Sociology Compass 1/2 (2007): 613–636, 10.1111/j.1751-9020.2007.00036.x

Simulation as a Social Process in Organizations

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Abstract

An emergent research literature is starting to cohere on simulation as a sociological process within organizations. This paper shines a spotlight on this scholarship, and offers new ways to think about the dizzying array of simulation we encounter in our organizational, institutional, and everyday lives. I define simulation as an empirical social process and show how they vary in consequence by their experiential modality, their referential frame, and their perceived realism. I then document three conceptual trends in the literature: (i) treating simulation as an organizational technique for risk management; (ii) a focus on virtual reality, video games, and moral ambiguity; and (iii) studies of the impact of computer simulation on scientific knowledge production and the reorganization of some technical fields, such as weapons research, artificial intelligence, and meteorology. Organizational uncertainty tends to coalesce around disputes about the appropriate qualities and functions of a given simulation technique or technology. I conclude the paper by identifying how the sociology of simulation can connect with more established areas of contemporary research within organizations, work and occupations, and institutional sociology.

Introduction

In this paper, I review a loosely conjoined, emerging research literature that analyzes simulation in its physical, virtual, and computer-based forms as a sociological phenomenon. Some of these studies look at physical simulations as a preparatory technique whereby organizations manage risk, uncertainty, and conflicting institutional logics. Others address the efficacy of virtual reality (VR) simulation and video game technology on educational institutions and moral behavior. A third looks at the impact of computer-based simulation technologies on the social organization of technical professions, in particular in terms of scientific knowledge production and controversies around standards of verification. This paper is not about social simulation techniques for enhancing research or pedagogy, nor does it consider whether we have entered a postmodern era characterized by simulation. Rather, it provides a synthetic review of research that conceives of simulation as an empirical social process. I focus here on how organizations use simulations, physical and virtual, and some of the problems and uncertainties that go along with it. To clarify, I start with an example.

I recently attended a cardiopulmonary resuscitation (CPR) and automated external defibrillator (AED) training session with about two hundred fellow Chicago Park District employees. We were given emergency relief kits, shown an instructional video, and led through simulated rescue scenarios on 'CPR Andy' clones. A bit comic in retrospect, the latex gloves in each emergency kit became an odd source of tension during our compression exercises. Soon after we were told to wear them, an elderly employee asked if he should wear the gloves at home in case his wife had a heart attack. Next came a series of questions about why we needed to wear them during the training at all. A few simply refused to put them on. Our frustrated instructors warned one such trainee that if she did put the gloves on, she would not be given her certification. She shot back angrily, 'There is no blood. I don't need to wear the stupid gloves!' The debate continued for several minutes before the lead instructor again warned that certifications could be withheld. Then he forged ahead, complaining that we were wasting too much time debating gloves. Everyone ended up receiving their certification that day, even the woman who for the rest of the day continued to rescue her Andy barehanded.

This seemingly trivial example reveals several ways that simulation is used by organizations to enhance efficiency, reduce costs, and manage workplace performance. At the most general level, simulation is a generic mechanism for institutionalizing standard workplace protocols and personnel procedures. While the video and instructions served to catalog different emergency scenarios, the simulation drills provided a way for Chicago Park District employees to engage in hands-on practice, with sustained, deliberate feedback from previously trained instructors. Simulations reduce employee and client risk by engendering a relatively casual, flexible, and uniquely controllable environment for employees to learn how to deal with fundamentally serious situations, such as a life-threatening trauma. Time and space are rendered manipulable. Emergency scenarios were segmented and stretched – sped up, slowed down, repeated, paused, and modified. Simulation is thus a key aspect of many cost-effective personnel training systems. It also provides a cost-saving mechanism by potentially preempting lawsuits from untoward property and physical damage with a relatively low capital outlay intended to harmonize personnel procedure and client relations.

Or so goes the functional ideal, at least. The gloves debate also revealed that simulation techniques can create, or at least be a venue for, uncertainty, disagreement, and the exercise of power (new institutionalist theory would refer to this as 'loose coupling'). The dispute hinged on the extent to which the simulation was perceived to be an accurate or useful approximation of the reality it was preparing us for. The woman who refused to wear gloves called attention to a disharmony between the simulation and an actual cardiac trauma, bringing to a head a more general tension around the perceived low realism of our training. This tension spread beyond the wearing of gloves. Several coworkers quietly told me during the session and days afterward that they were not confident that the training could prepare them for an emergency situation. Yet our trainers' somewhat unenviable task was to get us to buy into the simulation's realism, or at least to temporarily suspend the perception of ontological disharmony. Once this became openly challenged, the instructors appealed to procedure, formal authority, and efficiency norms in an attempt at situational repair. When their efforts failed to get everyone in line, they simply ignored the offenders and moved on.

This is an example of what I refer to as simulation as an empirical phenomenon, and this paper provides a synthetic overview of an emerging literature in the social sciences that looks at simulation in (roughly speaking) a similar way. It pulls together a somewhat disparate array of examples and areas of empirical research, from certification training to soldiers preparing for battle, from fire drills to virtual evolutionary ecosystems, from nuclear bomb testing to first-person shooter video games.

