliorate, if not solve, these methodological problems and, thus, holds promise as a new social psychological research tool. In this article, we first present an overview of IVET and review IVET-based research within psychology and other fields. Next, we propose a general model of social influence within immersive virtual environments and present some preliminary findings regarding its utility for social psychology. Finally, we present a new paradigm for experimental social psychology that may enable researchers to unravel the very fabric of social interaction.

Allport's (1985) well-accepted definition of *social psychology* as "an attempt to understand and explain how the thought, feeling, and behavior of individuals are influenced by the actual, imagined, or implied presence of others" (p. 3) points to the breadth of the discipline. Most social psychologists have become specialists within one or more of the major domains identified by Allport (thoughts or cognitions, feelings or affect, and behavior or actions). Some carefully isolate effects relevant to social interaction in one domain, whereas others examine cross-influences among the domains themselves (e.g., emotions and cognitions, cognitions and behavior).

We find it interesting, however, that social psychologists[1] have blurred Allport's (1985) presence distinctions (i.e., actual, imagined, or implied), at least in terms of the methods and stimuli they use. Many, if not most, social psychologists apparently assume that empirical reference to and experimental manipulations of actual, imagined, or implied human stimuli are essentially equivalent for understanding social psychological processes. The logic underlying this assumption is compelling only if one further assumes that identical processes underlie actual, imagined, and implied presence effects.

Although we can debate the substance and logic of this equivalency, the pragmatic value of its assumption makes it palatable and even appealing to laboratory researchers. Creating stimuli based on imagined or implied presence costs less, requires less effort, and quite importantly, provides a greater degree of experimental control than creating stimuli based on the actual presence of others. Not surprisingly, then, social psychologists have traditionally relied on creating illusions of reality based on scenarios in which imagined or implied presence plays a major role (Korn, 1997).

Traditional Methodological Problems in Social Psychology

At least three major methodological problems have dogged experimental social psychologists for decades: the experimental control–mundane realism trade-off, lack of replication, and the use of nonrepresentative samples. We discuss each of these problems before turning to a possible technologically-based solution to all three.

The Experimental Control–Mundane Realism Trade-Off

Social psychologists have based experimental scenarios (i.e., illusions) on empirical stimuli ranging from inexpensive and simple written vignettes (e.g., a

[1]We do not believe that social psychologists are alone among research psychologists in blurring this distinction.

choice–dilemmas item; Kogan & Wallach, 1964) to more expensive and complicated scenarios involving trained actors (i.e., confederates) and elaborate props (e.g., an experimental casino; Blascovich, Veach, & Ginsburg, 1973). The former facilitate experimental control (i.e., precise manipulation of independent variables), and the latter facilitate mundane realism (i.e., the extent to which an experiment is similar to situations encountered in everyday life; Aronson & Carlsmith, 1969).

Ideally, mundane realism increases participants' engagement within experimental situations and their sensitivity to independent variable manipulations, thereby increasing experimental impact (i.e., the degree to which experimental manipulations affect participants with the intended effect). As Lewin (as cited in Korn, 1997) stated:

> If one makes use of elaborate arrangements or even creates situations with strong forces, as theoretical requirements also demand shall be the case, then only a very small percentage of experimental subjects will act as though they feel themselves to be experimental subjects. Others soon get involved in the situation and accordingly become free and natural. (p. 42)

Most would agree that simple written vignettes are far less compelling (i.e., many participants will feel as though they are in an experiment) than the more elaborate staged scenarios that Lewin described. Thus, in general, the more elaborate and complicated the scenario, the more compelling the experimental situation will be for participants.

Unfortunately, however, our more elaborate experimental situations generally engender both increased costs (time and money) and a loss of experimental control. To the extent that experimental situations or scenarios are sterile or austere (i.e., simple and lacking in realistic stimuli and environments), control of extraneous variables is facilitated. A simple vignette, for example, is easy to control. Conversely, the more complicated the scenario is, the more control problems can arise, for example, keeping confederates unbiased and blind to condition. Furthermore, keeping confederates' verbal and nonverbal behaviors and other actions exactly the same (except when experimental manipulations call for differences) is difficult, if not impossible, to accomplish. Consequently, a trade-off typically exists between experimental control and mundane realism: the higher the mundane realism, the lower the experimental control. Thus, although experimental control is greater in more sterile scenarios, mundane realism is generally reduced, thereby lessening the overall experimental impact (Aronson & Carlsmith, 1969; see Figure 1a).

Many social psychologists have sacrificed experimental control in favor of mundane realism and generalizability by turning to surveys and field experiments. Both play an important role in social psychology and both have been used with great success. However, the laboratory, with its imbued sense of control, still holds great appeal as reflected by the fact that the overwhelming majority of studies published in major social psychological journals have been experimental or quasi-experimental in nature.

Historically, technological advances have allowed researchers to lessen the mundane realism–control trade-off. As telecommunications and computer technology and their integration have advanced, for example, the simple written vignette has given way in many instances to multimedia scenarios. Similarly, photographs began to accompany written vignettes early on, and audio-recording technologies facilitated an increase in the realism of human stimuli (e.g., Milgram's 1963 "learner"). Moreover, the advent of inexpensive video-recording technology allowed participants to hear and see controlled human stimuli (e.g., Simons, 2000).

More recently, computer-based digital recording and editing capabilities have enabled researchers to system-

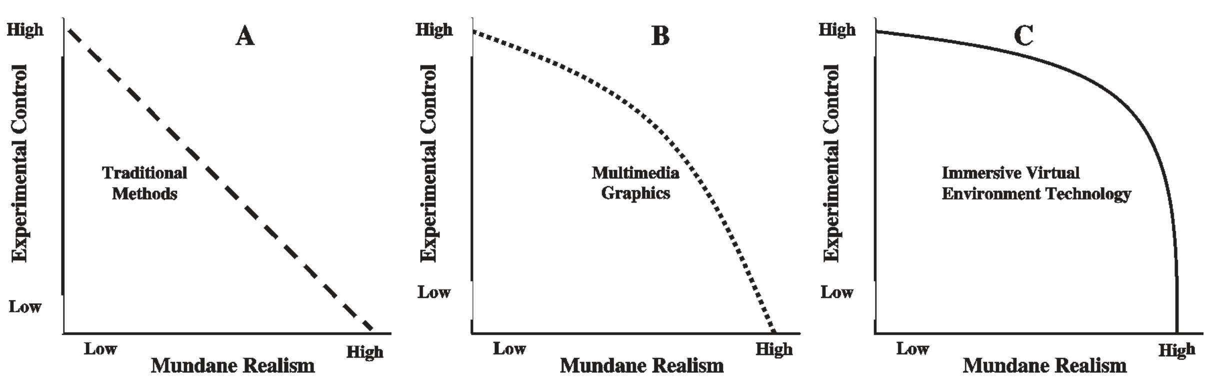

Figure 1. *(a) The experimental control–mundane realism trade-off and the impact of (b) multimedia graphics and (c) immersive virtual environment technology on this trade-off.*

atically and conditionally control the presentation of human images, even animated and three-dimensional ones. Thus, experimenters can arrange a sequence of human images that includes verbal and behavioral responses that are based on a participant's intervening responses (e.g., Massaro, Cohen, Daniel, & Cole, 1999). Sophisticated technology has enabled investigators to increase mundane realism without entirely sacrificing experimental control (see Figure 1b). However, the effects of incorporating such high-tech (e.g., three-dimensional computer graphics) or even low-tech (e.g., photographs) marvels into our illusions has seldom been studied systematically.

Lack of Replication

Replication, particularly exact replication, remains problematic in social psychology for at least two reasons. First, unlike its sister physical and life sciences, our gatekeepers (e.g., editors, grant review panels) do not seem particularly keen on publishing replications. Indeed, it is difficult to publish a purely cross-sectional replication from an independent laboratory in a major journal. Moreover, it is nearly impossible to publish a failure to replicate except perhaps in relatively obscure journals.[2] Not surprisingly, then, we may have a large "file drawer" problem (Rosenthal, 1979) in social psychology.

A second and more substantive reason for the dearth of replications in social psychology is the difficulty researchers experience implementing and using the exact methods and procedures of other investigators. This difficulty stems, in part, from a paucity of detailed information in the methods and procedures sections of articles in our journals. (e.g., How did the confederates dress? What tone of voice did they use? How were they trained? What color was the experimental room?) The transmission of "lab lore" (Aronson & Carlsmith, 1969) from lab to lab or even within the same lab over time occurs relatively infrequently. Hence, a procedures section that reports, "participants were led to believe … " without specifying exactly how, makes replication difficult without inside information on what worked and what did not work to create the illusion. Replication difficulty also stems from the fact that researchers do not share physically identical laboratories, thereby eliminating perfect replications of scenarios.

Nonrepresentative Samples

Finally, we have a sampling problem. Although experimental control and, hence, internal validity demands random assignment of participants to conditions (Campbell & Stanley, 1963), it does not demand random or even representative participant selection. However, lack of random assignment and selection poses a major threat to external validity and generalizability. Nonetheless, this does not appear to have halted experimental social psychology in its tracks—far from it. Most experimental social psychologists still use samples of convenience, typically college students, whom they do not select randomly, even from their own cohort.

Again, technological improvements may increase the incidence of more representative sampling in the future. The vast and relatively recent advances in computer networking technology (i.e., the Internet) hold promise for alleviating the problem of nonrepresentative sampling in social psychology, making more representative and possibly even random sampling from target populations more practical.

Virtual Environments

Virtual reality, or *virtual environments* (VEs) as many scientists prefer, caught the attention of both the public and researchers during the 1990s (Biocca & Levy, 1995), although the seminal ideas and even technical prototypes extend back nearly 45 years (Kalawsky, 1993). We define a VE as synthetic sensory information that leads to perceptions of environments and their contents as if they were not synthetic. An *immersive virtual environment* (IVE) is one that perceptually surrounds an individual. Immersion in such an environment is characterized as a psychological state in which the individual perceives himself or herself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli (Witmer & Singer, 1998). A shared, or collaborative, IVE is one in which multiple individuals are perceptually surrounded by the same VE. Typically, either a virtual human-like figure or some nonhuman object represents each user in a shared IVE.

