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Games For Good

Guest Editors

Rudy McDaniel, University of Central Florida
Erik Henry Vick, Rochester Institute of Technology

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RESEARCH ARTICLES

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From the Editor

Dear Readers,

Welcome to the next issue of *Cognitive Technology*. This represents our first special issue under the new editorial board and it illustrates our efforts to expand the scope of *Cognitive Technology*. Continuing with our work to include research and development in disciplines outside of psychology, this issue focuses on the exciting new field of "Games for Good". Guest edited by Rudy McDaniel of the University of Central Florida and Erik Vick of Rochester Institute of Technology, this special issue highlights some of the innovative and interdisciplinary research being done within the domain of cognitive technology as it relates to computer games. After several decades of research on cognition using computer games, the field has now broadened to include video games that impact cognition for a particular pro-social purpose — games known simply as "games for good." This field is rapidly growing and, in order to provide representative samples of the games being developed, we've created a double-issue. This allows us to showcase emergent technologies that need integration with the learning and cognitive sciences. In particular, our goal with this special issue is to introduce our readers to this area and encourage collaborations between game designers and cognitive technologists so as to produce powerful interdisciplinary research. We hope you enjoy reading about the unique and interesting developments in this field.

Sincerely,

Stephen M. Fiore

Stephen M. Fiore, Ph.D.
Editor, *Cognitive Technology*

Conceptualizing “Games for Good” as Cognitive Technologies

Rudy McDaniel
University of Central Florida

Erik Henry Vick
Rochester Institute of Technology

In this essay we introduce the special issue of *Cognitive Technology* on “Games for Good as Cognitive Technologies”. With this special issue we highlight a range of innovative and interdisciplinary research being done within the domain of cognitive technology. This essay introduces the issue and describes the rationale for our focus on *games for good*. The amount of new research focused on this topic is encouraging and exciting and our goal is introduce researchers in cognitive technologies to this important topic. Our hope is that, from this introduction, the field will recognize their promise and engage in a broader collaboration to develop, test, and refine these emerging complex forms of cognitive technology.

KEYWORDS: Video Games, Learning, Training, Technology

An Emerging Body of Research

In recent years, sophisticated video games have emerged as controversial harbingers of a new age of interactive, immersive, and ubiquitous computing. Modern video games are played not only on consoles such as the Playstation 3 and Xbox360, but also on mobile devices, PDAs, cellular phones, and social networking platforms. The proliferation of games and their penetration into so many different areas of contemporary society obviously has profound implications for the entertainment industry, but this phenomenon also presents unique new opportunities for understanding the mechanics of teaching, training, and persuading with networked gaming technologies.

Some researchers, like Steven Johnson (2005) and James Paul Gee (2003), cautiously embrace video games. They note their immersive and engaging characteristics and their capacity to simultaneously challenge, seduce, and frustrate players. They also acknowledge video games’ native ability to construct those combinations of complex physical interactions, interesting cognitive problems, and curiosity-piquing narrative scenarios that are appealing to human players. Others are more critical of these new technologies. For example, critics like Maggie Jackson (2009), see video games as nothing more than the latest gadgets in a long line of technologies designed to compete for our precious attention, gadgets that adversely affect important cognitive abilities like focus, judgment, and awareness. Building upon earlier work from critics such as Sven Birkerts (1994), Jackson argues that modern networked technologies are not helping us to become better thinkers and learners, but instead are de-socializing us, distracting us, and leading us to the brink of an impending dark age. Such thinking complements work by cognitive theorists such as Rich Mayer (1999) who have argued for a more human centered approach to the development of learning technologies.

Surely such a polarizing medium has something to offer the domain of cognitive technology. Regardless of which argument one finds more persuasive, it is clear that video games are doing *something* to the way players think and interact with technologies, and that this something may in fact be impactful enough to follow the player outside what Katie Salen and Eric Zimmerman (2004) call the "magic circle" boundaries of the gameworld and into the *real* world, where problems must be solved with real applicability, discussions must be had with real people, and solutions must be crafted in real physical space.

Even without this movement into real space, however, there are interesting things to learn from video games as encapsulated immersive and fantasy-laden environments. For instance, the safe virtual borders of the magic circle offer impressive cognitive and physiological benefits, such as the ability to minimize pain for burn victims or allow people with phobias or post-traumatic stress to safely deal with those issues in virtual environments (Hoffman, 2004; Jackson, 2009). It is the intent of this Special Issue to explore recent research in this area and to begin mapping out some conceptual boundaries for understanding games for good as cognitive technologies.

Video Games and Cognition

Before the recent attention of contemporary advocates and critics alike, video games were studied by scientists and researchers as a means through which to examine cognitive processes such as spatial aptitude (Dorval & Pepin, 1986), attention (Greenfield, DeWinstanley, Kilpatrick, & Kaye, 1994), and learning and training (Gopher, Weil, & Bareket, 1994). It was over 20 years ago that cognitive psychology saw one of the first serious attempts to create and use a computer game to examine cognition. *Space Fortress*, developed at the University of Illinois, was one of the first instantiations of a computer game as a cognitive technology for use in experimentation. This game-based technology, both developed and tested by cognitive psychologists, afforded a groundbreaking new way for researchers to observe complex sensory-motor processes (Mané & Donchin, 1989). It helped researchers study, for example, the interaction between skill levels, and the integration of component skill types (e.g., attentional skills, integration of spatial information), and their relation to overall performance (Shebilske, Goettl, & Regian, 1999; Shebilske, Goettl, Corrington, & Day, 1999). The game's utility has continued with revised versions still being developed to improve on its data collection and experimental manipulation capabilities (Shebilske, et al., 2005). It was most recently used in a neuroscientific investigation of the relation of brain volume and learning ability. In this study, Erickson and colleagues found that the size of a participant's striatum was related to their performance on *Space Fortress*, documenting an important connection between cognitive technologies as brain training devices (Erickson et al., 2010).

In addition to the work done with *Space Fortress*, there has been a fair amount of other research using games as cognitive technologies for experimentation and training. For example, in an early examination of transfer of flight training, Gopher and colleagues (1994) found that groups of cadets who received 10 hours of flight training using a computer game were able to perform significantly better on real-world flight tests than cadets who did not receive such video game training. Additional research analyzed the degree to which video games might provide a more valid test of learning. In a study to assess if the video game-based Atari Air Combat Maneuvering Task was a good prospect for a performance test battery for use training tasks conducted under unusual environmental circumstances, Jones, Kennedy, and Bittner (1981) not only found that video games were excellent prospects for such environmental research and training, but also that they displayed similar characteristics to other training methods.

In terms of spatial visualization and attention related research, Gagnon (1985) examined the relationship between spatial aptitude and video game use and found a correlation between scores on video games and spatial aptitude tests. The study also concluded that gender differences existed and that age was negatively correlated to both video game scores and spatial test scores. More recently, researchers determined that game-based training could not only be used to eliminate gender differences in spatial cognition, but also that even short treatment times (10 hours spent playing video games) produced an increase in spatial cognition for all subjects, regardless of gender (Feng, Spence, & Pratt 2007). Similarly, there is a positive correlation to performance on various tests of perceptual functioning in regular players of video games as opposed to individuals who do not play video games (Castel, Pratt & Drummond, 2005; Green & Bavelier, 2003; Green & Bavelier, 2006; Yuji, 1996). This increased performance could not be attributed to a different perceptual processing mechanism, however, leading researchers to hypothesize that the play of video games may lead to faster encoding of stimuli due to a modification of the visual system, thereby allowing for enhanced stimulus-response mapping.

The perceptual and cognitive benefits of video games during complex tasks are also well documented, particularly in the medical field. The Entertainment Software Association (2009) reports on a study from New York's Beth Israel Medical Center in which laparoscopic surgeons who played three hours of video games a week made 37 percent fewer errors than those who did not. Prior work suggests that video game skills can even be used to predict the level of laparoscopic aptitude in beginning surgeons (Rosenberg, Landsittel, & Averch, 2005).

Not all research is entirely supportive of computerized cognitive training, however. Though not exclusively focused on games, recent research from Owen and colleagues (2010) points out a general lack of empirical evidence for the successful use of computerized brain-training programs. In an online study of 11,430 participants, these researchers found no evidence for cognitive improvement after an average of 24.47 training sessions in two experimental groups – one emphasizing reasoning, planning, and problem-solving; the other training a broader array of cognitive functions including short term memory, attention, visiospatial processing, and mathematics. The authors note that these functions are similar to those found in commercially available brain-training devices. Owen et al. conclude by pointing out that computerized brain trainers have not yet been shown to improve generalized cognitive functioning *beyond those tasks that are actually being trained.* In other words, participants improved on those particular tasks being trained in the experimental conditions, but these improvements did not generalize beyond the boundaries of the test conditions. Such findings echo earlier work by Sims and Mayer (2002) who, in a study with the video game Tetris®, illustrated how spatial expertise gained from game play was quite specific to mental rotation tasks and did not transfer to other measures of spatial ability.

Cognitive Games for Good

These studies, and many others like them, suggest that video games have the potential to significantly affect cognition, though the link of training to transfer is not always supported by research. In the special issue that follows, we focus on additional research-centered types of video games that impact cognition for a particular prosocial purpose — games sometimes characterized as "games for good." By "games for good," we refer to those video games that bring about positive social change in the world. This may or may not be an explicit goal of the designers. Games for good may be developed to promote awareness of nutrition, to examine economic policies and their impact on low SES communities, to educate schoolchildren about history or geography, or to encourage the discussion of public health policy for individuals who might not normally think about this type of problem. Because of the representational and simulated nature of games, the type of good potentially done by these types of games is limited only by the resources and imaginations of the game designers and developers who produce them.

We can better understand the genesis of the games for good movement by tracing recent activity from the academics and independent games developers working in this area. Perhaps the best indicator of video games' rising status in the realm of academic discourse is the emergence of several communities, festivals, and conferences devoted to games for non-entertainment purposes in the early and mid-2000s. One of the earliest gatherings was the Games for Change series of conferences, the first of which was held in New York in 2004. The goal of Games for Change was to "bring together non-profits, foundations, and game developers to explore the use of digital games to advance organizational mission and societal change" (Sawyer, 2004, para. 2). From this initial gathering of technologists and researchers sprung numerous other conferences, festivals, and workshops, each with the goal of advancing the study and practice of game design to move beyond mere entertainment and leisure. The most ambitious groups of individuals were those who wanted to not only teach with games, but also to bring about positive social change through their use. The latest Games for Change festival, held in 2009, boasted an attendance of 430 and included well-known and prolific games scholars such as Henry Jenkins, James Paul Gee, Katie Salen, and Eric Zimmerman (Games for Change). Other prominent conferences devoted to game studies, such as the Games, Learning, and Society Conference—held annually in Madison, WI—generate additional workshops, conference presentations, and research papers devoted to games for good and related topics (Games, Learning, and Society).

This work is particularly important because of the many difficulties inherent in the process of building educational or socially responsible video games. Foreshadowing the current cautionary stance taken by Owen et al. (2010) and previously described above, Squire (2002) warns that educational games must also still prove themselves in terms of both knowledge transfer and the meaningful practice of learned skills outside the game. In his own words, "a skilled *Half-Life* player might develop skills that are useful in playing *Unreal Tournament* (a very similar game), but this does not mean that players necessarily develop generalizable 'strategic thinking' or 'planning' skills" (para. 25). In other words, if a game for good's imparted lessons do not transfer and generalize to the outside world, then they are useful and interesting as new mechanical models for gameplay, but not necessarily as catalysts for behavioral change or expanded awareness.

Although games for good are a subset of educational gaming in general, this broader category paved the way for independent and commercial games for good. Over the past several years, funding agencies and policymakers began paying an increasing amount of attention to video games as tools for teaching, learning, and training (one example is the Game Changers Digital Media and Learning Competition, funded by the MacArthur Foundation). Accordingly, there has been an increase in the amount of critical scholarly analysis applied to games, analysis performed from a variety of disciplinary perspectives. Violence in games, of course, has always been a favorite topic of the media, and until the early 2000s, much of what was covered by the media was focused on violence and the impact of violent video games. The debate as to the causal relation between violent video games continues and recent meta-analyses have shed light on both problems of publication biases in this area (Ferguson, 2007) as well as evidence that violent video games are a causal risk factor, potentially leading to aggressive behavior and cognition (Anderson et al., 2010; see Ferguson & Kilburn, 2010 for a critique).. More recently, though, academics and practitioners from all disciplines and walks of life began bringing positive example of games into the mainstream media's attention. Initiatives such as the Games-To-Teach project, a partnership between MIT and Microsoft designed to build new gaming prototypes for "interactive educational entertainment," emerged and gained popularity for exploring new teaching strategies for STEM disciplines (MIT, 2001). Additionally, social games designed to explore human values and morality have been produced; several prominent examples of these have surfaced from the NSF-funded Values at Play research project at Dartmouth College (Values at Play, 2007).

Characteristics of Cognitive Games for Good

What is it about games for good that makes them so interesting as examples of cognitive technologies? For one thing, as the research above indicates, games in general are particularly well-suited for exploring and evaluating the complex nature in which we think and make decisions under stress. Additionally, well-designed video games are intrinsically motivating (Malone, 1981), they implement a variety of optimal teaching and learning strategies with immediate feedback (Gee, 2003), and they encourage exploration and identification with virtual avatars in the pursuit of knowledge (Turkle, 1984). Video games also happen to be immensely popular. The average video game player is 35 years old and has been playing games for 12 years; computer or video game systems are installed in 68% of American households (Entertainment Software Association, 2009).

Individuals who play games engage and exercise complex cognitive processes such as metacognition, problem solving, inductive reasoning, and the interpretation of explicit and implicit information (Pillay, Brownlee, & Wilss, 1999). Narrative and fantasy are also an integral part of games which makes them useful for cognitive studies. Humans engage in fictional interactive environments—such as those found in video games—by simulating the events, characters, and other dramatic elements through mental modeling (Tavinor, 2005). This implies that the repetitive nature of video games may allow players to experiment with different behaviors, modes of problem solving, and interaction styles with complete safety (see also Gee's 2003 discussion of the psychosocial moratorium, or safe place for experimentation, provided by video games).

From these initial characteristics, we maintain that video games are useful as tools to explore and assess cognitive and affective processes such as attention, motivation, judgment, memory, decision making, metacognition, and empathy, systems and behaviors that are critical for fostering awareness of social issues or attempting to influence values or behaviors for the betterment of humanity. These goals are lofty, but attainable. When seen against the timeline of representational media, video games are still in their infant phase of development. Only time will tell the true impact of video games as the medium continues to mature and be shaped by new game designers looking to apply interactive gaming technologies for positive social change. This issue begins a dialog on this topic with cognitive technologists that we hope will continue on for many years.

Essays Included in this Special Issue

In this issue, contributing authors report on video games designed for a variety of purposes and examine those characteristics of game design best suited for designing effective games for good as cognitive technologies. Marjee Chmiel discusses game design as a tool for improving public science literacy, while Shlomo Berkovsky and colleagues examine the relationship between real and virtual environments in an attempt to combat the effects of sedentary lifestyles. Matthew Sharritt examines the design techniques used by both commercial and independent games as examples of strategies useful for educational game designers. The remaining two essays in this issue, from Scot Osterweil (MIT Education Arcade) and Jonathan Belman and Mary Flanagan (Values at Play) summarize the research that has grown from these respective initiatives and consider how video games can be designed to accommodate complex psychological tasks involving learning and prosocial behavior.

We bring together these researchers because we believe the complexity and sophistication of today's game-based technologies should be of great interest to cognitive technologists. Our goal is to introduce the research community to these potentially powerful new tools in the hopes that they will use them to examine complex cognitive processes. In order to truly be effective, however, we must also learn how to transfer the training deployed in these virtual environments to similar situations encountered in the real world. By studying these exciting and emerging forms of cognitive technologies, we can come to a better understanding of learning, memory, problem solving, and decision making in areas of research that have tremendous societal implications.

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AUTHOR NOTES

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Designing Games to Foster Empathy

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A diverse range of educational and activist programs have been created to foster empathy in participants. For example, it is often a priority in conflict resolution programs to encourage empathy between stakeholders on different sides of conflicts. Similarly, many interventions designed to reduce prejudice function by eliciting feelings of empathy towards victimized groups. Games are particularly well-suited to supporting educational or activist programs in which the fostering of empathy is a key method or goal. This is because they allow players to inhabit the roles and perspectives of other people or groups in a uniquely immersive way. This paper has been written as a resource for those who are interested in using games to develop or elicit empathy in players. We begin with an overview of what scholars have discovered about empathy, focusing on research in psychology, but also including insights from fields like conflict resolution in which empathy has been an important area of study. This is followed by a set of heuristic principles derived from the literature which are intended to have direct and practical applications to the design of games for good. Finally, we discuss three games – *PeaceMaker*, *Hush*, and *Layoff* – that engage players' capacity to empathize in innovative and exemplary ways.

KEYWORDS: Video Games, Empathy, Conflict Resolution, Activism

Games are often thought of as a purely entertainment-focused medium, but there is considerable and growing interest in harnessing their power for prosocial causes. One manifestation of this interest is the emergence of research projects and organizations that are devoted to developing resources and providing support for designers of "games for good." Over the past three years, the authors of this paper have worked with one such project, Values at Play (VAP). VAP has been devoted in part to assisting students who are interested in creating games that affirm human values like tolerance, equity, and justice. One of our project's main accomplishments is the development of a curriculum to introduce graduate and undergraduate students to this type of design. The VAP curriculum has been used and assessed in several major American game design programs, including at the University of Southern California, Georgia Tech, the Rochester Institute of Technology, and Carnegie Mellon.

Our analysis of students' feedback and work has revealed that they are particularly enthusiastic about designing games to foster empathy. Games are well-suited to this because they allow players to inhabit the roles of other people in a uniquely immersive way. One can read about Darfuri refugees in the news, but, in an admittedly limited sense, a game can allow one to be a Darfuri refugee. Many students using the VAP curriculum have created games (or design documents for games) that are intended to provide players with a vicarious experience of the disadvantages or persecution faced by another group. Some have focused on challenging players' social or political assumptions by allowing them to "see" events or topical issues from perspectives other than their own.

By and large, students' work designing "empathetic games" has been inspiring. This paper has been written as a resource for them, for non-student designers, and for scholars in a variety of fields, including cognitive technology, computer science, and game studies, who are exploring this area through diverse disciplinary lenses.

We begin with an overview of what scholars have discovered about empathy, focusing on research in psychology, but also including insights from fields like conflict resolution in which empathy has been an important area of study. This is followed by a set of heuristic principles derived from the literature which are intended to have direct and practical applications to the design of games for good. Finally, we discuss three games – *PeaceMaker*, *Hush* and *Layoff* – that engage players' capacity to empathize in innovative and exemplary ways.

Empathy

The social sciences have produced a rich and varied literature on empathy, including theory and research on how people experience empathy (Stocks, Lishner & Decker, 2009), whether and how it can be taught (Shapiro, Morrison & Boker, 2004), and its effects on attitudes and behavior (Berenguer, 2007; Nickerson, Mele & Princiotta, 2008). Empathy is also an important area of investigation in applied fields as diverse as conflict resolution (de Wied, Branje & Meeus, 2007), counseling psychology (Calley & Gerber, 2008), nurse and doctor training (Ancel, 2006; Bonvicini et al., 2009), parent training (Matthey, McGregor & Ha, 2008), rape prevention (Foubert & Perry, 2007), social work (Erera, 1997), and K-12 education (Stetson, Hurley & Miller, 2003). Partly because it has been studied through so many disciplinary lenses, there are a variety of ways in which empathy has been delineated as a concept. In the psychoanalytic literature, empathy is typically associated with the specialized mode of listening through which therapists gain access to their clients' emotional experiences (Aragno, 2008). In contrast, discussions of empathy amongst conflict resolution practitioners often focus on the ability to see issues and events from the perspectives of people on the other side of a dispute (Fisher, 1994; Rouhana & Kelman, 1994). While these two approaches are conceptually related, they are also distinct in ways that reflect the goals of the fields in which they are used. Since games for good are designed to further prosocial agendas in many different fields, it is appropriate for us to proceed with a broadly inclusive definition of empathy. This will allow us to offer design recommendations that can accommodate the priorities of the diverse individuals and organizations who create or support games for good.

Two broad categories of empathy are described in the social science literature: cognitive and emotional (Hoffman, 1987; Stephan & Finlay, 1999). Cognitive empathy refers to the experience of intentionally taking another person's point of view. For example, an American executive trying to understand how her Chinese business partners will perceive a negotiating tactic is engaging in cognitive empathy. Doing this successfully will likely require the executive to become somewhat familiar with her partners' personal and cultural norms, values, and beliefs. Generally, when there are significant differences between people or groups, cognitive empathy can require a lot of homework.

Stephan and Finlay (1999) divide emotional empathy into two distinct subtypes, parallel and reactive. Parallel empathy is roughly equivalent to the lay understanding of empathy as the vicarious experience of another's emotional state. For example, a high school student experiences parallel empathy if he sees a classmate mocked for wearing unfashionable clothes and feels emotions that are similar to his classmate's embarrassment. On the other hand, reactive empathy describes an emotional response that is unlike what the other person is experiencing. If the high school student feels pity instead of embarrassment, this is a reactive empathetic response because he is experiencing a categorically different type of emotion than his classmate.

Before we continue, it is important to note that studies in this area differ along at least two important dimensions.

1. Dispositional vs. Induced Empathy: Some studies focus on how people's attitudes and behavior are affected by their already existing levels of willingness and ability to empathize. Others induce empathy in participants by means of some experimental manipulation or intervention program, and compare the attitudes and behavior of participants who have received the empathy induction with control groups. While both types of research provide valuable insight, induced empathy studies are more directly generalizable to the design of games for good.

2. Low-involvement vs. High-involvement inductions: Most laboratory studies induce empathy in ways that require relatively low levels of cognitive or emotional involvement on the part of participants. For example, in one seminal study (Batson et al, 1997), participants listened to an interview of a young woman who had recently been diagnosed with HIV. Those in the high empathy condition were instructed to "imagine how the woman who is interviewed feels about what has happened and how it has affected her life." While this could certainly be an affecting experience, its impact on participants is limited by its brevity and probably also its remoteness from participants' day-to-day lives and concerns. In other studies, the empathy induction encourages far greater cognitive or emotional involvement. Often these studies are evaluations of real-world training programs. For example, Pinkston (2009) assessed an experiential learning intervention designed to increase medical students' empathy towards HIV/AIDS patients. The participating students adhered to antiretroviral therapy regimens for two weeks using jellybeans instead of real anti-retroviral medicine. Although they did not have to confront the emotional ordeal of living with HIV or AIDS, the program did provoke them to think regularly and over an extended period about the difficulty of integrating a complicated drug treatment regimen into one's daily activities. Involvement could have been increased further by pairing each student with an HIV-positive patient for periodic meetings. In the real world, both low and high

involvement empathy inductions can have practically significant effects on people's attitudes and behaviors, but designers of games for good may find one or the other type of research more directly generalizable to their work. Specifically, the empathy inductions in "low-involvement studies" seem to closely correspond with short activist games that have no community-oriented features, whereas "high-involvement studies" are more equivalent to games that immerse players in an extended experience, particularly those that create relationships between players through some online multiplayer component.

The following discussion will include studies of both dispositional and induced empathy, as well as studies using low and high involvement inductions. Although one category of studies may be most relevant to any particular design project, research in all of these categories has made vital contributions to our understanding of empathy.

Empathy, Attitudes, and Behavior

A consistent finding in the research literature is that empathy improves people's attitudes and behaviors towards other individuals or groups, while a lack of empathy is associated with more negative attitudes and behaviors. Oswald (1996) found that students experienced more empathetic concern when they were induced to attend to and discern either the thoughts or feelings of a prospective adult student. Students who were induced to empathize also volunteered more time to assist prospective students. Batson and his colleagues (Batson et al., 1997; Batson, Chang, Orr & Rowland, 2002) conducted several studies in which participants listened to interviews with members of various stigmatized groups. Participants are asked to either "take an objective perspective toward what is described" or "imagine how [the interview subject] feels about what has happened and how it has affected [his or her] life." They found that instructions to empathize resulted in more positive attitudes towards (and, in one case, more positive action on behalf of) people with HIV or AIDS, homeless people, hard drug addicts, and convicted murderers. When participants in one study were contacted two weeks after the empathy induction, their positive attitudes towards members of the stigmatized group had increased in strength.

In one case, however, Batson and his colleagues (1997) found that instructions to empathize actually worsened attitudes towards a stigmatized group. When women were asked to imagine the feelings of female interview subject who had contracted AIDS through unprotected sex, they expressed more negative attitudes towards women with AIDS than demographically similar participants who were not instructed to empathize. The experimenters argued that if some women participating in the study had previously engaged in unprotected sex, fears regarding their own risk of contracting HIV may have been activated by the interview. This might lead them to adopt negative attitudes as a way of distancing themselves from the interview subject whose life story had become associated with a threat to their well-being.

Dispositional empathy has been associated with a host of positive behaviors, including boys coming to the defense of victims of bullying (Caravita, Di Blasio & Salmivalli, 2008), college students providing assistance to emotionally troubled peers (Mueller, 2002), student helpfulness (Litvack-Miller, McDougall & Romney, 1997), and constructive and non-aggressive responses to conflict (Richardson, D., Hammock, G., Smith, S., Gardner, W. & Signo, M., 1994; de Wied, Branje & Meeus, 2007). Conversely, the research literature implicates a lack of dispositional empathy in many negative behaviors, including child abuse (Moor & Silvern, 2006), sexual aggression (Wheeler, George & Dahl, 2002), and alcohol-related aggression (Giancola, 2003).

The positive effects of empathy go beyond improving attitudes and motivating prosocial behavior toward humans. Berenguer (2007) tested the hypothesis that inducing both cognitive and emotional empathy towards animals and plants could increase people's pro-environmental behaviors. Participants in the high empathy condition recommended that a greater proportion of the university's outreach funds be allocated to environmental causes (thus also advocating a reduction in support to other community initiatives). They also displayed stronger feelings of moral obligation to help animals, plants, and nature as a whole.

A cursory review of the research literature might suggest an almost automatic relationship between empathy and prosocial behavior, but Sutton (1999) provides a fascinating overview of theory and research challenging this assumption. Researchers in developmental psychology have found that some bullies have superior perspective-taking abilities (Waterman, Sobesky, Silvern, Aoki & McCauley, 1981). Sutton argues that this allows them to more effectively manipulate their peers and harass them in ways that maximize psychological impact. He eloquently describes the paradox of the cognitively empathetic bully as follows: "A single bully and his/her chosen victim often appear to have a bizarre dyadic relationship, in which there may be more consideration of mind than is immediately evident in the bully's behavior … [The bully] may understand emotions but not share them" (Sutton, 1999, p.121). It is plausible that bullies with high perspective-taking ability are pathologically disinclined to feel emotional empathy towards their victims, and therefore represent a special case not easily generalizable to the wider population. Still, designers of games for good should consider the possibility that cognitive empathy may not, in and of itself, generate desired attitudes or behaviors unless emotional empathy is also activated through some mechanism.

