The Scientific Research Potential of Virtual Worlds

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Online virtual worlds, electronic environments where people can work and interact in a somewhat realistic manner, have great potential as sites for research in the social, behavioral, and economic sciences, as well as in human-centered computer science. This article uses Second Life and World of Warcraft as two very different examples of current virtual worlds that foreshadow future developments, introducing a number of research methodologies that scientists are now exploring, including formal experimentation, observational ethnography, and quantitative analysis of economic markets or social networks.

Recent sociotechnical developments involving online worldlike environments have made possible new kinds of research in the social and behavioral sciences, raise interesting challenges for computer and information science, and suggest new potential for education across all the sciences (*1*, *2*). We can use the term "virtual world" to describe an electronic environment that visually mimics complex physical spaces, where people can interact with each other and with virtual objects, and where people are represented by animated characters. The diversity of current virtual worlds can be represented by the creativity-oriented environment Second Life (SL) and the massively multiplayer online role-playing game World of Warcraft (WoW). To date, about 6.5 million people have entered SL and WoW reports that it has 8.5 million subscribers, so the impact of this technology is beginning to be felt by society.

The user enters each via a personal computer running special software that connects to one or more servers that pass information back and forth between users over the Internet. Both simulate very large three-dimensional environments filled with virtual objects through which the user may subjectively walk, swim, or fly, and in the case of WoW, with thousands of simple artificial intelligence (AI) characters to interact with. Each user is represented by an avatar and can talk with the others by typing in a chat channel or through optional voice communication (*3*). Both worlds sustain complex internal economies with their own currencies, both enable users to do useful work for each other, and both offer software tools to facilitate social interaction, although some of their specific features are quite different (*4*–*6*) (Fig. 1).

In terms of scientific research methodologies, one can do interviews and ethnographic research in both environments, but other methods would work better in one than the other. SL is especially well designed to mount formal experiments in social psychology or cognitive science, because the researcher can construct a facility comparable to a real-world laboratory and recruit research subjects. WoW may be better for nonintrusive statistical methodologies examining social networks and economic systems, because it naturally generates a vast trove of diverse but standardized data about social and economic interactions. Both allow users to create new software modules to extract data.

The present moment marks a major historical transition. Video games and computer games are in the process of evolving into something much richer, namely virtual worlds, at the same time that electronic games are surpassing the motion picture industry in dollar terms and beginning to cut into television. Already, many families forgo watching TV dramas to quest together in WoW. Previously separate forms of electronic communication are merging in what Americans call ubiquitous computing and Europeans call pervasive computing. The current generation of video game systems—XBox 360, PlayStation 3, and both the Nintendo Wii and the Nintendo DS portable—all connect to the Internet, and games designed for cell phones or Internet-connected pocket computers are proliferating. Researchers are exploring the methods needed to create an entirely new generation of games, called pervasive LARPs (live-action role-playing games), that have players act in the real world while simultaneously interacting over the Internet via wireless mobile connections (*7*–*9*).

During this time of transition, when there is active speculation about the investment opportunities, it is exceedingly difficult to estimate the current economic impact of virtual worlds, let alone project the future. For example, a Web site called *Wowhead* that was merely about WoW recently sold for 1 million dollars, and the game's $15 monthly charge across many subscribers could generate hundreds of millions of dollars per year (*10*). Virtual worlds differ as to whether their internal currency can be exchanged for dollars (SL, yes; WoW, no), so economists face the scientific dilemma of how to count wealth generation inside the games, in addition to the external dollar investments and returns. Exploratory studies by Nick Yee suggest that most players are in fact adults, disproportionately male but with a wide variety of occupations and demographic characteristics (*11*), so virtual worlds are not simply a childish fad. However

Fig. 1. The Stormwind Auction House in WoW. The three figures wearing vests and standing on platforms are the computer-generated auctioneers, whereas the dozen other figures are characters belonging to real human beings participating in auctions involving a thousand or more people. The one waving in the center is the avatar of a scientist who is studying this virtual world and the computer-assisted systems it provides to facilitate social interaction and economic exchange.

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important they may become, a few social scientists and computer scientists have shown that these new realms are already suitable environments for scientific research.