Let me lay out a few scope conditions before going further. Due to space constraints, academic parochialism, and a relative dearth of international or comparative studies, most of the examples herein are North American and European. Nonetheless, simulation is a widespread and general social phenomenon deserving of equally widespread and general study. I also omit the two bodies of literature that make up the most common ways that simulation enters scholarly discourse. First, I make no attempt, nor would I be qualified, to survey the massive amount of research that uses simulation techniques in technical applications, experiments, pedagogy, theoretical modeling, and the like (for overviews within sociology, see Bainsbridge et al. 1994; Gilbert and Heath 1985; Gilbert and Troitzsch 2005; Halfpenny 1997; Sawyer 2005). While this is far and away the most common treatment of simulation (using *Web of Science* database, on the order of about 2000 to 1), it treats it not as an empirical phenomenon in its own right but as a technical artifact for modeling an interactive process. Second, I mostly omit what could be called the philosophy of simulation. This includes work in ontology that asks how we can know whether or not we are currently living in a simulation (Bostrom 2003), as well as a fairly abundant literature on simulation and postmodernity that argues that use-value has been supplanted by exchange-value in post-industrial, consumer-driven economies (Baudrillard 1994 [1981]; Bogard 1996; Hayles 1996; Hayles 1999; Poster 1995). While the philosophy of simulation provides interesting thought experiments, engaging theoretical discussion, and even moral provocation, it tends to overstretch the concept with little attention to specifying its empirical forms. So, rather than engage in metaphysical and philosophical debate, I focus on scholarship that treats simulation as an organizational form, social process, or cultural location for social interaction.

In the first section, I formulate a working definition and then introduce an analytic heuristic for mapping diverse kinds of simulation. All simulations vary across three basic dimensions: their *experiential modality*, *referential frame*, and *perceived realism*. This analytic abstraction has the empirical payoff of suggesting that organizational and institutional uncertainties tend to coalesce around disputes over what sort of simulation something is, or ought to be. In the second section, I lump recent research that treats simulation as an empirical phenomenon into three general foci. First are studies that look at how physical simulations get tagged to particular organizational needs, primarily by utilizing them as techniques for constraining complexity and consequence around risk and organizational costs. The goal is to create scenarios that are realistic but, by necessity, not real. Next I review work that focuses on whether or not the experience of virtual reality can be too real. Scholars and laypersons alike are wrestling with issues of moral ambiguity in the institutionalization of virtual reality simulations within educational settings. A final theme involves the proliferation of computer-based simulation in scientific knowledge production, or simulation as a substitute for experience-based or experimental data. This work, emanating mostly from the sociology of science and technology, pays close attention to the impact of computer simulation on science, its methods, and its means of validating evidence.

What is simulation?

Philosopher of science Stephen Hartmann (1996) defines simulation as a technique that enables scientists to 'imitate one process by another.' Yet, scientists producing esoteric knowledge are not the only ones who use simulation. A softball coach is as likely to use them to prepare her team for an upcoming game as are climate modelers to use them to explore the impact of carbon dioxide emissions on global climate trends. Office managers employ simulation techniques to train employees on specific skill sets or to enhance staff relations and communication. Airplane pilot trainees spend more time flying through virtual space than in the air. Advertisement agencies use simulation to test new products or outdo a competitor, as do dissertation students preparing for job and conference talks. Automobile manufacturers ram dummy-carrying cars into concrete walls to ensure safety compliance. In the span of a few minutes, video game thrillseekers can get a first hand experience of a World War II air-bombing campaign, gun down invading space aliens, thwart a terrorist plot, and hit a grand slam at the 2008 World Series.

What do all these disparate examples have in common? At the most general level, a simulation approximates something else – a future task, game or scenario; a social, physical, chemical, or mental process; an experience; ecosystem, society, world, or universe. Simulation also simplifies that task, process, experience, ecosystem, society, world, or universe by rendering some key features more constrained, controlled, and predictable. The purpose of the simulation can vary: preparation for future tasks, knowledge creation, or an entertaining game or experience. While a bit broadly stated here, a useful working definition of simulation that ties together these different strands is that they *directly approximate an indexed reality or goal state via a simplified model for the purpose of preparation, knowledge production, or entertainment*.

One might wonder if this definition tries to cover too much ground. Should we consider all training and preparatory drills simulation? A key distinguishing feature of simulation is that they *ontologically* index a specific reality or goal state. In this sense, it is not very useful to call a boxer's floor exercises, such as a sit-up or push-up, a simulation of a competitive fight, but shadow boxing in front of a mirror is. Both are types of training, but only one directly approximates an indexed reality by creating a simplified but still dynamic model. Similarly, while reading a procedural manual is a typical part of workplace training, simulation is usually reserved for only the most consequential of duties outlined within it (most typically those that involve either open-ended employee–client relations or significant capital risk for the organization). More elaborate simulations will tend to be used where the capital risk to the organization is highest. Some, but not all, types of training and drills are also simulation, especially for organizational tasks and workplace settings where initiates need to practice a complex task several times before reliably performing them in the 'real world'. Simulations provide a kind of alternative ontological space for the construction of meaning and action, allowing in some of the complexities of a real situation within the abstracted confines of a not-quite-real one.

From this baseline definition, simulations vary across the following three dimensions: (i) the relative physicality versus virtuality of their experiential interface, (ii) whether they preenact a future scenario (usually for preparation) or create a relatively self-referential system (usually to promote knowledge creation or to provide an entertainment experience), and (iii) how realistic they are in the minds of those who engage in them. In this section, I briefly summarize each of these dimensions.

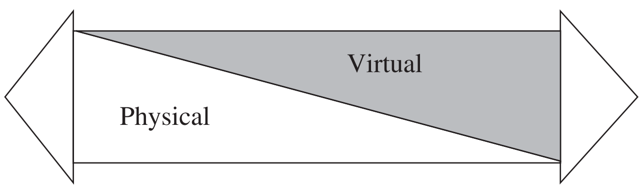
Modality

Simulations are typically categorized by whether their interface is physical or virtual, or some combination thereof. This distinction is about their *experiential modality*. Physical simulations, sometimes called 'live simulation', are those in which physical actors (usually, but not by necessity, human) engage in interactions within a Newtonian, physics-based environment that mimics aspects of a more complicated, stochastic, unpredictable, or highly consequential scenario. The archetypal example is a sports scrimmage used to prepare a team for a competitive game. Physical simulations are also common in theatre, art, music, and other live performance; military, law enforcement, and fire safety training; self-defense courses; vocational schools; certification courses; etc. Another familiar example of physical simulation is a firing range, in which cardboard mannequins stand in for criminals or enemies. A few of the more elaborate examples are full-scale village or urban physical simulations, such as the FBI's Hogan's Alley Complex or the military training center that mimics an Iraqi village at Fort Irwin, CA (Filkins and Burns 2006).