Empathy, Prejudice and Stereotypes

People have little inclination to thoughtfully consider the perspectives and experiences of groups towards whom they are prejudiced (Stephan & Finlay, 1999). In other words, they are averse to engaging in cognitive empathy with the targets of their prejudice. In such cases, their perceptions may be shaped primarily by stereotypes. When these stereotypes are negative, they create a self-reinforcing feedback loop: "I dislike group X because they are all dishonest (the stereotype contributes to prejudice). Because I dislike group X, I am not particularly interested in the way they see things (the prejudice discourages empathy, which increases reliance on stereotypes. This in turn reinforces the original prejudice)." This model of how prejudice perpetuates itself is admittedly basic in that it leaves out a host of mediating variables that have been identified as significant in the research literature. Still, it provides a basis for exploring a question that is directly relevant to interventions intended to reduce prejudice. Will inducing empathy render people more willing and able to seek out and accept counterstereotypic information about the groups toward whom they are prejudiced?

Bigler (1999) has written a thorough review of programs designed to counter racism in children over the past forty years. Typically, these programs are strongly oriented towards challenging or offering alternatives to existing stereotypes, with very little or no direct emphasis on inducing empathy in participants. Assessment reveals that these programs have by and large been ineffective, either producing no significant differences between pre and post-intervention measures of attitudes, or yielding effects that are weak or evanescent (Bigler, 1999). A plausible explanation for the failure of these programs is that they do not address the cognitive rationale for why people hold and maintain stereotypes. Stereotypes are a cognitively efficient mechanism for supplying actionable information about the world around us (Macrae, Milne, and Bodenhausen, 1994). For example, it would take a great deal of cognitive effort to evaluate the honesty of every member of group X who I meet in my daily life; however, my stereotype tells me that people belonging to group X are dishonest, and thus obviates the need to judge each member on his or her actual character. A prejudice-reduction program convincing me to abandon my labor-saving stereotypes would have to provide sufficiently strong motivation to do so.

Cognitive empathy could conceivably supply such motivation in prejudice reduction programs. Stephan and Finlay (1999) hypothesize that people who participate in cognitive perspective-taking exercises may come to believe that there are fewer differences between themselves and the targets of their prejudice than they had previously taken for granted. Once a fundamental similarity between groups is accepted it may become difficult or even uncomfortable to think about the outgroup in the unflattering terms dictated by negative stereotypes. Facilitating a perceived similarity between groups may be one of the most powerful mechanisms through which empathy reduces prejudice. A multitude of studies have found that we like people who we consider to be similar to ourselves (Terman & Buttenwieser, 1935; Berscheid, Dion, & Walster, 1971; LaPrelle, Hoyle, Insko & Blumenthal, 1990).

Emotional empathy may also serve as a catalyst in prejudice reduction. When one experiences a visceral empathetic response to another group's plight, this may transform the "emotional lens" through which one views the other group. Emotions commonly associated with empathy, such as concern or indignation, could disincline people to dismiss the outgroup's suffering as a justified result of their supposed negative characteristics. For example, I may become somewhat uneasy with my long-held belief that members of group X are discriminated against in hiring situations because prospective employers know they are all dishonest. Once my stereotypes no longer provide me with a personally satisfying way of viewing group X and their collective experience, I will be more open to discarding them because their utility as a "cognitive shortcut" is compromised.

Interventions in which Fostering Empathy is a Core Method or Goal

Although empathy may be a neglected focus in prejudice reduction programs, it is frequently a core method or goal in interventions designed to change attitudes in a variety of domains. Foubert and Perry (2007) describe an empathy-based rape prevention program designed for fraternity members and male student athletes. Participants were particularly affected by part of the program in which they viewed a videotape describing the rape of a male police officer by two other males. Their feedback indicates that they were induced to empathize with victims of rape to an extent they hadn't been able to prior to viewing the video. One participant related how while watching the video he felt "frozen like they said young women are in those situations," a remarkable statement of parallel empathy indeed! (Foubert & Perry, 2007, p.76).

Although the program gave participants a jarring experience of emotional empathy, cognitive empathy played a vital role as well. Participants were trained to provide effective emotional support for survivors of sexual assault, and for some at least, seeing the situation from the victim's perspective was an integral part of this. One participant described how after the program, he comforted a female friend who had been raped, and was actively "[trying] to imagine how horrible it must have been for her" (Foubert & Perry, 2007, p.80).

In a five month follow-up survey, a strong majority of participants reported lasting changes in attitudes and behaviors, with some providing concrete examples of how their behavior had been influenced by the program, including confronting peers who told rape jokes, and, in several cases, helping a sexual assault survivor. The program seems to have produced a shift in participants' self-concepts, specifically in regards to how they viewed themselves in relation to rape. Whereas before they had viewed rape as a rare occurrence not directly relevant to their own lives, afterwards they came to value their new roles as awareness raisers in their own communities, and providers of emotional support to victims (Foubert & Perry, 2007).

Eliciting empathy is frequently also a prioritized goal in conflict resolution programs. Kelman (2005) discusses the role empathy plays in "interactive problem solving workshops," which are programs designed to facilitate dialogue between politically influential Palestinians and Israelis, and jointly conceive solutions to the regional conflict:

> [Participants] are encouraged to deal with the conflict analytically rather than polemically – to explore the ways in which their interaction leads to escalation and perpetuation of the conflict, instead of assigning blame to the other side while justifying their own. This analytic discussion helps the parties penetrate each other's perspective and understand each other's needs, fears, concerns, priorities, and constraints. Once both sets of concerns are on the table and have been understood and acknowledged, participants are asked to engage in a non-adversarial process of joint-thinking, treating the conflict as a shared problem that requires joint effort to find a mutually satisfying conclusion (Kelman, 2005, p. 642).

Kelman's workshops use cognitive empathy to encourage (at least a temporary) shift in participants' self-concepts. Outside the workshops, they may be committed to defending their "side" in the conflict, and therefore reluctant to allow for the validity of or make concessions to the opposite position. This kind of defensive posture is antithetical to conflict resolution (Rouhana & Kelman, 1994). The workshops create an environment in which the ability and willingness to understand the other side's perspective is valued as a prerequisite to successful problem solving.

DESIGN PRINCIPLES

In the following sections, we propose a set of principles for the design of games to foster empathy. They are derived from the literature reviewed in this paper, and we plan to assess their efficacy as we use them to guide future design projects.

The creative and open-ended nature of game design necessitates that these principles be applied heuristically. Designers will have to explore for themselves what each one implies for particular design decisions. We expect that each new application will inspire us to add new principles or refine the ones presented here. Thus, we see them as evolving rather than as a comprehensive set of guidelines.

Principle 1: Players are likely to empathize only when they make an intentional effort to do so as the game begins. The game may explicitly ask players to empathize, or it may more subtly encourage them to take on a focused empathetic posture. However, without some kind of effective empathy induction at the outset, most people will play "unempathetically."

This principle is adapted from Stephan and Finlay's (1999) recommendations for creating empathy in intergroup relations programs. Designers may assume the content of their games is sufficiently affecting in and of itself to elicit empathy. However, the research of Batson and his colleagues (Batson et al., 1997; Batson, Chang, Orr & Rowland, 2002) suggests that this assumption is unwarranted. Recall that in their experiments, participants demonstrated no attitude or behavior changes when they merely watched video interviews of drug addicts, homeless people, and members of other stigmatized groups (though, presumably, this was powerfully affecting content). However, if, prior to viewing, they were asked to make an intentional effort to empathize, then the videos did improve attitudes and inspire altruistic behavior. Correspondingly, games may be more likely to influence attitudes and behaviors when players are induced at the outset to make an intentional effort to empathize.

With reference to games and learning, Solomon (2009) describes a mode of playing he calls "mindful." Mindful players may be highly engaged in the moment-to-moment excitement of a game, but on a meta-level they also continuously reflect of what and how they can learn from the game. People do not normally play mindfully unless prompted by teachers, other learners, or in-game messages. We propose an analogous concept called "empathetic play." Empathetic players intentionally try to infer the thoughts and feelings of people or groups represented in the game (cognitive empathy), and/or they prepare themselves for an emotional response, for example by looking for similarities between themselves and characters in the game (emotional empathy). As with mindful play, we strongly suspect that people will not engage in empathetic play unless they are induced to do so.

"Unempathetic play" may have an effect that is far from what designers of games for good hope to encourage. Imagine a game that immerses players in the role of a refugee camp administrator, who must allocated resources and expand facilities to accommodate a growing population of dislocated people. If the game is skillfully designed, players may become absorbed in the moment-to-moment balancing of resources against needs and time against tasks. But absent an empathy induction, the play experience will probably be roughly equivalent to entertainment-focused simulation games like *SimCity* or *Railroad Tycoon*, which is to say that it will be a well-crafted diversion that for most people is forgotten when the game ends.

Principle 2: Give players specific recommendations about how their actions can address the issues represented in the game.

Although the link between empathy and helping behavior is well-established, there is little research directly addressing the question of how people feel or react when they are unable to help those with whom they empathize. A popular theory is that empathy can be a painful experience in that it compels one to feel the suffering of another person (Schroeder, Penner, Dovidio & Piliavin, 1995). It follows that if one does not know how to help the other person, the pain caused by empathy will have no obvious remedy. Inducing empathy without providing a "way out" of empathetic pain through helping may have negative consequences. Specifically, people could guard themselves against feeling empathy in the future to avoid similarly unpleasant experiences.

In addition, desired behaviors can be modeled through game mechanics. For example, a game about assisting peers at risk for suicide might require players to notice symptoms of suicidal ideation in non-player characters (NPC's). It will often be important for such behaviors to be modeled accurately, which may be a daunting challenge. In this case, how could an NPC be designed so that symptoms like severe anxiety and impaired concentration are manifested to the player in a realistic way? In our experience with student designers, they often fall back on representations that are more iconic than realistic – for example, suicidal NPC's may be depicted as having thunderclouds hovering over their heads. While these kinds of iconic representations are often useful in game design (as when the player character's health is displayed as a red bar that shrinks when s/he takes damage), it should be decided on a case-by-case basis whether true-to-life representations are more appropriate given project goals.

Principle 3: A short burst of emotional empathy works well if desired outcomes to not require significant shifts in how players' beliefs about themselves, the world, or themselves in relation to the world. But if these kinds of shifts are a design goal, the game should integrate both cognitive and emotional empathy.

Imagine you are contracted to create a game for an organization that assists American families living in poverty. The game's purpose is to convince players to donate money through the organization's website. In the game you design, the player character runs a shelter with limited resources. Early play-testers report feeling pity and concern (in other words, emotional empathy) for families who cannot be accommodated by the shelter. How successful will the game be in soliciting donations? This probably depends greatly on players' existing beliefs.

Consider how two players with different belief systems might respond to the game. The first player, Suyin, thinks of herself as a good person, and also believes that good people help others in need. Moreover, she thinks there are many people in America who cannot afford necessities through no fault of their own, and that these people need help. Convincing Suyin to donate money should be relatively straightforward because this course of action is entirely consistent with her self-concept. In her case, the arousal of emotional empathy through the game activates her already existing beliefs about charity and poverty. Once these beliefs are activated, the act of donating reaffirms her self-concept in a pleasing way: She believes that good people help others in need, and donating gives her concrete evidence that she is a good person.

The second player, Marco, has a somewhat but not entirely different set of beliefs. While he also thinks of himself as a good person, and believes that good people help others in need, in his opinion America is a land of opportunity for anyone willing to work hard. People who are poor are simply too lazy to improve their situation, and "handouts" encourage their laziness. Marco may feel emotional empathy as strongly as Suyin – upon seeing families turned away from the shelter, he worries for their well-being and feels badly for the children. But donating to the organization would produce an uncomfortable incongruity between his actions and his beliefs. Since he believes poor people could improve their situation by applying themselves to finding and keeping steady work, giving them money would make him feel like a "patsy." It seems likely that in Marco's case the game would not produce the desired outcome.

In order to convince Marco to donate money for American families living in poverty, the game would probably have to change his beliefs about poverty. One approach would be to put players in the role of a parent who cannot afford to provide for the basic needs of his or her family. If Marco commits to engaging in cognitive empathy towards the player character, he would likely find that that the situation seems very different from the perspective of an impoverished parent than from his own. Assuming he accepts the accuracy of the game's portrayal, this creates psychological tension that may compel him to act differently than he would have prior to playing. Remember that Marco thinks of himself as a good person, and believes that good people help others in need. If he is open to the idea that poverty is a situation of genuine need rather than being the result of laziness, he may feel compelled to donate in order to maintain his image of himself as a good person.

Although cognitive empathy has the leading role here, emotional empathy can also play an important part. If Marco feels concern for characters in the game (reactive empathy), and/or has some vicarious experience of the family's hopelessness (parallel empathy), this could provide further motivation to consider and commit to changes to his beliefs and actions.

Principle 4: Emphasize points of similarity between the player and people or groups with whom she is supposed to empathize, but beware of provoking defensive avoidance.

We noted before that cognitive empathy may encourage people to perceive others as more similar to themselves, and this in turn could produce positive attitude changes. This process may be facilitated when games highlight specific similarities between the player and people or groups depicted in the game. For example, a game depicting a close-knit family of undocumented Mexican immigrants to the United States might particularly resonate with players who value close family relationships. If I can relate to the immigrant family's values in one area, this may anchor a more holistic consideration and appreciation of their perspectives and experiences. In contrast, if the family's value system is portrayed in a way that makes it seem alien to my own, I may find it difficult to empathize even if I am willing to do so.

There is some danger that perceiving common ground between myself and an outgroup might provoke insensitivity to their plight as a defensive reaction. For example, if I belong to another immigrant group, I may resist identification with undocumented immigrants as a way of reaffirming my identity as a "real American." In such cases, the research literature provides few clues on how to induce empathy.

EXEMPLARY GAMES

The activist design community has produced a number of games in which fostering empathy is either an explicit or implicit goal. In the following sections, we discuss several games that have met this design challenge in innovative and exemplary ways. In particular, we're interested in how their design features have anticipated the principles we've articulated in this paper.

To be clear, none of these games exemplify all of our design principles – indeed, there are no existing games that do. Yet each game we discuss here is a playable example of how one of the principles can be integrated into a larger design. While we try to provide detailed descriptions of the games, as always we strongly recommend that readers play them to fully appreciate what their designers have accomplished. Most are available for free online.

Exemplary Game: PeaceMaker by ImpactGames

In *PeaceMaker*, the player inhabits the role of either the Israeli Prime Minister or Palestinian President during a particularly volatile period of the Palestinian-Israeli conflict. Whichever role the player chooses, the goal is to create conditions in which a “two-state solution” to the conflict becomes viable. There are a wide variety of actions to choose from, some hawkish, some conciliatory, some unilateral, and some that require cooperation with groups on the other side of the conflict.

***Figure 1.* Screen shot from *PeaceMaker* by ImpactGames.**

The game’s message can be discerned by contrasting the types of actions that can be successfully used to reach the win state with those that lead to failure. Generally, a hawkish, unilateral foreign policy will exacerbate the conflict, while small conciliatory gestures will build trust between stakeholders on both sides. Small gestures set the stage for more significant peace-building policies which can eventually lead to lasting peace.

The game encourages empathy in several ways. The most obvious is that one can play from either side of the conflict, an especially interesting feature given how many people deeply identify with one side while feeling a strong antipathy towards the other. It is difficult to overstate how strongly a deeply charged political discourse will discourage people from considering the perspectives of their enemies. Especially in regards to the Israeli-Palestinian conflict, prevailing assumptions (on both sides) are that the other side acts as they do because they are in some way morally degenerate, and therefore efforts to appreciate or accommodate their perspective are foolish. Playing *PeaceMaker* (from the side with which one does not identify) forces one to at least temporarily put aside the notion that one’s enemy acts out of sheer malevolence. For example, to successfully play as the Palestinian President, one has to explore the nuances of his or her position. In other words, one has to engage in cognitive empathy. In particular, one discovers that stability and prosperity gives the Palestinian President the political capital to resist extremist militant groups who would otherwise greatly constrain his or her policy options.

Cognitive empathy is involved in gameplay in another way as well. To make progress in the game, players have to consider the perspectives of a variety of stakeholders, rather than only that of their own side. For example, while playing as the Israeli Prime Minister, players will face a violent revolt if their disapproval rating amongst Palestinians increases to a certain level. Reaching a win state from the Israeli side requires both understanding and accommodating the Palestinians enough to secure their cooperation on security policy. More generally, the game requires one to think carefully about the perspectives of a wide range of stakeholder groups, including extremists and moderates on both sides, the United States, and the European Union. Policy decisions that agitate a stakeholder group too much can potentially derail the peace process.

PeaceMaker incorporates real news photos and video footage from the conflict to punctuate gameplay at key points. Often these segments depict the conflict’s effect on individual’s lives, making it easier to empathize with Israelis and Palestinians on an emotional level. For the most part, the scenes depicted are disturbing – a Palestinian mother weeping over dead relatives, or a public bus in Israel destroyed by a terrorist attack. This provides a jarring emotional counterpoint to the more cognitively-oriented moment-to-moment strategy gameplay.

We consider *PeaceMaker* to be an excellent example of how our third principle can be implemented in game design. By masterfully intertwining elements that encourage both cognitive and emotional empathy, the game may effectively appeal to people who are usually attracted to more hawkish perspectives on the Palestinian-Israeli conflict.

Exemplary Game: Hush by Jamie Antonisse and Devon Johnson

Hush begins with a screen prompting us to take the perspective of the player character, who is a Rwandan Tutsi mother hiding in a shack with her baby during the genocide of 1994. Against a background of haunting music, this message appears:

> Rwanda, 1994: The Hutu are coming, Liliane. Hide your child. If you falter in your lullaby, he will grow restless. The soldier will hear him, and he will come for you.

Figure 2. **Screen shot from *Hush* by Jamie Antonisse and Devon Johnson.**

By addressing the player as "Liliane," the game encourages players to forego the emotional distance that usually separates them from what happens on screen. This can be regarded as a kind of empathy induction (as described in our first principle), in response to which we may be more likely to inhabit, explore, and identify with Liliane's experience. An interesting area for future research will be to investigate what kinds of inductions are most effective. For example, should inductions be relatively subtle (as in *Hush*), or more explicit (as in the experiments of Batson and his colleagues, where participants were explicitly instructed to imagine the thoughts and feelings of others).

Hush uses a singing mechanic to immerse the player in the role of the player character, a Rwandan Tutsi mother hiding with her baby in a shack during the genocide in 1994. The mother sings a lullaby to pacify her baby as soldiers pass by outside the window. If the lullaby falters, the baby begins to cry, and the soldiers may discover their hiding place.

The player "sings" the lullaby by typing it at the precise rhythm indicated by on-screen prompts. Players have reported that as they miss notes in the lullaby and the baby's cries grow louder and the soldiers come nearer, they feel an escalating sense of tension and dread.

Eliciting such powerful parallel empathy through a game is a rare accomplishment. In this case, it is probably in part achieved by the game's unusual interaction design. More than in most games, the player's actions closely approximate what the player character is depicted as doing (typing a lullaby to a precise rhythm feels more like singing than, for example, pressing a button feels like shooting a gun or throwing a football). Gaming platforms that allow players to control onscreen action through body movements, such as Nintendo's Wii and Microsoft's Project Natal, are probably particularly well-suited to this kind of interaction design.

Exemplary Game: Layoff by Tiltfactor

Like *Hush*, *Layoff* is designed to elicit empathy in players towards characters in the game (and, like *Hush*, towards the real world people those characters represent). However, it is a very different kind of game than *Hush*, and elicits a very different kind of empathy.

Layoff is a mod of the casual game Bejeweled, in which players swap adjacent gems on a playing board to create horizontal or vertical sets of three or more identical gems. When sets are created, their component gems disappear from the board and are replaced by new gems falling from the top.

In *Layoff*, one plays as "corporate management," tasked with cutting jobs during the financial crisis. The playing board is like Bejeweled, except each tile represents a worker instead of a gem. When players match sets of three or more workers, they fall off the bottom end of the board into an "unemployment office." From management's perspective, the workers are interchangeable parts that can be swapped and terminated to save money. The game, however, is designed to challenge this perspective, to contend with the idea that a worker is only a "part." Each worker has a detailed personal biography that pops up when their tile is selected. For example:

> Jaime, 39, is a client relationship manager at a small outsourcing company. This is a new job in Boston, and Jaime likes it very much except for the climate. Jaime works from home on Fridays to ease financial pressure for childcare, but the manager is possibly going to cut all employees down to a 4-day workweek.

Notice that in *Layoff*, unlike *Hush*, a bond of empathy is created not between the player and player character (who in *Layoff*, represents management), but rather between the player and non-player characters (i.e., the workers who are being laid off). *Layoff* also evokes a different kind of empathy than *Hush*. Players probably don't feel anything approximating what a worker might feel when s/he loses his or her job (whereas in *Hush*, you do experience the same broad class of emotions as the player character). But one might feel indignation at the callousness of management towards their workers, or sorrow for the plight of people who've lost their jobs in a bad economy. In other words, players feel reactive empathy.

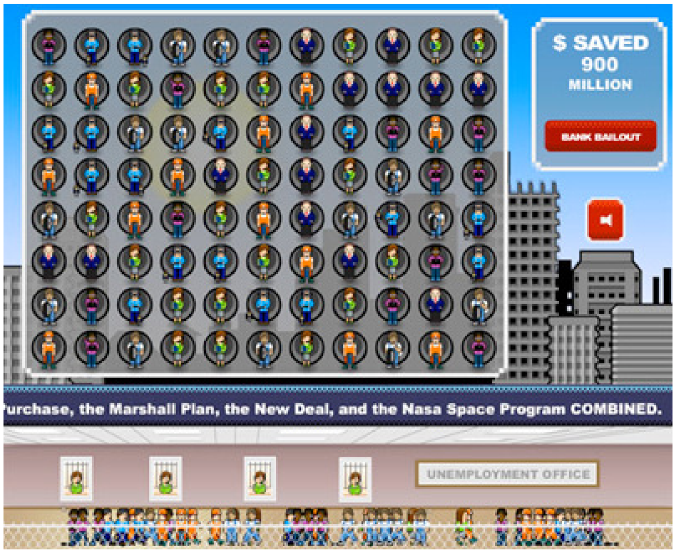

***Figure 3*. Screen shot from *Layoff* by Tiltfactor Labs.**

The player experiences reactive empathy when s/he is forced to use information about workers' personal lives to decide whom to layoff. Should I fire Rae the single parent or Kas the depressed divorcee? Obviously, from a business perspective, workers' personal biographies provide little useful insight. But absent any other information, they encourage an emotional response to the human suffering created by the economic crisis.

This emotional response is likely facilitated if the game creates a perceived similarity between the player and the workers (see Principle 4). This may happen when players notice some overlap between their own lives and the workers' biographies. Given the sheer amount of biographies in the game and their level of detail, it is likely that many players will find a worker with whom they share some hobby, career ambition, personal situation, or family crisis.

CONCLUSION

The focus of this paper has been translating research-based knowledge about empathy into practical design principles. In future work, we plan to apply these principles in real design situations to test their efficacy. Our long-term goals are to explore how particular design features and strategies are associated with eliciting different kinds of empathy, and to better understand whether and how "empathetic play" influences players' attitudes and behaviors.

More broadly, this line of investigation aims to highlight a sometimes neglected area in technology design. While most mainstream design methodologies include processes for optimizing usability from a cognitive perspective, many do not address the nuances of users' emotional responses to design features. While such considerations are likely relevant in many areas of technical design, they may be particularly essential in the design of games for good.

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AUTHOR NOTES

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Exercise and Play: Earn in the Physical, Spend in the Virtual

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Contemporary lifestyle is becoming increasingly inactive: a little physical (sport, exercising) and much sedentary (TV, computers) activity. The nature of sedentary activity is often self-reinforcing, such that increasing physical and decreasing sedentary activity is difficult. We present a novel approach aimed at combating this problem in computer gaming. Rather than explicitly changing the amount of physical and sedentary activity a person sets out to do, we propose a new game design that leverages engagement with games in order to motivate players to perform physical activity as part of a traditional sedentary game playing. This work presents the design and evaluates its application to an open source game, *Neverball*. We altered *Neverball* by reducing the time allocated for the game tasks and motivated players to perform physical activity by offering time based rewards. A study involving *180* young players showed that the players performed more physical activity, decreased their sedentary playing time, and did not report a decrease in perceived enjoyment of playing the active version of *Neverball*. A survey conducted amongst *103* parents revealed their positive attitude towards the activity motivating game design. The obtained results position the activity motivating game design as an approach that can potentially change the way players interact with computer games and lead to a healthier lifestyle.

KEYWORDS: Serious Games, Game Design, Physical Activity, Motivation, Behavioural Change, User Study

INTRODUCTION

According to the World Health Organisation, over *1.6* billion individuals are overweight or obese (WHO, 2006). A contributing factor for this phenomenon is the occurrence of a positive energy balance, i.e., where one's energy intake exceeds one's energy expenditure. This is often explained by an increasingly sedentary lifestyle: low amounts of physical activity (such as walking, sport, and exercising) and high amounts of sedentary activity (such as TV, computer games, and reading).

The nature of the sedentary activity is often addictive and self-reinforcing (Koezuka et al., 2006). Hence, adjusting one's energy balance by explicitly increasing the amount of physical and decreasing the amount of sedentary activity performed is not easy. In our research we present a novel approach to combat this problem. Rather than setting out to explicitly decrease the amount of sedentary activity in one's normal lifestyle, we propose to change a typical sedentary activity to incorporate certain forms of physical activity. This paper demonstrates a practical application of this paradigm in computer gaming. We present a novel computer game design, which leverages players' enjoyment and engagement to motivate them to perform physical activity as part of sedentary playing.

Our design can be applied to a wide variety of games in which a player's game character is represented by quantifiable features, e.g., time, energy, or speed. To encourage players to perform physical activity while playing, we propose to modify the design of computer games such that players can gain virtual game related rewards in return for the real life physical activity they perform (Berkovsky et al., 2009). Physical activity can be captured by wearable sensors attached to the player. According to our design, at any point in time players can perform physical activity, which will instantaneously provide them with the reward and reinforce the game character, e.g., gain time, boost energy or increase speed. This reinforcement increases the likelihood of accomplishing the game tasks and players' enjoyment, while gradually increasing the difficulty of the game tasks to further motivate players to perform physical activity. This game design is referred to as *PLAY, MATE!* (PhysicaL ActivitY MotivATing gamEs).

This paper presents and evaluates an application of the *PLAY, MATE!* design to a publicly available computer game, *Neverball* (http://www.neverball.org). In *Neverball*, players navigate a ball through a maze-shaped surface avoiding obstacles and collecting coins, while accomplishing these two tasks in a limited amount of time. We altered *Neverball* according to the *PLAY,* *MATE!* design by (1) reducing the time allocated to accomplish the game tasks, and (2) motivating players to perform physical activity by offering time based rewards. Each player was equipped with a tri-axial accelerometer configured to recognise jump events, such that for every captured jump the player gained one extra second to accomplish the game tasks.