VEs, IVEs, and shared IVEs, in theory, may be primarily visual, auditory, haptic (e.g., touch), olfactory, gustatory, or thermal or be any combination of these senses. Typically, VEs allow for action, movement, and sometimes speech on the part of users. Today, VEs are created in software and delivered to users via computer hardware (discussed later).

Arguably, social psychologists have been creating virtual (i.e., synthetic) environments, even immersive ones, for decades using hard scenery, props, and real people (i.e., confederates). Milgram's (1963, 1974) obedience environment, for example, is well known and has been well publicized. Its impact was unquestionably strong, indeed so strong and compelling as to have raised major ethical questions regarding the power of

[2] However, *Representative Research in Social Psychology,* published by the University of North Carolina Press, makes an effort.

such environments to convince participants of their own capabilities for immorality (Baumrind, 1964). Milgram's (1963) research became famous initially because his demonstration that so many of his participants obeyed an authority figure, even in the face of evidence that they were physically harming someone else, was thought to be counterintuitive. However, as Mixon (1972) pointed out, given the compelling nature of his synthetic environment, what should be counterintuitive or surprising is the number of Milgram's (1963) participants who did not obey. Similarly, Zimbardo's prisoner–guard study (Haney, Banks, & Zimbardo, 1973; Zimbardo, 1973) created a synthetic environment that was so compelling as to cause Stanford students randomly assigned to the role of prison guard to abuse fellow students assigned to the role of prisoners. Moreover, those "prisoners" assumed a stigmatized "criminal" identity. The impact of Zimbardo's synthetic environment was so great that he had to terminate the study halfway through its planned duration.

Clearly, social psychologists can create compelling scenarios, and just as clearly, such scenarios can create ethical issues. However, they need not, as there is no necessary relation between compelling experimental scenarios and the mistreatment of participants. Synthetic experimental scenarios created out of concrete props are costly, difficult to control, as Zimbardo (1973) found, and consequently expensive and difficult to replicate.

Today, however, we can create VEs and IVEs using laboratory computer technology. Using high-resolution graphics computers and sophisticated software, we can create and store VEs, or "worlds," as three-dimensional databases. With laboratory PC processing speeds currently in the gigahertz range and doubling approximately every 18 months, we can render appropriate visual, auditory, and even haptic information to users within milliseconds. This rendering rate is fast enough so that users typically do not experience perceptible lag between changing their orientation or position within a VE and the scene that they subsequently experience.

The Promise of IVEs for Social Psychology

We believe that social psychologists can, in many cases, ameliorate, if not solve, the dogged methodological problems described previously by adopting IVET as a research tool. Just as earlier advances in technology have helped expand the operating characteristic (i.e., the experimental control–mundane realism trade-off; see Figures 1a and 1b), we believe IVET will expand it even further (see Figure 1c), perhaps someday eliminating the trade-off altogether. IVEs provide a compelling sense of personal, social, and environmental presence for users (Heeter, 1992; Held & Durlach, 1992; Witmer & Singer, 1998), while allowing the investigator near-perfect control over the experimental environment and actions within it.

Replications, or at least near-perfect replications, become quite possible. Having access to another investigator's complete and exact experimental situations and procedures via access to a computer simplifies replication. Hence, one can replicate and extend experiments without fear of nagging differences or missing information (e.g., lab lore) between the replication and the original experimental environment. Another investigator's scenario is only an e-mail or a mouse click away.

Finally, the sharing of VEs allows not only for cross-sectional replication but also for more representative sampling. Whole experiments can be carried out concurrently in multiple laboratories via networked collaboratories. As Internet technology certainly makes possible, large demographically documented sampling frames will become available to researchers, allowing for equal probability sampling methods (Schwarz, Groves, & Schuman, 1998) and easy contact with potential research participants. As IVE entertainment technology reaches into homes in the future, it may even become possible to run experiments on participants that are truly representative of the populations to which we want to generalize.

In the remainder of this article, we discuss several topics that we believe necessary to understand the diffusion of IVET in social psychology. First, we briefly discuss key elements of IVET conceptually. Next, we propose a general model of social influence within IVEs. Finally, we review research and research ideas pertinent to the model and the adoption of IVET by social psychologists.

Immersive Virtual Environment Technology

The historical record traces continuous and exponential advances in the technology of analog representations of the physical environment and objects within it. From cave drawings and sculpture in ancient times to modern paintings, photography, movies, and audio and video recordings, humans have progressed markedly in their development of creative technology. These technologies have allowed us to produce analog or virtual representations of environments, including other people, whether actual, imagined, or implied. Although some of these technologies provide a fairly immersive experience (e.g., Imax® films), recent advances in digital computing and associated hardware and software have introduced new technologies that enable individuals to create even more compelling, immersive virtual experiences.

Overview of the Technology

Compelling IVEs require careful integration of hardware and software systems, including multimedia development software, databases, computers, rendering engines, and user interfaces. Figure 2 represents this integration. The user interface (Figure 2a) includes both a tracking system and a display system. The tracking system sends appropriate data to a computer (Figure 2b), which determines the user's position and orientation in virtual space and creates a set of coordinates by which to select appropriate information from a three-dimensional graphics database and appropriately render sensory information back to the user (Figure 2c). Thus, for example, with regard to visual information, if the user's head turns to the right, he or she views what is located on his or her virtual right, if the user's head turns to the left, he or she views what is located on his or her virtual left. Similarly, proper renderings are made for looking up or down and for moving toward and away or even for tilting and turning upside down. Acoustic and haptic renderings can similarly be generated by the systems of today.

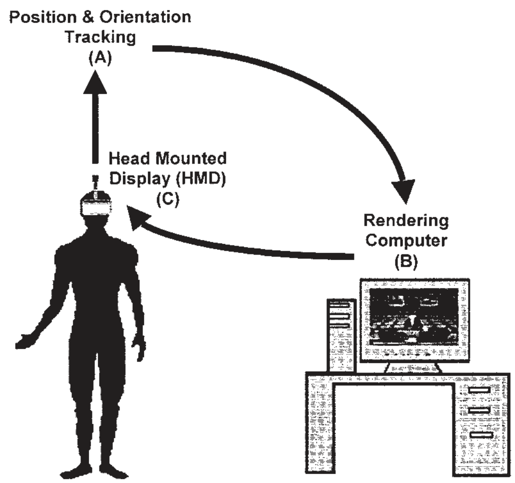

Figure 2. *Conceptual depiction of immersive virtual environment technology.*

Software

A *software toolkit* (i.e., an integrated set of individual software application programs) allows users to create VEs or worlds with a minimum of training but lots of practice. Much software is available freely (i.e., as shareware) or commercially.[3] Virtual worlds are simply synthetic representations of real or imagined physical worlds, albeit without the physical laws of nature necessarily applying. Like physical ones, VEs may appear seemingly boundless (e.g., the surface of the moon in space), or they may appear contained or delimited (e.g., the inside of a casino).

Basically, one needs to construct a three-dimensional model of a superordinate space (e.g., a room) and objects within it (e.g., chairs, computers, people). Every point in space is identified by three coordinates (e.g., x, y, and z) indexing a data point in a three-dimensional database. The size of the database is determined both by the overall dimensions of the world and the desired resolution within that world. Thus, three-dimensional databases representing virtual worlds can be relatively large.

High-level languages allow the creation of the superordinate space and the importing of three-dimensional models into it.[4] Both the space and the models are constructed with various two-dimensional polygons (e.g., triangles, squares). For example, Figure 3 depicts a wireframe model of a space constructed from six rectangles. Once the wireframe model of the space is created, surfaces of various patterns including photographs, colors, and translucencies can be added. Figure 4A depicts a textured or surfaced virtual space, the walls of a virtual casino. VE creators must also add light sources. Virtual light sources can be ambient or focused and can vary in terms of wavelength, intensity, saturation, and so on. Similarly, virtual worlds have neither a magnetic field nor gravity. The latter is useful to add via software if the virtual world is to be Earth-like, although one can fix objects in virtual space independent of the "gravitational pull" of other objects.

Object models are created and surfaced in the same way that virtual spaces are created. Indeed, a virtual

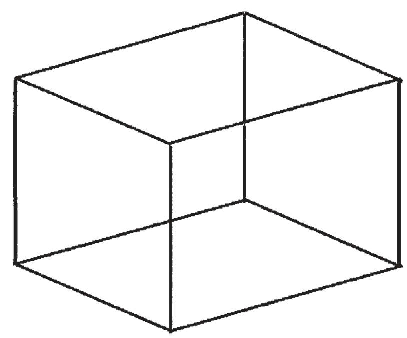

Figure 3. *Illustration of a wireframe room composed of six rectangles.*

[3]For a list of the current software we use, please contact Andy Beall: Beall@psych.ucsb.edu.

[4]For example, Vizard®, our own in-house rendering software library.