Virtual Laboratory Experiments

For at least a decade, experimentalists in the social and economic sciences have looked to the Internet as a mean of expanding the scope of their research, and virtual worlds may finally turn hopes into opportunities. A scientific agenda for online experiments was already enunciated in 1997, when the National Science Foundation (NSF) sponsored a workshop called NetLab to explore the potential for online experimental laboratories (www.nsf.gov/sbe/ses/soc/asi.jsp). The NetLab report said that the Web could enable experiments to (i) be scaled up from the usual few dozen subjects to hundreds or even thousands; (ii) cross sociocultural boundaries and include research subjects from previously underrepresented groups; (iii) study processes that take place over longer periods of time, including weeks or even months; and (iv) become integrated into the curriculum of undergraduates who do not happen to be in major research universities where such work traditionally takes place.

Over the 10 years since NetLab, a number of workshop participants have employed computer-based experimental methods, and some of these studies attempted to fulfill the vision of research on an expanded scale (*12*–*14*). Several groups have made progress in designing "collaboratories" (*15*, *16*). The effect of these efforts has been increased cooperation between researchers at different universities and improved use of experiments as teaching tools. However, the vision of vastly increased numbers of more diverse respondents interacting over longer periods of time has not been achieved yet.

The scientific motivations for achieving these goals are compelling. Today we understand better than in the past that individual humans, small groups, and large communities are all complex dynamic systems in interaction with each other. Traditional laboratory methods are the best way of testing simple causal theories by manipulating one or more experimental treatments, which are considered the independent variables (*17*, *18*). For statistical reasons, experiments with small numbers of research subjects are limited to detecting very strong effects, which is unlikely to be the case when many different variables influence both the outcomes and each other. To unravel complex causal systems using experimental methods, one needs a very large number of subjects. The background variables of the individuals may have important influences on the connections between the independent and dependent variables, so replication across multiple or diverse populations will be necessary.

Virtual worlds such as SL provide environments and tools that facilitate creating online laboratories that can automatically recruit potentially thousands of research subjects, over a period of months, at low cost (Fig. 2). SL offers scripting and graphics tools that allow anyone to build a virtual laboratory building, functioning equipment to run the experiment, and incentives to motivate participation, such as giving each research subject a virtual helicopter to fly around SL (*19*). It would be quite feasible to have advanced students replicate classic experiments inside SL, adding to our confidence in older results while giving young people valuable skills. Creative scientists may also be able to design experiments that are feasible in virtual worlds but were never possible before. For example, experiments can be done comparing the socioeconomic consequences of alternative government regulations, something next to impossible in society at large (*20*), perhaps taking advantage of the fact that issues of environmental pollution already loom large in WoW quests. A team led by Yasmin Kafai at the University of California, Los Angeles, has already used the children's virtual world *Whyville* in an experimental study of reactions to a measles-like epidemic affecting the avatars (*21*).

Makers of online games are always looking for interesting ways to enhance game play for their subscribers, so they might be willing to incorporate appropriate experiments. This would be especially true if the experiment were novel, if the company were facing stiff competition and were thus open to innovative ideas, and if the scientists had their own funding to cover the additional costs. Consider that players in WoW are split into two opposing factions of many races, called the Alliance and the Horde, engaged in a cold war comparable to the historical NATO/USSR split. In 2006, two years after WoW was originally released, features were intentionally added to two zones to increase conflict between the factions. Eastern Plaguelands gained four towers for the factions to fight over, and in Silithus they compete to collect samples of a valuable mineral. In both cases, much of the benefit is collective, what economists call a public good, given only to members of the winning faction, quite apart from how much the individual player contributed to the victory. Thus, the two zones are effectively field experiments on the question of how individuals can be induced to cooperate in producing public goods (*22*). The evolution of cooperation between individuals is the classic topic for multi-agent–system AI computer simulations in the social sciences, and the fact that virtual worlds combine both AI agents and human-controlled avatars implies that many rigorous experiments on this crucial issue can be conducted in them (*23*–*25*).