We conducted an experimental evaluation involving *180* participants aged *9* to *12*. The evaluation ascertained that applying the *PLAY, MATE!* design increases the amount of physical activity performed while playing and changes the distribution between the sedentary and active playing time. Although participants performed physical activity, they did not report a decrease in perceived enjoyment of playing. A survey conducted amongst *103* parents of the participants revealed their positive attitude towards the *PLAY, MATE!* design.

Hence, the contributions of this work are three-fold. Firstly, we proposed a novel *PLAY, MATE!* design for physical activity motivating games and exemplified its practical application to *Neverball*. Secondly, we experimentally evaluated the acceptance of the design by real players and its influence on their playing behaviour. Thirdly, we showed that the *PLAY, MATE!* design and active gaming paradigm were highly regarded both by young players and their parents. These results demonstrate the positive impact of the *PLAY, MATE!* design and clearly position it in the field of "games for good". Also, the results demonstrate the great potential of physical activity motivating games in changing the normally sedentary interaction style of young and adolescent players with computer games.

The rest of this paper is structured as follows. Section *2* surveys the related work on motivating technologies and games. Section *3* models the interaction between a player and a game and presents the principles of the *PLAY, MATE!* design. Section *4* illustrates ways of applying the *PLAY, MATE!* design to *Neverball*. Section *5* presents the experimental evaluation we conducted and analyses its results. Section *6* summarises the work and outlines our future research.

RELATED WORK

Information technology solutions to the obesity problem have been studied from various perspectives. Several works focused on the design issues of such applications. Consolvo et al. (2006) discussed general design principles of physical activity motivating technologies and applications. Campbell et al. (2008) focused on specific game design principles that can be applied to fitness applications. Following the design principles developed in these works, several practical applications have been developed.

Lin et al. (2006) developed a social application recording users' physical activity and linking it to the growth and activity of a virtual fish. Toscos et al. (2006) developed a mobile application recording a users' physical activity and sending persuasive messages encouraging exercise. In both cases, the physical activity of the users was quantified by the number of steps captured by a pedometer and then manually fed into the system. Hence, the users were requested to carry the pedometer everywhere and to periodically feed the counter reading into the system. From the technical perspective, physical activity self-reporting is often discovered to be unreliable and inaccurate (Klesges et al., 1990). From the behavioural perspective, these applications were aimed at changing the lifestyle of users by encouraging them to perform physical activity. The change was mostly accepted by previously motivated users, while other users resisted it.

Several applications take a persuasive approach (Fogg, 2003) to combating the obesity problem. Nawyn et al. (2006) developed a home entertainment system remote control promoting a reduction in TV viewing time and an increase in non-sedentary activities. Maheshwari et al. (2008) presented a user study evaluating the effectiveness of persuasive motivational messages for overweight individuals. Out of a plethora of Web based activity motivating applications surveyed by Zhu (2007), only a small number led to a short-term increase in physical activity. Similar to the above examples of information technologies, persuasive applications were mostly accepted by previously motivated users and resisted by others. In contrast, the *PLAY, MATE!* game design does not rely on extrinsic motivational factors, but rather leverages existing engagement with computer games to motivate users to perform physical activity.

Another area aiming to increase efficacy and sustainability of exercising and physical activity is of immersive virtual environment technologies. Ijsselsteijn et al (2006) presented a study investigating the effect of immersion and coaching on motivation of exercise bicycle riders. The results showed a positive effect of both factors on intrinsic motivation. Fox and Baileson (2009) presented a study evaluating the impact of virtual representation of self on the amount of voluntary physical exercising. It was found that rewarding or punishing the virtual representation of self depending on the amount of performed exercising (by visualising apparent weight loss or weight gain of the virtual representation) causes participants to engage and perform more exercise. However, these works deal with exercising, which is naturally a physical activity, and do not show whether a similar effect could be obtained for activities, which are naturally sedentary, and whether this effect would be beneficial in this case.

Game technologies involving players' physical activity have been developed and successfully disseminated in commercial products, like *Dance-Dance Revolution* (http://www.konami.com/ddr/) and the Nintendo Wii (http://www.nintendo.com/wii). The former is a dance pad, on which players step to control the game, and the latter is a gaming console, which uses an accelerometer-equipped device, allowing players to control the game by their body movements. Sales figures of these products demonstrate their tremendous commercial success: Wii alone sold over 45 million consoles in the first 2 years of sales. However, both technologies should be treated primarily as commercial products that provide natural bodily interfaces to interact with computer games rather than direct motivators of physical activity.

To the best of our knowledge, the only study of practical integration of physical activity into computer games was undertaken by Fujiki et al. (2008). A player's activity, captured by an accelerometer, were instantaneously transmitted to a PDA and visualised by a simple race-like game interface. The activity affected the visualisation of the game: speed of the game character, its standing in comparison to other players, and facial expression of the player's avatar. However, the race-like interface was designed exclusively to visualise the player's physical activity, lacking the attractiveness and immersion of contemporary games. Rather than designing new games and interfaces, our work aims to develop a new game design that, if integrated with a variety of existing and future games, will motivate players to perform physical activity as part of playing (Berkovsky et al., 2009).

PHYSICAL ACTIVITY MOTIVATING GAME DESIGN

We start the presentation of our physical activity motivating game design by modeling the standard playing process. Playing mainly consists of player interaction with a game environment, which is typically indirect and mediated by a game character. Hence, a game character can be considered as a player's virtual embodiment in the game environment. Hence, player *P* controls the game character *C*, which is actually involved in the game *G*. The interaction between a player *P* and character *C* is unidirectional: *P* manipulates and controls *C*. Conversely, the interaction between the character *C* and the game *G* is bidirectional: *C* executes the manipulations of *P* and influences *G*, which reacts according to the game logic and influences *C*. For example, consider a well-known *Pac-Man* computer game. There, the player manipulates the *Pac-Man* character to navigate through the maze, avoid ghosts, and collect coloured dots and bonus items. The arrows in Figure 1(a) schematically depict the interactions between *P*, *C*, and *G*.

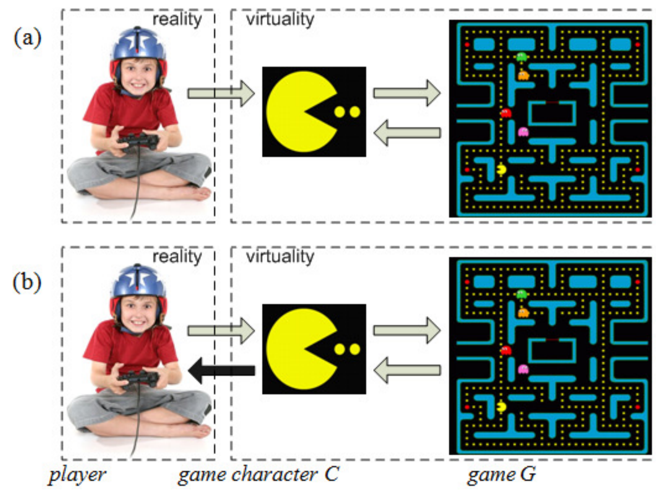

Figure 1. **(a) Standard Player Interaction with the Game, (b) Player Interaction Including the Motivational Feedback.**

Since no direct interactions normally occur between *P* and *G*, we consider *C* as the model of *P* in *G*. In most games, *C* is represented by quantifiable features and their respective values. For example, consider the following *Pac-Man* character representation *{remaining-time:40, maximal-velocity:14, dots-collected:16}*. The value of a certain feature can be modified in three ways: (1) directly by *G*, e.g., reduction of the remaining time, (2) by *P* manipulating *C*, e.g., changing the direction of motion, and (3) by *P* controlling the interaction between *C* and *G*, e.g., collection of dots in *Pac-Man*. It should be noted that these modifications mostly occur simultaneously and *P* controls *C* accordingly.

To sustain a prolonged engagement of *P* with *G*, the flow of *G* is divided into several tasks, i.e., levels, that need to be accomplished by *P*. Formally, accomplishing a task means reaching the required value of a certain critical feature (or combination of values across multiple features), while satisfying other constraints of *G*. For example, consider the following *Pac-Man* game task: to collect *50* dots within *3* minutes of playing time, while avoiding the ghosts. According to (Sweetser and Wyeth, 2005) and (Febretti and Garzotto, 2009), the ability to accomplish the tasks is one of the main factors for the enjoyment and engagement of playing.

DESIGN PRINCIPLES OF *PLAY, MATE!*

Although contemporary games are often related to negative social stereotypes, they can be leveraged to promote more active behaviour and potentially lead to a healthier lifestyle. The goal of the *PLAY, MATE!* design is to change the sedentary nature of the game playing activity to include certain forms of physical activity. According to the design, physical activity is introduced as an integral part of playing. In this way, the engagement of *P* with *G* is leveraged to motivate *P* to perform physical activity. In essence, the motivational factor establishes a positive reinforcement based persuasive feedback between *G* and *P* (Arroyo et al., 2005), illustrated by the dark arrow in Figure 1(b). The primary target of this feedback is to influence *P* and eventually achieve the desired behavioural change, i.e., physically active playing.

The motivation to perform physical activity is achieved by modifying the following components of *G* and aspects of interaction between *P* and *G*:

- Game related motivator. *P* is made aware of the possibility of gaining virtual rewards in *G* in return for performing real physical activity. In addition, *G* is modified to motivate *P* to perform physical activity, such that certain functions of *G* or features of *C*, which are disabled or diminished at first, can be enabled or reinforced by the activity rewards.
- Activity interface. *P* is provided with an external interface capturing the physical activity performed, processing it, and converting real activity of *P* into virtual rewards in *G*.
- Game control. Since performing physical activity and controlling *C* simultaneously could be over-complicated, *P* is given supplementary control over the flow of *G*.

Using the above modifications, *P* is motivated to perform physical activity in the following way. Firstly, *G* is modified such that certain functions of *G* are disabled or certain features of *C* are diminished. Secondly, *P* is made aware of the fact that performing physical activity will enable the functions of *G* or reinforce the features of *C*. A composition of these two factors, combined with the existing engagement with and the enjoyment of playing, motivates *P* to perform physical activity, enable the functions of *G* or reinforce the features of *C*. As a result, *P* uses the supplementary game control to interrupt the sedentary playing and perform physical activity. When performed, the activity is captured by the physical activity interface and converted into the virtual game rewards, which enable the functions of *G* or reinforces the features of *C*.

Consider the following example of the *PLAY, MATE!* design applied to the *Pac-Man* game. The game is modified such that the velocity of the *Pac-Man* character is decreased. However, the player is made aware of the possibility to reinforce the *Pac-Man* character, i.e., increase its velocity, by performing physical activity. The player is equipped with a wireless pedometer, which acts as the activity interface. The pedometer counts the player's steps and transmits the number to the game. The number of steps is processed and the velocity of the *Pac-Man* increases accordingly. It may be difficult for the player to control the *Pac-Man* character simultaneously with stepping. To perform physical activity and continue playing the game, the player can slow down or eventually pause the *Pac-Man* game at any point in time.

Premack's principle is a behavioural theory can be used to underpin the validity of the *PLAY, MATE!* design (Premack, 1959). According to this principle, if two activities have different a-priori probabilities of occurring, the high probability activity can be used to motivate or reinforce the low probability activity. That is, the high probability activity motivates the low probability activity by making the former contingent on the latter. A common example of Premack's principle is motivating children to eat vegetables by making ice cream (high probability activity) contingent on eating the vegetables (low probability activity). In computer gaming, we will assume that the sedentary playing is the high probability activity and physical activity is the low probability activity. The main motivating factor of the *PLAY, MATE!* design is allowing the player to gain virtual game rewards in return for performing real physical activity. That is, physical activity is motivated by making the game playing (precisely, game rewards that ease the playing) contingent on the physical activity.

We would like to highlight the non-coercive nature of the *PLAY, MATE!* design. Firstly, the game related motivators are introduced gradually, to keep the game tasks challenging while accomplishable (Sweetser and Wyeth, 2005). As a result, *P* can accomplish the tasks either in a difficult sedentary playing or in an easier way, by performing physical activity and gaining the rewards. Secondly, feedback about the functions of *G* that are enabled or features of *C* that are reinforced is instantaneously visualised, such that *P* can independently determine the desired amount of physical activity. Hence, *P* remains in control of the decisions regarding when and how much physical activity to perform.

Note that the effort required to apply the *PLAY, MATE!* design to an existing game (game related motivator implantation and physical activity interface calibration) is negligible in comparison with the effort required to design and develop a new game. This is due to the fact that when the design is applied to an existing game, many available components, such as game logic, input/output, visualisation, and others, can be reused rather than developed from scratch.

APPLYING PLAY, MATE! TO *NEVERBALL*

To experimentally evaluate the *PLAY, MATE!* design, we applied it to an open source *Neverball* game (http://www.neverball.org). In *Neverball*, players navigate a ball to a target point through a maze shaped surface and collect a required number of coins in a limited time. Ball control is achieved by virtually inclining the game surface, which causes the ball to roll. Figure 2 shows a screenshot of *Neverball*. *Neverball* consists of multiple levels (i.e., instantiations of the tasks) with gradually increasing degrees of difficulty: the structure of the maze, the location of obstacles and pitfalls, the number of coins to collect, and the amount of time allocated vary considerably across the levels. Out of the available levels, we selected and used *16* levels that would suit inexperienced *Neverball* players.

***Figure 2. Neverball* Interface and Accelerometer.**

We applied a time based game related motivator, which referred to the time allocated to accomplish each level. We shortened the level times[1] and made players aware of the possibility of gaining extra time in return for performing physical activity. We conjectured that players' engagement with the game and aspiration to accomplish the levels will motivate them to gain extra time by performing physical activity. Table 1 summarises the original and shortened level times (in seconds).

We used a compact (*42x42x10* mm) and lightweight (*15* gr) tri-axial accelerometer referred to as the *activity monitor* to capture player's physical activity (Helmer et al., 2008). The accelerometer was attached to the player's waist, so as not to interfere with player's motion, using an elastic band (see Figure 2) and wirelessly transmitted the three measured acceleration signals 500 times per second. This allowed us to reconstruct the magnitude of the acceleration, filter out noises and abnormal spikes, perform time based normalization, and discretise the acceleration signal into activity bursts, which are referred to as *jumps*. For every jump captured, players gained one extra second to accomplish *Neverball* levels. The increased remaining time was instantaneously visualised, such that players were in control of the amount of physical activity performed. Since manipulating the ball simultaneously while performing physical activity would be difficult for players, we provided them with a control function that allowed players to pause and restart *Neverball* at any point in time.

***Table 1*. Original and Shortened Level Times.**

level	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
t_{orig}	*240*	*90*	*120*	*180*	*180*	*90*	*240*	*120*
t_{short}	*60*	*38*	*40*	*75*	*75*	*38*	*100*	*40*

level	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
t_{orig}	*180*	*120*	*180*	*300*	*120*	*180*	*240*	*240*
t_{short}	*45*	*40*	*60*	*75*	*40*	*60*	*100*	*100*

In summary, the *PLAY, MATE!* design is applied to *Neverball* as follows. Players are motivated to perform physical activity by applying a *shortened level times* motivator and making them aware of the possibility of gaining extra time by performing physical activity. When the remaining time is perceived to be insufficient, players can pause the game and perform physical activity, e.g., jump, or step on the spot. The physical activity is instantaneously captured by the activity monitor, transmitted to *Neverball*, processed and visualised. When the remaining time is perceived to be sufficient, players can resume the sedentary playing.

EXPERIMENTAL EVALUATION

We conducted an experimental evaluation aimed at ascertaining the acceptance of the *PLAY, MATE!* design. The acceptance is indicated by the amount of physical activity performed and perceived enjoyment of playing (Hsu and Lu, 2004). *180* participants from three primary schools in Hobart (Australia) participated in the evaluation. We presumed that *Neverball* is appropriate for relatively young players aged *9* to *12* and recruited accordingly: *25* participants were *9* years old, *49* were *10*, *74* were *11*, and *32* were *12* years old. *88* participants were boys and *92* were girls. Participants having previous experience with *Neverball* or having limitations

[1] The shortened level times were based on playing times exhibited by an expert player in a pilot playing session.

preventing them from performing physical activity were excluded.

The recruited participants were randomly assigned to two equal size groups of *90* participants. The first group played the normal *sedentary* version of *Neverball*, i.e., no game related motivator was applied. This group is the baseline group, since it represents the current sedentary gaming requiring no physical activity. The second group played the *active* version of *Neverball*, i.e., the *PLAY, MATE!* design with the shortened level times motivator was applied.

The participants were involved in the following activities. Initially, the participants played three levels of *Neverball*, to familiarise them with the game. Then, the participants were equipped with the activity monitors and informed of the possibility of gaining extra time in return for performing physical activity. Then, they had a *20* minute playing session, in which they played the version of *Neverball* according to their group (*sedentary* or *active*). Finally, they answered a post-study questionnaire and reflected on their perception of the playing. In addition, we asked the parents of the participants to answer a survey to reflect on their attitude towards the *PLAY, MATE!* design.

It should be highlighted that all the participants regardless of their group were equipped with the activity monitor and aware of the possibility of gaining extra time in return for performing physical activity. Hence, even in the *sedentary* group the participants could perform physical activity and gain additional time, although they had no real motivation to do this. This minimised the effect of novelty of using the activity monitor.

Acceptance of PLAY, MATE!

To ascertain the acceptance of the *PLAY, MATE!* design, we focus on two indicators: the amount of physical activity performed and the players' perception of the enjoyment of playing. The first shows whether the *PLAY, MATE!* design can motivate players to perform physical activity, while the second shows whether they find the active games enjoyable.

The amount of physical activity performed was quantified by the number of jumps captured by the activity monitor. Figure 3 depicts the average number of jumps performed. The average number of jumps performed by users in the *sedentary* group, who had no real motivation to perform physical activity, was *41.87*. It was considerably lower than the average number of jumps performed by users in the *active* group, which was *257.54*. The difference between the groups was statistically significant, $p<0.01$[2].

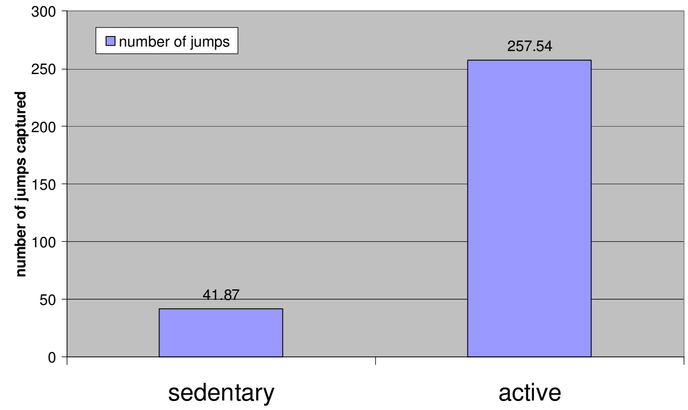

***Figure 3*. Average Number of Jumps Captured.**

To valdate this observation, we compared the sedentary playing time, T_{sed}, to the physical activity time, T_{act}, observed during the *20* minute playing session. These times were informed by the amount of time *Neverball* was played and paused, respectively, assuming that participants did not spend time on unrelated activities and neglecting the transition times. Figure 4 depicts the average relative time distribution between T_{sed} and T_{act}.

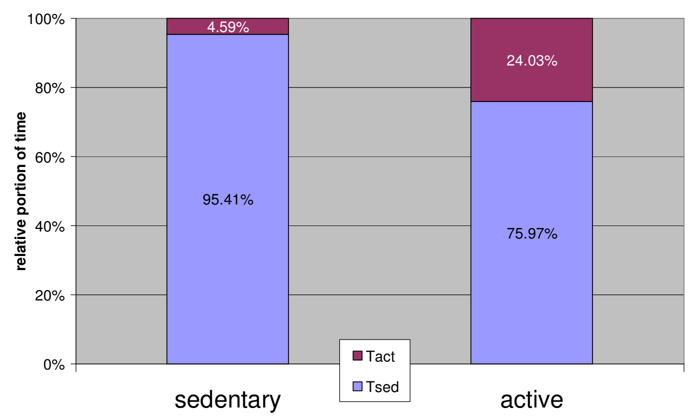

***Figure 4*. Distribution Between Sedentary and Active Time.**

Two patterns of behaviour can be clearly distinguished. For the *sedentary* group, *95.41%* of the *20* minute session time was spent on sedentary playing and *4.59%* on performing physical activity[3]. For the *active* group the time distribution was notably different. Only *75.97%* of time was sedentary, while *24.03%* of time was active.

[2] All statistical significance results hereafter refer to a two-tailed t-test assuming equal variances.
[3] The observed time distribution supports our assumption regarding the high and low probability activities in context of Premack's principle applied to computer games.

The difference between the groups was statistically significant, $p<0.01$.

In addition to the amount of physical activity, we analysed the participants' reported enjoyment and perception of physical activity performed while playing. In the post-study questionnaire, the participants reflected on their perception of the playing session on a [*-1*,*+1*] continuum, where *+1* is perceived as sedentary playing and *-1* is perceived as physical activity. Figure 5 depicts the average perception.

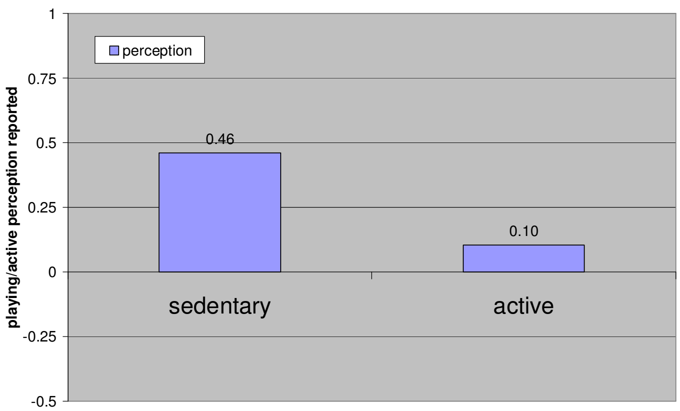

***Figure 5*. Average Perception of Playing.**

The average perception of playing in the *sedentary* group is *+0.46*, i.e., the participants perceive the playing session as mostly sedentary activity. However, in the *active* group the perception is *+0.1*, i.e., the participants perceive the playing session as almost equally sedentary and physical activity. The difference between the groups was statistically significant, $p<0.01$. This ascertains that the perception of the participants is realistic and corresponds to the amount of physical activity performed shown in Figures 3 and 4.

Although the participants realistically perceived the amount of physical activity performed while playing, they did not report a decrease in perceived enjoyment of playing. Figure 6 depicts the average enjoyment of playing reported on a 6-Likert scale ranging from "*absolutely hated*" to "*was cool, really loved*". The average enjoyment of playing in both groups is very high and comparable: *5.52* for the *sedentary* group and *5.48* for the *active* group. The difference between the groups was not statistically significant.
We conjecture that applying the *PLAY, MATE!* design to *Neverball* had mixed influences on the enjoyment of playing. Firstly, introducing physical activity as part of the game interrupted the flow of playing, as sedentary playing became interlaced with physical activity. This could have decreased the enjoyment of playing. Secondly, players were provided with a new game interaction means through the activity interface. It is a new interface not available in the state of the art games, which allows more control over the game and could have increased the enjoyment. The results in Figure 6 show that these factors balanced each other, such that the reported enjoyment of playing did not change significantly.

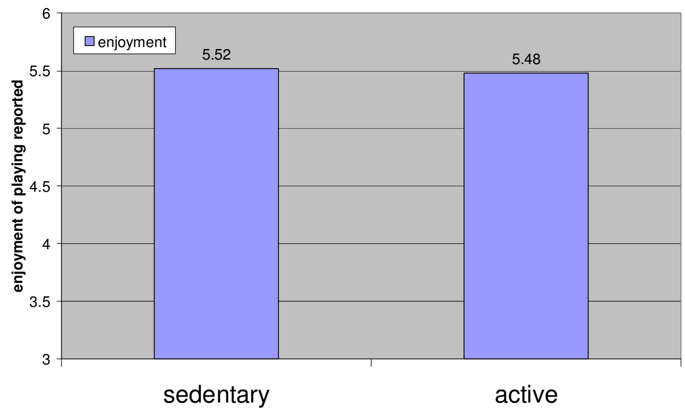

***Figure 6*. Average Enjoyment of Playing.**

We will summarise our main findings and statistical significance test outcomes in Table 2. The data refers to the number of jumps, relative active time, perception of playing, and reported enjoyment of playing for the *sedentary* and *active* groups. Statistical test outcomes include the *t* score, probability *p*, and Cohen's *d*.

***Table 2*. Results and Statistical Tests Summary.**

	sedentary	*active*	*t*	*p*	*d*
average number of jumps	*41.87*	*257.54*	*t(178)= -15.04*	*p*<.001	*2.25*
average relative active time	*4.59%*	*24.03%*	*t(178)= -15.19*	*p*<.001	*2.28*
average perception of playing	*0.46*	*0.10*	*t(178)= 6.37*	*p*<.001	*0.96*
average enjoyment of playing	*5.52*	*5.48*	*t(178)= 0.38*	*0.35*	*0.06*

Parents' Survey
We distributed a parents' survey, aimed at gauging their attitude towards the *PLAY, MATE!* design. Parents were asked to estimate the average daily amount of time they allowed their children to play sedentary games and their average monthly expenditure on sedentary games and accessories. Possible answers for the allowed times ranged from "less than 30 mins" to "more than 2 hours" and from "less than $20[4]" to "more than $100" for the expenditure. Then, we introduced the main ideas of the

[4] In Australian dollars ($AUD *1* = $USD *0.9*).

PLAY, MATE! design and the ways it can be applied to create future active games. Finally, we asked the parents to estimate the average daily amount of time they would allow their children to play, and the average monthly expenditure they would be happy to spend on games and accessories, if all the games were substituted by their active analogues.

The survey was answered by *103* parents. Figure 7 summarises the results. For the playing time of sedentary games, *52.43%* of parents selected "less than 30 mins", *35.92%* of parents – "30 mins to 1 hr", *10.68%* – "1 hr to 2 hrs", and only *0.97%* selected "more than 2 hrs". For the expenditure on sedentary games, *90.29%* of parents selected "less than \$20", *9.71%* of parents – "\$20 to \$50", whereas none selected "\$50 to \$100" or "more than \$100". The parents' answers considerably increased for the active analogues of the games created by applying the *PLAY, MATE!* design. For the playing time of active games, *16.50%* of parents selected "less than 30 mins", *47.57%* of parents – "30 mins to 1 hr", *28.16%* – "1 hr to 2 hrs", and *7.77%* selected "more than 2 hrs". For the expenditure on sedentary games, *55.34%* of parents selected "less than \$20", *39.81%* of parents – "*\$20 to \$50*", *3.88%* – "\$50 to \$100", and *0.97%* selected "more than \$100".

