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Immersive Virtual Environment Technology: A Promising Tool for Future Social and Behavioral Genomics Research and Practice

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Abstract

Social and behavioral research needs to get started now if we are to direct genomic discoveries to address pressing public health problems. Advancing social and behavioral science will require innovative and rigorous communication methodologies that move us beyond reliance on traditional tools and their inherent limitations. One such emerging research tool is immersive virtual environment technology (aka: virtual reality), a methodology that gives researchers the ability to maintain high experimental control and mundane realism of scenarios, portray and manipulate complex, abstract objects and concepts, and implement innovative implicit behavioral measurement. This report suggests the role that immersive virtual environment technology can play in furthering future research in genomics-related: education, decision-making, test intentions, behavior change, and healthcare provider behaviors. Practical implementation and challenges are also discussed.

Keywords

virtual reality; genetics; genomics; health education; methodology

In the genomics era, it will be crucial for social and behavioral scientists to identify ways in which genomic science can be used to meet public health needs (McBride, 2005). Key to this endeavor is the plethora of communications challenges that will be faced as we aim to assess opinion, convey the meaning of genomics, assist in decision-making related to genomic medicine, and consider a heterogeneous set of target groups. Most genetic and genomic technologies are still nascent and more potential than reality, yet waiting until these applications are fully developed and ready for public dissemination will leave us ill equipped to anticipate and address establishment of best practices. Thus we must now begin to consider new approaches and methodologies that enable us to advance a communications research agenda in public health genomics (Khoury, Gwinn, Burke, & Zimmern, 2007).

Traditional behavioral research methodologies (e.g., surveys, hypothetical vignettes) have brought us some distance in this endeavor. However, research programs could benefit from technologically-based methodologies that can enable researchers to address future genomics scenarios that may seem remote today. For example, the future of genomics may proffer situations that are difficult to clearly or accurately envision. Furthermore, concepts surrounding genetics and genomics in relation to personal health can be complex, technical, and at times unfamiliar requiring individuals to consider factors that affect their health in an entirely new manner. Many of our traditional methodologies and communication paradigms are ill-equipped to convey these complex themes in understandable and relatable ways. One tool, brought about by advances in computing, is uniquely suited to address some of the greatest challenges for

ongoing and future social and behavioral research in the service of genomics. This tool is immersive virtual environment technology (IVET), popularly known as virtual reality. IVET can confer great benefits in key methodological areas due to its ability to maintain simultaneously high experimental control and mundane realism, its ability to concretely portray and allow manipulation of complex, abstract, and even intangible objects and concepts, and its complement of innovative implicit behavioral measurement options. Immersive virtual environment systems may hold great advantages for advancing social and behavioral research related to genomics as users can be immersed in a variety of situations that can aid understanding, help predict emotions and behavior, and promote practice and learning in ways that were not previously possible with traditional technologies and methods.

In the following sections, we aim to introduce and discuss IVET and its associated benefits. We will then discuss the promise IVET holds as a tool for several areas within social and behavioral genomics including education, simulation in the service of decision-making and behavior prediction, behavior change motivation and intervention, and healthcare provider training and clinical interaction. Finally, we will present more detail regarding practical implementation and challenges of IVET use in research and clinical contexts.

The overarching objective of this report is to suggest how IVET has been used previously in social science research and how it might be used to advance the nascent field of research and practice related to genetics and genomics. Advancing a rigorous communications research agenda in genomics meets numerous current challenges as technologies are still underdeveloped but quickly evolving. In this report we discuss how use of IVET with its many benefits could advance this research endeavor.

Immersive Virtual Environment Technology

Digital IVET technology is essentially a collection of computer hardware and software designed to immerse users in artificially-created virtual environments (VEs) such that users perceive themselves to be included in and interacting in real-time with the environment and its contents. This gives users the sensation that they are on the inside, existing within an environment or simulation, as opposed to being on the outside watching it on a screen.