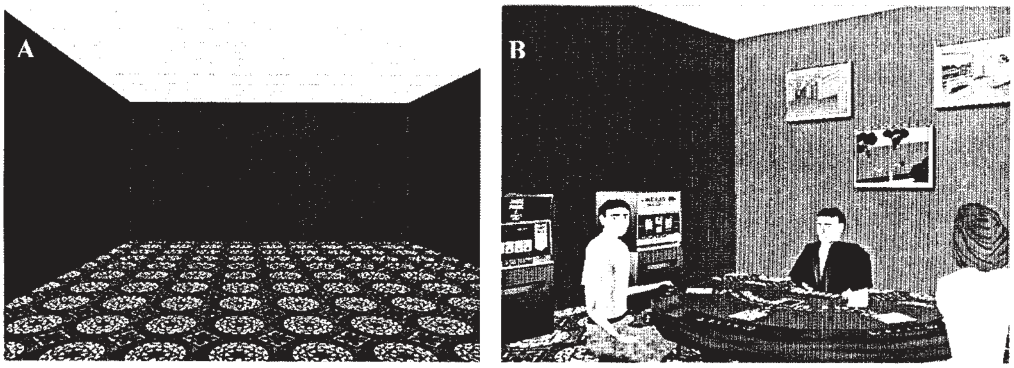

Figure 4. *Virtual space (a) with textured surfaces and (b) populated with virtual humans and other objects.*

world is simply a superordinate model of a space (e.g., a room) with smaller models (i.e., objects) within it. The creator can place and orient the object models at will in the virtual space or world. The virtual world need not be populated solely by visual models but can also easily be populated with models of sound and less easily, but possibly, with models of touch or smell. For example, we transformed the room depicted in Figure 4a into a casino by adding models of objects, including a blackjack table, slot machines, gaming chips, a dealing shoe, playing cards, stools, carpeting, light fixtures, and so on (Swinth & Blascovich, 2001). We also added human figures, including a dealer and blackjack players (see Figure 4b).

Once a model has been created, whether of a superordinate space or an object, the creator can store it digitally. Others can use it or change it, making their alterations available, in turn, to others. Thus, unlike with the use of physical objects or props (e.g., a real blackjack table), which must be replicated physically each time they are needed to create an illusory physical environment, digital object models need only be created once, a fact now well known among digital effects creators in the movie business. Perhaps tens, if not hundreds, of thousands of three-dimensional object models exist, and one may access many of them freely via the World Wide Web.[5]

Moreover, virtual worlds need not be static, a fact of great importance to social psychologists. Objects within VEs may move on their own, be controlled by real people or forces in the physical world, or react automatically, conditionally, or both to the actions of other objects. For example, when a human object representation touches a switch, a light, music, or both may "come on." Hence, worlds can be scripted (i.e., programmed) in the traditional sense of computer programming for action or change. By means of speech-recognition software, a user or participant saying, "Hit me," can cause a virtual blackjack dealer to give another card to him or her. Touching a key on a virtual keyboard can cause a character to appear on a virtual monitor.

If the past is any guide, software toolkits for creating VEs for scientific and other purposes will only become less expensive, easier to use, and more sophisticated as time passes. Libraries of three-dimensional models will grow exponentially. Even today, individuals in elementary school, junior high school, college, and graduate school are programming virtual worlds. Our students, if not ourselves, are or will be very facile with three-dimensional multimedia programming.

Hardware

Rendering engines. Digital computers are the heart of IVE systems today. As recently as the spring of 1998, the only computers that could provide the high performance necessary to track participants, store a database, and render virtual scenes properly were expensive (i.e., > $100,000) graphics computers. By the fall of 1998, however, inexpensive ($2,000) personal computers were capable of providing the necessary platform. The addition of a second processor and peripheral video-capture boards for video tracking and a dual video-display board for stereoscopic presentation of visual stimuli provide a sophisticated IVE computer engine.[6]

Tracking. A wide variety of available systems provide researchers with a choice of technologies for tracking the orientation and movements of users within an IVE. Tracking is important for two reasons. First, tracking is necessary to determine what portion of the scene or database is contained in the field of view to be

[5]Good sites to start with include: http://www.geometrek.com, http://avalon.viewpoint.com, http://www.web3d.org/vrml/vrml.htm, and http://www.dcs.ed.ac.uk/home/objects/vrml.html.

[6]At the time of writing, we used 800-mHz, dual-CPU, Intel Pentium III® computers with Evan and Sutherland Tornado 3000® graphics cards and 380 megabytes of RAM.

rendered to a user in an IVE. Second, tracking is necessary to render tracked objects themselves within a VE.

Simple, nonarticulated objects, such as tables, chairs, and wheels, require relatively simple tracking because the entire object moves (i.e., "translates") and/or rotates (i.e., "changing orientation") rigidly in the same direction at all times. Articulated objects, such as jackknives and people, generally require more complicated tracking. For example, if one wants to render a human user's representation in a VE, such as the reflection of the representation in a virtual mirror, one needs to track various user movements (e.g., limb, head, and torso movements) to render the mirror image representation veridically. The more of the user's simultaneous but independent motions that are captured via tracking, the more faithful and compelling the mirror image of representation (see Figure 5) will be.

If an analog device (e.g., joystick, computer mouse, or similarly functioning but more complicated mechanism) is used to move (i.e., translate and change orientation) an object (e.g., a person or a chair) within an immersive virtual world, tracking is accomplished via signals from the analog device itself. If the object moves physically in the real world, tracking can be accomplished in several ways. One way is to use video tracking of a light source firmly fixed to the object to be tracked (e.g., person, chair) to provide translation information in the usual three dimensions. Another is to use an inertial tracking device with built-in accelerometers to provide information about changes in orientation. Still another involves magnetic tracking. Some systems can track users within very large environments (e.g., greater than a 50m × 50m physical space).

Because human representations are important in social psychology and because humans are articulated objects (i.e., different parts of users' bodies can move independently relative to each other), multiple tracking devices become necessary. We often use a combination of video and inertial systems to track body and head movements of users (with the usual three degrees of information for each). For example, to track a user's position within a virtual photo gallery, we would want to know where in the gallery he or she is standing and the direction in which he or she is pointed because a user's head is not always looking straight ahead. To get even finer tracking of where a user is looking, we could use a specialized eye tracking system to determine the direction of gaze. If we want to track large muscle movement, such as that of limbs, exoskeletal devices providing tracking data on more than 50 skeletal pivot points are available. Likewise, technology has been developed for tracking small muscle movements, such as finger movements, with the use of specialized gloves. Various tracking systems are being developed for tracking facial muscle movements as well.

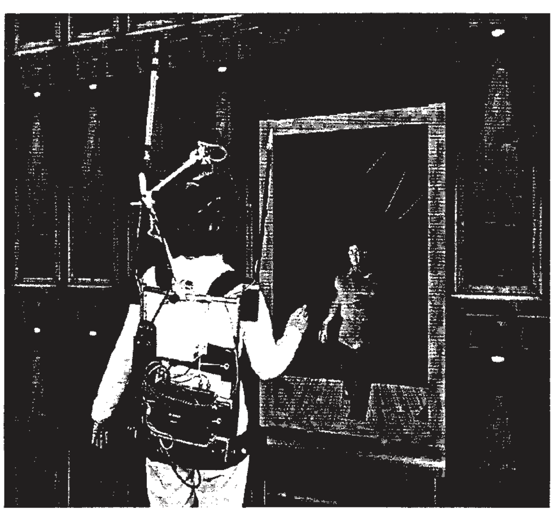

Figure 5. *Didactic illustration of an immersive virtual mirror.*

Rendering. Display technology for IVEs also provides several options, although costs vary considerably. Specialized rooms and head-mounted displays are the major options available today. Both require users to wear special eye gear.

The specialized rooms use Immersive Projection Display (IPD) technology to render appropriate scenes to users. These rooms are constructed of translucent screens as sides upon which scenes are back-projected via special three-dimensional projectors. Users wear special active-shutter glasses to provide the illusion of a three-dimensional world. IPD technology is effective, but suffers from several major problems. First, because of the projection techniques used, it requires a physical space that is many times larger than the workspace available to the user. Consequently, user movement within IVEs presented with this technology is restricted to a relatively small area. Second, the computer engines needed to drive and coordinate as many as six three-dimensional projectors (floor, ceiling, and four walls) must be powerful and, hence, are costly. Third, only one user's point of view can be used for rendering a perspective, forcing multiple users to share the point of view of a single user. Implementing a sophisticated IPD can cost well over $1 million, putting them out of the reach of most social psychologists.

Fortunately, three-dimensional VEs can be rendered to users much more economically (i.e., < $20,000) with the use of stereoscopic head-mounted display units. As they become less expensive, more and more individuals will use head-mounted display units to experience IVEs personally via the Internet. Such units do not require special physical rooms and can be used to render arbitrarily large VEs. Relatively inexpensive dual-output video boards in personal computers (discussed previously) can drive them stereoscopically. More important for social psychologists, multiple users can be immersed within the same VE at the same time and the correct perspective for each user can be tracked, rendered, and displayed, including real-time representations of each user.

Besides vision, other sensory modalities, such as hearing and touch (haptics), can be simulated with IVET. Researchers have investigated virtual sound for some time (Loomis, Hebert, & Cicinelli, 1990; Loomis, Klatzky, & Golledge, 1999; Zahorik, 1997; Zahorik, Kistler & Wightman, 1994; Zahorik, Wightman, & Kistler, 1995), providing ways to present sounds appropriately in terms of both direction and distance (i.e., coming from a specific three-dimensional location within a VE, e.g., a virtual audio speaker or a virtual dog's or person's mouth). Haptics are more difficult to render synthetically, but shapes, textures, and pressures can be rendered via specialized gloves, mechanical limbs, or both (Kalawsky, 1993). Placing real physical objects (e.g., a chair or a blackjack tabletop) in locations corresponding exactly to where they appear in the VE, however, can provide actual haptic information regarding objects for which such placement is practical, although accurately registering the virtual and physical spaces is challenging.

In sum, as digital computer, tracking, and rendering technologies have advanced and become relatively inexpensive, IVE systems have begun to proliferate. Sophisticated systems can easily cost less than $20,000 and should be even less expensive and more powerful in the future. This amount is well within the reach of funding sources, even local ones, for social psychologists. Given the opportunities for research that this technology provides, as well as the sharing of resources that it permits (i.e., experimental IVEs), the payoff can be quite high indeed.