Overall, *54.37%* of parents indicated that they would allow their children to play for longer and *38.83%* indicated that they would agree to increase the expenditure on games and accessories, if current sedentary games were substituted in the future by their active analogues. Furthermore, *33.01%* of respondents indicated that they would both allow their children to play longer and agree to increase the expenditure.

These results show a positive attitude of parents towards the active games played by their children. They are willing to increase both playing (screen) time if the games included aspects of physical activity and their monetary expenditure. Hence, the *PLAY, MATE!* design does not only provide a new gaming paradigm enjoyable by players, but is also highly regarded by their parents.

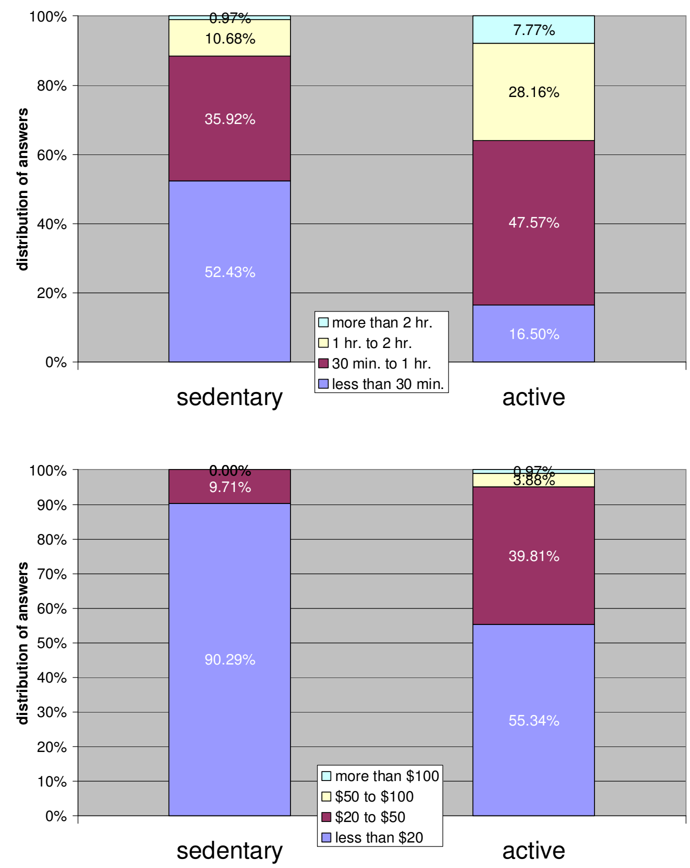

***Figure 7*. Parents' Attitude towards the *PLAY, MATE!* Design. Distribution of Answers for Average Daily Playing Time (Top) and Average Monthly Expenditure (Bottom).**

CONCLUSION

In this work we presented the *PLAY, MATE!* design for physical activity motivating games. The key concept underpinning the design is that players' engagement with computer games can be leveraged to motivate them to perform physical activity as part of playing. According to the design, physical activity is introduced as an integral part of playing, such that performing physical activity enables the players to gain game related rewards. We presented the components of the design and exemplified its application to the publicly available *Neverball* game.

We presented the results of a user study involving *180* participants aged *9* to *12* and *103* parents. The study allowed us to draw several conclusions. Firstly, it ascertained that young players can be motivated to perform physical activity while playing. Secondly, it showed that despite performing physical activity and realistically perceiving this, players did not report a decrease in perceived enjoyment of playing. Thirdly, the parents' survey showed their positive attitude towards physical activity motivating games. Hence, these results clearly demonstrate that the *PLAY, MATE!* design can potentially change the normally sedentary interaction of players with games and essentially lead to a healthier lifestyle.

Although these results are encouraging and demonstrate the potential of physical activity motivating games, they raise several issues, which we will investigate in the future.

- Game related activity. In the presented application of the *PLAY, MATE!* design, the physical activity was decoupled from the game, i.e., jumping did not match any particular player action in *Neverball*. However, this decoupling could potentially decrease the enjoyment of playing and discouraging players from playing activity motivating games. We will investigate ways to connect the type of physical activity performed by players and their actions in the game.
- Player dependency. The acceptance of the *PLAY, MATE!* design may be player dependent. For example, one would expect experienced gamers to be easily motivated by the game rewards, whereas users that do not play computer games often, may resist it and require other motivators. We will experimentally evaluate the impact of these dependencies and develop dynamic strategies for a player dependent application of the design.
- Preserving game flow. Interrupting the game to perform physical activity can potentially reduce the enjoyment of playing, as players will not be concentrating solely on the game, but also on the physical activity. We will investigate the use of activity interfaces that will allow the user to continue controlling the game character while performing the physical activity.
- Ubiquitous activity motivator. The *PLAY, MATE!* design instantaneously rewards players for the physical activity they perform. However, it can be modified to accumulate physical activity over time and eventually convert this activity into game rewards. We will enhance the design to support this functionality, which will transform it into a ubiquitous physical activity motivator.
- Longitudinal user study. We plan to conduct a thorough user study, in which we will observe players interacting with activity motivating games in a more natural environment, e.g., at home. This will help us to understand whether the *PLAY, MATE!* design eventually leads to the desired behavioural change and a healthier lifestyle, providing an alternative way to combat the obesity problem.

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Game Design towards Scientific Literacy

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As global citizens grapple with complex issues such as human impacts on the environment, the need for a scientifically literate public becomes increasingly urgent. This descriptive case study examines the design decisions behind *Operation: Resilient Planet*, a "game for good," and how those decisions reinforce or limit play in the context of fostering scientific literacy. By uniting research from the fields of science education, game design, and situated cognition, I underscore several important elements for mapping specific game design restrictions and mechanics onto authentic scientific inquiry. This paper provides an argument for how game designers can utilize contemporary research in science education and educational psychology with game design literature to make informed design decisions and develop a content-rich game experience requiring players to master certain "habits of mind" that map directly onto standards for scientific literacy.

KEYWORDS: Science Education, Game Design, Socio-Cultural Learning, Game Mechanics

INTRODUCTION

Concern about the character of American science education has been a perennial issue (Schwab, 1962; NCEE, 1989; Martin, Mullis, Gonzales, & Chrostowski, 2004), but current calls for scientific literacy emerge from the recognition that, "science is no longer the specialized activity of a professional elite" (Wilson, 1998, p. 2048). With U.S. Americans increasingly showing a lack of understanding in areas of scientific consensus like climate change (Jakobsson, Mäkitalo, & Säljö, 2009; Kohut, 2009) and evolution (Keeter, 2009), the need for scientific literacy among citizenry becomes increasingly apparent.

Scientific issues influence a variety of core public policy concerns, and a basic understanding of these issues is crucial for civic engagement in a democratic society. Science education must aim to produce students who are prepared to not only "increase economic productivity through the …knowledge…and skills of the scientifically literate person" but also "engage intelligently in public discourse and debate about matters of scientific and technological concern" (Yager, 2006, p. ix).

Many stakeholders in science education fear an apparent disconnect between current teaching methods in science and the habits of mind required to engage with contemporary science (NRC, 1996; NRC, 2000; AAAS, 2009). The etiology of this disconnect was elegantly diagnosed by population geneticist and science education thought leader Joseph Schwab, who wrote many decades ago that most students encounter science as a "rhetoric of conclusions" (Schwab,1978, p.134) in a textbook. Schwab noted that students see the results of years of study, questioning, professional dialog, revision, and argumentation as neat and sterile facts. In other words, the science we hear or read in the news about vaccines, climate, a newly discovered hominid, metabolism of "carbs," etc., is structured very differently from the science we learned in high school where all of our experiments had a predetermined right and wrong answers. Anomalies were "corrected," not pursued or explained.

Science that is current and alive is different from the neat "rhetoric of conclusions" often portrayed in curricula created for school science (Hodgson, 1988; Chinn & Malhotra, 2002). The actual work of scientists doesn't allow for looking up a correct answer in the back of a book. This dissonance between what we might call (for lack of a better term) "textbook science" and "authentic science" is particularly problematic when we consider the nature of scientific issues that arise in the public sphere. Students are rewarded for providing a singular, correct answer at the expense of developing reasoning and evidence-based arguments (Russ, Coffey, Hammer &Hutchinson, 2008). This leaves students unprepared to understand the nature of evolving problems in the public sphere.

Public policy does not take place around "textbook science." Scientific literacy requires an understanding of what science looks like on its way to the textbook. The most pressing scientific issues of our time occur at the frontiers of science: at the height of conceptual uncertainties with anomalous data. The problem with “textbook science” isn’t simply that students *aren’t learning* science, it’s that they are developing overt *misconceptions* about the nature of science. In establishing benchmarks for scientific literacy, the American Association for the Advancement of Science ultimately envisioned an education that would provide citizens with the habits of mind required to make sense of how the natural and designed worlds function, think critically and independently, and deal with problems that involve evidence, patterns, arguments and uncertainties (2009).

PURPOSE AND METHODOLOGY

In this paper, I use a descriptive case study to begin a dialog between disparate disciplines that have only recently begun conversation (Federation of American Scientists, 2006; NRC Division of Behavioral and Social Sciences and Education, 2009). I synthesize the guiding principles of scientific literacy, their implications for instruction, the challenges faced by classrooms attempting to implement such a curriculum, and link these issues to some of the findings in situated cognition (Brown, Collins, & Duguid, 1989). Next, I will examine the unique features particular to video games as instructional tools and integrate some of the overarching ideas from video game design into the domain of scientific literacy. Using a descriptive case study of the game *Operation: Resilient Planet* (*ORP*), I argue the unique features of video games, if purposefully designed, are well suited to address the contextualized, process and content rich curriculum associated with “scientific literacy” (AAAS, 2009). *ORP* is being described as a “game for good” on two levels. First, on a surface level, *ORP* challenges players to examine evidence demonstrating the serious impact humans make on even the most remote ecosystems. On a deeper level, *ORP* is a “game for good” in that it incorporates features of scientific literacy directly into its design mechanics, opening the doors for discussion on how game mechanics can advance or limit nuanced learning objectives.

Scientific literacy is something that takes years of deliberate instruction to develop. The best-designed curricular materials, whether they are video games or textbooks, are no substitute for well-trained, knowledgeable teachers. This paper makes no generalization that one well-designed game or a million well-designed games can change the ways science education proceeds in the classroom. Rather, I hope to raise some of the challenges faced in designing any learning environment for authentic inquiry and demonstrate that with appropriate design considerations, games can be uniquely suited to overcome some of these challenges.

CHALLENGES OF TEACHING SCIENTIFIC LITERACY

The most accepted pathway toward scientific literacy in the science education community is to teach a greater understanding of the nature of science (NOS) using inquiry as an instructional method (AAAS, 2009; Lehrer & Schauble 2004; Rudolph, 2005 p.804; Stewart & Rudolph 2001; Yager, 2006). NOS emphasizes science as a complex social activity where scientists work to identify and avoid bias, demand evidence, explain and predict phenomenon, and provide durable information (AAAS, 2009). “Inquiry” is the instructional method that aims to teach content standards in tandem with NOS, in order to engage students in activities cognitively modeled on the work done by scientists. Ideally, this approach towards scientific literacy rejects the notion of one single, universally applicable scientific method taught separately from content. Inquiry exposes students to the understanding that science is a context and community-dependent dialog of questions and evidence.

A number of challenges have been identified in implementing NOS through inquiry in the classroom. Traditional curricular materials offer impoverished understandings of NOS (Abd-El-Khalick & Waters, 2008; Chinn & Malhotra, 2002). Schools lack the time, money, resources, and equipment to develop authentic inquiry experiences (Chinn & Malhotra, 2002) and activities billed as "inquiry" are often straightforward, hands-on, design and engineering problems (Rudolph, 2005). While such task-oriented activities offer important pedagogical benefits, (Roth, 2001; Schneider, Krajcik, Marx, & Soloway, 2002) they do not represent a full or accurate picture of most scientists' work. Rather than designing objects, scientists are more often engaged in the construction of ideas (Rudolph, 2005). Highly constructivist (or “pure discovery”) approaches fail at teaching students the discourse and social nature of science (O'loughlin, 1992). Pure discovery or highly exploratory learning environments have been found to be ineffective (Mayer, 2004) with novice learners. Students need to be engaged in the dialog of idea creation, and they need scaffolding into this dialog. Science education needs to provide opportunities for structured arguments, public reasoning to develop claims, and evaluation of those claims using the language of science (Zembal-Saul, 2009).

These recommendations resonate with the theory of situated cognition. Situated cognition posits that knowing cannot be separated from context, culture, and activity (Brown, Collins, & Duguid, 1989; Greeno, 1989). Studies in situated cognition empirically demonstrate that the decontextualized "rhetoric of conclusion" often found in textbook science simply does not transfer into every-day scientific thinking. One of the primary recommendations that emerge from studies in situated cognition is that learners hold "cognitive apprenticeships," (Brown, Collins, & Duguid, 1989) a sort of purposeful coaching by a master who models a cognitive discipline to a novice in a contextually authentic environment. The importance of situated cognition in commercial games has been well documented by Gee (2003), but the implications for designing games for good remains under-theorized.

THE PROMISE OF GAMES FOR GOOD IN SCIENCE EDUCATION

The promise of video games in science education was acknowledged long before the technology was easily accessible to realize such hopes (Ellington, Addinall, & Percival, 1981; Sagan, 1978). Serious efforts investigating video games and their role as tools for science education have only recently been discussed. For instance, persistent multi-player spaces have been found to develop understandings of epidemiology (Kafai, 2008), informal scientific habits of mind (Steinkuhler & Chmiel, 2006) and pro-social values (Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005). The multi-user virtual environment River City promotes inquiry and self-efficacy in data gathering (Ketelhut, 2007). There is also an emerging body of work demonstrating the inquiry-like habits developed by students who design and build their own science-based video games (Sheridan, Clark, & Peters, 2009). These groundbreaking projects demonstrate the pedagogical possibilities of games, but they do not delve into specific design principles that can bridge desired cognitive outcomes and game design. The need for such a conversation is clear. During their Edugames Summit, the Federation of American Scientists summarized, "Research is needed to develop a sound understanding of which features of games are important for learning and why, and how to best design educational games to deliver positive learning outcomes" (2006, p.5).

Unlike traditional curricular materials such as textbooks and laboratory exercises, all video games are constrained by video game "mechanics". Video game mechanics are sets of rules that bind play, provide the foundation of the game, and make the game play experience at once enjoyable and challenging. Understanding video games as science curricula requires a specialized understanding that straddles a mastery of problems in science education and video game design.

Defining Game Mechanics

Game mechanics are the elements that are unique to games as a media. The mechanics of a game are what give the game interactivity; the designed features which allow the player to play the game. Game mechanics are frequently understood as the rules of the game. (See Prensky, 2001; Salen & Zimmerman, 2004). Salen and Zimmerman describe mechanics as the "systems of emergence, uncertainty, information, feedback, decision making, and conflict" which create play in games (p.124). Salen and Zimmerman focus on the way in which game rules limit player action in a fixed and repeatable fashion. It is also important to consider mechanics as a component of game genre. Focusing primarily on rules isolates that component from the interconnected set of issues embedded in decisions about what mechanics are viable in a given context. In commercial game design, genres provide broad frameworks for game development and serve an important role in setting player expectations for game play. Coming from a commercial game design perspective, Novak defines genres as "categories based on a combination of subject matter, setting, screen presentation/format, player perspective, and game-playing strategies" (2005, p.85). While genre is a broader category in game design than mechanics, discussions of genre illuminate critical elements for understanding mechanics. As Foster and Mishra have noted, different game genres support different learning objectives, for example role-playing games provide better scaffolding for identity development than puzzle games (2009). Most importantly, game players' experiences with specific game mechanics in specific game genres give players a clear set of expectations about the relationship between game mechanics and content. Those expectations are important considerations for deciding which mechanics are the best fit for different goals.

Gredler, an educational psychologist, offers another useful lens for examining mechanics by framing them as surface structures and deep structures (Gredler, 1994). The surface components are understood as the basic activities in which the player engages. For example, eating up dots, avoiding ghosts, acquiring points, moving to new levels, and the space of the maze are surface structures of *Pac-Man*. For Gredler, the deep structure of the game is the overarching cognitive and social interaction the game requires. Gredler proposed that educational games should reinforce behavior that leads to mastery of the concepts at the core of learning objectives (Gredler, 1994).

Mechanics are both the descriptions of the individual features surrounding player action as well as the deeper cognitive work, which supports the overall argument of a given game. Through this understanding of game mechanics and genre, we can see that authentic scientific inquiry can be understood as having its own sets of mechanics. The challenge is to map the inquiry mechanics onto game mechanics in a meaningful way.

DESCRIPTIVE CASE STUDY: DESIGNING FOR INQUIRY

A detailed investigation of the design challenges and resulting decisions of The JASON Project's *ORP* game allows us to fold together many of these concepts from science education, situated cognition, and game design. *ORP* is beginning to receive attention as an exemplar in science education (Clark, 2009; Squire, 2009). *ORP* was developed as part of the ecology curriculum for The JASON Project, a 20-year old organization that focuses on bringing the work of scientists and explorers to middle school students. Funded by the Kauffman Foundation, *ORP* is a free, downloadable, 3-dimensional game available from The JASON Project website (www.jason.org). For the past three years, The JASON Project, a nonprofit subsidiary of the National Geographic Society, has been developing digital labs and science games in accordance with best practices for classroom-ready games-based learning (Wilson, 2009). The JASON Project's curriculum presents standards-based middle school science content from the perspective of current scientific research being performed by scientists from any number of JASON partner organizations. In *ORP*, students accompany marine ecologist Enric Sala on his research in remote Pacific reefs and atolls as they reconstruct his investigations into the dynamics of apex predators and local food webs (Bascompte Melián & Sala, 2005). The specific game design challenge was to deliver an experience in which middle schoolers would be engaged in a virtual cognitive apprenticeship with a scientist working on the cutting edge of marine ecology. We wanted to design a game that would be approachable to students with a variety of previous video-game play experience and attractive to teachers with little gaming experience and concerned with teaching a standards-based curriculum.

From a genre perspective, *ORP* is most accurately characterized as an adventure game. Adventure games are story driven and require players to solve puzzles and overcome cognitive challenges, as opposed to physical ones (i.e., fighting, shooting) (Rollings & Adams, 2006). *ORP* uses a narrative structure situated in a 3-dimensional environment (Figure 1). The narrative is connected by mini-games (the puzzle-components of an adventure game) that simulate gathering evidence and are attached to a platform for scientific argumentation. The advantage of this genre is that the narrative component "tells the story" of a scientist's actual research agenda. It serves as the surface structure for the game play and provides the content components of inquiry: navigating the deep ocean; locating endangered monk seals; and counting tiger sharks. The mini-games, or puzzle components of the adventure game, provide opportunities for building in the deep structures of the game as the process components of authentic inquiry: evaluating data; supporting a hypothesis; and reconciling anomalous or unexpected findings. Both scientific process and content were central to the game design. Furthermore, both the content and process are presented in the context of a greater research agenda whereby process and content are not learned for their own sake, but as tools employed by scientists to investigate and probe greater questions and wider concerns as part of ongoing scientific discourse.

***Figure 1*. A View of Marine Life as Seen from the Game's 3D Underwater Environment.**

There are, of course, limitations to this approach. Closely following Sala's research trajectory means that the possibilities for independent exploration are somewhat constrained. As players retrace Sala's research, they can veer off and explore the 3D underwater game world. They are rewarded for doing so with extra points hidden away in the far corners of the map. Players also acquire points for photographing and identifying each of the species of aquatic life in the environment (Figure 2). Players have the freedom to choose whether they want to first explore what is happening with the seal population or the shark population. However, players do not have the ability to develop a research agenda outside of the process involved in understanding the research question Sala has presented to them. The design team decided to use this constraint to guide the players through the overall narrative of Sala's research trajectory. While more open-ended game structure might provide players with more freedom, this is not necessarily an asset (Gee, 2003, p.113). It would be difficult to ensure that players gain an understanding of the scientific process through the legitimate peripheral participation model (Lave & Wenger, 1991) where the students conduct and explore the existing research questions using scientifically sound methodologies. Furthermore, a solid structure to the game facilitates the creation and use of accompanying paper-and-pencil assessments, which facilitate the integration of the game into the classroom curriculum (Wilson, 2009, p.15).

***Figure 2*. Photographing Reef Fish from the Remote Operated Vehicle (ROV).**

A SCIENTIFIC DIALOG

As the player enters the game world she meets Enric Sala, the marine ecologist whose research trajectory she will recreate. Sala uses his research to scaffold the player through an authentic inquiry experience inspired by his own work. Sala briefs the player on the situation: The population of the endangered Hawaiian monk seals is dangerously low, but the population of a different predator, the tiger shark, is quite high in the Papahānaumokuākea Marine National Monument. A reputable (alas, fictional) scientist named Dr. Cull believes that the sharks are over-feeding on seals and has recommended opening the waters for shark hunting in an attempt to bring a balance to the region. Dr. Cull is used to represent a popular interpretation of the problem. Sala, however, cautions the player against this extreme solution and advocates the player join him in approaching the proposal with skepticism. This skepticism sets the stage for the investigation that directs the game play.

Observations and Theory-laden Methods

Sala establishes his reluctance to accept Cull's recommendation without evaluating the evidence. This sets the over-arching goal of the game (is Cull's recommendation a good one?) and starts the player on her quest of mini-games to evaluate Cull's recommendation. The player begins by selecting a research trajectory to either better understand the area's sharks or seals. If she chooses to explore the shark research trajectory, she starts with a mini-game identifying tiger sharks in the area by collecting photos from her underwater remote operated vehicle (ROV). In the next mini-game, she sneaks around the reef to tag and recapture some of the tiger sharks to gather an accurate population count. Since the mini-games re-enact segments of a research agenda, they introduce students to the methods scientists use to obtain data. As identified by Chinn and Malhotra (2002), an important epistemological feature of science is the "theory-ladenness of methods" (p. 187). That is to say that methods employed by scientists are driven by theory, a feature absent in the simple inquiry or simple illustrations frequently found in textbook science curriculum.

For instance, as Sala informs players, the tag-capture-and recapture method of population estimation is used primarily for large animals with a large range but the method has its drawbacks for different types of organisms. Later in the game, players perform several population studies on different animals, and use different population count methods accordingly. This demonstrates a theory-practice-theory loop that is essential to science but often overlooked in "textbook science". Scientific instruments and methods are built on theories. For instance, a mercury thermometer is built on the idea that heat accompanies accelerating atomic motion that causes mercury to expand. Radiometric dating is based on the assumption that organisms take in carbon atoms while they are alive, and a certain percentage of those carbon atoms will radioactively decay. The variety of theory-laden population count methods demonstrates this theory-practice-theory loop. Likewise, the shark stomach-contents analysis method comes from a theoretical perspective that discourages scientists from making an imprint on the ecosystem she is studying. Thus, rather than use a more traditional approach of performing a shark autopsy, some scientists choose the more ecologically conservative and humane approach of inducing the shark to vomit.

Another important piece of the mini-games is their integration with an "argument constructor." For instance, in the shark stomach analysis mini-game, the player is confronted with the shark hoisted above the water on the side of her ship, where she needs to place a hose into the shark's mouth to induce vomiting. The resulting vomit is displayed across the player's screen (Figure 3). The player is prompted to identify the contents of the shark's stomach (Figure 4). Each correct identification from a menu of organisms results in the player receiving a star. If the player incorrectly identifies an item in the shark's vomit, they have the ability to try again, without receiving a star. Each of these mini-games can be replayed again if the player misses a star to increase her overall game score.

***Figure 3*. Players Identify the Contents of a Tiger Shark's Stomach.**

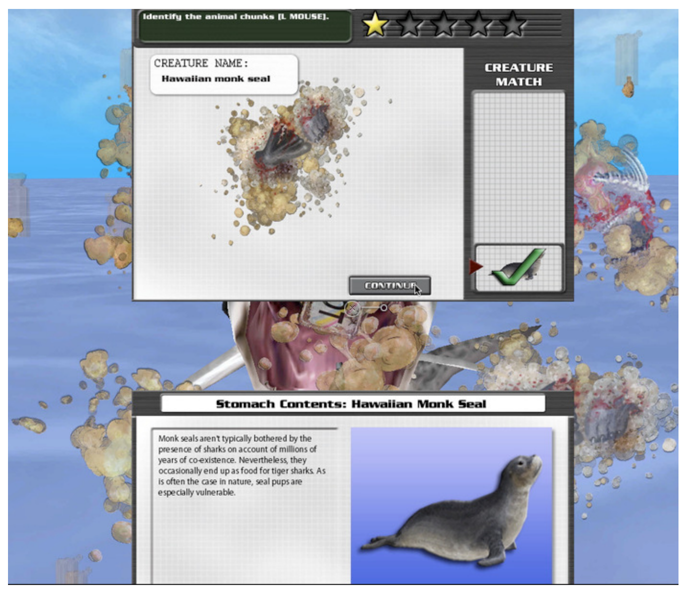

***Figure 4*. The Player Then Identifies the Contents of the Shark's Stomach from a List of Creatures in the Area.**

The example of the shark's stomach content analysis game is illustrative of the general decisions that guided the data-gathering mini-games. In each case we worked to translate the actual practice scientists engage in, into surface structures that involve calculating populations, identifying, and otherwise observing marine life using the same theory-laden methods employed by marine ecologists. On one level, these mini-games provide opportunities for authentic inquiry that are otherwise impossible to recreate in classroom lab experiences. At the same time, the mini-games are anchored in the standards-based needs of school science. It is not uncommon for students to examine the diet of an apex predator, for instance, by dissecting an owl pellet, or simulate an animal population count using candy scattered in a school prairie. However, in the game environment, each of those individual lab activities serves a purpose in a research agenda. This again models science in a more authentic fashion. Contemporary scientists don't examine animal's stomach contents "just because", they do so as part of a bigger research question. Stomach contents are examined to gather evidence to point them towards asking the right set of questions geared toward addressing a larger question, as part of a dialog with a larger community.

Translating Observations into Data

After performing the tasks in the mini-games, the player receives a "data item": an item that translates her observations into data. Upon receiving several data items, the player engages in a dialog with Sala to explore the research implications of their observations in the mini-game in a part of the game we have dubbed the "argument constructor". These dialogs with Sala serve to demonstrate the role of data in scientific argumentation while modeling the skeptical habits of mind that are key to scientific literacy. The argument constructor was inspired by the Capcom game *Phoenix Wright: Ace Attorney* for the Nintendo DS. In both games, players make claims, support those claims with discrete pieces of evidence they have acquired, and support their reasoning through answering follow up questions. The metaphor of an argument constructor provides a tangible interface focusing on the building of ideas and thus preventing us from falling into the common trap of making science appear overtly focused on engineering-type work (Rudolph, 2005). To customize this mechanic for robust scientific argumentation, *ORP* designers assigned an algorithm for each of the arguments and data pieces so that the game provides feedback evaluating the player's arguments as "perfect", "strong", "weak", and "confused". Sala asks the player to evaluate the data (Figure 5) and use the evidence to further inform the research agenda (Figure 6). The argument constructor provides targeted feedback and provides an interface for making scientific reasoning visible and public (Bell & Linn, 2000) (Figures 7 and 8).