Political science uses the experimental method almost exclusively in small laboratory studies that mimic committee deliberations, and none of the social sciences experiment aggressively with social movements, simply because the cost and the ethical issues are daunting. This situation could change online, especially in role-playing games such as WoW, as long as the given experiment harmonized with the mythology of the virtual world. In the days before university committees on research with human subjects, it was not con-

Fig. 2. Three avatars in SL making a door. In a virtual design studio, two scientists are admiring the work of a student intern (center) who is creating a set of displays demonstrating human-centered computing. After the combination lock has been set and made smaller, the door can readily be moved to its final location. Similar methods can be used to construct laboratory facilities and experimental equipment.

sidered unethical for a team of social scientists to join a small social movement in order to study it covertly, thereby seriously affecting its outcome, or to experiment with alternative government programs that had serious consequences for the beneficiaries, but those days are gone (*26*, *27*). Participants in WoW expect the others to be acting aggressively in pursuit of goals defined by the mythos. Thus, a team of agents provocateurs who are researchers in disguise would positively contribute to everybody's dramatic experience, if they promoted a movement that simultaneously supported the mythos and permitted scientifically relevant observations of human behavior. (See the conclusion for a discussion of ethical issues.)

Observational Social and Economic Science

Many scientists and scholars are already conducting research about virtual worlds, and they are beginning to use them as environments to ask general social-scientific questions. Economist Edward Castronova argues that an increasing fraction of human life, economy, and culture will take place in these novel environments, so they need to be studied as important phenomena in their own right (*28*). In a study of social and economic coordination, Castronova has shown that it can be fruitful to compare results from research in different virtual worlds, just as is true for nations on Earth (*29*). There is some evidence that they serve as hatcheries for new cultural movements; for example, facilitating the consolidation of post-Christian religious ideologies (*30*); and are substituting for disintegrating social institutions in the real world (*31*).

It is especially important to study virtual worlds now, because the current period of transformation may not last much longer, and because it may be impossible to reconstruct its key processes and phenomena entirely from historical records that are naturally preserved. Essentially all of the classic one-player electronic games can still be played, either because computer emulators of the old systems have been created or the games have been ported over to new systems. But the same is unlikely to be true for today's virtual worlds, because they depend on the extensive social infrastructure of the companies that support them and on the current population of people who inhabit them.

Virtual worlds are good environments in which to explore wider issues related to emerging technologies, such as intellectual property rights (*32*) and the sociotechnical implications of online misbehavior (*33*–*35*). Research concerning the cultural boundaries of virtual worlds includes studies of the extent to which gender-specific behavioral norms transfer to these nontraditional environments (*36*), comparisons with role-playing games that are not electronic such as *Dungeons and Dragons* (*37*), contrasting the human impact of alternative architectural philosophies (*38*), the emergence of cooperation (*39*), the possibility of addiction to virtual worlds (*40*), and exploration of the different meanings that participants attach to virtual life and death (*41*). To date, much of the research has followed the twin qualitative paradigms of anthropological ethnography and sociological participant observation (*42*), but quantitative approaches using rigorous statistical and computational techniques show very great promise.

WoW is a very conducive environment for quantitative research because it encourages individuals to write "mod" or "add-on" programs, and scientists can use some existing software as research tools or write their own. These range all the way from very simple sequences of character behaviors constructed using macros built into the WoW user interface to long programs written in the Lua language. For example, one widely used program called Auctioneer analyzes prices on the WoW virtual item auction system, and CensusPlus tallies all the players currently online by several characteristics (Fig. 3).

With census data on more than 200,000 WoW characters, a team centered at the Palo Alto Research Center analyzed the factors associated with the upward status mobility of individuals (*43*) and the dynamics of social groups (*44*, *45*). Another team, centered at the University of Illinois, has recently received NSF funding to develop new analytical tools while analyzing data taken directly from computer servers that run another major online role-playing game, augmented with a questionnaire administered to thousands of subscribers (www.nsf.gov/awardsearch/showAward.do?AwardNumber=0628036). In principle, the raw data from a game server record every single interaction between humans, including economic exchanges, the affiliation steps that build groups and networks, every "chat" communication between players, and all action choices that individuals make within the social environment.

Computer and Information Science

Online virtual worlds illustrate well the deficiencies of the Internet (*46*), notably its high latency (slow packet delivery speed) and low bandwidth (amount of information that can be delivered in a given period of time). WoW manages the bandwidth problem by placing all the graphics on the users' computers, but this means that they cannot create their own objects and at best can assemble existing components. This would not work for SL, because the whole point is to empower users to create everything in their virtual world from scratch themselves. The penalty for SL users is a delay whenever the avatar moves to a new location, because all the specifications for the environment must be downloaded from the server, often thousands of miles away.