Social Presence Within IVEs

Allport's (1985) definition points to social influence as the primary subject matter of social psychology. Surely, we can be and are influenced by the actual presence of others. Just as surely, we can be and often are influenced by the implied presence of others. For example, when rehearsing a speech, we often think about how members of our intended audience will receive what we want to convey. Sometimes speechmakers, such as politicians, use stand-ins to attend a rehearsal and to ask difficult questions so that the implied presence of the ultimate audience is more compelling. Finally, we are influenced by the imagined presence of others. For example, we know that small children often play with imaginary playmates and are often frightened by imaginary others such as "the bogeyman." Stephen King spins stories about imaginary others that even frighten adults. We can distract ourselves from writing papers on laptop computers by minimizing the word-processing program, opening a computer game, and playing hearts or poker with imaginary others. Hence, Allport's argument that the presence of others, whether actual, imagined, or implied underlies social influence effects is persuasive.

The presence of others is perceived primarily on the basis of sensory information conveyed by them in the case of actual presence, our memories or associations in the case of implied presence, or our imaginations in the case of imaginary presence. The advent and development of more and more sophisticated telecommunications technologies has made the concept of actual presence a somewhat fuzzy one. When social interaction could only be face-to-face, the concept of actual presence was defined as such. However, when long-distance, online communication became possible, such a strict definition became unrealistic, and actual presence could be either face-to-face or mediated by technology.

Several of the substantial mileposts in the history of telecommunications technology over the last century brought us a few steps back toward face-to-face presence, albeit technologically mediated. The telegraph, with its two-way communication based on a simple coded alphabet, gave way to Bell's telephone (and later two-way radios), allowing two-way voice communication. The telephone was succeeded by the videophone (and later "c-u c-me" Internet technology), allowing both voice and visual communication.

Unfortunately, in terms of actual social presence, these technologies left much to be desired. As Short, Williams, and Christie (1976) and later Daft and Lengel (1984, 1986) argued, telecommunications media differ in their capacity to transmit information. They lack many cues; for example, those signaling proximity and orientation, physical appearance and attractiveness, facial expressions, direction of gaze, mutual eye-gaze, posture, dress, and nonverbal and vocal signals. The absence of these cues contributes to differences in social presence elicited by those media. Similarly, even computer-mediated telecommunication technologies, such as e-mail, lack such important social cues (Kiesler, Siegel, & McGuire, 1984; Sproull & Kiesler, 1986).

Essentially, these researchers (e.g., Daft & Lengel, 1984, 1986; Short et al., 1976) have maintained that the fewer communication channels or signals that are available within a given medium, the less attention users will pay to the presence of others. Thus, it should not surprise us that even though these telecommunications technologies have been adapted for more than two-way communication (i.e., *n*-way), as in telephone conference calls, video teleconferencing, and computer chat rooms, the sense of others' presence degrades even more substantially when the number of interactants increases above two.

IVEs, however, promise to increase substantially the sense of actual presence in technologically mediated social interactions. IVET may hold the key to blurring the distinction between actual face-to-face and electronically mediated social interaction because such technology provides the bandwidth for transmitting the many types of signals by which the presence of other individuals is conveyed in actual face-to-face interactions.

Due to its immersive nature, IVET offers several advantages over other telecommunications media. Interactants, for example, can be immersed in a three-dimensional VE where they can interact with others who may or may not be present in their immediate physical environment. In addition, modeling certain critical aspects of the physical environment can provide important environmental cues. For example, setting an interaction in a virtual church conveys critical context information that would differ if the setting were a virtual casino.

Within IVEs, signals can be conveyed among multiple interactants via both verbal and nonverbal channels of communication. For example, cues regarding the sex, ethnicity, status, and so on of the interactants can be conveyed nonverbally via the physical features and adornments of their representations in the IVE. Likewise, information regarding physical proximity and orientation, eye gaze, facial expressions, and so on can be rendered and, hence, communicated to interactants nonverbally. Verbally, interactants can communicate via speech among themselves.

Compared to other telecommunications media, IVET offers the greatest sense of actual presence and also conveys important contextual cues. More specifically, we can expect immersive virtual social interactions to most closely resemble face-to-face interactions and, therefore, provide the basis for studying the effects of the actual presence of others, not to mention providing bases for studying the implied or imagined presence of others by social psychologists. When one considers the fact that IVEs provide for exceptional experimental control while maintaining a high degree of mundane realism, one can reasonably surmise that IVET is a formidable tool for conducting social psychological research.

Presence in VEs is not only important in terms of the presence of others, or social presence, but also in terms of the self, or personal presence, and in terms of the environment, or environmental presence. Heeter (1992) suggested a useful typology for these dimensions. *Social presence* reflects the degree to which one believes that he or she is in the presence of, and interacting with, other veritable human beings. *Personal presence* reflects the degree to which one believes that he or she exists within the VE. Finally, *environmental presence* refers to the extent to which the environment is responsive to perturbations of the user. Heeter (1992) and others (e.g., Delaney, 1992; Folz, 1991; Held & Durlach, 1992; Loomis, 1992) have suggested numerous aspects and features of IVEs that contribute to increased social, personal, and environmental presence within them.

A Model of Social Influence Within IVEs

To guide investigations of social interactions within IVEs, we have developed a threshold model of social influence. Specifically, we hypothesize that social influence will occur within IVEs as a function of two additive factors, behavioral realism and social presence, and two moderating factors, self-relevance and the target response system.

Additive Factors

Figure 6 depicts our threshold model. The threshold of social influence varies as a function of the additive, often complementary, relation between behavioral realism and social presence. For simplicity, the social influence threshold is depicted linearly, although it need not be. We expect social influence effects at or above the threshold, with stronger effects occurring farther above the threshold (i.e., high behavioral realism and high social presence).

Behavioral realism refers to the degree to which virtual humans and other objects within IVEs behave as they would in the physical world. *Social presence* refers to the degree to which the user (e.g., the participant) believes that he or she is in the presence of and interacting with another veritable human being and

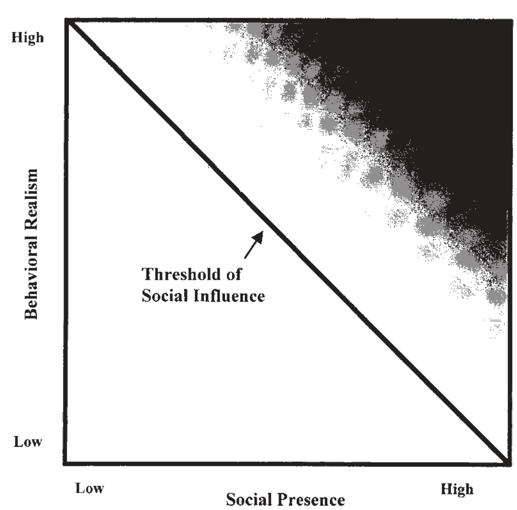

Figure 6. *Threshold model of social influence with immersive virtual environments.*

that the behaviors of virtual humans within IVEs represent the actions of real individuals in the physical world in real time.

Behavioral realism. Because we tend to think of IVET most often as a visual medium, one might be tempted to think of behavioral realism in photographic terms. However, photographic realism is only one aspect of behavioral realism and not even a necessary one in most cases (Bailenson, Blascovich, Beall & Loomis, 2001). Behavioral realism refers to the extent to which virtual humans and other objects behave like their counterparts in the physical world. Photographic realism refers merely to the photographically realistic appearance of virtual humans and objects. Cartoonists have known for decades that behavioral realism is more important than photographic realism in terms of social influence, devising compelling, behaviorally realistic, human-like characters whose cartoonish appearances (e.g., mice, ducks, pigs) are anything but photographically realistic. In our model (see Figure 6), we view behavioral realism as a continuous dimension, ranging from low to high.

Several actions or behaviors of virtual humans contribute to a sense of behavioral realism on the part of IVE users. Critical actions or behaviors reflect the virtual humans' apparent abilities to decode and interpret the verbal and nonverbal behaviors of other virtual humans, including those representing users, and to produce situationally and socially appropriate verbal and nonverbal responses. Such decoding and interpretation of verbal and nonverbal behaviors are a function of the "intelligence" of the virtual human.

We wish that artificial intelligence technology were advanced enough to allow IVE creators simply to import artificially intelligent virtual humans into their worlds. In fact, artificial intelligence is not nearly as far advanced as necessary to import artificially intelligent virtual humans for the kinds of virtual worlds social psychologists are likely to create. What is critical, however, is the appearance or illusion of intelligence on the part of virtual humans. We can create this illusion by programming critical virtual human actions or behaviors via software, for example, speech recognition and synthesis and nonverbal responding. Hence, virtual humans can respond in scripted and conditional ways, much like we train human confederates to respond. Unlike the latter, however, we can more easily and systematically program and control random variability into virtual humans' behavioral repertoires (or not), producing quite compelling virtual representations of humans (see, e.g., Massaro et al.'s [1999] "Baldi").

Social presence. As described previously, social presence reflects the degree to which a user believes that he or she is in the presence of and is interacting with other veritable human beings within an IVE. By definition, then, social presence increases the more the user believes that a virtual human within a shared VE is controlled by and represents a real person in the physical world in real time. Hence, all other factors being equal, if a participant believes that he or she is interacting with the representation of a real other, his or her sense of the social presence of that virtual human will be high. Within physical experimental environments, such representations are called *confederates.* Within VEs, such representations of real others have traditionally been called *avatars* (Stephenson, 1994), although we prefer and use the term *human–avatars* here. On the other hand, social presence decreases when the user believes that a virtual human within a shared VE is controlled by the system (i.e., the computer) itself. Hence, all other things being equal, if one believes that he or she is interacting with the representation of a nonhuman other (i.e., a completely computer-generated and computer-controlled representation), his or her sense of the social presence of that virtual human will be low. Such representations have traditionally been labeled *agents* (Karla et al., 1998), although we prefer and use the term *agent–avatars* here. In our lexicon, then, an avatar is a representation of either a real person (i.e., human–avatar) or a synthetic one (i.e., agent–avatar). Like behavioral realism, (see Figure 6), we view social presence as a continuous dimension ranging from low to high. Users may be certain that a representation is a human–avatar or an agent–avatar or may be uncertain in the same way that participants may be certain or uncertain that a fellow participant is or is not a confederate.