***Figure 5*. This image of the Argument Constructor Shows the Player about to Suggest that according to the Data, Tiger Sharks Eat More Reef Fish than Monk Seals.**

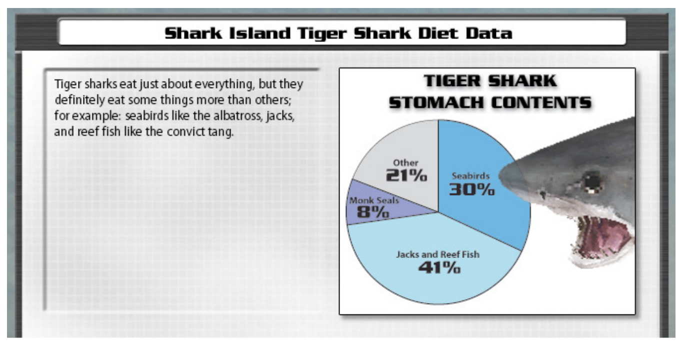

***Figure 6*. A Pie Chart the Player Constructed from Her Analysis of the Sharks' Stomach Contents.**

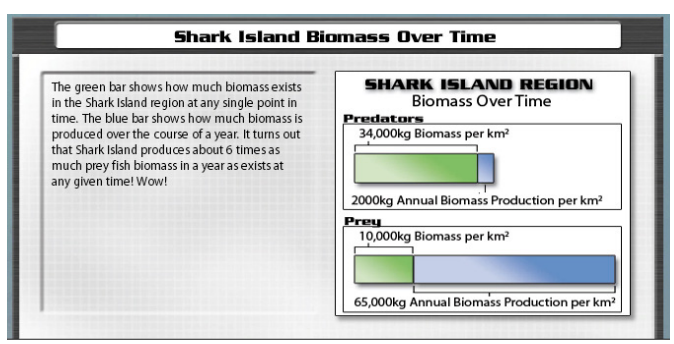

***Figure 7*. The Shark Island Biomass Data is Synthesized from Multiple Data Sources.**

***Figure 8*. The Player is Using Shark Island Biomass Data to Argue that Shark Island Has Considerably More Bottom Level Biomass than Tabuaeran Atoll. This Indicates a Healthy, Pristine, Ecosystem.**

After gathering a wide range of data about tiger sharks and monk seals, the player enters the final round of argumentation with Sala. Marshaling the full range of the data players have gathered, Sala scaffolds the player into the discovery he made a few years ago. Sala points out some of the anomalous data they have gathered, and guides the player into an analysis of this data. While the shark populations are very high, the data suggests that this is actually an indicator of a particularly healthy ecosystem. Sala's research shows that apex predator biomass (total population x average adult mass of organisms) is greater in ecosystems with fewer humans (Figures 9 and 10). These ecosystems contain a greater overall biodiversity. Sharks keep the ecosystem healthy because they eat so many reef fish that the overall reef fish population is very young and very small. Smaller fish eat less coral. Thus, the coral is not over-eaten. Additionally, players learn that monk seals and tiger sharks have healthfully co-existed for 40 million years. Human impact may have been the factor that threw the monk seal population off-balance in other areas. Contrary to Dr. Cull's recommendations, killing the sharks would only hurt the fragile balance which nature has developed in this marine sanctuary.

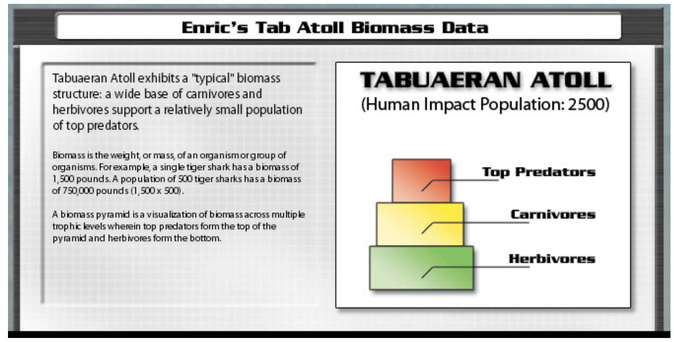

***Figure 9*. Sala Provides this Data on Nearby Tabuaeran Atoll.**

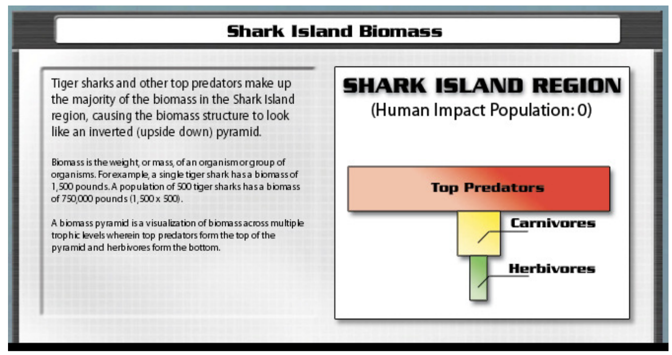

***Figure 10*. The Player Creates the Shark Island Region Biomass Pyramid by Combining Her Observations of Sharks, Reef Fish, and Monk Seals. She then Uses this Combined Data in Later Arguments.**

DISCUSSION

Genres and game mechanics will have implications for how they can or cannot foster scientific literacy and these implications must be explored in order to fulfill the call for research set out by the Federation of American Scientists. One notable caution moving forward is to understand that according to the best practices outlined by organizations such as the National Research Council and the American Association for the Advancement of Science (and the state standards influenced by these organizations) as well as what we know from the situated cognition body of literature, the cure for didactic science instruction is not overly constructivist, open-ended game environments. Alone, such games cannot address some of the most challenging cognitive requirements attached to scientific literacy. To neglect the role of contextualized scientific work recapitulates the misconceptions of past science curricular materials. Games have a chance to do something new, and students need the language and context of real scientific work in order to learn the dialog of science literacy. After examining some of the design-decisions that went into *ORP*, some of the primary lessons learned include:

1) Because of the narrative-puzzle mix, adventure genres are particularly useful for integrating and balancing content and process learning objectives. This balance of process and content can be difficult to achieve in designing learning activities for authentic inquiry. The apparent interplay of surface and deep game structures in adventure games help mitigates some of this difficulty.
2) Adventure genres, by nature, will restrict the degree of open-endedness of a game. This is an asset or limitation depending upon the individual learning objectives, envisioned usage, and cognitive theory guiding game development.
3) The interactive, visual nature of video games allows them to capture some of the work of scientists that might otherwise be challenging to make tangible. In particular, the notion that scientists construct ideas and arguments.
4) Because place, context, and story are so important to adventure games, not all science can realistically be translated in this format. Ecology, especially when it takes place in remote, tropical oceans, creates an engaging backdrop for a 3-dimensional adventure game.

CONCLUSION

The core design elements of *ORP* presented in this paper are consistent with the principles of scientific literacy as well as the prescriptions for learning from situated cognition. Scientific literacy asks that students prioritize argumentation and evaluation over experimentation and exploration (NRC, 2000) using the language of science (Lemke, 1990). A model of situated cognition provides us with a clear understanding that through cognitive apprenticeships and legitimate peripheral participation, students can be scaffolded into such a discourse. Some of the key implications for designing educational science games are that: 1) there is a limit to how "open-ended" the game can be if it is to facilitate a cognitive apprenticeship, 2) players need to engage in cognitive apprenticeships in order to understand how scientist might approach encountered problems, 3) a mechanism must be in place to facilitate argumentation and evaluation, and 4) core content and the language of science need to be central to the game's story arc. Students need purposeful, deliberate opportunities to engage with scientific subject matter from the point of view of scientists.

ORP is a "game for good" in that its surface structures address issues of ecological responsibility, while its deeper structures help target issues of scientific literacy that may be challenging to achieve in the typical classroom. As we consider game mechanics that foster science learning principles, the literature from science education and situated cognition should serve as guideposts. While there are many game mechanics to consider, some offer more hospitable templates towards scientific literacy than others. We cannot imagine the science policy arguments waiting for our children and future generations, so we owe them the insights from the greatest scientific imaginations of our own generation. Video games can offer engaging yet authentic contexts in which students can apprentice scientists as they work through today's most pressing problems and engage students in a discourse towards scientific literacy that can prepare them for a lifetime.

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AUTHOR NOTES

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Designing Game Affordances to Promote Learning and Engagement

Matthew Sharritt
Situated Research

Applied research will be presented from a qualitative study that highlights high school students' learning and use of several game interfaces, describing how particular affordances and game interface designs can encourage learning. Inductive generalizations from several 'commercial' games for good, including *Civilization IV*, *Making History: The Calm & the Storm*, and *RollerCoaster Tycoon 3* describe patterns of learning among game players, showing how the design of in-game visualizations either led to success or failure to learn to use basic game controls. This analysis, inspired by ethnomethodology and grounded theory, sought patterns from gathered video data of student gameplay to highlight learning episodes and patterns of interface use. Patterns in affordance use (uptake of a perceived action potential) during collaborative gameplay reveal relationships among the video game interface and player behavior, giving focus to how an interface design can guide game player interaction. In line with Csikszentmihalyi's concept of flow, a proper balance of difficulty (between feelings of boredom, and too much difficulty) encouraged player engagement and learning. As evidenced in transcripts of collaborative gameplay, feelings of frustration with a game interface often led students to abandon in-game tasks, as did boredom with a given task. However, frustrated goal achievement often led to the re-negotiation of in-game strategies: an indication of engagement. Additionally, games that presented information using multiple channels encouraged learning, as did the use of specific visualizations such as the animation of in-game objects. Finally, a discussion of the affordances created by different game designs will offer educators and game designers guidelines to encourage motivated gameplay.

KEYWORDS: Video Games, Collaborative Learning, Affordances, Interface Design, Representational Guidance, Engagement

INTRODUCTION

Game challenges can add or remove motivation for game players to continue playing a video game. Ducheneaut et al. (2006) found a direct correspondence between the level number and the average time required for players to ‘level-up’ when examining game data from the game *World of Warcraft*, a very successful MMORPG (Massively Multiplayer Online Role-Playing Game). Each successive level averaged slightly more time for players to complete, creating an exponential curve when graphed. This sheds light on the addicting nature of *World of Warcraft*, as the game’s difficulty structure is designed very well, giving new players the satisfaction of leveling quickly while challenging more experienced players. The authors hypothesize that either a too-difficult or too-easy leveling structure in a game leads to player boredom or frustration, while varying levels of difficulty can be particularly annoying. The level structure in *World of Warcraft* draws novices into the game while keeping skilled players motivated to keep playing. Additionally, the slowly increasing level of difficulty keeps intermediate players from getting stuck too long on an unusually challenging level. An appropriate difficulty structure is one of many factors influencing one's motivation to play a game.

Hidi & Renninger (2006) describe a ‘Four-Phase model of Interest Development’ which can help in examining elements contributing to motivation in educational gaming environments. These four phases are: triggered situational interest (a short term spark); maintained situational interest (a prolonged situational interest); emerging [less-developed] individual interest (a longer term, personal mind-state, with a supporting environment); and well-developed individual interest (a long term mind-state, characterized by enjoying something very much). These phases vary based on personal experience, genetics, and predisposition to a subject. Hidi and Renninger imply that the earlier stages are characterized by affect, while the latter stages are more cognitive in nature (the person has an innate curiosity and wants to return to the subject). The progression through the phases of interest development is typically not done in isolation: peers, and the gaming environment, can raise learners' curiosity and feeling of self-efficacy, helping to progress through the phases of interest. Cognitive technologists should be concerned with ways that the gaming environment can be designed to properly scaffold interaction for the game player, structuring performance based upon the level of the learner. This is similar to Vygotsky's zone of proximal development, or "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers" (Vygotsky, 1978, p. 86).

Motivation to play a game can come from various sources: curiosity about the subject, being drawn into the game through good gameplay and design, or by being motivated to win the game by the game's goals and challenges. The design of in-game visualizations (representations of game objects and behaviors) can influence gameplay. As described in Sharritt & Suthers (2009):

> Feedback from in-game features and behaviors could trigger new strategy development by game players. Cues may come from a game's ability to detect user behavior, a game message or pop-up, or from user interaction with game objects. Feedback mechanisms triggered learning by prompting students to take up new tasks during game play. The design of in-game triggers is important, as they may serve in cueing game players to pursue related tasks that encourage learning. Feedback channels can also serve to reduce uncertainty and increase a game's ability to present a scaffolding interface, thus aiding in gamer interpretations and corresponding informed activity. (p. 48)

While focus in Sharritt & Suthers (2009) was on learning, the research described how a game's design can influence motivation to play by analyzing how particular affordances (perceived action potentials) created by the game could help to encourage game players to take up tasks within the game while playing. In this paper, affordances, or potentials for action (Gibson, 1977; Norman, 1988) will be examined, focusing on the usability (game player use) of particular in-game interface objects and their potential to create meaningful interaction. Cognitive technologists should be concerned with concepts such as affordances, zones of proximal development, and information design because of their utility in identifying opportunities for motivated cognitive development and creating optimal situations for those opportunities to occur.

BACKGROUND

Various theoretical perspectives on cognition have addressed how learning occurs in group contexts and generated a continuum of theory that focuses on learning at the individual level to learning at the group level: socio-cognitive / socio-constructivist (Piaget, 1976) focusing on learning through a process of cognitive disequilibrium; socio-cultural and socio-historical (Vygotsky's activity theory) where learning takes place as a transformation between the social and individual planes; and distributed cognition and group cognition (Hutchins, 1995; Stahl, 2005) where learning takes place at the group level of analysis (Webb & Palincsar, 1996; Dillenbourg, Baker, Blaye, & O'Malley, 1996).

According to Vygotsky (1978), "the social dimension of consciousness is primary in time and in fact. The individual dimension of consciousness is derivative and secondary" (p. 30). Vygotsky (1981) views collaborative learning as a process that puts the social plane first, which then moves to the internal plane through a process of internalization:

> Any function in the child's cultural development appears twice, or in two planes. First it appears on the social plane, and then on the psychological plane. First is appears between people as an interpsychological category, and then within the child as an intrapsychological category. This is equally true with regard to voluntary attention, logical memory, the formation of concepts, and the development of volition. … It goes without saying that internalization transforms the process itself and changes its structure and functions. Social relations or relations among people genetically underlie all high functions and their relationships. (p. 163)

Blending Vygotskian cultural-historical psychology with Leontiev's activity theory, activity theory concerns itself with the relationship of the individual to a community, engaging in motivated activity (the 'object' or objective of the activity), and is useful for studying collaborative computer-mediated activity such as gameplay. Pairs of links in Figure 1 can be analyzed to examine mediational roles (of the item at the vertex of the links; i.e., how rules mediate between subject and community, etc.). This provides a good conceptual diagram with which to frame game player activity.

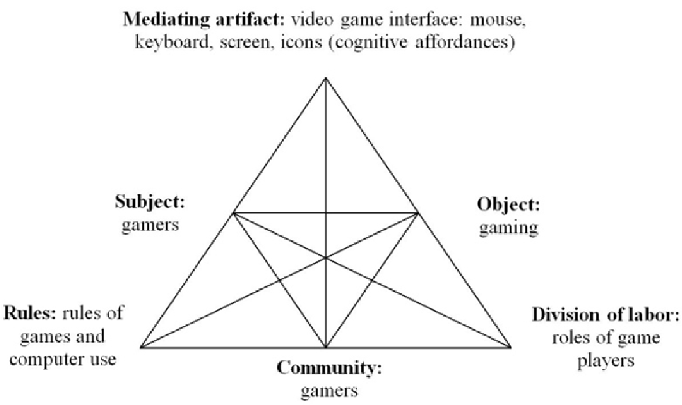

***Figure 1*. Example of Gameplay using Cole & Engeström's Mediational Triangle (1993, p. 8).**

As described in Sharritt (2010), activity theory can be very useful to describe the game setting by examining the affordances created by the video game interface:

> The roles of subjects, objects and community can be analyzed by examining the mediating artifacts, rules, and division of labor. With a focus on gaming, it is possible to analyze students, gaming to win, and the student-gamer community by examining the video game interface and its cognitive affordances, the rules of computer game play and computer use, as well as the roles of game players playing the game. (p. 8)

An affordance, or a potential for action (Gibson, 1977, 1979; Norman, 1988) can occur on various levels. Sharritt (in press) describes levels of activity theory at which an affordance can occur: on the *operational level*, as a potential to act on an 'object at hand', or something immediately perceptible through direct manipulation; on the *action level*, as a potential to use available in-game tools to satisfy in-game goals, and at the *activity level*, as a potential to form larger motivations to play the game, serving the motives and gratifications of the game player. When examining gameplay, the first stage in learning to play a game consists of mastering the game interface to accomplish basic gameplay (Sharritt, 2008). The aims of this paper are to examine affordances at the operation and action levels of activity theory, focusing on how the design of the video game interface can serve to create meaningful gameplay for game players. Research will describe how different game interface designs are learned and used by game players, showing how different interface designs cause particular game-player behaviors.

THEORETICAL MOTIVATIONS

Affordances

The idea of an affordance originates with James Gibson (1977, 1979). In his words, "… the affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill" (Gibson, 1977, p. 5). McGrenere & Ho (2000) describe three main properties of Gibson's affordances: "An affordance exists relative to the action capabilities of a particular actor; the existence of an affordance is independent of the actor's ability to perceive it; and an affordance does not change as the needs and goals of the actor change" (p. 179). However, Kaptelinin & Nardi (2006), in discussing affordances from an activity theory perspective, argue that affordances are directly tied to an actor's ability to perceive action on an object, called "action capabilities" (Kaptelinin & Nardi, 2006, p. 81). Donald Norman helped to popularize the idea of affordances in his seminal work *The Design of Everyday Things,* one of the foundations of human-computer interaction (HCI) research, where an affordance is described as:

> ... the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used. [...] Affordances provide strong clues to the operations of things. Plates are for pushing. Knobs are for turning. Slots are for inserting things into. Balls are for throwing or bouncing. When affordances are taken advantage of, the user knows what to do just by looking: no picture, label, or instruction needed. (p.9)

Norman (1988) discusses affordances with technology in mind, describing how well designed interfaces "provide strong clues to the operation of things" (Norman, 1988, p. 9) and "suggest the range of possibilities" (Norman, 1988, p. 82).

Representational Guidance

The concept of representational guidance (Suthers, 2001; Suthers & Hundhausen, 2003) examines how the design of computer interfaces can serve to both constrain and provide salience to particular actions on an interface. Sharritt & Suthers (2009) examined ways in which representational guidance guides player interaction in a collaborative educational environment, finding that "games might guide action by providing a constrained set of action potentials" and that "games might aid gamers by making certain aspects of the game state salient" (p. 29-30). When examining affordances and usability in video games, representational guidance provides a useful frame for analysis, showing how the design of a game interface can influence the resulting gameplay. The research presented in this paper is inspired by this concept, and analysis will be presented that describes how game interfaces can constrain and provide salience to particular game player activity.

Ethnomethodology

Ethnomethodology can be examined from both a theoretical perspective as well as a source for descriptive methods. Clayman & Maynard (1995) describe the theoretical foundation for ethnomethodology:

> Ethnomethodology offers a distinctive perspective on the nature and origins of social order. It rejects “top-down” theories that attempt to explain social order in terms of cultural or social structural phenomena which are conceived as standing outside of the flow of events in everyday life. Adopting a thoroughly “bottom-up” approach, ethnomethodology seeks to recover social organization as an emergent achievement that results from the concerted efforts of societal members acting within local situations. (p. 2)

Koschmann, Stahl & Zemel (2005) discuss several key principles of ethnomethodology by providing an updated and clear description of Garfinkel’s policies (1967), summarized below:

- *Indifference.* Ethnomethodological indifference states that “any occasion whatsoever” (Garfinkel, 1967, p. 32) is useful in studying the construction of social order
- *Contingently-achieved accomplishment.* Socially constructed order is specific to the situation in which it was accomplished. When making generalizations, those generalizations only apply to other situations with similar contingencies
- *Relevance.* The researcher must ‘bracket out’ any preconceptions about the situation being studied; categories can only be produced as a direct result of observing participants’ discourse and behavior (a-priori definitions and researcher preconceptions shall be avoided)
- *Accountability.* Social actors’ actions (social group members’ behavior and communication) construct social order by giving ongoing accounts of their activity; participants’ actions are representative and real to their experience
- *Indexicality.* Ongoing, contingently-achieved accomplishment is tied together as a sequence of actions, all building upon previous action, and shaping the context of future action, thereby constructing social order

Of the above principles as summarized by Koschmann, Stahl & Zemel (2005), several are important to this study’s research design. While the concept of *contingently-achieved accomplishment* limits generalizability of findings, it helps to form initial hypotheses about learning with games and the use of affordances. This property leads to using the hybrid approach involving grounded theory (presented in the following section), in order to raise generalizability. Our preference for emergence relates to the ethnomethodological principle of *relevance* to the situation being studied, allowing the data to speak to us directly (inductively) rather than running deductive tests on preconceived concepts. The principle of *accountability* states that participants’ actions give an account of their experience, so an analysis of their interactions represents their experience. Finally, in the unpacking of learning, sequences of actions can be studied that are *contingently-achieved* and serve as context-building activities that can be analyzed by studying the sequence of actions of players while engaged in gameplay.

Ethnomethodological principles guided initial data analysis, allowing for an open look at what was being constructed and accomplished by game players. As themes began to emerge, methods of grounded theory helped to abstract patterns in gameplay.

Grounded Theory

Grounded theory is a sociological method that concerns itself with the "discovery of theory from data" (Glaser & Strauss, 1967, p. 1), which is not "based on a preconceived theoretical framework" (Glaser & Strauss, 1967, p. 45). This concept of *emergence*, where theories emerge from gathered data, opposes typical deductive research that tests a predefined hypothesis. Glaser & Strauss describe grounded theory as a "general method of comparative analysis" (Glaser & Strauss, 1967, p. 1), where the researcher makes constant comparisons of ideas while studying data: looking for themes or "theoretical categories" (Glaser & Strauss, 1967, p. 23-24) and constantly reevaluating those categories (taking advantage of replication to test those ideas). This re-evaluation is accomplished through *theoretical sampling*, or "the process of data collection for generating theory whereby the analyst jointly collects, codes and analyzes his data and decides what data to collect next and where to find them, in order to develop his theory as it emerges" (Glaser & Strauss, 1967, p. 45). The constant-comparative process of grounded theory uses the human brain as a "pattern-matching tool" to move through several processes in the abduction of theory (Charmaz, 2006).

METHOD

Three video games were selected for study and are discussed below. Games were played collaboratively by dyads (two high-school students) using a single computer. For each of the games, two dyads situated side by side played the game (four students playing each game; two per computer). Each student played only one of the games. Students played their respective game over four study periods of approximately 50 minutes each in a high-school setting. A complete video record was made of the gameplay, with a video camera filming each dyad and their computer screen.

Game Selection

Three games were chosen (Table 1) for the study so that theory may be discovered that applies across different kinds of games: both *RollerCoaster Tycoon 3* and *Civilization IV* are COTS (Commercial-off-the-shelf games, created by large game corporations) games, while *Making History: The Calm & the Storm* is a Serious Game, made for educational purposes. Making History and *Civilization IV* are historically-based (*Making History* focuses on World War II, while *Civilization IV* focuses on world history), and can be applied in world history or 20th century history classes. In contrast, *RollerCoaster Tycoon 3* could be applicable to a business course such as Economics or Marketing since it enables the creation of products and services, and the managing of finances (such as balancing supply and demand). This allowed for generalizations to be made between COTS and Serious Games, and between subjects (history vs. business) during analysis, allowing for inductive generalizations across these categories.

***Table 1*. List of Games Chosen for Study.**

Game:	Brief Description:	Game Website:
RollerCoaster Tycoon 3 (Atari) ESRB rating: E (Everyone)	Build a virtual theme park; building rides and managing attractions within the park	www.atari.com/ rollercoastertycoon
Making History: The Calm & the Storm (Muzzy Lane Software) ESRB rating: E (Everyone)	Take the role of a country in World War II and can play scenarios from that country; managing resources, etc.	www.making-history.com/edu
Sid Meier's Civilization IV (2K Games) ESRB rating: E 10+ (Everyone 10 and up)	Build an ancient civilization (e.g., Greeks, Romans) and make dynamic decisions affecting success compared to other civilizations	www.2kgames.com/civ4

Data Gathering and Procedure.

Four high-school students played each of the three games over four days (for a study period per day, approximately 50 minutes per day) in a school setting, as research supports that group phenomena require three or more participants (Wiley & Jensen, 2006). Two video cameras recorded a pair of game players and their computer screen. Two cameras were used to record all four students playing at once while maintaining resolution satisfactory for viewing their computer screens, with a view similar to that in Figure 2. Student assent and parental consent were obtained.

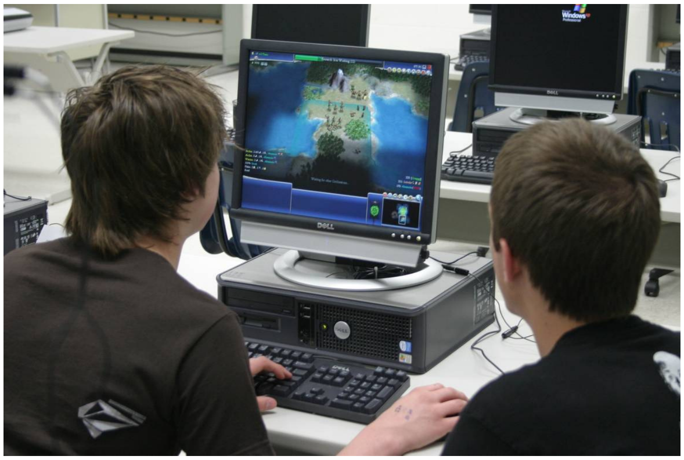

Figure 2. **Collaborative Gameplay in *Civilization IV*.**

Analysis

The videos were imported into the Transana™ system. Transana supports Jeffersonian transcript notation[1], a notational system developed for the annotation of transcripts to convey differences in intonation or speed, pauses, overlapping speech, and non-verbal behavior (Jefferson, 1984). Analysis followed a hybrid qualitative research strategy that was data driven and inductive, influenced by ethnomethodology and grounded theory as previously described, to identify and abstract patterns in the gathered video data.

Ethnomethodology and the principle of emergence guided the first portion of data analysis, seeking episodes of learning (a change in behavior as a result of experience). Multiple passes looked at what participants were "constructing as doing," followed by the incorporation of grounded theory and the initial coding process to further develop emergent hypotheses. Initial coding consisted of attaching memos to video clips that exhibited learning, qualifying them for further analysis. Following the identification of learning episodes, methods of grounded theory (Charmaz, 2006) were used to develop hypotheses based on patterns in the video.