In contrast to physical simulation, virtual simulations abstract and formalize an indexed reality in digital, algorithmic, or theoretical form, freeing the experiential interface of the simulation from the constraints of Newtonian physics. VR simulations, such as flight simulators, provide an archetype. These too run an extremely wide gamut: first-person shooters in which a 'human-in-the-loop' player experiences the game environment from the viewpoint of a virtual agent; 'God games' such as the Sims series that enable players to control macro-level variables that affect avatar behavior according to parameters governing the virtual world; vocationally based technologies, surgical simulators, battle simulators used by the military, and the like.

This dimension could be operationalized as a binary/dichotomous variable (i.e., physical *or* virtual), or in ordinal/comparative terms (i.e., mostly or more physical). The latter is typically more accurate. Figure 1 suggests that physicality and virtuality are not necessarily mutually exclusive properties. Any given simulation will have tendencies in one direction or the other.

Figure 1.



An example should help clarify this point. Open-heart surgical simulators often combine a VR interface with a physical mannequin (Prentice 2005). This makes them physical and partially virtual. They might be placed close to the mid-point of Figure 1. More philosophically speaking, all virtual simulations possess nontrivial physical elements, from the electrical power and computer infrastructure needed to run them to the hand cramps of the 'humans-in-the-loop' that build, maintain, and use them.

Referential frame

The second dimension that differentiates one simulation from another is its *referential frame*, or the extent to which it is a preenactment of some future scenario or, in contrast, provides a reenactment and/or models a relatively self-referential process or system. A preenactment simulation makes explicit reference to a future event, task, or goal state for the purpose of training or preparation. A self-referential simulation still approximates a real scenario or process, but uses that approximation for a distinct, internally organized purpose. Tom Ray's evolutionary ecosystem simulator, Terra, for example, very loosely reenacts the evolutionary instincts of carbon-based microorganisms with digital organisms that evolve, mutate, and proliferate within a computer-generated 'life world'. Helmreich's (1998) ethnographic study of this and other 'artificial life' programs examines how their designers understand these entities not as preenactments of carbon-based life forms but rather as real life forms in and of themselves (needless to say, theirs is a controversial interpretation). In a similar vein, Hartmann (1996) argues that what distinguishes scientific simulations from more traditional theoretical modeling is that simulations are used less for predicting outcomes and more for exploring complex processes. While examples of physical simulation that are self-referential are much rarer than their virtual counterparts, one could consider Civil War reenactments. Such theatrical displays are clearly not intended to prepare participants for 19th-century-era musket battle. Rather, participants reenact historical battles for entertainment, education, and the ritualistic reconstruction of collective identity. As in Figure 1, it is the most descriptively accurate to think of this dimension in ordinal/comparative terms, rather than mutually exclusive categories.

Realism

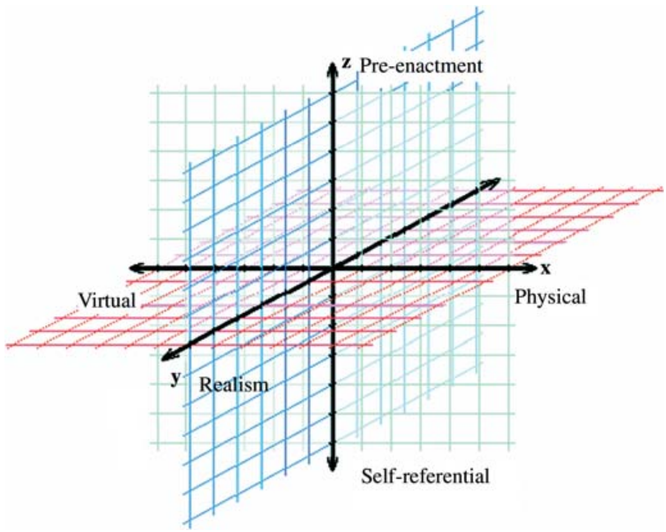
A third and final dimension on which simulations vary is in their *perceived realism*, or the extent to which participants, designers, or audiences consider it an accurate representation of the reality it imitates. In Irwin's (2005) study of military training, the most realistic simulations involved live ammunition, and were used, not surprisingly, very sparingly. In competitive boxing, full-exchange sparring is regarded as the most realistic simulation of a match. In contrast, punch pads held by a trainer, hitting a leather punching bag, and shadow boxing rank in a descending interpretive order of realism (Hoffman 2006). Similarly, Kaplan (1955) described how symphony practices become increasingly realistic as a performance approaches.

While this dimension typically varies in ordinal terms (a simulation is deemed more or less realistic), it is worth noting that it is sometimes treated in a completely dichotomous fashion. For example, Canadian soldier's use the term 'no-duff' to signal when a communication needs to be considered real and not part of a training simulation, such as when a soldier accidentally twists an ankle during a simulated battle or someone is hurt from an accidental live fire exchange (Irwin 2005). In this case, what is important from a pragmatic perspective is not how real the simulation is but its metaphysical category, either real or not.

Mapping simulations

Imagine now a three dimensional Cartesian grid that incorporates each of these three dimensions, modality, referential frame, and realism, along *x*, *y*, and *z* axes, as shown in Figure 2 below.

Figure 2.



The *x* axis refers to the modality or degree of physicality versus virtuality. The *y* axis refers to the degree of perceived realism. The *z* axis refers to the frame, pre-enactment versus self-referential. Any given simulation could be plotted along each axis of Figure 2. This would then place a simulation into one of eight octants created by the intersecting axes. Moving left to right and top to bottom, Octant I resides at the top left position (mostly virtual, preenacted, and realistic), octant II at the top right (mostly physical, preenacted, and realistic), etc. The four octants on the opposite side shown here would begin with octant V (mostly physical, preenacted, and low realism). In this way, we can think of simulation as varying across eight different possible condition states, as outlined in Table 1.