Latency is a big issue for action-oriented online games (*47*). WoW's user interface includes a latency meter so that the user can decide whether to log off and then back on later in hopes of getting a better connection. Humans can detect latencies of as little as 50 ms, whereas in normal use, Internet latency may be five times that long. Games cover this delay as best they can, typically by restricting players to scripted movements, but this is far from ideal.

Currently, virtual worlds use some variant of client/server architecture, in which a centralized company computer handles interactions among all the players, although WoW does employ a partial peer-to-peer network in distributing its updates. The Nintendo DS portable game system is an example of local peer-to-peer wireless

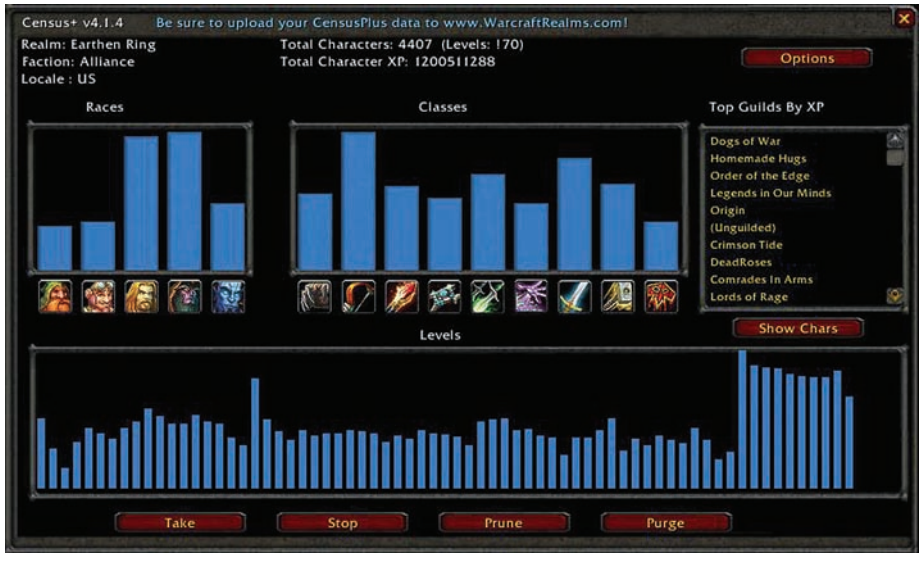

Fig. 3. Example of CensusPlus output from WoW. This display graphs the results of tabulating 4407 active characters for one faction in one of the hundreds of realms of this online game, and exact census numbers are also provided. The bar graph at top left shows the distribution across five "races": dwarves, gnomes, humans, night elves, and Draenei; whereas the other bar graphs show the nine classes (such as warrior or priest) and the distribution across levels of experience.

networking, suggesting the range of alternatives that may be built into a future successor to the Internet.

Virtual worlds are a good proving ground for virtual people, namely AI nonplayer characters (NPCs) like the thousands that inhabit WoW. NPCs can be either friendly (such as merchant characters that serve as portals to the database of virtual objects) or unfriendly (such as the animals that a game player can gain points by killing). Carnivores constantly patrol territory at random and attack the user's avatar if it comes within what players call the "aggro radius" and ethologists of real animals call "reaction distance." The AI system for such an animal is extremely simple, but it often models running away or becoming enraged when it suffers damage. AI representations of humans potentially could be much more complex. Notably, a team led by Mary Lou Maher has been developing conceptual frameworks and detailed methods for giving these agents the motivation to seek novelty and respond creatively (*48*, *49*).

Other fields of computer and information science that may use virtual worlds as laboratories include human/computer interaction (HCI), where "machinima" videos shot in virtual worlds may be used to develop prototypes of a wide range of systems (*50*) and new methods of information visualization (*51*). Today's virtual worlds contrast strongly with the concept of totally immersive virtual reality (VR) that has long been popular with science fiction writers (*52*) but has proven so difficult for computer scientists to achieve in the real world. SL and WoW images are restricted to the screen of an ordinary computer monitor, rather than filling the walls of a VR cave or a binocular head-mounted display. On the one hand, this may suggest that people really do not need visually perfect VR. On the other hand, today's virtual worlds may be preparing millions of people to demand full VR in the future.