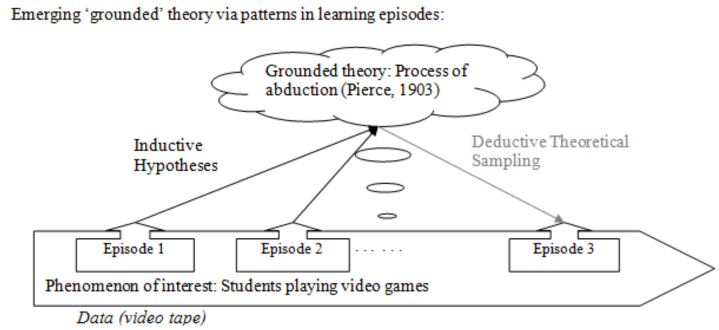

Figure 3. **Finding `Learning Episodes and Emerging Patterns of Learning.**

Additionally, an analysis of affordances was performed by analyzing student interactions (Jordan & Henderson, 1995) in the learning episodes. This attended closely to what was being accomplished during interactions, describing ways in which the game and peers were used in these accomplishments. After affordances were identified, methods of grounded theory were applied to the affordance analyses to look for patterns among affordances used by students while interacting with peers and the game.

RESULTS

Three examples of video game interaction are presented, describing collaborative gameplay resulting from interaction with the video game interface and how game players learned to use the game interface. Focus is on the affordances (perceived action potentials) created by the video game interface itself, describing how particular game interface designs promote or constrain behavior. Patterns reveal how the design of a video game interface can guide player behavior and interaction.

Staffing in RollerCoaster Tycoon 3

In *RollerCoaster Tycoon 3*, staffing represents component of gameplay that is important in maintaining one's theme park. Staff includes characters such as janitors to keep the park clean, mechanics to fix rides, and entertainers to entertain park visitors. A main goal of *RollerCoaster Tycoon 3* is to learn to manage all the aspects of a theme park (building rides, managing staff, setting prices), and realize a profit. Therefore, when hiring staff, a fine balance is required; too much staff is too expensive (hurting profits), while too small of a staff results in park problems (broken rides, a dirty park, and unhappy guests).

[1] Transana (2008). *Jefferson Transcript Notation*. From http://www.transana.org/support/OnlineHelp/Team1/transcriptnotation1.html
Originally described in: Jefferson, G. (1984). Transcript Notation. In J. Heritage (Eds.), *Structures of Social Interaction*.

In the following transcript, the pair learns approximately how many staff members are ideal for their theme park. Additionally, they become more efficient in adding staff to their park over time. The first episode[2] shows the first hiring of staff:

> L: We want staff. ((Clicked on 'Staff' icon)) ((Opened up all of their current staff members)) Ok. (.) We want Janitors.
> R: Janitor 1. We can name 'em.
> L: ((Clicked on Janitor 1)) Ok. Dooo ((Double clicked on the name 'Janitor 1' and hit the backspace button to put in a name))

As afforded by the staff management screen, the representation of staff names in text boxes affords naming the staff. Figure 4 conveys changing the default name from 'Janitor 1' to a custom name.

Figure 4*. Personalizing Staff Names in *RollerCoaster Tycoon 3.

The 'Staff' summary screen as shown above can be reached by clicking 'Park Operations' in the main menu (fifth icon down from the top), then 'Staff' (third from the top in the submenu, as highlighted in Figure 4). The pair continues to customize staff:

> R: Name him Water Boy because he's watering.
> L: (hhh) ((*Types in name of janitor*)) ((*Humming*))
> R: ↑Jackie?↓ ((*Laughs*)) (1.5)
> L: ((*Laughs*)) I'll be the mechanic and you can be the Janitor. ((*Clicks on mechanics name*)) ((*Changes it to a different name*))
> R: Ok. ((*Laughs*)) (1.0)
> L: ((*Laughs*)) 'Park Inspector' ((*Reading names of staff off of staff screen*)) His name is Park Inspector. Let's hire him. ((*Clicks at bottom of screen on the icon for hiring a janitor*)) ↓Let's hire a Janitor.↑

To hire staff, one needs to click the icons at the bottom of the Staff screen:

Figure 5*. Hiring a janitor in *RollerCoaster Tycoon 3.

Following hiring (the five icons at the bottom of the Staff screen, listed after 'Hire:,' are used to hire employees of particular types), one can place the employee (drop them somewhere in the park to begin working). The pair continued hiring additional employees:

> R: You're hiring more. How many [Janitors do we need?]
> L: [Let's hire (.) mechanics.] We need mechanics. ((*Clicked on hiring a mechanic*))
> R: Make like five janitors. (.)
> L: We need a bunch of mechanics. And a couple more janitors. ((*Clicked on hiring a janitor*)) Couple of security people. ((*Clicked on security*

---

[2] Transcripts follow Jeffersonian notation. L and R refer to the 'left' and 'right' game player (play was done in pairs). Information in double parentheses refers to non-verbal communication. Numbers in single parentheses (1) correspond to a pause in speech, in seconds, while (.) refers to a very brief pause. Up and down arrows refers to voice intonation (up or down tone). [bracketed text] refers to overlapping speech.

people to hire)) Couple entertainers. ((*Clicked on hiring entertainers*)) Animal Keeper. Ahh. We don't-
R: Animal Keeper.
L: 'You need at least one enclosure (unclear speech) ((*Reading from pop up when L scrolled over 'Animal Keeper'*)) Alright, we don't need him. (.)
R: What is this person doing?
L: It's an entertainer.
R: OH.
L: He's not really entertaining. ((*Laughs*))
R: ((*Laughs*))

The pair hired several of each type of employee. The ‘Animal Keeper’ could not be hired (as conveyed by the pop-up) because the pair did not have an animal enclosure in their park. Following, the pair customizes an ‘entertainer’:

L: Like (hhh) ((*Clicked on costume option for entertainer*)) costume to wear.
R: Make it like an animal. Cute one or something.
L: ((*Clicked on costume options for entertainer*)) A shark. (.)
R: A <u>whale</u>. Oh [it's a shark.]
L: [It's a shark.]
R: Make it a Panda. Oh ok good.
L: He's not really happy. ((*Viewing face next to staff member*))
R: Click the costume colors.
L: ((*Clicks on costume colors as suggested by R*))
R: Oh pink. (.)
L: ((*Clicks on pink*))

Selecting an employee (clicking on the employee) will display a menu in the bottom-right corner of the screen with icons surrounding the employee (actions for the employee). Discussion focused on exploring these icons and negotiating the choice of employee characteristics. The pair customized the employee’s costume, and then proceeded to explore other icons, starting with the employee’s thoughts:

((*Clicks on the entertainers 'Thoughts' icon*))
R: It's just his [thoughts.]
L: [Thoughts.] 'I hate working [here.']
R: What the - hate working [Here]. Make him like (.) happy.
L: Uh ok. 'Laziness.' ((*Laughs*)) 'Happiness' ((*Reading icons that are options for the entertainer*))
((*Clicked on wage*)) (.)
R: Oh no. Don't make his wage higher.
L: Why? That's why he's <u>sad</u>.
R: Well. ((*Laughs*)) Make it higher and see if he gets happier.
L: ((*Clicked to increase wage*)) It only goes up to °there.°

***Figure 6*. Wage and Statistics for an Employee in RollerCoaster Tycoon 3.**

In the above figure, the employees are happy; however, in the episode transcript, the employee is not. The pair attempted to make him happy: they hypothesized that raising his wage would improve his happiness. After this did not work, the pair considered firing him:

L: Maybe we should ↑like not have ↓him.
R: He's a horrible employee.
L: We should fire him.
R: ((*Points to a different entertainer*)) There he is. Is that him? Oh no that's another entertainer.
...
L: I think that's him. ((*Scrolls across the different staff members at the bottom of the 'Staff' window*))
((*Clicks on a staff member*))

Sad employees appear hunched over and sluggish. The pair noticed that he was now standing up straight, indicating happiness. The effect of raising the employee's wage took a little time before manifesting in a better 'happiness' rating:

> R: Is he happy now? He's standing. ((*Scrolled to bottom right of screen the entertainer is now standing*))
> L: Yep. ((*The entertainer's mood is now happy because his face turned green with a smile*))
> R: ((*Laughs*)) (1.5)
> L: Yeah he's happy now. So let's check everybody else what they're doing.
> R: Everyone else seems happy. (.) Like Jackie's happy.
> L: Everybody else is happy. ((*Scrolling through all the staff members faces*)) °Happy, happy, happy, happy.° Cool. (1.5)
> L: Awesome. ↑Now↑

After verifying that the entertainer was happy, the pair checked the other employees' happiness. By opening the Staff screen, the pair is able to view a summary of their employee's happiness ratings (the smiling or sad face icons to the right of the names):

***Figure 7*. Staff Screen in *RollerCoaster Tycoon 3*.**

The staff screen affords management, as demonstrated by discourse: providing a summary of employees and some statistics of each employee (their current task, patrol area, uniform color, and happiness rating) encouraged employee management behavior by the pair, verifying that all employees were happy. As cognitive technologists, this is an important design consideration: by supporting the game goals (of managing a theme park), the Staff screen is a representation affording staff management, and can be used in the manner shown to encourage goal achievement.

By the third day of gameplay, a difference could be seen in the pair's behavior in hiring staff. After starting a new game, the pair hires staff:

> L: ↓More mechanics?↑
> R: Yeah.
> L: Alright, where's that again? ((*Scrolls through side menu*))
> R: The mechanics 'Park Management'. (.)
> L: ((*Clicked on 'Park Management'*)) ((*Clicked on 'Staff'*)) ↓Oh we don't have anybody.↑

The first line of the transcript is a response to a game message about a broken ride. This in-game feedback prompts the pair to pull up the Staff screen. The design of in-game feedback is also very relevant for cognitive technologists, as it highlights how feedback can cause meaningful, related action.

The pair focused first on finding the Staff screen while exploring the persistent icons on the left side of the screen. After realizing they had no staff, the pair quickly hired employees:

> R: There's a mechanic. ((*Points to Mechanic icon on staff menu*))
> L: °We need a janitor.° ((*Clicked on 'Mechanic'*)) ((*Clicked on 'Janitor'*)) (.)
> L: ° We need a couple of mechanics.° ((*Clicked on 'Mechanic'*))
> ((*Clicked to add another Mechanic*)) ↓We need a couple of everything.↑ ((*Scrolled over the staff that the pair can hire*))
> ((*'Animal Keeper' popped up*)) °No we don't need an 'Animal Keeper' though.°

The pair seemed to have an idea of how many of each type of staff they need for their park, possibly based on previous gameplay. In the final day of gameplay, the pair repeated the process of hiring staff for their park (again, a new game was being played). Initial focus was on finding the Staff screen:

> L: Where is it again? ((*Scrolled over left side menu*))
> R: Underneath the eyes.
> L: No that's save.
> R: No go up again. The eyes. Those little things. This thing. ((*Points to 'Park Management'*))
> L: °That's not it.° (.)
> R: It's not?
> L: °No.°
> R: Are you sure? [Oh no,] it's just the statistics with the graph.
> L: [Yeah.] ((*Clicked on 'Park Management' icon*))
> ((*Staff screen popped up*))

Upon finding the staff screen, the pair learned they had only one mechanic and one janitor, and determined that their park was under-staffed:

> R: ↑Hey. We only have one mechanic.↑ (.5) And one janitor.
> L: ((*Scrolls over the mechanics and janitors*)) (2.0)
> ...
> R: We've got to place him.
> ...
> R: Just drop him right there.
> L: ↑How about (.) a janitor?° ((*Scrolls through staff menu*)) (.5)
> L: Ok. He's on his route. (.5) °Janitor do your job.° (.5) 'Going to broken ride. Going to inspect a ride. Rovering. Rovering. Rovering. Entertaining. ((*Reading off what each staff member is doing by clicking on each staff member*)) °You better start entertaining bud. You're not scary either.° (.5)
> R: ((*Laughs*))

Again, as evident by action and discourse, the Staff screen affords management of employees and in-game feedback (employee behaviors and thoughts) confirm that staff are working. The pair exhibited this behavior by evaluating employees, one at a time, and reading their thoughts to gauge their effectiveness. Following, the pair discovered an unhappy janitor and took action to fix the problem:

> L: °'I hate working.'° ((*Reading thoughts of the janitor*))
> Let's go to (.) to there. ((*Increased the staff members pay*)) Now he's happy. (.)

After improving the janitor's happiness by increasing his wage, a strategy that worked previously, the pair returned to working on their theme park's attractions.

A slight change in behavior can be seen from previous episodes. The pair appeared to have a handle on how many staff they needed for their park, and proceeded to quickly hire them. However, in this episode, the pair made use of the Staff screen to manage their employees, verifying that employees were happy before moving on to other tasks. This additional behavior demonstrated a greater degree of understanding of how to manage employees: the pair grasped that happy employees are more effective and less likely to quit. After several days of gameplay (including observation of game console messages of employees quitting) their actions showed priority being placed on their staff's happiness, indicating a preference for staff productivity to satisfy larger game goals and objectives. The pair made use of the Staff screen as a management tool, a representation provided by the game lending itself to management of staff. In *RollerCoaster Tycoon 3*, the game provides other 'summary' style screens that lend themselves to management of other aspects of the game, including rides and attractions, park visitors, and finances. These summary / management style screens, coupled with in-game, real-time feedback, are an important consideration in the design of games for good. They assist gameplay by providing indications of accomplished, meaningful action for game players.

Using Airplanes in Making History: The Calm & the Storm

The following example is a sequence of two episodes, showing the use of airplanes in *Making History: The Calm & the Storm*, a "serious" game aimed at learning history and strategy, set during World War II. The first episode presents a pair struggling to use airplanes to bomb Canada (they are playing as the United States, and declared war on Canada):

> L: Alright this guy (.5) ((*Clicks on a plane in Georgia*)) needs to go (.5) over here. ((*Clicks on*

> *an area in Michigan*)) (1.0)
> L: ((*The plane does not move*)) How do you move 'em again?
> R: The planes won't move (1.0) like I can get the (1.0) armies to move but I can't get the planes to move.

The pair identified their problem: to move and use airplanes. The goal appeared clear: to use airplanes to fight Canada, but the execution of the goal appeared difficult. The left-hand player asked how to move planes, and the right-hand player restated the problem based on previous unsuccessful experience with airplanes. Following, the pair consulted a peer team for information but received little help, while continuing to struggle with the interface:

> L: ((*Clicks on a plane in Georgia*))
> ((*Clicks on Washington*)) Do you know how to move planes? ((*Clicks on the same plane in Georgia*))
> ...
> ((*Clicks on 'Operational' map*))
> ((*Asks the peer team for help with moving planes*))
> Peer team: Do you?
> L: Do you know how? ((*Scrolls through US continent*))
> Peer team: No. Do you know how?
> L: No ((*Laughs*))
> Peer team: ((*Laughs*))

Figure 8*. Airplane Actions in *Making History: The Calm & The Storm.

Perhaps potentials for action on the interface are not clear enough for students to learn how to use their airplanes. Movement in the above figure does not appear obvious from in-game feedback. Following, the pair continues to lose states (territories) to Canada, which frustrates them:

> L: Alright, somehow we just need to get... uh↓ what the heck?↓
> L: What the heck? ((*Scrolling across Midwest region of US*))
> ((*Right clicked on an army in Canada*))
> ((*Clicked on an army in US that was engaged with Canadian forces*)) °What the heck?°
> R: We are going to kill them. ↓How do you move those planes?↓

The loss of states seems to re-motivate the students into learning how to use airplanes. Cognitive technologies can take note, as a bit of failure can often increase interest and motivation to win a game. In this case, failure to move planes led to frustration as they saw an opportunity for action (a military unit of airplanes on the map that the gamers inferred could be used in warfare), coupled with a goal (using the airplanes to fight Canada). The students could not seem to determine how to accomplish their goal, suggesting that the experience of failure can motivate by creating a challenge; however, failure to operate a game interface appears to be frustrating when unable to execute a course of action. This is exhibited in the following transcript as the pair attempts to move airplanes, located in Georgia, to fight Canada:

> L: ((*Clicked on an airplane in Georgia*))
> ((*'Air Force' menu popped up*)) ((*Clicked on 'Rebase' in the 'Air Force' menu*)) Oh here we go. (.5) Canada. What the heck? Why isn't Canada in here? ((*Scrolls through list of states / countries to find Canada)*))
> R: Maybe you gotta send (.5) try sending the one from New York to Canada. (.5)
> L: ((*Continues to scroll through states / countries*)) ,Or to Michigan., ((*Continuing to scroll through list of states / countries*)) (1.0)
> L: ((*Continues to scroll through the list of states / countries to attack*))
> R: Yeah go to Minnesota. Then we can attack them from there. (1.0)
> L: ((*Clicks on Minnesota*)) Go ((*Scrolls over continent*))
> ((*Sighs, places hands up by mouth*))
> ((*Scrolls through map along green active path from Georgia to Minnesota*))

The pair could not attack Canada with their planes from Georgia. The game offered the ability to rebase airplanes, which suggests that airplanes might need to be closer to enemy targets in order to launch missions. While this does not achieve the goal of bombing the enemy, the 'rebase' option infers to gamers that they need to first move planes closer to their targets. Generalizing to other games, displaying potential actions that can both hint at and lead to solutions of a problem seems to be a helpful feature. Players hypothesized in the above episode that moving the planes closer would allow them to be used to engage the enemy. This led into the next episode in the sequence, after moving planes further North:

> R: ((*Clicked on different airplanes around the map*))
> ((*'Air Force' menu popped up*))
> ((*Right clicked on an airplane*))
> ((*Options for the airplane popped up*)) (.5)
> ((*Clicked on American flag*))
> ((*Clicked on a plane in Massachusetts*))
> ((*'Army' menu popped up*))
> ((*Clicked on an airplane in New Hampshire*))
> ((*'Air Force' menu popped up*))
> Oh they took over so many of our ((*Scrolling map across Northeastern U.S.*))

Success was achieved after airplanes had been moved closer, and the pair employed the strategy of right-clicking enemy targets (a technique used to move other types of military units):

> R: ((*R*ight-*clicked on an enemy target in Maine*))
> ((*A menu appeared offering the option to bomb them*))
> ((*Mouse control traded from R to L*))
> R: Oh crap =
> L: Oh how did you =
> R: = They're taking over all of our states.
> L: = no we can actually bomb someone now. (.)
> R: Oh (.5) how did you do that?
> L: I don't know you did it. ((*Laughs*))
> R: ↑Did I?↑
> L: Yeah ((*Laughs*))
> R: Ah geez↓ (.5)
> L: Ah sweet (1.0) alright bomb them. ((*Clicked on one of their airplane units*))

Apparently both students were confused about how they actually achieved the bombing of enemy targets, and each attributed success to the other game player. Both seem to have overlooked exactly how success was achieved, potentially because the game interface did not make evident what had actually happened. However, the pair seemed excited that their airplanes could actually be used in warfare, and went about determining exactly how they accomplished bombing the enemy:

> L: ((*Clicked on an enemy targeted army*))
> R: It's like (.) hold it down or something.
> L: ((*Double clicks on airplane*))
> ((*'Air Force' menu pops up*))
> ((*Right clicks on enemy army*))
> ((*Clicks on their army*))
> ((*Clicks on an airplane*))
> ((*'Air Force' menu pops up*)) (1.0)
> L: There. (1.5) Wait. (8.0) ((*Clicked on airplane*))
> ((*Mouses over airplane*))
> ((*Options for the airplane moused over pop up*))
> ((*Chooses air mission*)) Air mission. Alright there we ↑go.

The pair learned how to conduct air missions and use airplanes. Right clicking on nearby enemy targets, after selecting a plane, displays a menu with an option for air missions, similar to what is shown in the following figure in the top-center of the screen (the mouse pointer was not captured in the screenshot):

Figure 9.* Bombing Enemy Targets in *Making History: The Calm & the Storm.

This sequence of actions was at first unclear, as players struggled to figure out the correct sequence of actions to obtain a desired result. While a common method of right-clicking is present for moving other military units, the lack of a common place for action-items (like icons in *RollerCoaster Tycoon 3*) appeared to break the flow of gameplay; a significant amount of time was spent figuring out how to control the game to achieve a relatively simple goal.

Civilization IV: Combining Military Forces

A final example describes a sequence of episodes from *Civilization IV*, a game involving the management of an ancient civilization (one controls the diplomacy, economy, religion, technology, military, etc. of a civilization). The pair was waging a war with another computer-run civilization, and began to realize that they needed to join and fight with multiple military units for greater success (after experiencing defeat in previous animated battles). The first episode shows military units being lost by fighting individually:

> R: No send the other guys into the oh ,wait are those warriors too?, ((*Points to warriors on screen*))
> L: >Yeah, Yeah, Yeah.<
> R: Send them down.
> ...
> L: ↓Whoa↓ ((*Clicked on warriors in enemy territory*))
> ((*Clicked on enemy warriors fighting began*))
> R: Uh oh. That's not good. ((*The warriors are dying from battle*)) (.5)
> L: ((*Moves warriors to another location on enemy territory*))
> ...
> R: Ah send them down. ((*Points to group of warriors at top of map*))
> L: ((*Clicks on the group of warriors that R suggested*))
> L: ((*Moves the warriors four spots down, where R suggested*))
> L: ((*Ends turn*))

Early in the episode, a battle is lost with an enemy civilization. This appears to motivate the pair, as plans are made to send more military units down to fight the battle. Following this loss, the students express both surprise and remorse at the defeat of their military unit (military units are represented by a group of three military personnel, as shown in the battle illustration in Figure 10). The loss of the battle draws the pair's attention as they appear engaged after the loss of their military unit.

Figure 10. **A Typical Battle Animation in Civilization IV.**

In the second episode, the pair questions a peer team by asking if it is possible to join military units (combine forces), making use of the peer team as a source of information. The peer team responds and offers advice. This results in the pair searching for a way to group military units together on a single tile in the game (a land area). Once this is completed, they try moving the military as a whole to fight the enemy civilization:

> L: ((*Pair moves amassed military forces into Greek city*))
> R: Oh that thing is deep in their village isn't it? Uh huh. ((*Enemy was killed by military*))
> ((*Military takes conquered city*)) (1.0)
> R: ↑Yeah.↑ We need to keep it. ((*Given the choice to keep the city or to burn it to the ground*)) Hold on. Ok. We need to keep it? (1.0)
> L: ((*Clicks on burn the city to the ground*)) No. ((*Laughs*)) We just earned money from destroying the barracks.

The pair successfully won the battle and took away the enemy civilization's city after strategizing how to be more successful in battle (by grouping military forces together). From here onward, the pair shows a change in behavior by travelling with combined military units when engaging in future battles. The original failure (a lost battle animation) appeared to motivate the students, prompting their new understanding of the game interface when using military units. By drawing attention to a lost battle through an animated battle scene, the game prompted new strategies in subsequent gameplay, an important design consideration for cognitive technologists to consider. The design of in-game feedback and related behaviors can serve to motivate player goals, which should then be accomplishable through an evident course of action within the game interface.

DISCUSSION AND CONCLUSION

Results showed a relationship among game player behavior and the usability of the game interface, as shown in the discussion of transcripts and related game screenshots. The design of in-game representations such as a game's user interface and the behavior of in-game objects has a large impact on corresponding gameplay, with the resulting lessons useful for the design of cognitive games for good.

Plurality of Channels of Information to Aid Understanding

To aid feedback and reduce uncertainty, a plurality of information channels can be utilized by the game. For example, battle animations in *Civilization IV* conveyed meaning well and motivated the pair to take up new goals after experiencing a lost battle. However, players from *Making History: The Calm & the Storm* showed frustration when unable to control the use of airplanes to attack an enemy, as evidenced when the pair asked peers for help. Additional feedback might have been provided by the game to guide interaction and raise motivation; the taking-up of the task of using airplanes several times by the group indicates a difficulty in using the game interface to achieve their goals in the game.

Impact of Content Visualizations on Player Strategies

Students exhibited a preference for visualized information, ranked as follows:

1. Animation-based
2. Static visualization-based
3. Text-based

Animated sequences were better at grabbing attention and creating emotional responses than information presented textually. A difference in student discourse is visible when comparing interaction among the three games: *Civilization IV* animated battles, achieving an emotional response followed by new player strategizing; *RollerCoaster Tycoon 3* used visuals to indicate staff happiness, which took the group some time to notice; and *Making History: The Calm & the Storm* presented textual information after players right-clicked on objects in the game, something that was initially overlooked. The animated feedback in *Civilization IV* was most effective at eliciting an immediate reaction from game players in the form of new strategy development.

Future Work

Future work will examine in-game failures at a deeper level, taking a look at how game interfaces can lead to situations that lead to either the abandonment of a game task (typically from frustration with a game interface, or the lack of ability to execute strategies), or the uptake of new game strategies (when failures lead to new game goals from increased motivation). Additionally, further comparisons among affordances and activity theory will be explored, as this is an interesting model for breaking down game player interaction.

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AUTHOR NOTES

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Learning and Change — A View from MIT's Education Arcade

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In recent years, the neuro-cognitive science behind the biological imperative to play has gained increasing attention in the scientific and lay press. And yet little has been written so far in regards to play in video games despite the centrality of play to this medium. For this case study, we examine the Education Arcade's design philosophy and best practices for creating playful and pedagogically rigorous games in terms of the neuro-cognition of play. Focusing on our recent health-oriented puzzle game for children ages 8-12—*Caduceus: Staff of the Alchemist*—we discuss the process of design as both an act of play and as itself a mechanism for play. By abstracting the essential mechanism underneath a complex task and overlaying it onto puzzle mechanisms, we encourage the essential habits of mind that undergird complex problem solving. Just as the science of play shows that play prepares the young mind for situations requiring creative adaptation, we at the Education Arcade believe that games can prepare young learners for future learning. In *Caduceus*, we approach health messaging through both game play and narrative, embedding one in the other as a compelling means to scaffold young players through the logic of medical and scientific practice. Good design is a fundamental part of any intervention and one that that is often overlooked by investigators, especially where games are used as the method of intervention. We hope that this paper, in detailing our approach to learning and play, will make clearer the value of games as powerful cognitive tools.

KEYWORDS: Video Games, Education, Problem-Solving

INTRODUCTION

"All work and no play makes Jack a dull boy"

The familiar proverb first appears in print in James Howell's *Proverbs in English, Italian, French and Spanish* (1659). So for at least 350 years the notion that play has intrinsic value has been enshrined in Western popular culture. Unfortunately, the same proverb also instantiates a societal conviction that play is entirely distinct from work. As we celebrate play's value for entertainment, relaxation and escape, we simultaneously discount its role in all the activities we think of as work, and this includes learning. We do so today even in the face of growing evidence that play is the fundamental, robust source of learning and indeed an evolutionary necessity throughout the animal kingdom. Much of this evidence is summarized by Brown and Vaughan (2009). Though the authors cite current research from the fields of neuroscience and evolutionary biology, their fundamental premise is not new. For decades, scholars as diverse as Huizinga, Dewey, Piaget, and Papert have all argued for the primacy of play, exploration, and experiential, hands-on learning. Nevertheless, the enforced separation of play from formal education continues largely unabated. Indeed, in an era of mandated curricula tuned to standardized tests, play's exile from the classroom is as pronounced as ever.