These eight condition states are suggestive of rough tendencies that characterize variation across different empirical examples of simulation. There is an obvious analytic problem here – how does an analyst decide how realistic a simulation is, whether it is a preenactment and not self-referential, or determine when its interface is more physical than virtual? There are two general solutions. First, such analytic decisions are like any other. They are made in a way that make good logical sense and are as empirically faithful as possible.

Table 1 The symbol ‘>’ symbolizes mostly, highly, or tends toward, and ‘<’ the opposite. Other short hand symbols stand for the following: v, virtual; ph, physical; pre, pre-enactment; sr, self-referential; and r, realism

Octant	Modality (*x*-axis)	Perceived realism (*y*-axis)	Referential frame (*z*-axis)	Examples
I	> v	> r	> pre	Realistic computer simulation of nuclear explosion; educational VR games; violent video games (critics’ perspective).
II	> ph	> r	> pre	Physical nuclear explosion tests; ‘live fire’ battle simulation; competitive sparring.
III	> v	> r	> sr	Artificial life systems and some AI systems (true believer’s perspective); violent video games (gamers’ perspective).
IV	> ph	> r	> sr	‘Authentic’ Civil War re-enactments; *The Truman Show*/*The Matrix* movie scenario (pre-aware perspective of Truman and Neo).
V	> ph	< r	> pre	Shadowboxing; fire drills; CPR training (non-glove wearers).
VI	> v	< r	> pre	First-generation surgical simulators with no haptic interface; unrealistic simulation of nuclear explosion.
VII	> ph	< r	> sr	‘In-authentic’ Civil War re-enactments; *The Truman Show* movie (third person/audience perspective; Truman’s post-conscious perspective); paint ball games.
VIII	> v	< r	> sr	Artificial life and AI systems (skeptics’ perspective); *The Matrix* Neo’s post-conscious perspective.

Second, and more empirically interesting, analytic difficulties around where to place a simulation are more than just a scholarly problem. They are also symptomatic of dilemmas within the organizational and institutional environments a given simulation is embedded within. Debates around simulation tend to crop up when there is an organizational uncertainty around which octant they *ought to* reside. Most of these debates involve disagreements around how realistic a simulation is. For example, in the CPR/AED example that I began this paper with, the instructors sought to establish simulations that fell within octant II: mostly physical, oriented to preenactment, and very realistic. However, the woman who refused to wear the gloves called this into question, suggesting that the simulation actually belonged in octant V: mostly physical, highly preenactment, but not very realistic. The micro-drama of the glove dispute hinged on an uncertainty over whether the simulation, which both parties agreed ought to be in octant II, was actually in octant V.

Organizational and institutional troubles tend to coalesce around relatively predictable movements between the octants. As noted already, debates about the realism of physical preenactments, or movement between octants II and V, will be a frequent source of organizational tension. Debates around realism will also tend to occur around virtual, preenactment simulations, or between I and VI (e.g., weapons scientists regularly dispute if computer simulations are an appropriate way to manage and test armament stockpiles). Other common disagreements involve whether self-referential virtual simulations are really real or not, or debate between octants III and VIII. This is a long-standing problem of professional legitimacy within the sciences of simulation such as artificial life and artificial intelligence (AI) in which critics suggest that their technologies may be complex machines but not particularly life-like or smart (Collins 1990; Crevier 1993; Helmreich 1998). While physical simulations that are self-referential, like war reenactments, are fairly rare, science fiction writers tend to exploit imagined and fantastical ambiguities between octants IV (virtual, self-referential, and realistic) and either octants VII or VIII. For example, the dramatic arc of the *The Truman Show* and the *The Matrix* movies centers on whether the lead characters will awaken from their false consciousness in order to realize they are actually living in a simulation (in the former, physical, in the latter, virtual). The debate around violent video games and youth culture hinges on whether or not the realism of an immersive, interactive video game transforms it from pure entertainment (a self-referential system) to a preenactment of violent behavior in the real world – an ambiguity between octants III and I.

I return to some of these dilemmas below, and am not trying to be exhaustive of the possibilities here. The general point is that if we think of simulation as varying in intensity across each of the three dimensions, organizational change is likely to result if and when a case is perceived to be problematically moving from one octant to another by a mobilized group willing to take a normative stance and with adequate resources to enact their interests. Most often, such disputes involve contrasting perceptions of realism, or problems, you might say, of practical (as opposed to idealist) ontology.

In summary, simulation can be considered a technique used by individuals and organizations to deal with problems related to individual bounded rationality (Simon 1997 [1945]), disharmony in institutional logics (Coleman 1990; Olson 1971), risk (Bosk 1992; Heimer 1985a; Heimer and Staffen 1998), and unpredictability (March 1994). Simulation can be characterized alongside other, more widely studied mechanisms for managing these problems, such as administrative record-keeping, formal and informal trust (Barber 1983; Coleman 1990; Heimer 1992), contingent problem-solving (March 1994; March and Olsen 1976; Stinchcombe 1990; Stinchcombe and Heimer 1985), or firm-level strategies for combining contract, market, and internal hierarchy (Coase 1937; Williamson 1975). I add the following to my earlier working definition of simulation. What distinguishes simulation from these other, more familiar organizational mechanisms is that it involves an *ontological transformation of a particular indexed reality, experience, or goal state into either segmented preenactments for preparation or a relatively self-referential process for knowledge exploration or entertainment.* Viewed in this way, the empirical study of simulation clearly involves both cultural and material processes. It can also be seen to have a number of institutional and organizational realities, to which I now turn.