The technology has the added benefit of alleviating a number of the shortcomings of traditional social and behavioral research methodologies (see Blascovich et al., 2002; Loomis, Blascovich, & Beall, 1999). Three major benefits are particularly germane. In traditional research settings there is an inherent tradeoff between mundane realism (or how much an experimental situation is like reality) and experimental control (elimination of extraneous variables and confounds). In general, the more like real life an experimental situation becomes the less control experimenters can have over the environment (e.g., the more the environment becomes like a real clinic, the less control researchers tend to have over features such as appearance, background noise, etc.). IVET allows us to conduct experiments and simulations in very realistic, true-to-life environments where, by the very nature of the technology, every element is tightly controlled. This type of realism is crucial for external validity and generalizability, clearly key concerns in the healthcare arena.

The second major benefit of IVET is our ability to present and/or manipulate characteristics and objects that in real life are immutable, invisible, or intangible. In an immersive virtual environment (IVE) one can change any person's physical characteristics (e.g., appearance, race, stature) or physical behavior (e.g., decoupling verbal and non-verbal behavior) to hold constant or isolate the effects of a particular dimension. Crucial for communication about the complex, abstract scientific topics that form the basis of genomics is the ability of the technology to dynamically represent objects and concepts that are without an accessible real-world counterpart (e.g., typically intangible, too small to observe).

Finally, there is great benefit in the expansion of implicit and covert behavioral measures that IVET can bring to social and behavioral experimentation. Behavioral measures are clearly the gold standard in behavioral research, but have traditionally been difficult to design and administer. In IVEs, physical behavior forms the backbone of system operation and behaviors such as attentive gaze can be unobtrusively recorded making spatial and temporal measurement straightforward. These sorts of measures can have much to tell us about how individuals respond to the experimental context.

Like genomic technology, IVET is continually evolving and advancing. At present, there are a few common forms the technology takes, one of the most common being a head mounted display-based IVET system where users view three-dimensional computer-generated images within a helmet. Users are often free to move naturalistically within a defined space while their position and orientation information is tracked used to control events in the VE.

Education

Determining how to best educate an uninformed public about genetics and genomics is a widely noted challenge. Related communication in these arenas is inherently complex and probabilistic, a problematic match for levels of genetic and health literacy found in the general population (Richards, 1996).

Experiential educational formats have been shown to have promise in conveying abstract scientific constructs (Winn, Windschitl, Fruland, & Lee, 2002). IVEs offer an experiential setting in which to investigate and arrive at pedagogical best practices. Strengths of virtual learning environments (e.g., active engagement in content) have been identified as key elements in optimal teaching strategies in other scientific education content areas (Dede, Salzman, & Loftin, 1996) hinting at the potential for IVET-based learning aids in the future of genetic and genomic education.

In fact, IVET holds several major advantages for the development of teaching tools and platforms for educational research. The first and most obvious advantage is the immersive nature of IVEs, wherein users are enveloped by the environment allowing for focused and naturalistic interaction with educational materials. Because virtual learning environments are digitally constructed, they allow for presentation of objects not usually visual or tangible and for demonstrations of events not possible given real-world constraints. IVET provides previously unimagined access to, for example, walk around within the nucleus of a cell as it divides, witnessing the action in 3-D from whatever angle we might wish without having to master a complex interface. Behavioral measures that map to psychological constructs like attention can be assessed. Lessons in virtual learning environments can be repeated as many times as necessary, adapting to and charting incremental learning, continually offering up new viewpoints and frames of reference. Though no work evaluating IVET as a tool for genomics education has yet been published, a review of the small number of related science education studies suggests that the benefits of IVET would apply to this arena as well (Winn, 2005).

Simulation for Decision-Making and Behavior Prediction

Offers of genetic testing require potential test-takers to make important decisions in an area that is likely to be unfamiliar. Currently, the common methodology for assessing predicted test uptake involves collecting responses to a hypothetical scenario or vignette outlining test and/or disease details that a particular research team deems worthy of inclusion (Persky, Kaphingst, Condit, & McBride, 2007). Though this methodology is widespread, there is often a considerable disparity between predicted test interest and actual test uptake (e.g., Pasacreta, 2003) suggesting that the ways in which people are asked to predict their future thoughts, feelings, and behavior may not get at crucial factors influencing actual decisions.