Many in the field of educational technology have implicitly bought into this separation through the products they have created. Most so-called "educational games" merely re-present the traditional worksheet, albeit through an interactive format skinned with animations and music. These animated quizzes are dressed up as computer games, but they have been bled of anything that might be called play.

At the same time there is growing appreciation for the learning that occurs in the "commercial" computer and video games that have come to occupy a prominent place in children's culture. Gee's (2003) work is of course central to this discussion, but many other researchers have also engaged with this notion. As we have written elsewhere, game players regularly exhibit persistence, risk-taking, attention to detail and problem solving skills, all behaviors that ideally should be demonstrated in school (Osterweil & Klopfer, in press). Much of this games research has focused on learning that happens entirely in the informal sphere. It concludes (rightly in our opinion) that practices fostered by game play are critical elements in what are called 21st century skills. However, to the degree that we only attend to the learning occurring in the informal sphere, we abandon formal education to the domain of grinding work suggested by the old proverb's dichotomy. In the current environment, *all work and no play makes school a dull place*.

In recent years, MIT's Education Arcade has focused on the ways in which authentic game play can be harnessed for traditional academic subjects and the ways in which games can successfully be deployed as a beachhead of play in the too-sterile environment of contemporary schools. This strategy rests on identifying what is genuinely playful in a discipline, and on finding ways of easing teachers into the process of using games without putting undue stress on their need to "cover" curricula.

To this end, the Education Arcade creates cognitive environments following what we call "the freedoms of play." Rather than sanctioning only one method of cognitive skill acquisition (i.e. deduction & hypothesis-testing, spatial reasoning), we create free game environments that allow the player to approach problem-solving in as many ways as possible, encouraging experimentation and, ultimately, play. Our purpose in discussing this design approach is not merely to speak to the designers in our audience, but to highlight those qualities in learning games that make them effective educational tools. It is our hope that this article will be part of the broader conversation about what makes for meaningful cognitive technologies.

THE EDUCATION ARCADE'S DESIGN APPROACH

The Education Arcade sees the role of games not necessarily as direct teaching implements, but as environments in which students experiment with, and manipulate new ideas and concepts in preparing for future learning. Preparation for future learning (PFL) is an approach to transfer that emphasizes the ability to learn rather than the capacity to store knowledge (Bransford & Schwartz, 1999). The PFL stance emphasizes the development of strategies in students that allow them to adapt to new situations through experimenting and elaborating on their previously acquired skills. By engaging directly with a subject area via invention and experimentation preceding the classroom encounter with the subject, students have been shown to learn more thoroughly and effectively the concepts of the subsequent lesson (Schwartz & Martin, 2004).

The first encounter with the new subject must take a form that makes subsequent learning more clear, not more confusing. For example, children who learned fractions without having access to learning toys that illustrated in a tactile way that fractional pieces actually compose a whole were likely to transfer in their previous understanding of whole numbers, leading them to misunderstand the fundamental nature of fractions (Schwartz & Martin, 2006). Being given the opportunity to explore and play with learning toys before tackling subjects in the classroom only prepares a student for future learning if the learning toys are designed to facilitate the lesson. This is exactly where The Education Arcade makes its intervention on the learning process – by providing the right tools for students' first encounter with new learning areas.

We see our games as preparation for the classroom setting, activities that can easily be undertaken outside of the classroom in order to get the student ready for the next lesson. Through play, our games provide a virtual, experimental environment where students become familiar with a lesson area before they even necessarily know what they are learning. All this may be done at their own pace, on their own time, and without the pressure of classroom time constraints. In the next section, we discuss how the Education Arcade realizes this approach to learning game design through the example of our latest health-focused game for younger players.

AN EXAMPLE: *CADUCEUS*

Figure 1. Caduceus: Staff of the Alchemist.

Caduceus: *Staff of the Alchemist* is a web-based game designed for children from the ages of 8 to 12. As part of the larger Generation Cures campaign launched by Boston Children's Hospital to reach families, *Caduceus* served as one component of a multimedia property under the Zebrafish story line. In the Zebrafish narrative, a band of high schoolers raise money to fund research when one of their own develops cancer. The sibling of the ill girl, to work through his feelings regarding the illness, creates the game *Caduceus* and populates the fantasy world with alternate versions of his friends. Composed of five puzzles linked by a continuous narrative, *Caduceus* introduces children to the world of Alterica, which is currently being ravished by a plague. Exploring Alterica as an apprentice healer, the player learns the healing arts by mastering the game puzzles to find a cure.

***Figure 2*. An Illustration from the Online Graphic Novel Accompanying *Caduceus*.**

With such a young audience, the objective of *Caduceus* was not to teach the specifics of medical practice, but to interest players in the practice of medical science, and to inculcate in them the broader habits of mind that guide doctors and epidemiologists in their work. "[W]e are not tricking the player into engaging with the topic (a claim that many games, particularly math games often make) but are rather enabling them to partake in those pleasures of the discipline that motivate its expert practitioners." (Klopfer, Osterweil & Salen, 2009, p. 32) To this end, our approach to design focuses on identifying a heuristic of scientific practice to capture each lesson. Finding an engaging game in this practice requires a robust metaphor that assists in simplifying the issue. Ideally, the metaphor should reveal the underlying mechanisms and patterns of medical thinking rather than obscure them. This metaphor or central mechanism also serves to scaffold or structure the learning such that the player may later reflect on and mobilize this metaphor for later encounters in the classroom. We hope to elucidate this approach further with the example of three puzzles within *Caduceus*.

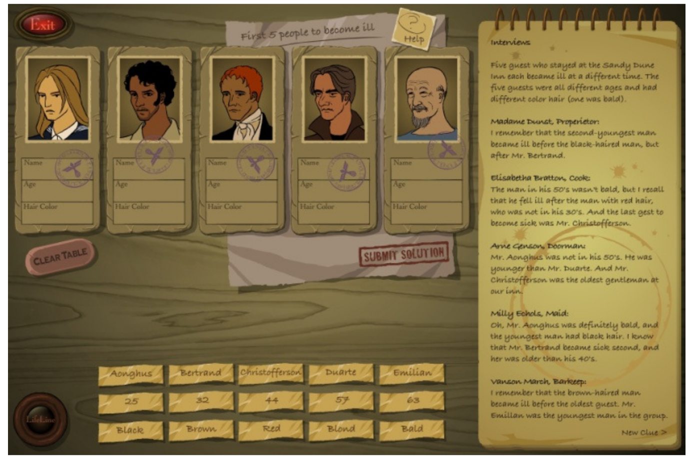

***Figure 3*. The Player Must Deduce the Identity of the Plague's First Victim.**

Windholt

When players in *Caduceus* arrive at the port city of Windholt, they encounter a puzzle about epidemiology. Epidemiology represents an entire field of specialized knowledge. To communicate where the pleasure and play of such an abstruse topic lies, we did not instruct players about epidemiology as such. Instead, we posed the challenge and intrigue of the field of epidemiology through the analogy of a mystery. The player must assist Inspector Plinkerton in the Department of Hygiene to collect evidence and trace the spread of the plague from its point of first contact, much like an epidemiologist in the field would collect interviews and samples. This puzzle uses a logic structure that enables the player to find the identity of "patient zero" from a series of partial clues. The lesson of this puzzle elaborates on the nature of epidemiology, which requires deduction and logic. Pursuing epidemiological outbreaks can be very like solving a mystery—the desire to detect a "culprit," confirming hypotheses, and mapping how events unfolded across time and space. In the Windholt puzzle, the metaphor becomes both narrative and structural, simplifying and revealing the key lessons of investigation and deduction (Jovanovic, Starcevic, Stavljanin, & Minovic, 2008).

In this approach to game design, we find the *game already present in the learning* as opposed to *making a game out of learning*. These two statements require different design mindsets and produce games of arguably divergent quality. In brief, the weakness of the latter approach lies in seeing the learning as distinct from the game, perhaps even as a barrier the player must overcome in order to play. In other words, the game designer's implicit bargain is, "suffer through this boring learning, and I'll reward you with a little game play."
The Education Arcade philosophy seeks to find instead what is playful in the act of learning itself. Play is

learning. To lose sight of the element of play is to lose the very thing that enables us to learn. To design for playful learning, we must begin at the pedagogical issue itself and design from that issue to the larger game rather than the reverse. Each lesson must be examined as its own creative design problem and matched to a game mechanism that echoes or further elaborates the pedagogical aim (Gunter, Kenny, & Vick, 2007).

***Figure 4*. Players Isolate Microbes in Search of the Plague's Source.**

Microbes

In the very first puzzle of *Caduceus*, the player is sent to the flying city of Nimbus Cumulon to work in the laboratory of famed scientist Alfonso Tidewater. There, the player works to isolate the bacterium that causes the epidemic. The object of this puzzle was to introduce the basic principles of the scientific method and the type of experimentation that it engenders. The scientific method, of course, is a fundamental technique for knowledge generation in medical science. We saw this as a key topic in science education and an early introduction to how we come to make knowledge seemed potentially valuable. In order to build a puzzle that addressed this issue, we began by identifying the crucial elements of the scientific method.

The scientific method relies on the collection of data that can be grasped by human senses, things that can be seen and counted. To gain knowledge from this data, the scientific method requires that scientists create hypotheses, a proposal that posits a correlation or causal relationship between two or more categories of data, and experimentation to verify or invalidate these proposals. In the case of germ theory, hypothesis testing often seeks to isolate differences between ill experimental animals and healthy control animals in order to pinpoint the bacterial disease agent.

The history of rationalist thought developing out of the Enlightenment and the philosophy of positivism, of course, was more than could be conveyed in a single puzzle. For that reason, we focused on the act of experimentation and the logic of isolating differences between control and experimental samples. The actual game mechanism for the Nimbus Cumulon puzzle rests on a casual gaming format of matching pairs.

The player-avatar becomes inspired to compare control samples of her healthy blood with the blood samples of ill patients. The puzzle presents the view from the microscope eyepiece onto the glass slide. In this view, the player uses an eyedropper of dye to "mark" pairs of microbes. Each pair of identical "species" of microbe disappears over progressive play until the player is left with the one microbe that did not have a corresponding partner in the control sample. Matching allows the player to make comparisons—in this case, looking at the features of the microbes—and eliminate the microbes found in both the control and experimental samples from consideration. The microbe that remains after the pairs have all been eliminated may thus be the disease-causing agent. This game mechanic is a metaphor illustrating the logical process of science rather than a detailed example. We chose the simplest experimental form in emphasizing comparison, allowing the narrative to scaffold the larger concept of the scientific method in medical investigation (Wechselberger, 2009).

It is worth noting here that the term “scientific method” is usually presented to students in the form of a recipe of steps, a strict procedure that bleeds science of any sense of exploration, creativity, or invention. In fact, observation, hypotheses formation and testing, and controlling for variables are all activities players regularly demonstrate while playing computer games. We have long believed that if students could be given to understand the similarities between science and decoding a challenging game, interest in science would be much higher.

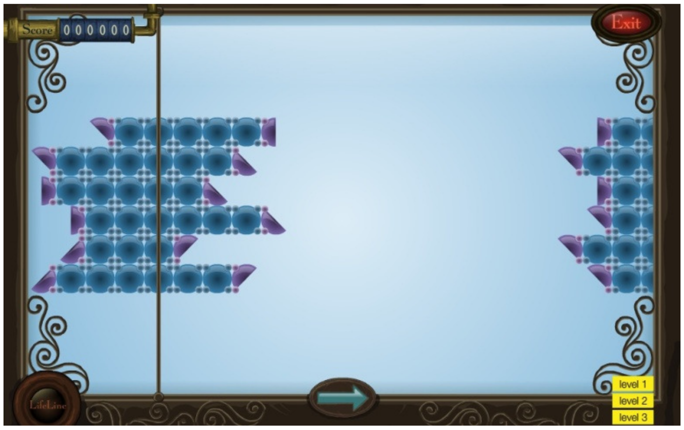

Figure 5. **Spatial Reasoning is Exercised in the Molecule Puzzle.**

Molecules

Good game design concerns more than just posing a thoughtful metaphor through narrative and game mechanics. Game design must also embody other principles of play. In particular, the Education Arcade believes in the concept of "freedoms of play" (Osterweil & Klopfer, in press). Using the fourth puzzle in *Caduceus* as an example, we can see these principles in action. Firstly, games should create environments that foster a sense of freedom in play. Of particular, importance is the freedom to fail, and consequently to learn from failure. When failure occurs, it should satisfy the senses, be humorous, and most importantly, give constructive feedback on not only what players did incorrectly, but what they did correctly. Failure in games need not be demoralizing, but can add critical information to the players' evolving mental model of the game mechanics. Refining our mental models of both reality and games is crucial to learning as play.

In the fourth puzzle at the Caverns of Biyu, the player helps an herbalist create a cure for the plague by manipulating a molecule until it fits into the cell's receptor. The puzzle allows the player to move and swap parts of the molecule until the "key" fits into the cell-receptor's "lock." The molecule slowly moves from left to right until it touches the receptor, limiting the number of turns the player can use to experiment. When the molecule collides with the receptor, if it does not fit, will become unstable. The atoms consequently blow apart in a spectacular fashion. In this puzzle, the player learns spatial reasoning, making judgments about distance, symmetry and reflection. The game format encourages the player to test the molecules to see where the shapes do not fit. With both the information and the entertainment of exploding atoms, frustration is deferred.

Additionally, good games allow for free experimentation. In the molecules puzzle, players can adjust and shift the atoms as much or as little as they wish with no time limit. This interface accommodates both players who learn by experimentation and those who enjoy thinking through the entire solution before executing their plan. The most enjoyable games allow for multiple ways of arriving at the answer, and thereby enable discovery-based learning (Jovanovic et al., 2008). Additionally, this format allows for a freedom of effort. In the Biyu molecules puzzle, players may engage with as much or little investment as they wish. Only a reasonable minimum score is required to pass the puzzle and move on to the next stage. The game should not take away the freedom to control one's engagement with a task. If players dislike one of the game puzzles in *Caduceus*, they are not punished by having to master the puzzle at a competitive level. Games that enforce one level of effort quickly become alienating (Zhang, Wang, Zhao, Li, & Lou, 2008). This freedom is reinforced through the presence of more frequent save points, allowing players to return to the game later, and through the removal of time pressures in favor of turn/resource limits.

Finally, we believe in the freedom to interpret both the game narrative and the game mechanics. In *Caduceus*' puzzles, minimal instruction is provided in favor of allowing the players to discover the meaning of the game for themselves. To win, the player must fully grasp the rules of the game, which can only be derived by experimentation and failure. As the player masters the rules of the game, they actively create models for the game play dynamics, thus making learning a fundamental aspect of play. Players consequently learn the lessons in each puzzle at their own pace and on their own terms. Games should, above all, respect players' ability to make meaning for themselves. Like the advice given to both novel writers and movie directors, the game designer should remember to show, not tell. The ability to make meaning of an experience is a skill well developed by all humans, including children. Attempting to over-determine the meaning taken away by the player becomes as obstructive to learning and play as an inappropriate game mechanism.

Rules, consequences, points, measures, and win states must exist for a game to truly be a game. Structure exists to give a point of reference and make play meaningful within a particular imaginative context. Rules create fairness and provide necessary information for players to make judgments about their models of, and progress in, the game. Structure and rules are what actually turn computational mechanisms into real games. A game, by definition, creates a circumstance wherein players do not have enough resources to complete their goals, forcing players to refine their strategies in order to achieve the win-state. Without the circumstance of challenge, there exists no game and no incentive to play. Yet in spite of this structure, within the bounds of any good game the player still has freedom to experiment and fail, to invent and interpret. Games provide a safe place to play.

If we do our job well, then *Caduceus* is a fun and engaging (i.e. challenging) game for our target audience of upper-elementary students. While that alone might be a worthy goal for us as designers, if we are serious about facilitating learning, than we must provide opportunities for students to reflect on their in-game experiences, and relate them to their burgeoning understanding of science and medicine. Toward that end, we are currently working with our partners at Children's Hospital Boston, and the non-profit Learning Games Network to develop classroom materials that teachers can use to reinforce the game's deeper lessons. If we are serious about games as preparation for future learning, than we must be committed to facilitating the learning as well as the preparation.

CADUCEUS AND SOCIAL CHANGE

In our discussion so far we have focused on *Caduceus*' role in science learning, but the game is also an exploration in the ways in which games can effect social change. Key to the game play of *Caduceus* is the principle of philanthropy. The Generation Cures campaign aims to reach families through their children in hopes of cultivating a civic connection between the community and the Children's Hospital of Boston. As a consequence, we introduced models of philanthropic behavior and altruism to the players via a central game mechanism. To move between levels in *Caduceus*, players must contribute some portion of the points they win to various philanthropic projects in the game. For example, to travel from Windholt to Honigstadt, the player must contribute a reasonable threshold of game points towards feeding the poor. The game rewards altruism by doubling the points contributed if the player chooses to donate anonymously. Players may not sign up for the game without an adult sponsor. This sponsor—a parent, teacher, or family member—receives periodic updates on the progress of the player. When players become stuck in a puzzle, they have the option to use a "lifeline," which sends emails to their sponsor for tips and hints. As part of the game's outreach mechanism, these emails prompt parents and teachers to talk to their young players about the issues raised in the game. This game mechanism becomes a strategy for involving parents and children in a larger conversation about both the game and the medical and health issues that are central to the Children's Hospital mission. The modeling of civic engagement in the game via social interaction is not a trivial factor. Recent literature shows that just the idea of social interaction introduced into a learning environment can increase the learning that occurs (Chase, Chin, Oppezzo, & Schwartz, in press).

In attempting to foster social change, we do not depart from the principles that undergird our approach to academic learning. We see the game's philanthropic activities as preparation for the future learning that will occur through the child's conversations with parents, teachers or other adult sponsors. Although we imagine some children will learn directly through the game interaction, we presume that a more substantial number will receive the greatest benefit when they have opportunities to reflect on those game interactions with the adults in their lives. There exists a fundamental sociality to learning and, indeed, to many forms of cognitive technologies that extend our thinking abilities beyond the realm of our own minds. Speech itself is a tool of cognition, and the social dimension of parent-child ethical discussions offers a way to both involve the family in social change and to develop the seed of philosophical thought introduced by our games.

DESIGN AS PLAY

Game design itself, in the best cases, becomes a form of play. At the heart of design lies creative problem solving, finding unusual solutions for new problems with only the resources of one's experience as reference. This is nothing if not a game. Especially where the challenge of designing for pedagogy is concerned, designers benefit from both intellectual curiosity and embracing the spirit of play in themselves. Games and game-like activities occur everywhere in everyday life. From packing everything you need into the smallest possible suitcase or strategizing to maximize the efficiency of a grocery store visit—a game exists in everything we do if we choose to create the conditions for it. If you can find the game-in-life, you will find the game-in-play.

For precisely this reason—the intense pleasure of creative problem solving—do we see practices like players building their own levels in their favorite computer games, which they often share with the community (Nambisan & Sawhney, 2008). Or, in the case of commercial games, players unlock the level-building capacity to further extend the game world with their own challenges and puzzles. The ability to make something compares to the ability to teach (Bransford, Schwartz, & Bransford, in press). They are both ways of articulating oneself within a system that requires mastery of the system itself. Teaching each other forces students to master concepts much more firmly than simply being taught. Likewise, building their own levels put players in the position to refine their understanding of the game mechanism.

As designers of learning games, it becomes our job to master the conceptual core of each lesson. From middle-grade math to microbial evolutionary ecology—good design in learning games necessitates an attitude of intellectual curiosity. If we cannot find the play in our own learning, how can we possibly hope to convey that to our players? In any kind of design, we must excavate our own human experience to find the moments of joyful learning, of epiphany and pleasure in mastery if we hope to enable them in our players.

DESIGN AS INTERVENTION

As hinted at in our discussion of *Caduceus*, we have begun to ask whether our approach can be as effective in fostering individual growth and change as they are in other forms of learning. Sadly in our experience, too many "games for change" merely appropriate the form of a game to be used as a platform for sermonizing or pamphleteering. If we doubt that in the educational sphere students can be taught through the didactic recitation of facts, does it not similarly follow that games cannot effect change by simply telling players "how it is?"

In our experience, mimicking the appearance of a game does not a game make. Neither will simply reproducing the formal system of a recognized game genre with new content (Kickmeier-Rust & Albert, 2009). We must design from the content to the game and not the reverse for games as interventions on learning to be effective (Gunter et al., 2007). For investigators interested in using games as a mode of intervention, this paper hopefully makes a convincing argument for the importance of design that allows for meaningful play in the efficacy of a game. A game as intervention depends not only on how well the game communicates the principles of said intervention, but how deeply it engages the player in struggle and reflection, in other words how effective it is *as a game*. The medium of games is not, at the end of the day, an empty box into which content may be placed. Media structure the way we interact with content, and Marshall McLuhan's insistence that the "medium is the message" points to how fundamentally media shape what can be said. The medium of film, in its brevity, will never capture the interiority of novels. But films offer, however, a different kind of visual immersion and capacity for action that often escapes print media like books. Likewise, games as active and procedural media lend themselves to more experiential types of expression. Pedagogically, the medium of games is thus suited to procedural skill acquisition rather than declarative knowledge learning (Zhang et al., 2008). Not every message can be told equally well in every medium. In ideal circumstances, the game-as-intervention emerges in a holistic way from the nature of the intervention itself, just as it does in our work with curricula.

Games may or may not be capable of changing player behavior, but they can certainly give players new tools with which to explore and reflect upon their world. The creators of effective games must anticipate the ways in which players will encounter those games and design them to fit within a broader system of reflection and conversation. Indeed, if the challenge of good design is to solve problems and find elegant solutions that meet disparate needs, then the designer of games for learning or change must also design for the larger system in which the player lives and acts.

CONCLUSION

James Paul Gee views the exploration of game worlds as parallel to the brain's manner of interacting with information in the real world. "Basically, how we think is through running perceptual simulations in our heads that prepare us for the actions we're going to take. By modeling those simulations, video games externalize how the mind works." (Johnson, 2005, p. 1) Learning in this manner becomes a cognitive loop. Players enter a game world whose operant rules remain hidden, which only become sensible to them as models based on data derived from exploratory actions taken in the environment. As players test the environment, they form hypotheses, which they further refine in their course of play. These models determine future actions that lead to affirmation or disaffirmation, which feed back into the cognitive model players build of the game world. Learning cognition relies fundamentally on this recursive loop of deduction and induction, which is a primary skill that our games attempt to isolate and encourage.

"When we externalise our minds, we create an object. This object, in its turn, is not just an object in space: it is something we consider, relate to, love or hate, in short, work with in our minds, hence internalise." (Gorayska & Mey, 1996, p. 6) This exact relationship represents, for our design philosophy, the struggle that learning games hope to foster. The "object" that our players create in their encounters with the game should, hopefully, be a model or metaphor to some deeper and widely applicable cognitive skill. And as the player attempts to master the game, their relationship to this simulation or model becomes internalized, ready for deployment in the classroom when scaffolding lessons are brought to bear on these models. We aim to create the seeds of learning that lie in wait for activation and propagation.

The question for both educators and cognitive technologists will lie in whether our game design approach effectively cultivates broadly applicable cognitive skills rather than merely training the player's expertise in that particular task. We believe that our design paradigm accomplishes the former rather than the latter. If games succeed as cognitive tools, an externalizing of certain human mental processes that allows us to cultivate skills to robust mastery, then games might transform the way we think about education. Rather than focus on content, educators, cognitive technologists, and learning game designers could all begin from common ground of focused development of cognitive skills. This paper, while elaborating on the discipline of game design, will hopefully also speak effectively to cognitive technologists about the ideas of *play as cognition* and the *game as a tool*. Education and gaming have an established partnership, one that would greatly benefit from the interdisciplinary insight of cognitive science.

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Games for Good: Why they Matter, What We Know, and Where We Go from Here

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This concluding essay compares games for good and cognitive technologies in order to articulate the importance of these interactive media technologies for the discipline. By better understanding what we know about games for good as cognitive technologies, and by considering what cognitive technologists can learn from game designers as well as what game designers can learn from cognitive technologists, we can continue our move toward exciting and productive new lines of research in both theoretical and applied domains. This essay integrates ideas from the work of the contributors for this special issue and speculates on new directions for future work in this area.

KEYWORDS: Video Games, Learning, Cognition, Characteristics, Future Research

INTRODUCTION: WHY THEY MATTER

Games for good as a genre of video games and cognitive technology as a domain of study have much in common. In their applied forms, both rely heavily on interdisciplinary practices. They borrow ideas and inspiration from several of the same fields, such as engineering, psychology, computer science, artificial intelligence, art and aesthetics, sociology, interface design, and sound design. Both attempt to open technologies to human audiences in order to augment, extend, educate, or enlighten the human experience. They often do this by using new forms of information visualization and enhancing usability in order to keep people focused, on task, and free of frustration. Both have had profound goals at their origin, with the potential for significant societal impact.

One of the earliest proponents of cognitive technology, Vannevar Bush, wrote in his famous 1945 essay *As We May Think* of the need for scientists to turn information technologies developed for the military into tools for augmenting human intellect and improving the world. In a similar thrust, today's games for good researchers hope to turn technologies developed primarily for commercial entertainment into something more beneficial to society. These designers advocate grassroots solutions, experimental and guerilla game design, and the promotion of awareness for issues such as poverty, climate change, and global conflict through the capabilities of interactive, multimedia gaming.

The above characteristics describe cognitive technologies and video games primarily in terms of their technological and operational capabilities. However, both of these forms also have social and cultural implications depending on the communities and practices in which they are embedded. Cognitive technologies and games for good can be used in a variety of ways for a variety of purposes. These purposes might be characterized as "good," "evil," "neutral," or any other number of things, depending on a particular audience and their beliefs. These descriptors are admittedly nebulous concepts tangled in notions of personal value systems and idiosyncratic interpretations, so we conceptualize games for "good" as systems that attempt to propagate social justice, expose the underlying mechanics at work in personal or organizational value systems, or make a positive change in the world according to the criteria of a reasonable social agenda. Of course this is mired in politics and ideological values, so one community's "game for good" might be another community's "game for moral corruption" or even "game for liberal (or conservative) propaganda." Regardless of personal perspectives and community value systems, though, since video games have the *rhetorical potential* to be so persuasive and engaging for audiences (see Bogost, 2007), we, as cognitive technologists, should have them on our radar. How we react to and shape the cognitive technologies of the future might expand from what we learn about video games and human behavior.