Task preparation and risk management

Simulations have long been used to prepare people for risk, particular in disaster scenarios. During the Cold War, American schoolchildren regularly simulated orderly evacuation and rescue routines in case the Soviet Union were to launch a nuclear attack. Contemporary geopolitical uncertainties involve grave fears of terrorist attack. In preparation, schools, workplaces, and governmental agencies practice simulations aimed at emergency preparedness for dealing with anthrax poisoning, indiscriminate bombing, and other terrorist-related catastrophic events. The Hurricane Pam simulation, in theory at least, was supposed to help coordinate plans for an evacuation of New Orleans in the case of levee breach. Oil industrialists use simulation before confidently predicting their ability to clean up an oil spill from the ocean (Clarke 1999). More mundane, fire drills are standard organizational practice and earthquake, hurricane, or tornado disaster drills remain routine.

Most work on physical, human-in-the-loop simulation tends to focus on how they serve particular organizational needs. Physical simulation techniques are mobilized in workplaces and schools to train employees on specific skill sets, workplace safety, discrimination law, technology implementation, job orientation, etc. (Guetzkow et al. 1972, especially Pt. III). In fact, in some fields like market research, the ability to use such techniques has become a source of interorganizational competition. The general goal of physical simulations is to enable trainees to 'learn by doing' without overwhelming them or putting too much organizational capital at risk. The greater the physical, psychological, or capital risk of the endeavor, however, the more difficult this task is. Military training, for example, involves getting soldiers to perform reliably under extremely tense, life-threatening, and highly unpredictable conditions. Yet, few military simulations involve the exchange of live ammunition.

This last example raises a basic organizational problem – the ethical and practical constraints around regularly subjecting soldiers to authentically dangerous battlefield scenarios limits the sorts of simulations that can be devised (Irwin 2005). Simulations of this sort are only useful if they keep some aspects of their indexed reality simplified or bracketed out of the frame of action (Bateson 2000 [1972]). The medical profession faces a similar problem of needing to develop institutional mechanisms for preventing misdiagnosis, life-threatening surgical error, or other forms of malpractice. A recent technique involves the development and spread of 'standard patient' simulation in medical school pedagogy (Islam and Zyphur 2007; Wallace 1997), in which medical trainees practice open-ended diagnostic consultations with theatrically simulated patients (often fellow trainees pretending to be patients lacking in medical knowledge and authority). The goal here is to develop an interactive pedagogy that institutionalizes the idea of the 'whole patient', which includes cultivating a physician's interpersonal skill with patients. By design then, physical simulations oriented to preenactment, especially those that involve humans-in-the-loop, only imperfectly approximate the indexed reality or goal state. Their usefulness to an organization hinges on the extent to which they successfully bracket out some of the uncertainty and risk of a given reality condition as well as adequately prepare trainees for it. This is obviously true of the armed combat characteristic of military training, but is also true for the complex vagaries of doctor–patient relationships.

I explored this theme in detail in a study of an amateur boxing program, focusing on gym simulations as a necessarily imperfect mechanism for managing organizational risk and institutional contradiction (2006). Two conflicting institutional logics of action characterized the gym. First, it was part of a nonprofit, municipally funded public program where coaching staff are responsible for teaching the sport in a mutually beneficial manner. This requires cooperation and a limiting of favoritism. In contrast, the larger organization of amateur boxing, governed by a national boxing association, employs highly individualistic metrics of success – wins and losses in competitive matches. In addition, the professional backdrop of the sport involves a fertile mixture of economic desperation, opportunism, and exploitation. Subject to these conflicting logics, it is not in the immediate self-interest of aspiring boxers to 'work with' or 'go light' with training partners, nor for coaches to treat everyone the same. To manage this tension around public goods (Coleman 1990; Olson 1971), coaching staff and experienced boxers forged a simulated normative order that marks a key *everyday ontology* – sparring and other gym activities are not to be construed as a 'real fight'. This requires an ongoing transformation of subjective uncertainties into intersubjective understandings (i.e., when boxers get hit hard in sparring, they might not think that is happening is 'just practice'), or a continual reestablishment of the negotiated order.

Simulation introduced four key qualities into gym practice: *playfulness* (the socially sanctioned ability to experiment with new and difficult techniques and social roles without undue commitment to them), *risk and consequence reduction* (limiting or suspending formal metrics and long-term consequences of failure), *constrained innovation* (acquiring technical knowledge within well-specified, segmented simplifications of a more complex goal state), and *transportability* (relative independence from particular space and time constraint). With these qualities in operation, boxers could layer on progressively harder techniques while forging an interpretive infrastructure in which individual skill acquisition occurred in a relatively altruistic, cooperative way.

This example also illustrates that different sorts of simulation get tagged to different organizational needs. In the case of a boxing program, simulation aids in risk management as well as a public goods tension between competing institutional logics of individual opportunism and collective welfare. In military training, the goal is to produce reliable soldiers absent the extreme conditions of risk characteristic of their future tasks (Irwin 2005). In less physically demanding workplace training simulations like CPR, diagnostic pedagogy, or discrimination law and diversity training programs, the goal is to efficiently train employees on workplace or organizational protocols, assure compliance with current legal code, and reduce organizational costs.

Organizational troubles crop up when physical simulations, such as battle preparation, are oriented to preenactment yet are not perceived to be very realistic. Returning to Figure 2 and Table 1, such disputes turn on whether an octant II simulation (physical, preenacted, and realistic) is dismissed as an octant V simulation (physical, preenacted, but not realistic enough). Boxers get confused by, and might resist, simulation drills that they do not think will help them in a competitive match. Military commanders worry that simulated battles might never prepare soldiers for the psychological and physical trauma of actual warfare. And as the initial example from a CPR training session indicates, employees may rebel when they sense that an aspect of a training protocol is unrelated to the reality it is supposed to prepare them for.

Moral ambiguity and virtual reality in education

Simulation is not only an organizational mechanism for constraining uncertainty and risk; it can also forge novel debates around moral ambiguity and institutional ethics. This theme comes up most prominently in research that tracks the institutionalization of virtual reality simulations within educational settings.