Behavioral realism plus social presence. According to our model, social influence effects occur when the combination of behavioral realism and social presence complement each other so that a threshold is met or surpassed (see Figure 6). If social presence is high (i.e., the user or participant knows the representation is a human–avatar), behavioral realism need not be high for social influence effects to occur. For example, we can imagine a compelling IVE in which one is flirting with another. The human–avatar (i.e., high social presence) could be merely a smiley face on a beach ball (i.e., low behavioral realism), and the user will likely be socially influenced by the actions of the other person (i.e., experience appropriate emotions himself or herself). However, if both social presence and behavioral realism were low, according to our threshold model social influence would not occur. For example, it is hard to imagine someone flirting with a beach ball known to be an agent–avatar.

If social presence is low (i.e., the user or participant knows the virtual other is an agent–avatar), behavioral realism must be very high, including perhaps even photographic realism, for social influence effects to occur.

Although it is difficult to imagine a user flirting with an agent–avatar represented as a beach ball, we believe it is at least theoretically possible that a user would flirt with an agent–avatar if its representation were attractive and its actions were completely realistic; that is, if the agent–avatar passed a kind of intuitive "Turing test"[7] on the part of the user.

Moderating Factors

As mentioned previously, at least two additional factors moderate the threshold of social influence: self-relevance to the user and the user's target response system.

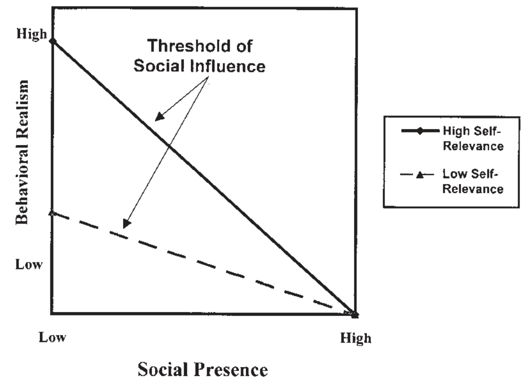

Figure 7. *Variation in threshold of social influence slopes as a function of self-relevance.*

Self-relevance. In the physical world, individuals engage in a multiplicity of social interactions that vary in value or meaning (from low to high) to their self-concept. Many social interactions are quite mundane and have very little self-relevance, for example, making a small withdrawal at a bank teller's window, ordering a hamburger at a fast food restaurant, or asking other occupants what button to push on an elevator. On the other hand, many social interactions are high in self-relevance and meaning to the interactants' self-concept, for example, participating in a job interview, defending a dissertation before a committee, developing a close friendship, or participating in an individual therapy session with a clinical psychologist.

We believe that self-relevance moderates social influence within VEs such that self-relevance is related positively to the steepness of the slope of the social influence threshold. When self-relevance is low, the slope of the threshold of social influence is relatively flat, but when self-relevance is high, the slope becomes relatively steep (see Figure 7).

For example, most of us would probably consider an interaction in which we are making a small withdrawal from a bank low in self-relevance. If we were to make the withdrawal using virtual technology, whether we believed the virtual representation of the bank teller was a human–avatar (i.e., a representation of a real teller) or an agent–avatar would make little difference to us in terms of social influence. Furthermore, in this case the level of behavioral realism need not be high (see Figure 7). Indeed, most of us make virtual transactions of this type frequently by using bank automated teller machines (ATMs), knowing that we are communicating with the bank computer (i.e., agent–avatar). If the machine "eats" our ATM card, we can get quite upset, even though we know we are dealing with an agent–avatar (and not a very realistic one at that). On the other hand, if we were to participate in a virtual social interaction with high self-relevance, such as a job interview, whether the virtual representation of the interviewer was a human–avatar or agent–avatar would make quite a difference to us, and only the most behaviorally realistic agent–avatar should influence us.

Target response system. Another factor that moderates the slope of the threshold of social influence within VEs is the level of the behavioral response system of interest. The steepness of the threshold slope increases as the ontological complexity of behavioral response system increases. If one targets very low-level behavioral response systems to index social influence processes, the slope would be quite flat. For example, when a virtual representation, whether an agent–avatar or human–avatar, unexpectedly fires a virtual pistol in the air, a loud report is likely to engender the same level of defensive response (as indicated by a defined set of reflexive responses). If one is interested in behavioral response system indicators of somewhat higher level social influence processes, the slope is somewhat steeper. For instance, when a virtual representation approaches a user in an IVE, the user is likely to be more troubled by an invasion of personal space (as indicated, for example, by psychophysiological indexes such as increases in skin conductance) by a human–avatar than by an agent–avatar. If one is interested in behavioral indicators of high-level social influence processes, the slope becomes quite steep. For example, when a virtual representation provides a user with positive perfor-

[7]The *Turing test* is a behavioral approach to determining whether or not a system is intelligent. It was originally proposed by mathematician Alan Turing, one of the founding figures of computing. Turing argued in a 1950 paper that conversation was the key to judging intelligence. In the Turing test, a judge has conversations (via teletype) with two systems, one human, the other a machine. The conversations can be about anything and proceed for a set period of time (e.g., 1 hr). If, at the end of this time, the judge cannot distinguish the machine from the human on the basis of the conversation, Turing argued that we would have to say that the machine was intelligent.

mance feedback, the user is more likely to be influenced (as indicated, for example, by a change in state self-esteem) by a human–avatar than by an agent–avatar.

Investigators availing themselves of IVET need to be aware of these moderating factors. Although self-relevance in a particular social interaction varies somewhat among individuals and even within individuals over time, this variability can be controlled experimentally, as in most experimental social psychological research, via random assignment of users to conditions. Self-relevance can also be controlled statistically by assessment and covariation when analyzing resultant data.

Applicability of the Threshold Model to Traditional Experimental Social Psychological Scenarios

Although we feel compelled to model the differences in social influences we expect as a function of the level of illusion (based on both behavioral realism and social presence) and participant-based moderators (self-relevance and target response system) in proposing IVET as a research tool in social psychology, we are aware that generally, this model has not been specified for other more traditional illusion-based tools. What if vignettes were clearly thought to be fictional (or nonfictional) by research participants? How realistic do role-playing scenarios need to be? Does self-relevance matter in the experimental tasks we use? Do we always need to convince participants that our confederate actors are not actors? Our model is applicable to these methods as well, although a discussion of this topic is beyond the scope of this article.

Research Using IVET

IVET has been and is being used by investigators to conduct basic research on human behavior in a variety of disciplines and areas including cognition, communication, education and training, geography, perception, and psychotherapy. IVET-based efforts have advanced research in these fields and, as a byproduct, advanced IVET. However, only recently have social psychologists begun to explore the utility of using IVET (Loomis, Blascovich, & Beall, 1999), although many have foreseen its possible value as a social psychological research tool (e.g., Biocca & Levy, 1995).

One of the reasons for the relatively late foray of social psychologists into IVET has been the presumed difficulty of representing social interactants within IVEs. Yet, as we proposed previously, it is not necessarily the case that human representations have to be perfectly behaviorally and photographically realistic. Even so, behaviorally and even photographically realistic representations are now quite possible (e.g., Capin, Pandzic, Magnenat-Thalmann, & Thalmann, 1998; Karla et al., 1998; Massaro et al., 1999; Sannier & Thalmann, 1997). Hence, social psychology may be poised to take great advantage of IVET by minimizing, if not eliminating, the threefold methodological problems described previously: the experimental control–mundane realism trade-off, lack of replication, and nonrepresentative sampling. A major benefit of serious social psychological research involving IVET is the value of the application of the resultant knowledge to the development of sophisticated virtual humans in terms of their social behaviors.

Exploration of recent and current nonsocial psychological research provides some insights into the uses of IVET for studying behavior in general, perhaps even for social psychological investigations. Hence, we provide some brief examples of the types of research in some of these fields next. We then return to the main topic at hand, IVET as a social psychological research tool, reviewing some beginning work (mostly our own) in social psychology. Finally, we identify additional possibilities for social psychological investigators, including discussion of a new paradigm heretofore practically impossible but made practical by IVET for social psychology.

Psychological (Nonsocial) Research Using IVET

Although rendering behaviorally realistic human-like representations using IVET has been relatively slow to develop, rendering simpler objects, especially their visual properties, has become quite sophisticated. Unsurprisingly, areas of psychology not primarily concerned with social interactants have been relatively quick to adopt IVET for research purposes and have enjoyed its methodological advantages.

Visual perception. Decades ago, the tachistoscope, and more recently the microcomputer, served as enabling tools for visual perception researchers. These provided researchers with the ability to exert great control over two-dimensional visual stimuli, allowing many important basic psychophysical investigations. The downside was, of course, that investigations of topics with greater ecological validity, such as three-dimensional scene perception and visually controlled behavior, remained relatively unexplored (Loomis et al., 1999). Three-dimensional computer graphics and, more recently, IVET, however, have made controlled psychophysical investigations of these other topics possible and visual perception researchers have taken appropriate advantage.

In particular, IVET has made it possible to ask and answer research questions that would have been impossible prior to its development. For example, using IVET, visual perception researchers can investigate the psychophysics of motion, distance, and size on much larger scales than without it. For example, controlling the visual angle of an arbitrary object as it moves around is impossible in the physical world. Yet, with IVET, this control can easily be achieved, allowing visual perception researchers to decouple the effects of this variable while investigating the effects of other variables (e.g., binocular cues) on the perception of size, distance, and motion.