Conclusion: Human Challenges

Virtual worlds may help unify some branches of the social sciences and give them greater scientific rigor. Whereas economics and cognitive science have made great strides in recent decades, some other disciplines remain fragmented in myriad competing schools of thought, poised ambiguously between the humanities and the natural sciences. For example, concepts such as "identity" and "self" have been used for nearly a century to describe aspects of human individuality, initially by the psychoanalytic school in psychology and symbolic interactionists in sociology (*53*, *54*). Some contemporary cognitive scientists are skeptical of scholarly conceptions of self (*55*), finding them to be more like literary metaphors distilled from the surrounding folk culture than like rigorously measurable scientific concepts. The cognitive and emotional relationships between a human user and his or her online representation are very actively debated and could become the focus of increasingly rigorous research and a point of convergence for the social sciences (*56*, *57*).

Interestingly, SL and WoW have different orientations. The simulated people in SL are avatars, supposedly expressing the identities of their human owners, just as avatars within Hindu religion personify aspects of the deities. WoW uses the term character, implying that many players may keep a psychological distance from them, considering them toys, puppets, perhaps even friends, but not selves. Avid players tend to run several characters, commonly referring to them as possessions.

Given the great variability across virtual worlds and human participants, the multiplicity of feasible research methodologies would permit a range of overlapping research studies, adjudicating between alternative theoretical propositions and thereby connecting the currently isolated schools of thought. Some studies could examine how humans conceptualize their own avatars or characters, while others could focus on mutual perceptions during social interaction. A third category of studies could look at how humans react to the currently rather simple AIs. A fourth could explore social cognition by designing ever more complex and lifelike AIs, watching their interactions with people, and even modeling them on specific human individuals to better understand the cognitive processes that shape human behavior.

The tremendous research potential of virtual worlds cannot obscure the fact that there are problems as well. A number of organizations hold meetings in SL, from IBM to informal friendship groups, but it is unclear what enhancements are needed to make it a really good environment for serious distributed collaborations of the kinds often undertaken by scientists. Given that university departments hire faculty in a diversity of fields, research collaborations in highly specialized fields often of necessity span institutions, but scientists do not seem to be rushing into SL to find a shared virtual location. What value virtual worlds might add to the existing modes of communication between distant scientific collaborators remains to be seen.

Online research involving human beings may require ethics scrutiny by institutional human subjects review boards, or it may not, depending on the circumstances. Arguably, both SL and WoW are public places, and the fact that both discourage people from using their real names seems to provide anonymity, but these points can be contested. In WoW, for example, some combat arenas and chat channels are accessible only to groups formed by invitation, so these might qualify as private places. Many frequent users of SL craft their avatars to look like themselves and give them portions of their own names. Any avatar is subjectively a second self, so its reputation becomes important to the owner even if its deeds cannot be traced back to the person in the real world.

Academic social scientists are often required to follow NSF's *45 CFR Part 690: Federal Policy for the Protection of Human Subjects*, even if their project does not have federal funding (www.nsf.gov/bfa/dias/policy/docs/45cfr690.pdf). However, people doing research outside the regulatory context of a university or other employer are free to do anything not prohibited by law or the enforced policies of the particular virtual world. Given the low cost and ready accessibility of online virtual worlds, students are already undertaking research projects, from middle school upward, raising a host of ethical issues, starting with the question of whether one can require informed consent from every individual in an online public space. We cannot expect such issues to be resolved in any definitive fashion, because both social norms and the technology are constantly changing, but researchers need to be sensitive to them.

A related human issue concerns the transformation of some kinds of education at precollege levels, which might harmonize with scientific values more than with traditional values. NSF has supported the development of two virtual worlds devoted to science education: *River City*, where students explore public health issues in a simulated 19th-century town (*58*), and *Quest Atlantis*, where preteens develop fundamental research skills by solving environmental problems (*59*). A number of educational institutions are active in SL, including Ohio University, the University of Texas at Dallas, the University of Cincinnati, Bowling Green State University, the University of North Carolina at Chapel Hill, and Vassar College, often giving students educational experiences in creating content for SL.

Many virtual worlds may foster scientific habits of mind better than traditional schools can, because they constantly require inhabitants to experiment with unfamiliar alternatives, rationally calculate probable outcomes, and develop complex theoretical structures to understand their environment (*60*–*62*). Probably for better, but conceivably for worse, virtual worlds are creating a very new context in which young people are socialized to group norms, learn intellectual skills, and express their individuality (*63*). The "graduates" of SL and WoW may include many future engineers, natural scientists, and social scientists ready to remake the real world in the image of the virtual worlds.

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