Simulation as a source of debate about professional morals and ethics is nicely illustrated by the ongoing pedagogical debate around the possibility of replacing human and animal cadavers (the most common physical simulations of live bodies) with simulated surgical technologies (which generally combine a VR interface with a mannequin or other physical substance). Those who support the continued use of cadavers see no foreseeable substitute for physical bodies because a cadaver provides not only the best interface for learning highly tactile surgical skill, but also are fundamental in acquiring an appropriate professional morality and disposition. They argue that the limited number of physical cadavers available and obvious sacrifice to medical science made by the once living person creates an atmosphere of ethical gravity fundamental to both learning skill and professional ethos (Amadio 1996; Cahill and Leonard 1997; Prentice 2005; Warnick 2004). On the other hand, the proponents of simulation technology point to the ethical dilemmas of cutting up once living bodies, their overuse, cost, and difficulties in procurement, the potential cost efficiencies of simulators, the greater flexibility and repeatability of the pedagogical procedures, and evaluations that suggest students taught with the technologies score at least as well, and in some areas better, than students using traditional methods (Zirkel and Zirkel 1997). This institutional debate is ongoing (for an overview of the Swedish medical professions' ongoing integration of simulations into medical practice, see Johnson 2004), and will continue at least until simulated surgical techniques more closely approximate traditional dissection methods.

This debate turns on the dimensions of simulation outlined in Figure 2 and Table 1: Does the technology provide a sufficient preenactment of surgery? What is the appropriate distribution of virtuality and physicality in an interface that needs to model a highly tactile skill? And finally, do virtual simulations provide an adequate way to learn professional ethics and moral judgment?

Another prominent example of where virtual reality technologies have raised moralistic disputes is in the integration of video game technologies within K-12 schools. The most vitriolic side of this debate involves a kind of moral panic around whether violent video games such as the Grand Theft Auto series and several first-person-shooter games like Doom, Half-Life, Halo, and Counter-Strike are responsible for school violence and the school rampage shootings over the last decade (for a review of empirical research on video game effects, see Anderson 2003; Sternheimer 2007 provides a review that treats this as a moral panic). This debate involves a host of organizational factors, in particular the deeply entrenched capital interests of the video game industry, uncertainty over the efficacy, scope, and professional domain of traditional educational practices, the multivocal and often conflicting input of university researchers, and on the reception end, gamer enthusiasts and anti-youth violence advocates and reformers.

Moral admonishments of youth culture are nothing new, and in this sense a moral panic around the impact of violent video games is not much different from past fears of the negative influence of rock and roll, the counterculture, marijuana, violent or sexually themed movies, etc. Indeed, one might suggest that a moral panic around youth culture is a rather old saw, a fully institutionalized part of American culture in which content may change but not form. Yet, VR simulations add a new twist to an old institutional dilemma. Scholars have pointed out that VR games go beyond mere spectatorship by subjectively, experientially involving a player in an immersive, interactive, and open-ended virtual world (Forbus and Feltovich 2001; Shaffer et al. 2005; Turkle 1997). Similar to the fears of antisocial behavior and Santanism provoked by immersive role-playing games like Dungeons and Dragons in the mid-1980s, the fear around violent video games are that they blur fantasy and reality to a dangerously pathological degree (Sternheimer 2007). Thus, on one hand, the video game industry is accused of profiting from 'killing simulators' that purposely provoke and misguide innocent youth, and on the other, schools that resist VR tools in pedagogy are accused of a conservatism that undermines their mission.

Simulation creates the possibility for experiences that are otherwise beyond reach, for either practical or ethical reasons. Some worry that the problem with VR technologies is that by providing otherwise unobtainable experiences, we lose a proper appreciation for cultural boundaries, normative sanctions, and basic mechanisms of causality. Turkle (1997) points out that the fears and uncertainties underlying VR technologies are actually tied to a more general cultural transformation around our understanding of computers:

> In 1980, most computer users who spoke of transparency were referring to a transparency analogous to that of traditional machines, an ability to 'open the hood' and poke around. But when users of the Macintosh talked about its transparency ... they were referring to an ability to make things work without needing to go below the screen surface ... In a culture of simulation, when people say that something is transparent, they mean that they can see how to make it work, not that they know how it works.

The problem with this focus on surface-level functionality over understanding the mechanism of the machine is illustrated nicely by a tenth-grade player of SimCity, a city planner simulation. The player told Turkle that one of the most useful lessons she learned from the game was that 'raising taxes always leads to riots'. For Turkle, this reply contains much of what is problematic in a 'culture of simulation'. Without a sophisticated understanding of either social policy or the algorithmic constraints of an 'expert system' (see also Giddens 1990), the tenth grader generalizes the game's internal rule to a universal. This closes off other interpretations of the impact of raising taxes, such as more adequate funding of social programs, greater social cohesion, reduction in poverty, and the like.

In contrast to Turkle, who worries about the negative social and institutional impacts of a culture of simulation, other scholars actively advocate for its pedagogical possibilities. Educational advocates of VR and gaming technologies in the classroom, many coming out of university-based education and computer science departments, argue that these technologies can provide an essential new platform for creative pedagogy (for an overview, see Forbus and Feltovich 2001). Here we have come full circle. Flipping from the underlying logic animating the concerns with violent VR games (that virtual, 'unreal' norms will supplant the physical, 'real' norms that guide youths' moral and ethical decisions), advocates of the pedagogical possibilities of game technology insist that it is in fact the traditional practices of the American educational system, memorization-based teaching, that are now out of touch with the contemporary realities of the postindustrial economy (Shaffer et al. 2005). They suggest that (i) the modality of an immersive, interactive computer simulation is better suited to learning skills necessary in a postindustrial economy than are more traditional, memorization-based pedagogical techniques (some refer to traditional techniques as the 'pre-information society model' of learning), and (ii) these games can have positive pedagogical effects if playing time is appropriately structured.