Using IVET to engage in role-playing or personal time-travel exercises may provide a unique opportunity to examine factors influencing decision making surrounding events such as offers of genetic testing and/or receiving test results. Such exercises also may permit better estimates of target groups' interest in and response to forecast genetic testing developments or currently unavailable tests. Role-playing and time travel may, following evaluation, find their way into practice as decision aids, allowing individuals to better mentally approximate the experience of making testing decisions and receiving results. Though IVET has yet to be used in this manner, IVET users in the domain of role-playing for development of social competency report high levels of engagement and the perception that their behavior in the virtual environment did not differ from how they would have behaved in an identical real-life scenario (Paschall, Fishbein, Hubal, & Eldreth, 2005).

IVET can be well suited for immersing individuals into vivid role-playing scenarios as it is able to provide a life-like simulation for certain types of situations that has been shown to result in altered attitudes and behavior (Yee & Bailenson, 2006). In addition to genetic testing scenarios, these simulations can include situations that would be difficult to simulate in real life. Immersive virtual environments also provide the unusual ability to remove oneself from an event, allowing time to stop and reflect, or placing the self in an alternative viewpoint as the scenario unfolds.

Non-directive simulation also may have a role to play in testing and refining genetic counseling practices, an area in need of evidence-based counseling and counselor training techniques (Biesecker & Marteau, 1999). Virtual environments could be integrated in some of the forms discussed previously as role playing or decision-making tools or even as a way to explore possible social identities associated with genetic diagnoses or disease outcomes (e.g., being a carrier; having type II diabetes) through perspective-taking exercises.

Behavior Change Motivation and Intervention

In contrast to decision-support approaches that are intentionally neutral, giving individuals information to use in deciding between courses of action, behavior change interventions are intended to be persuasive and motivate message recipients towards behavioral actions that reduce risk or improve health outcomes. In many cases, these behavior change appeals have been found to be most persuasive when tailored to the individual's particular mental states and health needs (Skinner, Campbell, Rimer, Curry, & Prochaska, 1999). IVET offers a format in which interventions can not only be personalized to individual characteristics (e.g., preferences for instruction format, health educator characteristics) but be taught interactively, via experience of trial and error, vicarious learning, and experiencing outcomes of behavior change with a high degree of realism.

There are a number of prevention-related interventions that could be readily adapted and possibly improved by use of IVET. For example, prevention metaphors (e.g., comparing genetic ability of the lungs to clean smoking residue to a chemical car wash; McBride et al., 2000; McBride et al., 2002) used to convey health risks have shown mixed effectiveness for behavior change in written forms. These metaphors could readily be experienced, that is, individuals could interact with the car wash, turn on and off the nozzles that show how the body's enzymes are functioning, for example, in ways that may be more engaging and in turn, more motivational. Work using a virtual risk elevator in which individuals learn about gene and environment interactions via pressing different combinations of buttons has shown promise for providing an experiential metaphor format for improving risk comprehension (Kaphingst et al., 2009). Additionally, IVET allows unobtrusive investigation of how and when these techniques are useful. Researchers could assess the ways participants attend to metaphors (via

gaze behavior) and their messages and assess changes in attitudes and/or behavioral intentions along the way.

Perhaps more concretely, the malleability of personal representations in VEs can also provide users the opportunity to experience alternative forms of self. For example, the goal of persuading youth toward preventative action is cited often as a challenge in the attempt to bring distal health outcomes to a more proximal and relevant risk in the present (Lipkus & Prokhorov, 2006). IVET could be used to evaluate experiences that are most salient and motivational for young people, such as experiencing representations of themselves and their bodies in the future given the presence or absence of prevention behaviors in the intervening time.

Users could learn about and practice prevention behaviors such as smoking cessation in ways similar to previously successful video game-based health promotion tools (Kato & Beale, 2006; Lieberman, 2001) and through VEs specially designed to desensitize users to addiction cues in a controlled environment (e.g., Bordnick, Traylor, Grapp, Copp, & Brooks, 2005). Such practice could increase efficacy expectations and reduce the negative impact of occasional failure (Bandura, 1977). Furthermore, prevention efficacy exercises could be fertile ground for research investigating efficacy and prevention in a realistic atmosphere where real behaviors can serve as outcome measures eliminating the need to rely solely on self-report.