Studying visual perception processes with IVET that otherwise cannot be investigated easily or at all has its analogs in social psychological research. For example, social interactants can be kept at the same eye height, controlling for social influence effects that may be confounded with height (e.g., the relative persuasiveness of tall compared to short public office seekers; Kassarjian, 1963).

Spatial cognition. Many aspects of spatial perception and cognition have benefitted from IVET (Peruch & Gaunet, 1998). Spatial navigation, for example, relies on a combination of piloting (i.e., the use of environmental cues such as landmarks) and path integration (i.e., continuously updating one's estimate of his or her own current position on the basis of perceived self-motion). The use of IVET makes it possible to control one while studying the other, as well as their joint operation (Chance, Gaunet, Beall, & Loomis, 1998; Klatzky, Loomis, Beall, Chance, & Golledge, 1998). Other aspects of the study of spatial cognition that benefit from IVET include cognitive mapping and spatial memory (Wilson, Tlauka, & Wildbur, 1999). To at least some extent, social psychological research has involved various aspects of spatial cognition and can, therefore, benefit from IVET in the same ways as spatial cognition research; for example, detection and memory of members of large audiences expressing negative affect (Hansen & Hansen, 1988).

Education and training. Learning represents a major area of research that has and continues to benefit from IVET (Albright & Graf, 1992; Auld & Pantellidis, 1994; Emerson & Revere, 1999; Neale, Brown, Cobb, & Wilson, 1999; Roussos & Gillingham, 1998; Roussos et al., 1999; Salzman, Dede, Loftin, & Chen, 1999). Educational psychologists have traditionally evaluated the didactic and training value of new media and technology as they have become available in our society. Indeed, the success of so-called distance learning depends largely on new multimedia and digital technologies including IVET.

Certain questions are obvious, such as the didactic value of using IVET to allow learners to explore target objects in three rather than two dimensions. For example, can one learn human anatomy by being able to navigate inside and outside of organs (e.g., walking inside and outside of the heart, literally exploring the lungs) and systems (e.g., the vasculature)? Can one more easily learn the operation of complicated mechanical systems (e.g., jet aircraft engines) in similar ways?

Many investigators have focused research efforts on the use of IVET for training purposes. Some of these have involved technical training, such as engine mechanics (Caudell & Mizell, 1992; Feiner, MacIntyre, & Seligmann, 1993; Loftin, 1993; Taylor, 1998) and surgery (Downes, Cavusoglu, Gantert, Way, & Tendick, 1998; Satava, 1993). Other efforts, however, have involved training in the human services realm. For example, the utility of IVET is being explored to create training scenarios in primary care (R. Berger, personal communication, June 23, 2000) and emergency medicine (Chi et al., 1997) by modeling virtual patients. Immersive virtual classrooms, complete with virtual students, are also being developed. Some (e.g., M. Gerber, personal communication, July, 2000) hope to use them to allow teacher trainees to experience important but rare classroom events, whereas others (e.g., Rizzo et al., 2000; Strickland, 1997) are using them to diagnose and treat learning, developmental, and behavioral disorders (e.g., attention deficit hyperactivity disorder and autism).

Of course, these human services training scenarios are inherently social in nature, and similar uses for social psychologists are many. For example, IVET has been used to create virtual audiences (Slater, Pertaub, & Steed, 1999) to train individuals to give speeches. Moreover, one can easily imagine leadership researchers using IVET to develop small-group training scenarios.

Psychotherapy. Clinical and counseling psychologists have begun to avail themselves of IVET technology as well. Some (e.g., L. Beutler, personal communication, June, 1999) are interested in training scenarios modeling virtual clients for therapists in training. Others (Hodges et al., 1995; Riva, Wiederhold, & Molinari, 1998; Rothbaum et al., 1995; Rothbaum, Hodges, Smith, Lee, & Price, 2000; Vincelli, 1999) are developing actual IVET-based therapeutic tools. One of the most obvious IVET applications in this regard is the treatment of phobias such as acrophobia and arachnophobia. Indeed, one of the most interesting demonstration worlds in our own and others' laboratories is a deep chasm with a narrow board bridging it. A large proportion of visitors (and some researchers themselves) express reluctance and anxiety about walking across the chasm on the bridge, and some refuse to do so, even though rationally they know they can only fall virtually and not physically. This suggests the ease of using IVET to mimic Dutton and Aron's (1974) rope bridge scenario to study the relation between shared anxiety and physical attractiveness.

Social Psychological Research Using IVET

We decided to explore the utility of IVET as a research tool in social psychology by attempting to replicate classic social influence findings within IVEs. Our logic was that if we could replicate classic social influence phenomena using classic albeit virtual experimental situations, IVET would hold promise for social psychological research. Furthermore, we believe that successful replications would add credibility to future findings involving IVEs not modeled on already proven physical experimental scenarios but on ones created and implemented wholly within IVET. At the same time, we were developing our social influence threshold model (discussed previously) and we began to incorporate manipulations of behavioral realism (high vs. low), social presence (i.e., agent–avatar vs. human–avatar), or both into our exploratory studies. To date, we have conducted IVET-based social influence studies using proxemics, social facilitation–inhibition, conformity, and social comparison paradigms.

Proxemics. Interpersonal distance and personal space appealed to us as a quite feasible area for exploring social influence effects within IVEs. In our first proxemics study (Bailenson, et al., 2001), we manipulated the behavioral realism of agent–avatars standing in a virtual room approximately 5m × 5m.[8] Our agent–avatars were male and wore sweatshirts with their names printed on the front and a number on the back in a relatively small print (approximately 1.5 in. high). We asked participants (who had donned a head-mounted display and tracking unit; see Figure 2) to try to learn the name and the associated number for several agent–avatars. Participants saw only one agent–avatar per trial and engaged in 10 trials, in which they walked around the agent–avatar to read the print on the back of his sweatshirt. We used a two-way mixed factorial design. Participants were randomly assigned to either a high or low behavioral realism condition, the between-subject factor. Within subjects, participants experienced a block of 5 trials of photographically realistic agent–avatars and a second block of 5 trials of nonphotographically realistic agent–avatars.[9] The order of blocks was counterbalanced, and the order of trials (i.e., agent–avatars) within blocks randomized. In the low behavioral realism condition, each agent–avatar (i.e., a single trial) stood alone, "frozen" in the room with his eyes closed. In the high behavioral realism condition, the agent–avatar's eyes blinked naturally and his head and eyes followed, or tracked, the head and eyes of the participant (as long as the participant remained within 85° of the agent–avatars's nose when pointed straight ahead).

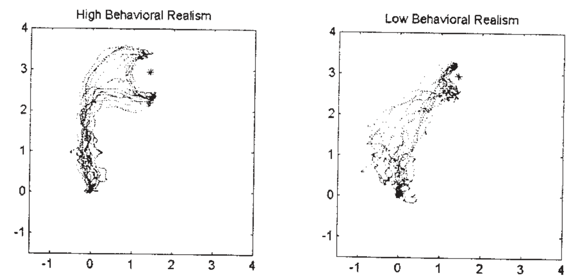

Figure 8. *Tracking data illustrating participants' proxemic behavior as a function of the behavioral realism of virtual humans.*

Because IVET requires tracking of participants' movements within the physical space corresponding to the VE, the system sampled participants' location information at 20 Hz, making the collection of physical movement data within the VE automatic and easily archived. As predicted by our threshold model, we found no proxemic differences as a function of photographic realism. Also, as predicted, we found that participants maintained greater distance between themselves and an agent–avatar when it behaved more realistically. This effect was particularly strong for female participants and for participants whose perceived self-presence in the virtual world was high. Figure 8 provides tracking data for a typical participant in both the high and low behavioral realism conditions. Participants' memory of agent–avatar's names and associated numbers did not differ as a function of behavioral realism.

The data from this study and from further pilot work confirmed our hypothesis that low-level (i.e., proxemics) social influence effects can be produced and studied with IVET and can be used to make theoretical advances in this area. Although we manipulated behavioral realism, we did not manipulate our other major theoretical variable, social presence, in this proxemics study. Participants were given no information as to whether or not the avatar was an agent or a human one. However, based on comments made during postexperimental debriefing sessions, we assume that most, if not all, participants believed the represen-

[8] Our tracking system allowed our virtual worlds to have the same footprint (i.e., circumscribed floor area) as the physical environment in which they were implemented.

[9] We created the photographically realistic virtual humans using a technique of "wrapping" a front and side view facial photograph of a real person on a polygonal model of a face.

tation was an agent–avatar. Nevertheless, in studies currently underway, we are manipulating both social presence and behavioral realism, as well as the apparent sex of the avatar and the sex of the participant.

Social facilitation–inhibition. Social psychologists credit Triplett (1898) with the first report of experimental social psychological research. Hence, social facilitation represents the earliest experimentally investigated social influence effect. Adapting a methodology we used in a recent social facilitation study (Blascovich, Mendes, Hunter, & Salomon, 1999), we (Hoyt, 2000) replicated the laboratory and equipment in which our experimental study took place using IVET.

In this study, participants learned one of two randomly assigned categorization tasks (Blascovich et al., 1999; Maddox & Ashby, 1996) to criterion (80% or better correct on two consecutive blocks of 20 trials). Task trials were presented on a virtual computer monitor while participants sat alone in the IVE. Following the learning phase, participants were randomly assigned to perform either the well-learned or the novel task either alone or in the presence of both a male and female virtual observer. We led participants to believe that the virtual observers were either agent–avatars or human–avatars, although in fact, they were always agent–avatars.[10] We predicted no performance differences between the alone and agent–avatar conditions for either the well-learned or novel tasks. In contrast, we predicted performance differences between the alone and human–avatar conditions for both tasks such that compared to the alone conditions, participants would perform worse on the novel task and better on the well-learned task.