Both anti-video game critics and pro-game educational proponents share a belief that simulation enables youth to learn by doing. In the dimensions laid out in Figure 2 and Table 1, the moral ambiguity stems from on uncertainty about when a VR simulation moves from octant III to I, or when highly realistic VR experience shifts from entertainment to a preenactment of behavior in the world of flesh and bone. The concern, engaged in by scholars and laypersons alike, is that moral lessons learned in a virtual reality are not always amenable to the constraints of Newton's world.

Computer simulation and scientific uncertainty in technical fields

A third emphasis in research on simulation comes out of the subfield of science and technology studies. This work has focused on computer-based simulation as a relatively recent method for tackling scientific and engineering endeavors that are difficult, cost prohibitive, or politically, ethically, or functionally infeasible with traditional methods (Edwards 1996b). This points to another key organizational function of simulation more generally, which is that it can provide data where direct access to experience- or observation-based information is lacking, difficult, or forbidden. In a study focused on information processing, Heimer (1985b) explores the problems of risk assessment of Norwegian offshore oil drilling. At the time of writing, offshore oil drilling was new and lacked experiential precedent. Faced with this problem, 'one can create *experimental or simulated* information by doing laboratory research or computer simulations ... Computer simulations and laboratory experiments are used to study the patterns of waves and the effects of waves of various heights ... to estimate the effects of oil spills' (Heimer 1985b, 185. *italics* in original). Here, we see a clear example of where computer simulation is used by an organization to hedge potential costs in the face of uncertain capital risk by creating substitute information where there is a dearth of experience-based data.

Computer simulation as a substitute for more traditional, experience-based information is explored in detail in studies that look at scientific and engineering controversies. Galison, commenting on the impact of Monte Carlo simulations on hydrogen bomb development, has said that nondeterministic, stochastic simulation methods introduced 'a tertium quid, a simulated reality that borrowed from both experimental and theoretical domains ... and used the resulting amalgam to stake out a netherland at once nowhere and everywhere on the methodological map' (1997, 691). Where simulation technologies are used in this new capacity for scientific knowledge production, controversies around reliability and verification tend to crop up (Winsberg 2006). Case studies on such scientific uncertainties include nuclear arms and weapons testing (Gusterson 2001; MacKenzie 1990), simulation models of global climate trends (Edwards 1996b; Lahsen 2005; Shackley and Wynne 1996), the production of artificial life technologies (Helmreich 1998), and AI (Collins 1990; Forsythe 2001; Suchman 1987).

Gusterson's (2001) research on simulated nuclear testing provides a useful example to explore in more detail. Nuclear weapons science turned toward simulation technology after the explosion of nuclear weapons became politically unfeasible under President Clinton, beginning in 1993 and culminating in the 1996 UN Comprehensive Test Ban Treaty. During this transformation, new scientific, political, and ethical controversies arose. Traditional weapons research involved physical prototypes that were tested to see if they responded in the way predicted by the engineering model. After physical testing was forbidden, weapons scientists scrambled to construct new ways to evaluate simulation models, which typically involved comparisons between simulation output with an increasingly aging corpus of observational data from past field experiments. New standards for determining scientific and engineering proof were invented in situ, amid much professional and lay skepticism.

This fractious institutionalization of new scientific standards also plays out in more general political and ethical debates around the nuclear arsenal. Conservative critics of global test bans suggest that the dearth of physical testing compromises American autonomy and military strength. This side of the debate questions the degree of preenactment and realism in the nuclear simulations. In contrast, liberal critics worry that these technologies create a false sense that the weapon stockpiles are no longer dangerous, while simultaneously creating the possibility for an ever greater weapons build up. Gusterson points out that simulation technologies can amplify preexisting political and ethical debates, since they transpire within a 'hyperconstructible terrain' devoid of clear empirical referents, resulting in 'incommensurable narratives about the new simulation technologies ... [that] spiral within their own logics' (2001, 426).

These controversies can create new organizational divisions within technical fields. Sundberg (2006), for example, focuses on how simulation technologies within meteorology cleaved the field into two contentious professional subfields: (i) climate modelers who simulate atmospheric conditions with computer technology and (ii) traditional fieldworkers who rely on observational data from the physical world. While there is overlap between them, meteorologists tend toward one side or the other and are distrustful of the others' claims.

Other studies have taken a more detailed, laboratory-level view of simulation technology production, exploring how laboratory culture, social organization, and the epistemological assumptions of developers and users factor into the design capabilities and limitations of simulation technologies (Helmreich 1998; Jelsma 2003; Johnson 2005; Lahsen 2005; Oudshoorn and Pinch 2003; Suchman 1987; Sundberg 2006). Suchman (1987), for example, showed how AI scientists developed a laboratory culture that regarded everyday human interaction as trivial to their work. This bias toward formal decision-making and planning mechanisms was then built into the technologies that came out of the laboratory, which tended to treat plans as perfectly determinative of action. She documented how this could lead to breakdowns in interactions between humans and machines, sometimes to great comic effect, such as when frustrated laboratory workers would attempt to use a prototype AI-based office photocopier help system. Forsythe (2001) makes a similar point, showing how AI scientists' epistemological assumptions about what constitutes 'work' and 'knowledge' bias them toward formal knowledge representation and away from informal or tacit knowledge, severely limiting their system's real-world applicability. These points have not been lost on the computer industry or professional AI scientists, who since the late 1980s have placed a much stronger emphasis on human–computer interaction and user-friendly design (Jelsma 2003; Rose 2003).