Clinician Training

IVET interactive simulated patient training tools have proven effective in increasing students' knowledge and competencies (Stevens et al., 2005) in safe learning environments where failure does not hold the grave consequences of real clinical experience. These diagnostic and social interaction training tools could be adapted for use with genetic counseling trainees, health educators, lay advisors, and other interventionists, providing an opportunity for repeated practice with a wide range of clients and situations and with built-in evaluation techniques for trainees and their instructors. Such systems can also allow users to gain insight from a second viewpoint, experiencing, for example, one's own counseling technique from the perspective of the client.

Though there is a history of IVET use in physician training, there has been no work to date in the direction of interaction surrounding genetics and genomics. This will become increasingly important as physicians have been enlisted to field genetic susceptibility testing inquiries and participate in discussions surrounding testing. Practicing testing discussion and referral scenarios with patients could help physicians become more comfortable in delicate interactions whether or not testing is indicated. IVET also could be useful for evaluation of physician interaction style and clinical assessment with respect to patients with various genotypic and/or phenotypic profiles. Interactions with virtual patients can allow unobtrusive measurement of verbal and non-verbal behavior, highlighting performance or other behaviors (e.g., biases) of which physicians and their trainers should be aware.

Practical Implementation and Challenges

Practical implementation of IVET requires resources, planning, and imagination. The first and most obvious issue is the cost of obtaining these resources. The cost of IVET systems has continued to decrease to being within the reach of many institutions. IVET typically runs on off-the-shelf PCs, however, the other hardware varies substantially in terms of type and quality, each requiring a different level of financial outlay. One company, for example, advertises high quality entry-level head mounted display-based systems with position tracking at approximately \$20,000 USD (Worldviz, 2007). While a research laboratory could potentially function with a single setup, any protocols requiring multi-user interaction will require at least two systems.

In terms of software, there are a number of commercially available VEs for more common applications (e.g., psychotherapy), however, more novel applications typically require custom programming work. Cost and time required for VE programming will depend upon the scope of the project and the skill and experience level of the programmer. Software packages designed for creating VEs are continually becoming more functional and user friendly and one would expect that with the currently high rate of computing power expansion and software sophistication these costs as well will continue to diminish.

Once an IVET facility is up and running, it requires a good imagination and pilot testing to create engaging simulations that tell the desired story, provide for the desired interaction, and properly measure the theoretical variables of interest. The state of computer technology and the extensive programming necessary for realistic interaction with virtual humans can require voice recognition and complex artificial intelligence schemes and can limit the extent to which a naturalistic verbal give-and-take can occur. However, through careful planning, it is possible to appropriately constrain a scenario so that a social exchange can be psychologically natural. Furthermore, once an experimental scenario is mapped out and created it can be used for as many iterations as desired, replicated in any facility with the required equipment, and altered for use in future related or unrelated work. These environments can test ideas that move from the lab into the real world and vice versa, thus creating an interface for tested concepts moving back and forth from the empirical to the applied.

IVET also brings with it some technology-related issues such as cybersickness, a sensation similar to motion sickness that can, in some cases, arise from equipment use. Some published studies report high incidence rates of cybersickness (e.g., Cobb, Nichols, Ramsey, & Wilson, 1999), however, many other studies (e.g., Bailenson & Yee, 2006; Schneider, Prince-Paul, Allen, Silverman, & Talaba, 2004) suggest much lower symptom rates. A more positive byproduct of the technology, however, is the enthusiasm that study participants typically hold IVET, a technology commonly considered to be novel and quite enjoyable to use. In our own anecdotal experience, we find this reaction to IVET to be a boon for recruitment and participant engagement.

In summary, the benefits conferred by IVET have a number of important potential advantages for advancing a communication research agenda related to applications of genomics for public health in the areas of education, simulation decision-making, behavior change intervention, clinical practice, and training. Research in each of these domains could contribute substantially toward improving the tools and techniques providers have to communicate ideas and the ability of target audiences to respond to and understand them.

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