As predicted, there were no facilitation or inhibition effects between the alone and agent–avatar conditions. Also as predicted, participants performed significantly worse on the novel categorization task in the presence of human–avatars than alone, the predicted social inhibition effect. However, no performance differences emerged on the well-learned categorization task, whether participants performed it in the presence of human–avatars or alone. Figure 9 depicts the relevant means. We were not overly disappointed by the lack of a significant social facilitation finding in this study, however, because of the likely operation of ceiling effects (due to our 80% performance learning criteria), which diminished the power of our design (Blascovich et al., 1999; Bond & Titus, 1983).

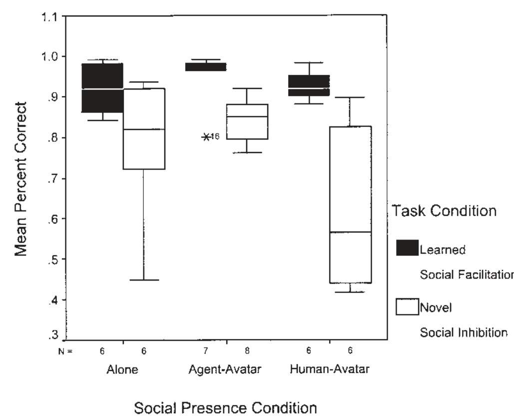

Figure 9. *Summary performance data from immersive virtual environment technology social facilitation–inhibition experiment.*

Conformity and social comparison. Conformity and social comparison are among the most prototypical of social influence processes. Since Asch's (1955) pioneering research on the power of conformity pressures and Festinger's (1954) introduction of social comparison theory, hundreds, if not thousands, of studies of these processes have been published. To explore the operation of these processes within an IVE, we created an immersive virtual world modeled on Jim Blascovich's experimental blackjack casino built and used in a variety of studies in the early seventies (e.g., Blascovich, Ginsburg, & Howe, 1975; Blascovich, Ginsburg & Veach, 1975; Blascovich et al. 1973).

More specifically, we (Swinth & Blascovich, 2001) attempted to replicate Blascovich and Ginsburg's (1974) study of emergent norms and risk taking. In this study, participants initially played 20 hands of blackjack alone with a dealer and then a second round of 20 hands in a group of three, consisting of themselves and two other virtual human players. Unknown to the participants, the virtual players bet according to a prearranged plan. In the low-betting norm condition, the virtual players bet less than the participants' average bet during the last 5 hands they had played alone. In the same-betting norm condition, the virtual players bet the same. In the high-betting norm condition, the virtual players bet more.

Using IVET, we created an immersive virtual casino complete with a blackjack table, gaming chips, seats, slot machines, cards, a dealing shoe, a dealer, and so on.[11] As in the original study, participants played 20 hands of blackjack alone and then the second

[10]The general procedure we used for this deception in all the studies reported here was relatively straightforward. We scheduled two other individuals (e.g., research assistants, confederates, or participants) to come to the laboratory at the same time as the target participant. Each, including target participants, was shown a picture of what he or she would look like virtually. Typically, all individuals were fitted with head-mounted display units, although when confederates or research assistants were used, these units were nonfunctional.

[11]The IVE we created for this study was probably the most technically complicated one built for research purposes. This is mentioned to illustrate the fact that one does not need to be some sort of computer wizard to create useful immersive worlds for research purposes. A totally novice social psychology graduate student programmer (i.e., one who never did any programming before in her life) created this particular virtual world.

round of 20 hands in a group of three players. As in the IVET-based social facilitation study, we randomly assigned participants to either an agent–avatar or human–avatar condition for the group play. In addition, as in the original blackjack study, we randomly assigned participants to the low-, same-, or high-betting norm conditions.

In terms of conformity, our results replicated Blascovich and Ginsburg (1974). A significant main effect for betting norm condition and significant effects of the appropriate a priori comparisons of the low- to same- to high-betting norm conditions demonstrated the predicted conformity effect. Furthermore, this effect was significant for individuals in both the agent–avatar and human–avatar conditions. In addition, as Figure 10 illustrates, we found a significant main effect of social presence condition such that participants' bets in all three betting norm conditions were higher in the human–avatar compared to the agent–avatar conditions.

We were quite intrigued by the results of this study. In it, we demonstrated that conformity occurred independently of our social presence manipulation but that an additional process operated such that betting was higher in the human–avatar condition across betting norm conditions. Our explanation of the latter finding is based on social comparison explanations (e.g., Blascovich, Ginsburg, & Veach, 1975) of risky shifts. Specifically, if risk tasking were culturally valued as Brown (1965) originally argued, exposure to others' levels of risk taking (e.g., bets) would drive individuals to take greater risks (i.e., bets) than their comparison others. Hence, in this IVET-based study, we believe that social comparison processes contributed to our results independently of conformity processes. We are currently replicating and extending this study.

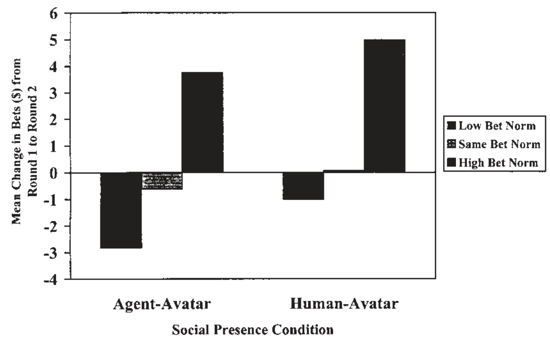

Figure 10. *Summary of betting data from the immersive virtual environment technology conformity–social comparison experiment.*

The Fit of Exploratory IVET-Based Research to our Threshold of Social Influence Model

Although it is much too soon to draw any firm conclusions, the data from these initial IVET-based studies appear to fit our threshold model of social influence within IVEs. Recall as mentioned previously that the slope of the social influence threshold within immersive environments involving social interaction (see Figure 7) varies as a function of moderator variables including self-relevance to the user and the target response system of the user being measured. Specifically, the higher the self-relevance for the user or participant is, the steeper the expected slope of the social influence threshold will be. Similarly, the higher the level of the target response system is, the steeper the expected slope of the social influence threshold will be.

The tasks and measures we used in the initial studies we described previously varied on these theoretically important moderator variables and provide useful hints of the validity and utility of our theoretical model. The social facilitation–inhibition task arguably held the most self-relevance for users. In the audience (i.e., social interaction) phase of the experiment, participants had to perform an evaluative task in the presence of observers. As our model predicts, given that behavioral realism of the virtual representations was the same, we would expect a large difference between participants being observed by agent–avatars compared to those observed by human–avatars, reflecting the steepness of the social influence threshold in our model. Indeed, our significant social inhibition effect demonstrated that difference (see Figure 9). Arguably, the inherent social comparison aspects of betting in the blackjack game represented the next most self-relevance for users in our IVET experiments. Again, given that the behavioral realism of the virtual representations was the same, we would expect differences between participants playing blackjack with human–avatars compared to agent–avatars. Indeed, the social presence main effect in the blackjack study (see Figure 10) confirmed this expectation. Finally, we regard the inherent pressure to conform in the blackjack study to be the least self-relevant to participants, at least on a conscious level. Here we found, as might be expected from our model, no differences between participants playing with agent–avatars and human–avatars, reflecting a relatively flat slope of the social influence threshold.

Our failure to find a social presence by conformity interaction in the blackjack study might also or alternatively be regarded as a difference due to the user target system being assessed. Perhaps conformity pressures activate a lower level behavioral response system than social comparison processes. If so, we would expect no conformity differences as a function the social presence variable, and we did not find any. Certainly, proxemic behavior represents the lowest level behavioral response system we investigated. On the basis of our model, then, we were not surprised that we found significant differences in the maintenance of interpersonal distance between the high and low behavioral realism conditions, even though we believe our participants assumed the virtual human that they approached was an agent–avatar.

Additional Possibilities for IVET-Based Social Psychological Research

IVET has sparked our imaginations from the moment of our introduction to it,[12] and as described previously, we believe that IVET will be extremely fruitful for social psychologists in terms of its use for the investigation of social influence phenomena. However, we have by no means exhausted its possibilities for social psychology, whether one is interested in investigating social influence or other topics within our field. Next, we explore some IVET-based possibilities within more traditional social psychological paradigms. Finally, we describe a possible IVET-based paradigm, one quite theoretical at this point but one with great potential in our field.

Using IVET Within Traditional Social Psychological Paradigms

Surprisingly, the major difficulty we have faced in implementing IVET-based social psychological experiments has not been technical. Rather, our difficulty has revolved around what lines of investigation to pursue and what studies to conduct. We have thought of literally dozens of lines of investigation to pursue and hundreds of ideas for future studies. (So many studies, so little time.) This exuberance, however, can be attributed largely to what Kaplan (1963) described as the "law of the hammer." According to Kaplan, if you give a child a hammer, he or she will try to hammer everything in sight. Similarly, if you give a psychologist a new research tool, he or she will try to use it to study everything. Forewarned by Kaplan, when we realized that IVET was a shiny new hammer, we knew that we needed to select our lines of investigation very carefully and to invest in research programs with relatively high payoffs. Consequently, we decided to develop and test our threshold model of social influence within IVEs to determine the important limiting parameters of the method. We will continue to do so but also will pursue substantive lines of investigation in the future. However, we invite investigators to adopt our IVET[13] and use it to pursue other substantive questions on which they are experts.

We take the liberty here of suggesting a few examples of substantive research areas to which IVET might lend itself. In particular, we suggest examples of experimental variables and VEs or worlds that cannot be manipulated or created easily, if at all, using physical environments and scenarios. The combination of this creative power and the increased experimental impact inherent to IVET can only be to the advantage of social psychology.