Echoing this concern with scientific uncertainty, Lahsen (2005) takes a shop-level view of climate modeling (simulations of global and often long-range trends in weather patterns) to peel away at the multiple layers of uncertainty beneath these technologies' confident veneer of prediction. Modelers get deeply invested in the veracity of their simulation technologies, despite or perhaps because of the constraints of limited observational data and thin empirical understanding of some of the physical processes that are modeled (e.g., meteorologists lack consensus on the effects of clouds on the heating and cooling of the Earth's surface). In sum, theoretical assumptions, pragmatic decisions made on the shop floor, deeply rooted cultural frameworks, personal and emotional biases, and professional investments all become deeply embedded into the simulation technologies that are then reified as empirical windows onto the natural world. Much of the work of climate modelers is to quell this 'distribution of uncertainty' and the interorganizational professional skepticism that results. This uncertainty is endemic to this professional world, however, in the sense that the very 'seduction' of simulation is in its ability to provide substitute data for experience-based information.

A somewhat different emphasis emerges in a group of studies that look at the lasting legacy of computer simulation's military-based history. During and after World War II, the US government was the primary funder for the emerging research fields of systems research and cybernetics with the explicit purpose of enhancing these technologies ability to assist in combat preparation (DeLanda 1991; Edwards 1996a; Norberg et al. 1996). In this effort, the military implemented a wide array of novel simulation techniques such as training films, mock 'live' and virtual combat, flight simulators, battlefield strategy games and software, etc., each of which has slowly been marketed in some form for nonmilitary purposes by the technology and entertainment industries. Similarly, cybernetics, AI, and other information and communication technologies were nurtured for their promise to enhance military command and control operations (Edwards 1996a). The US military and other government research and development funding agencies continue to play a key role in the development and funding of numerous 'smart' weaponry initiatives, from self-correcting and targeting bombs, automatic antiballistic missile systems, unmanned reconnaissance and bombing aircraft, and other 'smart modules' embedded into a soldier's physical person (Lenoir 2000).

Analysts speculate on the social traces left by this history when these technologies are used in contemporary organizations, focusing primarily on warfare administration and domestic surveillance and policing. DeLanda (1991) argues that these kinds of simulation technology dramatically enhance a profound bureaucratic detachment between the clinical administration of modern warfare and its brutal physical and material consequences (see also Baudrillard 1995; Brown 2003). Bogard (1996) provides a postmodernist interpretation of the 'simulation of surveillance', covering domestic surveillance techniques like the remote policing of urban streets with street corner cameras, or the increased panoptic capacities rendered by the digitalization of workplaces and social life more generally. Marx (2005) provides a more straightforward review of recent research on 'new surveillance' technologies, such as computer-based criminal profiling, electronic location monitoring, and DNA testing.

Conclusion

I will now make explicit what has been implicit throughout this paper, which is to suggest that a sociology of simulation ought to be appreciated within the broader subfields of organizations, work and occupations, and institutional sociology. The emphases outlined in this paper articulate well with previous mechanisms identified in these literatures by which organizations manage risk and uncertainty, such as centralized and decentralized administration, task segmentation, dispute resolution, assessment, negotiation, organizational routine and style, formal and informal trust among organizational members and within professional fields, the loose coupling of formal procedures and protocols, etc. As simulations are increasingly integrated into organizational and workplace settings, they will become more and more important objects of study for analysts of organizational behavior. More theoretically, simulations are particularly interesting because they call clear attention to the relationship between culture and materiality. Simulations provide a window into both the material reorganizing of common organizational practices (i.e., segmenting difficult tasks, or modeling work routines, etc.) as well as the interpretive and cultural practices that go into making sense of these reorganizations (i.e., dilemmas around whether members think of the simulation as realistic, or whether they serve an appropriate function, or provide reliable data). Put differently, simulations are cultural boundary objects par excellence. They are borrowed, copied, imitated, and remade within particular material contexts in ways that roughly fit particular organizational needs. One cannot miss the complex intertwining of material and cultural issues in their use and proliferation.

In particular, I believe that the empirical study of simulation can add precision to the cultural emphasis of recent organizational and institutional sociology. Research in 'new institutionalism' tends to focus on the spread of cultural ritual, standard organizational templates and procedures, and cognitive schemas within organizational fields and institutions (DiMaggio 1997; DiMaggio and Powell 1991; Meyer and Rowan 1977; Schneiberg and Clemens 2006; Scott 2004). Yet, as Stinchcombe (1997, 2) points out, such analyses of innovation diffusion tend to lack clear causal mechanisms: 'collective representations manufacture themselves by opaque processes, are implemented by diffusion, are exterior and constraining without exterior people doing the creation or the constraining'. Further research on the production, implementation, and proliferation of simulation can give us renewed analytic leverage on the 'inner guts' of institutional diffusion. Similarly, a focus on the interface between organizational uncertainty and simulation offers an empirical anchor for what Hallett and Ventresca's (2006) usefully characterize as an 'inhabited institutions approach' to organizational analysis.

This is because simulations provide a uniquely flexible interpretive arena within which macro-cultural logics, standard protocols and behavioral models can be locally developed, practiced, coordinated, routinized, experimented with, mulled over, debated, and resisted by actual people in actual organizational settings. Simulations set boundary conditions for the enactment of negotiated meanings among participants charged with the task of learning a standardized, modeled, but always malleable and contested institutional script. While the macro-level diffusion of these scripts is best measured with historical hindsight, as is common in institutional sociology, their implementation within local organizational settings is an interactive phenomenon. Perhaps this is a phenomenon that with sufficient technical virtuosity can be effectively modeled in a computer program, but better it is first documented in its full ethnographic complexity.

Acknowledgments

In the production of a journal article, the analogue for simulation is a draft sent around to friendly critics. This process helps develop a paper from early mock-ups to published reality. In addition to the wise counsel of Section Editor David Shulman and two anonymous reviewers, I thank the following colleagues for helping spare you, dear reader, from earlier versions of this paper: Ellen Berrey, Renee Beard, Alan Czaplicki, Gary Alan Fine, Carol Heimer, Laura Beth Nielsen, Susan Silbey, Laura Stark, and Art Stinchcombe.

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Note

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