For the purposes of this issue, we have chosen to feature games that embody these types of goals—several of the games for good discussed here educate, empower, encourage empathy, and elicit compassion. Values such as these are easily classified as prosocial. This subset of video games does not, however, provide us with a fully generalizable understanding of the relationship between video games in general and the typical types of research undertaken by cognitive technologists. In order to better understand this relationship, we must a step backwards and consider the larger relationship between cognitive science, technology, and video games. We must create a conceptual space for research in which video games and cognitive technologies can be explored in various permutations as holistic systems.

WHAT WE KNOW

We can start this process by considering some of the work done in conceptualizing video games as subjects for scholarly and critical analysis. Perhaps no book has done more for positioning the field of video game design as a legitimate academic subject than Katie Salen and Eric Zimmerman's (2004) *Rules of Play: Game Design Fundamentals*. The book is notable not just for its attention to detail and focus on video games as a subject deserving of rigorous academic scrutiny, but also for its comprehensive treatment of the medium from a variety of perspectives and analytical lenses. As an interdisciplinary subject of discussion—much like cognitive technology—a balanced discussion of video games must include not only engineering and design principles, but also principles of human behavior, psychology, economics, art, and culture, to name but a few essential components. One of the interesting discussions provided by Salen and Zimmerman concerns the complex relationship between the activity of play and games. As the authors note, games can be seen as a subset of play, in the sense that "most forms of play are looser and less organized than games" (p. 72), but at the same time, play can also be characterized as a component of games, since "the experience of play is but one of many ways of looking at and understanding games" (p. 72). In this sense, then, how might we relate the similar concepts of games and cognitive technologies, where the goals of behavior are likely to be more goal-directed and prescriptive?

Following Salen and Zimmerman, one direct way of relating games and cognitive technologies is to conceptualize video games as a subset, or particular type, of cognitive technology. Certainly games can function as tools to enhance cognition—one need only to look at Matthew Sharritt's discussion of the staff happiness algorithms running in *RollerCoaster Tycoon 3* or Jonathan Belman and Mary Flanagan's mention of the mathematical models used to represent diplomacy in *Peacemaker* to realize that such computations would become cumbersome if done exclusively by the human mind—but they can also serve as technological tools for enhancing social, cognitive, or emotional functioning. This may occur through the simple act of enabling connections to other human beings in a technology mediated environment or through allowing the cathartic act of bringing down zombies in an alternate universe. From this perspective, then, games are specialized instances of cognitive technologies.

Alternatively, though, we can also think of cognitive technologies as components of games. The staffing mechanism in *RollerCoaster Tycoon 3* that Matthew Sharritt discusses is a cognitive technology, and so is the keyboard pressing mechanism recounted by Jonathan Belman and Mary Flanagan in their analysis of *Hush*. This classification of particular game components as cognitive technologies is fairly sound; both devices augment players' thinking by abstracting the details of the physical acts away such that the players' can focus on the experiences crafted by the game designer. The purposes of these two games, however, are quite different. The designers of *RollerCoaster Tycoon 3* wish for the player to understand and excel at the systems-based approach of running a theme park, while the designers of *Hush* wish for the player to experience the tension, angst, and terror of being one small cry away from a massacre at the hands of soldiers. The implementation of these tools is also dissimilar: *Hush* uses a basic keyboard press to allow player interactivity, while *RollerCoaster Tycoon 3* requires a more complex and investigative approach. From this perspective, games as cognitive technologies must be further analyzed by facets such as game genre, purpose, functionality, and audience.

Yet another way of considering games for good and cognitive technologies is as a Venn diagram in which each entity has its own individual properties and then there is shared space between them in which common properties overlap (Figure 1). For example, games must have quantifiable outcomes, rules, and conflict (Salen & Zimmerman, 2004) whereas cognitive technologies need not necessarily have quantifiable outcomes nor conflict. Rules are arguably an important component for cognitive technologies, but even rules operate differently than the mathematically precise rules we find in video games (see Table 1). Rules in a video game need to be clear and unambiguous, but rules for cognitive technologies, since they are designed to be in tune with the actual ways in which we think and process information, may be more fuzzy and open-ended. For example, returning to our opening example of the visionary cognitive technologist Vannevar Bush, a well-known early example of a cognitive technology was his memex machine. The memex was a hypothetical device designed to record the associative trails of memory and cognition that accompanied one's personal research efforts when looking up information about a particular subject. The sheer difficulty involved with collecting, arranging, and indexing these associative trails of information seeking is evidenced by the fact that no such device exists to this day. Humans are just too curious and too unpredictable; their thinking is too complex to easily and naturally categorize in the same fashion as we do with video game rules.

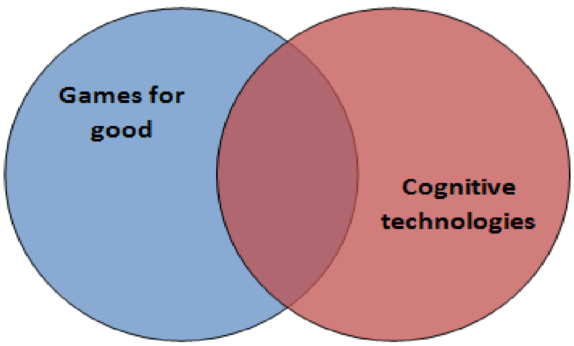

***Figure 1*. Venn Diagram of Games for Good and Cognitive Technologies.**

Given these three manners of conceptualizing this relationship of game genre and academic discipline, how do we approach the study of such a diverse and admittedly complex intersection with any sort of methodical plan? A systems-based approach is useful for this task. Returning to Salen and Zimmerman (2004), we see the authors articulating a three-pronged attack for understanding the complex space inhabited by game design and game studies. They suggest that an analysis of games can be performed according to understanding game systems through the lenses of rules, play, and culture. From the perspective of *rules*, games are mathematical formalisms in which logic and order construct the boundaries and challenge conditions which make gameplay enjoyable. This view is of a closed system since rules do not change once they are authored (unless, of course, there is a rule for that operation). As players *play* games, however, the elements of psychology and emotion are introduced and game design becomes observable from an active, human dimension. This may be an open or closed system, depending on whether or not we exclusively consider the player's interactions with the game itself or if we also consider the ways in which the players are shaped by the outside world as they play. Finally, the purely open dimension of games from a systems perspective is seen through a *cultural* lens in which games impact and are impacted by the cultures and communities in which they are embedded and played. For example, the discussion of violence in the *Grand Theft Auto* series (CBS News, 2005), or sex in the game *Mass Effect* by Fox News analysts (Grant, 2008) are examples of frequent and typical exchanges between culture and games in an open system.

Clearly, each of these perspectives can offer useful research ideas for cognitive technologists, and many of these areas have already been explored. For example, studies of violent acts in the real world after playing video games study the transfer of rules from the virtual to the real, while the socioeconomic impact of such studies and their use to influence public policy is a cultural phenomenon, ripe for analysis by those scholars interested in the sociopolitical implications of cognitive technology. Those more interested in player learning and the transferability of knowledge are engaging both the rules and the play layers of video games; in this case, rules are engaged as the player interacts with the game world, but the player's cognition is also influenced by the game and by the avatar in the game (refer back to Figure 1 in Shlomo Berkovsky et al. in this issue for a visual representation of this feedback relationship).

It stands to reason, then, that given the complex relationship between the open and closed systems at work in video games, play, and cognition, conceptualizing games for good as cognitive technologies is a sophisticated process. If we think of the prototypical "game for good as cognitive technology" as an applied product that must pass a series of tests along the dimensions of rules, play, and/or culture, then one potential matrix for building a general cognitive game for good might look something like what is shown in Table 1. The key characteristic added by cognitive technology in each dimension is italicized in the final cell of each row.

***Table 1*. Characteristics of Games for Good as Cognitive Technologies.**

	Cognitive Technology	**Game for Good**	**Game for Good as Cognitive Technology**
Rules (Closed/ Formal)	Procedural systems are in place to augment human cognition (e.g., by directing attention, limiting decision points, etc.).	Procedural systems are tied to game mechanics; these systems limit player action and create pleasurable challenges for players.	Procedural systems are designed based upon real world systems or linked to those systems through fantasy or metaphor. *What we know about cognitive science informs what we know about how to build good video games, and the two are seamlessly entwined.*

Play **(Closed / Gameplay)** **(Open / Experiental)**	The technology presents a flexible and configurable mechanism for people's individual settings and personal approach.	The technology encourages people to explore, both in terms of in-game mechanisms and the gameworld.	As an open system, the player is encouraged to play with her own value systems or beliefs and make decisions based on those beliefs. *The game system should adapt and provide feedback based on these systems accordingly.*
Culture (Open / Socio-political)	The technology is designed with the knowledge that it will be used in a particular place by a particular group of people, not in a sterile laboratory under controlled conditions. As such, adjustments are made to the tolerances and limits of cognitive technologies	Many of the prosocial benefits of games for good come from the cultural impact of the games: community discussions, media impact, and word of mouth. Feedback from communities continually improve games as open systems.	Best practices from over 35 years of cognitive science research can inform how community feedback and participation shape evolving games for good. *Games become organic, evolving entities that continue to mature and have impact as they are shaped by group cognition and collective intelligence over time.*

WHERE WE GO FROM HERE

Based on the preliminary matrix in Table 1, it seems logical that there is some benefit in these two disciplines getting to know one another a little better. To begin, we can consider how cognitive technology can learn from game design. There are two additional concepts from the game design literature that are worth pointing out to cognitive technologists. The first is the metaphor of the "magic circle," a concept described at length by Salen and Zimmerman (2004, pp. 93-99) as an imaginary set of boundaries in which players enter and agree to substitute game rules for the rules of ordinary life. In other words, the rules to make oneself visible, available, and noisy are thrown out by a young child when that child enters the magic circle formed by an impromptu game of hide-and-go-seek with a parent. Similarly, the rules of how we use a dining room table are thrown out when we sit down with guests for a rousing game of trivial pursuit. Now, the table serves as a defensive buttress, as a shared space for strategizing and perhaps even insulting the losing team, and as a virtual boundary in which both strategic and formal rules have been substituted in for the implicit, contextual rules describing how that physical space is normally used. Players are expected to behave according to the rules—both implicit and explicit—when they agree to enter the magic circle of a game.

We can also borrow from game design a unique way of thinking about interaction through three conceptual schemas—formal, experiential, and contextual (Salen & Zimmerman, 2004). These directly relate to the three lenses of rules, play, and culture described above. Rules are formal schema, play is characterized as experiential schema, and culture is a contextual schema which depends on the particular ideologies of a cultural system. Those familiar with the long line of research exploring scripts and schema theory (Schank & Abelson, 1977; Minsky, 1985; Schank, 1995) may find this approach familiar. Schema are ways to organize and frame knowledge that have variables, embed information, "represent knowledge at many levels of abstraction," and "represent knowledge rather than definitions" (Salen & Zimmerman, 2004, p. 103). Computer scientists might equate schema with object-oriented programming, or the practice of writing computer code that is abstracted, encapsulated, and modularized so that complex programs can be written that rely upon fairly simple base structures. The same idea is true for cognitive schema; they allow for a certain degree of mental efficiency when encoding and organizing information.

Since a schema is essentially an encoded experience in memory that creates placeholders for new variations of those experiences rather than encoding entirely new representations each time the event is encountered; this is more efficient when hundreds of thousands of events must be stored and eventually recalled from long term memory. As we move from one event to another, we simply substitute schema and recall the appropriate data relevant to the new schema along with our expectations and prior experiences with older, but related schema. We also have general expectations about behaviors and actions that are associated with these schema. For example, when we walk into a grocery store, we know from prior experience that the store holds various purchasable goods, that cashiers will be manning the registers and accepting money for said goods, and that if something goes horribly wrong there is generally an authority figure or manager available to help sort things out. Regardless of the particular type of grocery store being visited, we can generally store the same set of assumptions, expectations, and facets of knowledge related to this experience in memory using what Schank and Abelson (1977) call scripts, or our expectations about what is likely to happen in this type of situation. We can then react to the real world experiences of these encoded events using scripts. And when an event occurs which is not currently engaged by our current script, such as walking back to the pharmacy section of the grocery store, a new and appropriate script is substituted in.

The functioning of the magic circle is in fact very much like the functioning of a script substitution in which one experience is replaced by another one and needs to be responded to based on prior experiences as stored in memory. What makes the magic circle interesting, however, is the playfulness that generally accompanies this substitution of rules. For instance, if I am leaving a restaurant and I replace my "eating in a restaurant" script with a "walking down the street" script, I am not likely to assign much affective importance to that transaction or feel a particular sense of pleasure as I do it. With the magic circle found in gaming, however, this sense of playfulness is an essential requisite to the entrance fee. Further, a sense of commitment is required of the player before they are allowed entry (the entry is generally agreed upon by the former occupants of the magic circle who may choose to welcome the new player with open arms or deny that player altogether). Imagine if current tasks involving cognitive technologies, such as detailed searches with autonomous agents or even simple search engines, which can sometimes be quite tedious, engendered within humans the same type of playful willingness to engage, experiment, and suspend disbelief as even the simplest game experience is likely to produce in a player who has entered the magic circle? Certainly information retrieval and access would be more pleasurable and less stressful.

The second concept worth noting for cognitive technologists was one originally articulated by the philosopher Bernard Suits (2005). This is a state of mind Suits coined the "lusory attitude" (p. 34). As Salen and Zimmerman explain, the basic idea behind the lusory attitude is that the player agrees to accept a more complicated set of rules than is necessary to accomplish a task in order to enter the domain of gameplay and increase the level of challenge. So, instead of simply sending airplanes to war in *Making History*, as Matthew Sharritt explained, the players must first position their planes at an adequate launch base before this action is enabled. To use an even simpler example, instead of walking over to a garbage can to throw away a piece of useless paper, we crumple the paper in a ball and make a game of trying to launch it across the room and into the basket. The lusory attitude is the psychological state of being that makes playing a game both challenging and enjoyable.

The concept of a lusory attitude is something interesting to think about from the perspective of cognitive technology, which generally exists to create a *more* direct path to an informational resource. The reason that players are willing to accept the lusory attitude is because games are enjoyable, engaging, and rewarding. The decisions made by a designer that encourage such an attitude are worth noting and perhaps adapting for other types of assistive technologies. For example, one finding well supported in literature is the importance of practice for building expertise (Ericsson, Krampe, & Tesch-Römer, 1993). As practice becomes boring, a new level of challenge can be introduced in order to make the material elevate in difficult according to a player's growing competency with the subject. At some point, the lusory attitude becomes an important psychological state for learners to recognize that they are taking a more difficult approach to the task of learning material that could be internalized in an easier way. A simple example is one that is often used by mathematics teachers: pupils are shown a longer way to complete a problem that demonstrates the nuances and theories behind a particular principle, then in a later lesson they are given the shortcut that allows them to complete the problem more speedily.

Our argument is not that cognitive technologists should learn from game designers the ideas of the magic circle and the lusory attitude, but rather the principles and techniques used by game designers to bring players into that mindset. Salen and Zimmerman (2004) call this a double seduction: first, we must convince players to enter our magic circle, but then, we must further convince them to stay. While inside, we must persuade them to solve problems and overcome obstacles in a more roundabout way than is normally necessary.

This is not to say that the relationship between game design and cognitive technology is one way. There is much the former can learn from the latter, and cognitive technologists may wish to take a role in building games that embody best practices in research from cognitive science. For example, despite promising early work from researchers such as Malone (1981), there has been a general lack of empirical research examining the impact of games and testing games for educational effectiveness and for transfer of learning. Recently, there have been a few promising studies looking at particular elements of games (such as story and interactivity) for particular types of learning content (Greenwood-Ericksen, 2007) and game features such as fantasy and reward (Derouin-Jessen, 2008), but much remaining territory in this area remains unexplored. Well-established research protocols from cognitive science, including methodologies for behavioral experiments, brain imaging studies, computational modeling, and neurophysiological methods offer additional research heuristics for further assessing the credibility of claims made by educational game designers. Similarly, qualitative and ethnographic work from cognitive technology bears potential for improving and extending the possibility space of game design, particularly with educational games and games for good. It is important to, figuratively, see into the minds of players to assess whether or not they are thinking about the same things that the designers hoped they would think about during design. Specifically, there is always going to be a need to dig deeper and in ways not possible through quantitative studies; case studies, ethnographies, and observational recording sessions can do much to help us understand how players play in practice rather than in theory. This is why qualitative data analysis such as that done by Matthew Sharritt in this issue will continue to be important, as will the quantitative and statistical approaches such as those done by Shlomo Berkovsky and colleagues.

Fortunately, there is a large body of general work from cognitive technology and related fields that can be of use to designers of games for good. One research area from cognitive science that has been frequently connected to game design is the flow concept as conceptualized by Csikszentmihalyi (1990). The flow state, referenced by Matthew Sharritt in this issue, is a particular mode of functioning in which a person is highly immersed in an activity—such as an engaging game of chess, a bout of rock climbing, or an athletic event—and as a result they experience a specific set of cognitive effects. These effects include the merging of action and awareness, intense concentration, the loss of self-consciousness, and the transformation of time (Salen & Zimmerman, 2004). In other words, a person in a flow state loses track of time and feels intensely and personally connected to an experience to the extent that they feel “in the zone” and both comfortable and confident in their abilities. From the perspective of a game designer, such characteristics are highly desirable for players to possess; gamers in a flow state will be easier to seduce into entering the magic circle, will more likely feel immersed in the game, and will be more likely to stay within the game for longer periods of time. Cordova and Lepper (1996) found that additional characteristics such as contextualization, personalization, and choice further engaged learners to stay intrinsically motivated, to become more deeply engaged, and to learn more in a fixed period of time. Refining and more fully operationalizing and testing this concept of “flow” represents an important growth area for interdisciplinary research with cognitive technologies.

Designers of games for good can also learn from studies of transfer done in the domain of cognitive technology. As an essential problem of game design and education referenced in the introduction to this issue (Squire, 2002), transfer is perhaps the most important question we can attempt to answer as cognitive technologists and game designers. If a game for good does not allow players to transfer their newfound knowledge, empathy, or awareness to the outside world, then their usefulness is of a very limited nature. The problem here is that even very general problem-solving abilities, such as those used to complete mathematical word problems, do not transfer well when students encounter problems of a similar type (Cooper & Sweller, 1987; Willingham, 2009). Cooper and Sweller (1987) have suggested three potential reasons for this difficulty: people have trouble recognizing the relationships between problems, they have trouble activating the appropriate cognitive schema to deal with the new problems, and they have trouble automating the problem-solving process, which leads to an overload of working memory. More open collaboration between game designers and the cognitive science community is needed to fully explore the enabling and boundary conditions of transfer of learning in the context of games.

CONCLUSION: MAKING A DIFFERENCE THROUGH RULES, PLAY, AND CULTURE

Given the suggestions above for conceptualizing a research space and applying best practices to design, how do we use this knowledge for maximum impact? In other words, which lines of research are most likely to produce meaningful gains in the areas described above? We cannot yet know the answer to this, but we can certainly speculate based on what we know about the current state of the field in both video game design and in the design and study of cognitive technology. Below, we suggest several areas which seem to hold promise for generating data related to the production of more cognitively-sound games for good and more pleasurable and engaging cognitive technologies. These ideas are extracted from or inspired by the essays contained in this issue.

First, rules present a rich area of opportunity for research in cognitive games for good simply because rules are so important to existing research in the field. The research cited above has studied rules in all different areas of cognitive technology, from knowledge acquisition to memory and retention, but studying games for good as cognitive technologies brings new types of rules into scholarly discussion. For example, Jonathan Belman and

Mary Flanagan ask us to consider the ways in which a prejudice-reduction program might be used to combat stereotypes if motivation were at a sufficient level, or to think about how research in cognitive and emotional empathy might translate into a set of guidelines for activist game designers. Such rules and ideas suggest exciting new avenues for the field of cognitive technology to pursue.

Second, in the "play" or experiential category, we should pay attention to the design of future studies to determine whether or not playing games for good increases knowledge acquisition and retention of relevant learning outcomes (and what such learning outcomes might be in the area of games for good). Some research suggests that video games trump textual training materials in both knowledge acquisition and retention (Ricci, Salas, & Cannon-Bowers, 1996), but these studies are generally done for a particular audience (in this case, for military training) and have not been replicated on a wider scale or for the particular topic of games for good. Similarly, work being done in embodiment and embodied cognition has direct bearings on the concept of play as an open system between the real and the virtual. As Shlomo Berkovsky and colleagues suggest, if we are motivated by the virtual to exercise more in the real, then certainly this can be considered a positive solution to the health problems posed by sedentary lifestyles.

Third, we should pay close attention to cultural issues as they pertain to cognitive technologies and games for good. In some ways, culture is easier to capture in video games because it can be represented with atmospheric and descriptive game design elements rather than explicit and unambiguous rules. For example, a game designed to showcase the importance of family values for Hispanic cultures might provide images of family photographs, afford numerous interactions with family members, and design game rewards based on helping family members in a general sense rather than trying to build specific and precise rules for every possible interaction between the player's character and her virtual family members. In this sense, atmosphere and game design can capture culture quite well. In another sense, however, the particular nuances and details that are representative of discourse communities are difficult to capture and embed in games and technologies.

This type of cultural training model is familiar to the designer who attempts to change the behaviors and thinking processes engaged during the process of teaching about scientific communities of practice, something that is challenging to design from the bottom up (i.e., starting with scientific data rather than a set of generative questions). Marjee Chmiel calls this the process of teaching authentic scientific inquiry, while Scot Osterweil and Lan Le write of the "heuristics of scientific practice." In these cases, transmitting cultural knowledge with games is more difficult because of the somewhat intangible and tacit nature of knowledge seeking and knowledge representation in general science.

Regardless of which model for relating video games to cognitive technologies seems the most appropriate, it is clear that each domain relies heavily on a similar cross-section of scientific theory and application, although the goals of each may or may not be directly in line with one another. An awareness of the principles, objectives, and methods of both game design and cognitive science can make development easier and results more powerful, *if* this process is done in a controlled and carefully planned fashion.

This Special Issue only scratches the surface of what is possible when exploring the relationships formed by video games and cognition. Several additional areas of expansion and exciting new opportunities for research exist in this area, for example: embodiment and embodied connection, the link between physicality and cognition, personality and personality dynamics, creativity, engagement in fictional environments, the nature and power of learning through endogenous fantasy and play, the nature of exploration, experimentation, and inquiry, and so on. These areas of exploration may lead us to broader understanding of the human condition and suggest more effective means of teaching, learning, and socializing with technology. They also may offer us a more comprehensive understanding of how to encourage a prosocial way of thinking in the minds of individuals. Research that combines theoretical principles from the game studies literature and applied inspiration from prosocial initiatives and experimental or activist game design further expands the interdisciplinary problem space formed by human behavior, technology, and cognition, and generates possibilities for new and exciting areas of research that are sure to advance the field of cognitive technology.

As Vannevar Bush reminds us in the closing of his essay, "the applications of science have built man a well-supplied house, and are teaching him to live healthily therein." As cognitive technologists, it is our job now to use this science, a science that has further progressed another 65 years since Bush's time, to peek out the window, to see what is happening in our communities, our neighborhoods, and our global societies, and to pass along this behavior to the young people who will soon be the policy makers and the primary stakeholders in the 21st century. If for no other reason than the immense popularity of video games with this young demographic, we owe it to ourselves as an open-minded community of scholars to further explore the implications, possibilities, and capabilities of video games and carefully investigate their possibilities for use as cognitive technologies.

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The Last Page

Brad Brubaker, *Indiana State University*

With this essay we introduce a new occasional format to the journal. Our goal with this new section is to provide our readers with a capsule view and brief introduction to developments in cognitive technology related research as well as to highlight cognitive technology in the news.

As this special issue illustrates, the old stereotype that computer games, video games, and electronic games in general were for entertainment purposes only, has been replaced with a more optimistic view of gaming which acknowledges that games can be a useful platform for learning (e.g., Hodis, 2010; Korkeila, Kaarlas, Jääskeläinen, Vahlberg, & Taiminen, 2010). Electronic games and virtual worlds have been used successfully in treatments for anxiety disorders in adults and electronic gaming is increasingly developed to provide ancillary teaching formats for math, reading, and problem solving. in games such as *Reader Rabbit* and *Leapfrog* just to name a few. Recent research finds that experienced teen gamers are better than non-gamersat extracting information from the visual presentation and could act on that information. Further, many fields now include a gaming experience to teach and to evaluate a variety of skills. And the US Army uses a game environment to demonstrate battlefield situations for new recruits.

College students are but one demographic familiar with a wide variety of electronic games and who are motivated to master the game skills particularly when they are given an opportunity to compare their scores to their peers. The many games on Facebook allow the user to display the performance (level, points, coins etc.) of their friends that are also playing the game which may serve as motivation to continue to play the game. Many such games as well as those on other gaming platforms such as Playstation, Xbox, and Wii are not games that can be "won," but, rather, are games to be played regularly, where performance and progress is displayed. The motivation for playing is not to win but to get better (Paraskeva, Mysirlaki, & Papagianni, 2010). There are certainly games that users play to win like *Bejeweled* and *Majong* (and chess and backgammon as well), but, in the electronic environment, the motivation to play is also to beat your recorded high score rather than to simply win the game.

Recent research in the news has indicated that "nearly winning" a game is a strong motivational component in continuing to play the game (Clark, Lawrence, Astley-Jones & Gray, 2009). These researchers found that reward areas in the brain were activated by near wins to about the same extent as an actual win. The idea of the motivational component of near wins is not new but it may be quite useful in explaining the popularity of Facebook games since many of those games use the "you are almost there" feedback to stimulate the "near win" feeling. The display of other players' scores (both players above and below in ranking) may allow the gamer to "win" by ranking higher than another player and "nearly win" by comparing their score to the next ranked player.

Educators are using a similar strategy in allowing students to compare their performance in gaming type tasks with others in the class (Mayer & Johnson, 2010). Students compete with each other in "rate the correlation" games where they are given scatterplots and asked to guess the value of the correlation. The game records how many problems in a row the players get correct and displays a list of the scores for all players. Students are also motivated to play the Brain Buddies Facebook game that presents several cognitive tasks involving memory and decision making and which records the players scores so that they can compare their performance with others in the class (McLeod & Lin, 2010).

In sum, games have always been a popular pastime, so it is no surprise that college students play electronic games (Shin, 2010). As educators we would like to harness the motivational aspect of games and use a similar medium to allow our students to spend time mastering the material we present. Let's use *Games for Good.*

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Notes for Contributors

Manuscript Submission – Manuscripts may be submitted electronically directly to the editor (Stephen Fiore, sfiore@ist.ucf.edu) or the managing editor, (Brad Brubaker, brad.brubaker@indstate.edu), or to any associate editor (see inside front cover).

Manuscript style - All submissions must include a title, a short title for the running head, an abstract (less than 150 words), the names and affiliations of all authors, a list of 4 key terms (to aid electronic searches), a reference section and complete contact information (including address, phone number, and email address) of the principal author.

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