Social identity. Over the last decade or so, social psychologists have been intrigued by the ways in which social identity influences behavior. For example, group-identification-based theories underlie much work on intergroup behavior and relationships, including stigma (Crocker & Major, 1989), stereotyping and prejudice (Fiske, 1998), collective self-esteem (Luhtanen & Crocker, 1991), and social power (Raven, 1999; Raven, Schwarzwald, & Koslowsky, 1998). Often, social identity is marked by the appearance characteristics of individuals, for example, sex; skin color; physical size; age; abominations of the body such as birthmarks, hairstyle, body markings, and piercing; and uniforms and other clothing. Because it is impossible or nearly impossible to manipulate many of these identity markers experimentally, researchers have typically relied on quasi-experimental manipulations of identity by selecting participants from different apparent social groups, for example, for sex and race.

IVET, however, makes it quite possible and relatively easy to manipulate social identity experimentally. For example, if one is interested in examining how perceivers interact with individuals with a particular group identity, it is relatively easy to create avatars bearing appropriate visual or auditory markers with IVET.

It is not surprising that organismic characteristics, such as sex, skin color, birthmarks, and so on, of virtual humans can be manipulated independently of their verbal and nonverbal behavior quite easily via IVET. However, IVET also makes manipulation of participants' self-identity relatively easy. For example, we have created a virtual mirror that looks and behaves like a dressing mirror (see Figure 5). Participants can see themselves in this mirror within any IVE. The mirror reflects their movements and actions much like one in the physical world. However, unlike mirrors in the physical world, the investigator controls the reflection

[12]On the initial demonstration of Jack Loomis and Andrew C. Beall's IVET system, Jim Blascovich's initial response was, "Do you realize what a social psychologist can do with this?"

[13]Our most sophisticated system as of this writing costs under $20,000. Contact the Andrew C. Beall (beall@psych.ucsb.edu) for details.

in the virtual mirror. Thus, a participant's reflection (i.e., his or her avatar's reflection) can have a different physical appearance than his or her appearance in the physical world. A participant can be made old or young, Black or White, male or female, tall or short, fat or thin, and so on or any combination of these characteristics. In addition, with this virtual mirror, participants can be led to believe they look one way when, in fact, other users view them differently. Using IVET, then, social psychologists can manipulate participants' group identity experimentally rather than quasi-experimentally, and one can think of many studies that can be performed, for example, conducting stigma (i.e., birthmark) studies similar to those done with the more difficult procedures developed originally by Strenta and Kleck (1984) and more recently by Blascovich and his colleagues (Blascovich, Mendes, Hunter, Lickel, & Kowai-Bell, 2001).

Self. If an investigator can manipulate group identity relatively easily using IVET, perhaps manipulating other aspects of the self can be accomplished as well. Investigators can now manipulate limited dimensions of the self using traditional procedures such as providing individuals with personality "profiles" based on their responses to supposed diagnostic questionnaires or false feedback on bogus aptitude tests. Using IVET, however, investigators can experimentally socialize participants within a VE by means of lengthy immersion in it or repeated visits to it. Thus, investigators can gauge the effects of an experimentally controlled socialization experience including multiple social roles and norms. This is not dissimilar in concept to Zimbardo and colleagues (Haney, Banks, & Zimbardo, 1973) prisoner–guard simulation. However, unlike his simulation, IVET is much less costly and, more importantly, allows better control and actual experimental manipulations.

Terror management. We, like many others, have been intrigued by the work of terror management theorists and researchers (e.g., McGregor et al., 1997; Pyszczynski, Greenberg, & Solomon, 1999). We believe, however, that the impact of experimental manipulations of mortality salience can be increased using IVET. Instead of having participants write about death, for example, participants could literally attend their own funerals, seeing themselves placed in caskets and buried. More importantly, IVET can be used to manipulate what might be labeled immortality salience to test previously untested hypotheses drawn from terror management theory. For example, if a participant is assured of immortality, the participant should be less likely to uphold cultural norms. Although participants cannot be guaranteed immortality in the physical world, they can be assured that their self-modeled avatars can and will exist forever. Hence, this hypothesis can be tested with IVET methods.

Media effects. Social psychologists and communications researchers have investigated the possible pejorative effects of depictions of various kinds of behaviors on individuals, particularly children, for example, depictions of violent and sexual behaviors in motion pictures, on television, and in computer games (e.g., Caruso, 1999; Linz, Donnerstein, & Penrod, 1984). As IVET-based entertainment becomes more and more widespread, producers are likely to use this new medium to depict these kinds of behaviors. Given the increased level of experimental impact of research manipulations using IVET, it is quite likely that the psychological impact of depictions of violence and sex for entertainment will also be increased. Furthermore, given the addictive nature of television and the Internet for some users, one can expect similar problems for IVET, given the highly compelling nature of IVET experiences.[14] Hence, we believe it is incumbent on media researchers within social psychology and other fields to investigate thoroughly the possible increase in pejorative effects of these behaviors within immersive virtual worlds.

Of course, just as with television and the Internet, IVET will have positive benefits to individuals and society as well. Some researchers have used entertainment media, such as video games to increase healthy behaviors. For example, Lieberman (1995, 1997) developed very effective computer games to teach children with diabetes mellitus or asthma how to engage in healthy behaviors specific to their medical conditions. We believe researchers should and will investigate the utility of IVET for similar purposes.

Other research areas. We certainly did not intend an exhaustive list of ideas for the use of IVET in social psychology, nor do we put them forward as necessarily the best ideas. Rather, we provide them as examples of the value of IVET for increasing the power of social psychological research and for enabling social and other psychologists to investigate topics experimentally in ways they cannot using traditional physical experimental environments. Readers can undoubtedly think of many other areas of social psychological research in which IVET can play an important role including, attitudes, close relationships, emotions, small-group behavior, and so on.

[14] A popular American comedian is reported to have remarked facetiously that in terms of its addictive properties, immersive virtual reality will make crack cocaine look like a cup of Sanka. Its facetiousness aside, the substance of this remark warrants ethical study.

Reverse Engineering Social Interaction Using IVET

IVET has the potential to enable a major paradigm shift within social psychology or at least to introduce an additional one. The traditional experimental paradigm in social psychology is modeled after natural and life sciences experimentation (Bhaskar, 1989; Harre, 1981; Popper, 1977) and rests on logical positivism. Furthermore, this paradigm has survived several decades of criticism (e.g., Gergen, 1985, 1991; Harre & Secord, 1972). One reason for its survival may be the lack of alternative empirical paradigms.

We believe IVET may offer an alternative possibility, one based on a reverse engineering metaphor. To determine how a device works, engineers (and children) often systematically and selectively remove or disable its various subcomponents. In this way, they can determine the critical, necessary components and operations of whatever mechanisms they happen to attempt to reverse engineer. Similarly, social psychologists may be able to use IVET to reverse engineer social interaction to identify its critical components.

Imagine a simple social interaction within an IVE between two real but geographically separated individuals represented to each other and themselves by behaviorally realistic avatars. One might simply ask the two individuals to get to know each other by sharing information about their backgrounds, personalities, life goals, and so on. Each individual can speak to the other via an audio system. Imagine also that each individual is wearing an exoskeleton, a device that allows online tracking and rendering of all body movements, such as movements of hands, wrists, elbows, arms, thighs, calves, ankles, fingers, and so on. Furthermore, within each participant's local physical environment, external devices are tracking and rendering their facial movements, including jaw, lip, and the muscles of expression. Finally, eye-tracking devices are built into the head-mounted displays worn by the individuals, allowing tracking of eye movements and gaze.

A participant or even an observer would marvel at the resultant immersive virtual environmental experience, particularly the richness of the behavioral realism of the interactants. They would converse, experiencing the same multiplicity of verbal and nonverbal communication channels as in the physical environment. Indeed, such a scenario is valuable in its own right merely as a sort of supertelecommunications system, and we are currently working toward developing and implementing the technology for it.

More importantly, however, the same technology could be used by social psychologists to reverse engineer social interaction in all its richness because of an inherent feature of IVET. Specifically, IVET systems do not require veridical rendering. Rather, investigators can intervene, causing what is rendered to be something other than what is tracked.

In the physical environment, for example, two individuals may be getting to know each other. Seeing each other, they have a sense of one another's demographics (i.e., sex, race, age, etc.). When one speaks to the other, he or she expects the other will hear the words he or she has spoken. If one gazes at the other, he or she could assume that the other individual could observe the gaze. One individual might smile or frown at the other, communicating some affect or emotion in response to what the other individual might have said. One or the other individual may even try to deceive the other in some way.

However, in an IVE, images and behaviors can be rendered nonveridically without the knowledge of the user. Hence, physical appearance can be changed. Spoken words or inflections could be altered to change the semantic meaning of the communication. A gaze could be rendered as an avoidance of eye contact, a smile rendered as a frown, and so on. The veridicality of verbal and nonverbal communications could be manipulated.

In other words, investigators can take apart the very fabric of social interaction using IVET, disabling or altering the operation of its components and thereby reverse engineering social interaction. With this approach, social psychologists could systematically determine the critical aspects of successful and unsuccessful social interactions, at least within specified domains and interaction tasks. Using knowledge gained in this way, social psychologists could help artificial intelligence and software experts build truly intelligent and behaviorally realistic avatars. The test of the validity of the aggregate knowledge of social psychological processes underlying social interaction would be kind of a Turing test. If a sufficient knowledge base existed, social psychologists could create agent–avatars that interactants would be unable to distinguish from veridically rendered human–avatars. Science fiction? Time will tell.

Summary

We have put forth technical information, theory, research, possible research areas, and even a new paradigm for experimental social psychology involving the use of IVET. Whether or not IVET causes a paradigm shift within social psychology, it can be independently valuable to social psychologists. IVET can help us lessen or eliminate the trade-off between mundane realism and experimental control, thereby increasing experimental impact and helping us sample target populations more representatively and reduce the difficulty of replication. Together, these potential benefits represent a major methodological leap for the field.

Notes

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